# CAPE COD PERMEABLE REACTIVE BARRIER INITIAL HYDROGEOLOGIC SITE CHARACTERIZATION RESULTS AND EVALUATION OF SITE SUITABILITY FOR PERMEABLE REACTIVE BARRIER INSTALLATION

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Prepared by:

Danna Truslow, P.G.

Samantha Wright

Peter Shanahan, Ph.D., P.E.

Emily DiFranco

Ken Hickey

WaterVision, LLC

481 Great Road, Suite 3
Acton, Massachusetts 01720
(978) 263-1092

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## Executive Summary

As part of its Southeast New England Program (SNEP), Region 1 of the U.S. Environmental Protection Agency (U.S. EPA) is partnering with the United States Geological Survey (USGS) and the Cape Cod Commission (CCC) to characterize hydrogeologic and geochemical conditions at a number of sites across southern Cape Cod to help identify suitable preliminary site locations for further Permeable Reactive Barrier (PRB) characterization pilot tests.

WaterVision LLC (WV), contractor to U.S. EPA for Contract #: EP-BPA-13-W-0001 completed Initial Site Characterization (ISC) activities at five sites selected as part of the local partnership program. The sites selected included:

- Barnstable – Prince Avenue near Prince Cove
- Mashpee – Timber Landing Road near the Mashpee River
- Falmouth – Sailfish Drive near Great Pond
- Dennis – Vinland Drive near Bass River at Kelleys Bay
- Orleans – Herring Pond Way near Lonnie's Pond

The following report provides data, evaluation of results and summaries based on the work under Task 2 of the contract: Initial Site Characterizations. The objective of the Task 2 ISC work was to collect hydrogeologic and geochemical information to calculate dissolved nitrogen flux and to generally assess the suitability of sites for installation of PRBs for pilot-scale demonstrations of the technology.

Field work to complete the ISCs was completed from January 2016 to May 2016 and included completion of continuous cores using Geoprobe direct push technology, installation of water table wells, installation of piezometer clusters, measurement of water levels at all wells and piezometers, analysis of field parameters at all wells, and sampling of wells and piezometers for a range of laboratory analyzed parameters. Water level measurements and field and laboratory analysis of parameters was completed twice each site. Sampling rounds were completed approximately one month apart. Evaluation of site hydrogeologic and geochemical data and calculation of mass flux of nitrate-N was then completed for each site.

Each study site presented a range of subsurface conditions and apparent influences on water quality and is summarized below. The field data collection and analysis completed for the initial site characterization provided adequate information for this initial assessment work and allowed for valuable comparison of site information to determine which sites could be suitable for pilot PRB studies. Table 20 provides a summary of site characteristics at the five ISC sites.

In general sediments were fine to coarse sands with intervals of finer materials. The western sites (Falmouth, Mashpee, and Barnstable) sediment characteristics and sequences were most similar. Greater thicknesses of finer materials were encountered in Dennis and Orleans. At Dennis a significant thickness of clay and silt was encountered beneath a shallow saturated zone of medium to coarse sand, bounding the site hydrologically. Orleans sediments were estimated to have the lowest hydraulic conductivity overall due to silt and clay in shallow sediments.

Water levels at the Barnstable, Mashpee, and Orleans sites were shallow compared to Falmouth and Dennis, with Dennis having the greatest depth to water. Highly oxidized zones of sand and gravel were encountered across all sites. These zones were often much coarser than the surrounding sediment. Organic sediments were encountered at several sites especially at shallow wells close to the edge of the nearby water bodies (Orleans, Barnstable, Falmouth). Estimated groundwater velocities were greatest at Dennis and lowest at Orleans.

The greatest concentrations of nitrate in wells completed for these investigations were at Dennis and Falmouth. However field testing of nitrate during boring advancement and testing of the piezometer clusters showed that the greatest concentrations of nitrate are at some locations well below the water table. Since many of the wells installed were shallow water table wells with short 5-foot screens, those wells may have missed some of the higher nitrate concentrations. Thus, the areal distribution of nitrate at some sites may be underestimated (Falmouth, Dennis, Barnstable). Even at wells where shallow reducing conditions have lowered nitrate concentrations, deeper zones may still contain elevated nitrate.

The greatest depth of investigation for the projects was 100 feet at Mashpee. ISCs at other sites were terminated at shallower depths due to difficult drilling conditions for the Geoprobe (Falmouth) or significant thickness of low conductivity materials (Dennis). At Barnstable, Mashpee, and Orleans, reducing conditions coupled with low nitrate concentrations were encountered at depth, which helped to limit the depth of nitrate impacts. At Dennis the significant depth to water and the thick underlying clay unit limited nitrate impacts to a short depth interval below the water table. The thickness of zones affected by nitrate concentrations greater than 1 mg/L varied from approximately 20 feet at Mashpee and Dennis to over 60 feet at Falmouth. The saltwater/freshwater interface was not encountered at any of the five ISC sites. At several wells where organic sediments were encountered close to the water table, nitrate concentrations were low compared to other shallow wells (Orleans, Barnstable, Falmouth).

Mass flux of nitrate was estimated for all sites based on the ISC-estimated hydrogeologic characteristics and nitrate concentrations measured at adjacent piezometers to the study depth at each site. Dennis appears to demonstrate the largest nitrate flux over a relatively short treatment interval, however the depth to the upper treatment zone boundary is over 40 feet, which may present practical design and engineering problems. Barnstable also appears to have considerable

nitrate flux even though the relative concentration of nitrate over the treatment interval is lower than at Dennis. Mass flux remains high despite lower nitrate concentrations due to a combination of high K combined with a moderate hydraulic gradient. That said, two very different estimates of hydraulic gradient were determined at this site, creating uncertainty in the estimated mass flux. The depth to the treatment zone is less than at Dennis but the total depth of treatment at Barnstable is high.

Initial conclusions and recommendations are included in a separate Technical Memorandum dated July 22, 2016. Work to be conducted under Task 3 will depend on site selection decision-making arising from review of the data provided in this report and final recommendations.

## Introduction and Purpose of Initial Site Characterization

As part of its Southeast New England Program (SNEP), Region 1 of the U.S. Environmental Protection Agency (U.S. EPA) is partnering with the United States Geological Survey (USGS) and the Cape Cod Commission (CCC) to:

> (1) Assess the feasibility of employing a streamlined characterization regimen for identifying potentially suitable site locations for Permeable Reactive Barrier (PRB) technology for treatment of dissolved-phase nitrogen in groundwater on Cape Cod;
> (2) Employ the characterization regimen to a number of site locations across southern Cape Cod to help identify suitable preliminary site locations for further PRB characterization pilot tests (Task 2); and
> (3) Further characterize one or more of the preliminary site locations to develop sufficient data to support PRB design (Task 3).

This report provides data, evaluation of results and summaries based on the work under Task 2: Initial Site Characterizations. Initial conclusions and recommendations are included in a separate Technical Memorandum dated July 22, 2016. Work to be conducted under Task 3 will depend on site selection decision-making arising from review of the data provided in this report and final recommendations.

The objective of the Task 2 Initial Site Characterization work under U.S. EPA contract number EP-BPA-13-W-0001 was to collect hydrogeologic and geochemical information to calculate dissolved nitrogen flux and to generally assess the suitability of sites for installation of Permeable Reactive Barriers (PRBs) for pilot-scale demonstrations of the technology. A longer-term objective of this and related investigations is to formalize, if appropriate, the streamlined characterization regimen identifying site conditions appropriate for installation and implementation of in-situ remediation approaches, such as permeable reactive barriers (PRB) and related technologies.

WaterVision LLC (WV), contractor to U.S. EPA for Contract #: EP-BPA-13-W-0001 completed Task 2 Initial Site Characterization (ISC) activities at five sites selected as part of the local partnership program. The sites are shown on a map of Cape Cod in Figure 1. (Figures are included at the end of the report.) The sites selected included:

- Barnstable – Prince Avenue near Prince Cove
- Mashpee – Timber Landing Road near the Mashpee River
- Falmouth – Sailfish Drive near Great Pond

- Orleans – Herring Pond Way near Lonnie's Pond
- Dennis – Vinland Drive near Bass River at Kelleys Bay

Between January and July 2016 WaterVision managed and conducted an ISC at each site which included:

- Preparation and organization of all drilling and laboratory subcontractors;
- DigSafe and ground-opening permitting and related town permissions;
- Completion of continuous cores and installation of five to six water table monitoring wells;
- Completion of a deep continuous core (up to 100 feet below ground surface);
- Completion of six to ten piezometers at discrete depths near the deep core location;
- Completion of a survey to locate and measure elevations at each well and piezometer and associated features;
- Measurement of depth to groundwater at all wells and piezometers (two rounds);
- Collection of field-measured water quality parameters at each well and piezometer (two rounds);
- Sampling of each well and piezometer for laboratory analysis of groundwater samples for water-quality constituents (two rounds);
- Evaluation of field-collected and laboratory data;
- Evaluation of mass flux of nitrate-nitrogen;
- Assessment of sites for use of nitrate treating PRBs; and,
- Recommendations for Full Hydrogeologic Assessments at candidate sites.

## Quality Assurance and Quality Control

WV developed a Quality Assurance Project Plan (QAPP) under Task 1d of this contract. The QAPP was reviewed by U.S. EPA and approved on January 15, 2016. A copy of the QAPP is included in Appendix A.

## Work Performed

Prior to starting field work, the Task 2 scope developed by USEPA for this project was reviewed by WV as part of Task 1c. WV visited proposed sites with other members of the project team in December 2015 to further refine the field work. The scope of work was slightly modified to include installation of additional water table wells and field testing for nitrate during boring advancement. In addition, well decommissioning was removed from the scope of work as each participating town wished to continue monitoring at these wells after the initial site characterization work was complete.

In summary the tasks included:

- Task 2a – Complete continuous cores and water table well installation at five to six locations to determine groundwater flow direction and area-wide groundwater quality information. Obtain in-situ water samples as part of well advancement and analyze using field nitrate-nitrogen test kits.
- Task 2b – Complete a continuous core up to 100 feet deep to characterize subsurface sediments and to estimate depth to saline water transition zone.
- Task 2c – Install six to ten piezometers adjacent to the continuous core location to provide water quality and vertical hydraulic gradient data. Survey well and piezometer elevations and locations.
- Task 2d – Complete two full rounds of water level measurements at all wells and piezometers and measure field parameters in preparation for groundwater sampling.
- Task 2e – Complete two full rounds of groundwater sampling to assess nitrogen species concentrations and other groundwater chemistry characteristics.

Table 1 summarizes the dates of field work completion at the ISC sites and the number of wells and piezometer installed at each site.

**Table 1 – Schedule for Completion of Field Tasks at ISC Sites**

| Site Name | Task 2 a, b & c | Depth of Continuous Core | Number of Piezometers Installed | Number of Water Table Wells Installed | Task 2 d & 2e – Round 1 | Task 2 d & 2e – Round 2 |
|---|---|---|---|---|---|---|
| **Barnstable - Prince Cove** | January 18 to 22, 2016 | 90 | 10 | 5 | March 14 to 15, 2016 | April 18 to April 19, 2016 |
| **Mashpee - Timber Landing Road** | January 26 to January 28, and February 11, 2016 | 100 | 10 | 7 | March 14 to 15, 2016 | April 27 to 28, 2016 |
| **Falmouth - Sailfish Drive** | February 1 to February 4, and February 10 and 11, 2016 | 80 | 9 | 7 | March 22 to 23, 2016 | May 4 to May 5, 2016 |
| **Dennis - Vinland Road** | February 16 to February 22, 2016 | 80 | 6 | 6 | March 31 and April 1, 2016 | May 6, 2016 |
| **Orleans - Herring Brook Way** | February 17 to February 26, 2016 | 90 | 10 | 5 | March 30 to 31, 2016 | May 9 to 10, 2016 |

After completion of Tasks 2a, b and c, WV prepared a technical memo for each site detailing well installation and preliminary testing results. A second WV technical memo was prepared after completion of the first round of water level measurement and sampling (Tasks 2d and 2e) to describe the water level and water quality sampling work and present data obtained during the first round of measurement and sampling. A review of methodologies used for these tasks are included below. For more detail on field tasks beyond that described below, consult the project QAPP.

### Well and Piezometer Installation and Subsurface Characterization

Boring advancement and well installation was performed using a Geoprobe direct-push drilling rig operated by New England Geotech, Inc. of Jamestown, Rhode Island. Depending on field and access conditions, either the truck-mounted Model 6600 or track-rig-mounted Model 7822dt was used for site work. Danna Truslow, PG and Samantha Wright of WaterVision LLC oversaw boring advancement, well installation, and sampling.

As borings were advanced, a five foot core was collected into a clear plastic sleeve. NE Geotech opened the sleeve for measurement, sediment description and sample collection by WaterVision LLC (WV). The length of the core recovered was recorded along with subsurface characteristics including degree of saturation. Samples were taken into bags and labeled by well location and sample depth for later inspection and sieve analyses as part of Task 3. Typically, these cores were completed to a depth of 15 to 20 feet below the water table at each well site.

Water table wells were constructed from two-inch diameter PVC riser and were completed with five foot screens. Wells were screened across the water table as estimated by initial saturation encountered during core advancement.

In addition the Geoprobe SP-15 method was used to obtain discrete groundwater samples at regular intervals. This method entails driving a small diameter casing fitted with tubing to the depth desired and pumping groundwater for real time sample analysis. This method was limited to a depth of 50 feet (the limit of the driller's equipment) and groundwater levels less than about 25 feet deep that could be pumped with a peristaltic pump. Samples obtained were field analyzed for pH and specific conductance, using a YSI Model 556 multi-parameter water quality meter and nitrate-nitrogen concentrations of each sample was estimated using a Hach colorimetric test kit (Model NI-11).

A deep core up to 100 feet bgs was also completed at each site. This core was completed to obtain subsurface sediment characteristics and to evaluate the depth to the freshwater/saline interface if present. Some cores were terminated at depths shallower than 100 feet at several locations due to coarse sediments that could not be penetrated by the Geoprobe or due to thick clay or fine sediment below which no further anthropogenic effects were expected.

Up to ten 1-inch-diameter piezometers were completed with one-foot-long screens at each site adjacent to the deep boring location. The screened intervals of the piezometers were evenly spaced vertically from the water table to the bottom of the boring or located so as to sample from subsurface sediment intervals. Well construction details for each site are provided included in Appendix B. Tables listing field-measured parameters and nitrate-nitrogen concentrations (using the Hach test kit) measured during well installation at each site are included in Appendix D. The locations of wells and piezometers at each site are shown in Figures 2 to 6. Detailed maps of piezometer locations are included in Appendix B.

### Well Elevation and Location Survey

Comprehensive Environmental Inc (CEI) of Merrimack, NH completed a survey of all newly installed wells and piezometers for the project. The top of PVC casing, top of road box casing, and ground elevation adjacent to each well were surveyed for elevation and location. The survey was completed using a TOPCON AT-G4 Series autolevel and survey rod, tape measure, and a Trimble Global Positioning System (GPS) receiver. Hydrants and catch basins were used as benchmarks for each site. Elevation was recorded by using an auto level and survey rod, while horizontal location (x, y) was recorded using a Trimble Global Positioning System (GPS) receiver. The well and piezometer box covers were removed to measure top-of-PVC-casing elevations. In certain situations, when the survey rod could not fit into the well box to record an elevation, a tape measure was used to record the vertical distance to the top of the PVC casing. GPS Pathfinder software was used in the office to extract the data from the Trimble GPS. These data were uploaded to make an ArcGIS shapefile and an AutoCAD file. Point elevation data were recorded in a spreadsheet. A table of latitude and longitude for all sampling locations is included in Appendix B.

Where available, the survey tied in to an established benchmark and converted elevation data to NAVD88. If NAVD 88 benchmark data for the site were not available, the benchmark elevation was approximated to the NAVD88 datum using the CCC 2-foot elevation data. Elevations listed throughout the report for Barnstable and Falmouth were tied to the NAVD88 datum by a surveyed benchmark in the field. Elevations listed throughout the report for Mashpee, Dennis, and Orleans were approximated to the NAVD88 datum by using the CCC 2-foot elevation data. The shapefile and elevation data were incorporated by WV into GIS mapping for each site. Details on the benchmark elevations used are included in Appendix B.

### Water level Measurement

As part of each water quality sampling round, a full round of water levels was taken at each well and piezometer after well caps were removed to allow equilibration with the atmosphere and before water quality sampling commenced. A Solinst

water level meter was used to measure water levels to the top of the PVC casing at each well. The water levels were recorded for later evaluation and analysis.

### Field Parameter Measurement

Water temperature, pH, dissolved oxygen (DO) in mg/L, specific conductance (SC), and oxidation/reduction potential (ORP) was regularly measured using a YSI Professional Series and/or a YSI 556 multi-parameter meter during well pumping. A visual description of the purged water was also noted. Initial samples were taken and measured using the calibration cup, however after initial sediment buildup in the wells declined, the YSI was mounted in a flow cell to allow for more accurate parameter measurement and for improved parameter stabilization during sampling. All field measurements and observations were noted on field sheets.

### Water Quality Sampling and Analysis

All wells and piezometers were purged of at least three well volumes and/or until all field parameter measurements had stabilized. Water samples were taken in laboratory-provided and pre-preserved sample bottles for the parameters listed in Table 2.

**Table 2 – List of Laboratory Analyses for ISC sites**

| Laboratory Analysis | Purpose |
|---|---|
| Nitrate-N, Nitrite-N, Ammonia-N, Total Kjeldahl nitrogen (TKN), Chloride, Sulfate, Total Alkalinity, Orthophosphate, pH | General chemistry |
| Organic carbon (dissolved) | Carbon analyses |
| Boron (dissolved), Iron (dissolved), Manganese (dissolved), Arsenic (dissolved) | Metals and minor elements |

Samples taken for dissolved iron, manganese, arsenic, and boron and for dissolved organic carbon analyses were first field-filtered with a single-use 0.45-micron cartridge filter before collection into sample bottles. Water samples collected for the remaining analyses were not field-filtered. All samples were kept chilled at 4° C and under proper chain of custody until either sample courier pickup or delivery to Alpha Analytical, Inc. of Westborough, MA for laboratory analyses.

# Data Evaluation

## Continuous Core and Well Completion logs

Boring and well completion logs were developed for each site. Subsurface sediment characteristics were described in detail in the field and this detail was transferred into boring logs for each well. After evaluation of sediment characteristics between borings, a broader classification and description of color and texture of subsurface units was developed for use in evaluating overall sediment character and estimating hydraulic conductivities of saturated material for each site. Note that the unit designations are unique for each ISC location.

In addition, a specialized well log was developed for the deep continuous core at each site, which includes the generalized lithologic descriptions, the screened interval for each piezometer and the corresponding vertical hydraulic gradient, nitrate concentration, and dissolved oxygen concentration at that interval. Continuous core logs with well construction diagrams and the consolidated piezometer logs for each site are included in Appendix B.

## Water Table Elevation and Gradient Calculations

Water level data were reduced to water table elevations and hydraulic head for wells and piezometers. Groundwater elevations were mapped and the water table surface and overall groundwater flow directions and horizontal groundwater gradients were estimated for each site. Horizontal gradients were also calculated for each site using the formula:

$$i_x = \frac{(h_2 - h_1)}{l} \quad (1)$$

Where:

$i_x$=hydraulic gradient (ft/ft)
$h_2$=groundwater elevation at upgradient location (ft. msl)
$h_1$=groundwater elevation and downgradient location (ft. msl)
l = distance between $h_2$ and $h_1$ (ft)

Vertical gradients were also calculated between adjacent piezometers at each site using the formula:

$$i_z = \frac{(hz_2 - hz_1)}{l} \quad (2)$$

Where:

$i_z$=hydraulic gradient (ft/ft)
$hz_2$=groundwater elevation at lower piezometer (ft. msl)
$hz_1$=groundwater elevation at upper piezometer (ft. msl)
l = distance between $h_2$ and $h_1$ (ft)

Tables 3 through 7, which are included following the text of the report, summarize site water level and gradient data.

## Groundwater Velocity Estimates

Using the lithologic characterization and hydraulic gradients developed from the field data for each site, we used Darcy's Law to estimate groundwater velocity:

$$V = ( K * i_x)/n \quad (3)$$

Where:

V is the groundwater velocity (ft/day);
K is the hydraulic conductivity (ft/day) of near-surface sediments from Masterson et al. (1997);
$i_x$ is the horizontal hydraulic gradient (ft/ft); and
n is the porosity (dimensionless).

These results are summarized in Table 8 and discussed in following sections.

## Water Quality Data Evaluation

Water quality data were tabulated and then graphed to determine the spatial and vertical distribution of nitrogen compound concentrations and to better understand groundwater chemistry and anthropogenic impacts at sites. The Alpha Analytical Laboratory reports are included in Appendix D. Measured field parameter and laboratory analyzed concentrations of analyzed groundwater constituents are summarized in Tables 9 through 18, which appear following the text.

All data were subject to QA/QC review and some water quality data were flagged due to relative percent difference (RPD) variations greater than 20% between duplicate samples. A summary of QA/QC data reviews is included in Appendix D.

## Mass Flux Analysis

A calculation of the mass flux of nitrate through the depth of investigation was completed for each site. The mass flux was estimated based on subsurface hydraulic characteristics estimated for sediments documented in the continuous core logging. The calculation also required the assignment of nitrate-N concentrations at vertical intervals measured at piezometers installed adjacent to the continuous core. To this

end, we defined water quality intervals and within each water quality interval, sediment sub-intervals.

A portion of the spreadsheet developed is included below (Table 5) to illustrate how vertical intervals were divided first by water quality interval and then by sediment sub-interval to assess nitrate flux.

Each water quality interval was defined as the vertical distance between the midpoints of vertically adjacent piezometer screens. If several lithologic units were present within one water quality interval then the interval was subdivided accordingly. The calculated horizontal hydraulic gradient and the nitrate-N concentration from the first round of water quality sampling for each piezometer depth were used to estimate flux within the water quality interval.

**Table 5– Segment of mass flux spreadsheet calculation showing discretization approach for water quality intervals and sediment sub-intervals**

| Reference Piezometer | Top of sample depth | Bottom of sample depth | Top of water quality interval | Bottom of water quality interval | Sediment description | Top of sediment sub-interval | Bottom of sediment sub-interval | Thickness of sediment sub-interval |
|---|---|---|---|---|---|---|---|---|
| | feet bgs | feet bgs | feet bgs | feet bgs | | feet bgs | feet bgs | feet |
| VLZ-44 | 43.0 | 44.0 | 42.3 | 45.5 | Medium to coarse sand with gravel | 42.3 | 45.5 | 3.2 |
| VLZ-48 | 47.0 | 48.0 | 45.5 | 49.5 | Medium to coarse sand with gravel | 45.5 | 48.55 | 3.1 |
| | | | | | Clay with silt and sand | 48.55 | 49.5 | 1.0 |

Using these defined vertical intervals, unit nitrate mass flux was calculated for each sediment sub-interval using the relationship (ITRC, 2010):

$$J = K*i*C \quad (4)$$

Where:

J = unit mass flux of constituent within the sediment sub-interval ($g/day/m^2$);
K = hydraulic conductivity of the sediment sub-interval (ft/day);
i = horizontal hydraulic gradient (ft/ft); and
C = concentration of $NO_3$-N in mg/L within the water quality interval.

K was estimated based on the sediment properties of each unit characterized for the given ISC site. These K values were based on Cape Cod specific data collected and have been utilized by USGS for several groundwater modeling studies (Masterson et al., 1997). Horizontal hydraulic gradient values used were those calculated for each site based on measured groundwater elevations. The same horizontal hydraulic gradient was assumed for all piezometer depths.

This calculated unit mass flux was then multiplied by the thickness of the corresponding lithologic unit within the water quality interval to arrive at the total mass flux for that sub-interval. These individually calculated mass fluxes were then summed over the study interval to arrive at the total mass flux through the study depth per meter of PRB length.

## ISC Site Descriptions

The locations of the five sites investigated as part of this project are shown on Figure 1. All sites are located upgradient of coastal embayments, which have water quality impairments for nitrogen, but the overall physical setting of each site is unique. All wells were installed within town-owned road rights-of-way or on town-owned lands. Universal at each site is that all homes and businesses in the immediate area are serviced by individual on-site wastewater disposal systems. Other physical and cultural characteristics of each site are summarized below.

### Barnstable – Prince Cove

This study site is located on Prince Avenue adjacent to Prince Cove just north of Osterville. The Marstons Mill River flows from the Mill Pond just north of Route 28 southeast of Prince Avenue to a salt marsh that borders Prince Cove. An unnamed stream drains an area west of Prince Avenue to a tidal creek that forms part of the same Marstons Mill marsh. Prince Cove drains via Marstons Mills River to North Bay and Cotuit Bay before emptying into Nantucket Sound. Prince Avenue is located on the edge of a bluff topped by Dory Circle. The elevation change from Dory Circle to Prince Cove is 40 feet and from Marshview Lane to the marsh is just over 10 feet.

Widely spaced older homes along Prince Road and a newer development to the north along Barnacle Drive and Dory Circle surround the study site. Conservation land, several homes on Marshview Lane, the town marina, and several homes northeast of the marina lie east of Prince Avenue. Storm drains, water lines, and gas lines are buried within the Prince Avenue right of way. Electric, telephone, and cable are currently on overhead wires.

Wells were installed along Prince Ave. The upgradient well (PC-6) was sited on a town-owned lot west of Prince Avenue. Other wells and piezometers are located on the east side of Prince Avenue between the intersection of Marshview Lane and Prince Avenue and the Town Marina (Figure 2).

### Mashpee – Timber Landing Road

The Timber Land Road ISC site is located east of the Sandalwood neighborhood off of Great Neck Road South. The site drains to the Mashpee River and the Mashpee River flows south to Popponesset Bay before entering Nantucket Sound. An extensive salt marsh lies between Timber Landing Road and the main stem of the river and a tidal tributary to the river drains the immediate Timber Landing Road area. This area was once used extensively for cranberry production and many ditches and ponds related to the cranberry operation remain. There are no buried or overhead utilities along Timber Landing Road. The elevation change along

Timber Landing Road is nearly 20 feet and between Timber Landing Road and the river is about 15 feet.

Most of the project wells and piezometers are located on Timber Landing Road, a dirt track that runs through town conservation land (Figure 3). One downgradient well is located on a spur road that runs to the river's edge. Many of the wells are located in the low area close to the marsh but several wells are located on higher ground to the north and south.

### Falmouth – Sailfish Drive

Sailfish Drive is in the Fisherman's Cove neighborhood in East Falmouth south of Route 28. It lies on the eastern side of a north-south peninsula bisected by Davisville Road. The tidal Bourne's Pond lies to the east of the neighborhood. The freshwater portion of the stream that feeds the pond flows through a golf course and then drains a cranberry bog operation before crossing to the tidal portion of the drainage area. A tidal stream surrounded by a salt marsh parallels Sailfish Drive and flows east to the pond just south of Sailfish Drive. Homes in this subdivision date from the early 1970s and are generally closely spaced. All utilities are buried along Sailfish and Tarpon Drive. This includes cable, electric, water, stormwater, and gas utility lines. The elevation difference between Sailfish Drive and the pond is approximately 20 feet.

Most of the wells for the ISC project are along Sailfish Drive. Two of the water table wells and the piezometer cluster are located just north of a neighborhood park that borders Bourne's Pond (Figure 4). The upgradient well is located on eastern Tarpon Drive north of Sailfish Drive.

### Dennis – Vinland Drive

The Vinland Drive site lies within a neighborhood on a bluff that borders the eastern edge of Kelleys Bay, an upper embayment of the Bass River. Homes in this large subdivision date from the 1960s and are generally closely spaced. Town-owned land used for recreation lies east of the neighborhood. A narrow beach lies at the bottom of the bluff but there is no apparent salt marsh bordering the water's edge in this area. Buried utilities include gas, water, and storm sewer. Electric, cable, and telephone are overhead. The site is located north of Route 6. The elevation difference between Vinland Drive and the Bay is approximately 45 feet.

Most wells and piezometers are located on the west side of Vinland Drive (Figure 5). The upgradient well is located on the north side of Thorwald Drive.

## Orleans – Lonnie's Pond

The Orleans site is located on Herring Brook Way, which borders the west end of Lonnie's Pond, also known as Kescayogansett Pond. This nearly round pond is tidal and drains to Pleasant Bay. Freshwater ponds including Pilgrim Lake and Crystal Lake surround the pond. A small cranberry bog is located upgradient of Monument Road just west of Herring Brook Way. A town landing runs from Herring Brook Way to the pond and a narrow beach and marsh area border the pond near the landing. Homes are fairly widely spaced and are located on both sides of the road. A fish passage has been installed on a brook south of the project area and a stormwater treatment system for the area is also located near the south end of the project area adjacent to the fish pass. Town water and stormwater are buried. Electric, cable, and telephone utilities are on overhead lines. The project drainage area slopes towards the pond with an elevation difference of nearly 30 feet between Monument Road and Lonnie's Pond.

Most of the project wells are located on the east side of Herring Brook Way (Figure 6) and the piezometers are located just north and south of the town landing road. The upgradient well for the project is located on Monument Road.

## Results

The results of the ISC studies are summarized below by site and then compared at the end of this chapter. The summaries are presented in the order of field work completion. Well construction details and elevation tables are included in Appendix B. Two rounds of water level measurements and water quality sampling were completed for each site (schedule detailed in Table 1).

Round 1 and Round 2 water level, field parameter, and laboratory analytical results are largely similar between rounds. Therefore the values for Round 1 are generally referenced in the summary below. Where there are distinctions or variations both data measurements are mentioned in the text. Round 1 groundwater flow maps are presented in the main body of the report and Round 2 maps are included in Appendix C. DO and nitrate-N are highlighted in blue and green respectively in Tables 9 to 18 for ease of review.

Continuous core and well completion logs are contained in Appendix B. Piezometer clusters are represented on one continuous core log and also include the vertical gradient, nitrate-N concentration, ORP and DO measured for the piezometer interval. Analytical laboratory reports are contained in Appendix D.

### Barnstable – Prince Avenue

Wells installed for this ISC are PC-1, PC-2, PC-4, PC-6, and PC-7 and are screened across or just below the water table. The suffix on each of the nine piezometers installed for the ISC – PCZ-13 through PCZ-88.5 – indicates the total depth of the well in feet and each piezometer is completed with a one-foot screen at the bottom of the well. These piezometers were installed adjacent to water table well PC-4.

#### Subsurface Sediment Description – Barnstable

The borings for the water table wells were completed to about 25 feet below ground surface (bgs) and the continuous core for the piezometer cluster was completed to 90 feet bgs. At all locations but PC-2 a thin soil layer was underlain by medium to coarse sand to about sea level. Below this a fine to medium sand was encountered for about 10 feet then medium to coarse sand predominated the study interval with minor layers of fine silty sand. At PC-2 an 11-foot deep layer of silty sand and organics were encountered below the soil layer. At the deep core (PC-4 area) a four foot layer of silt, clay and organics was encountered at about -44 feet msl. Also within the deep core a color change from tan/light brown to grey occurred at about 20 feet bgs (-7 ft. msl.) A similar color change occurred at other wells but at slightly different depths. Zones of sand colored orange to red were encountered throughout

the grey sand at PC-4. Quite often, these prominent bands were also made up of coarser sand than the surrounding matrix.

### Summary of Water Level Data – Barnstable

Figure 7 shows the water level elevations at each well and an estimate of the water table surface elevation and flow direction based on these measured levels and their relationship to Prince Cove. Table 3 lists the measured depths to water, water level elevations, and horizontal and vertical gradients calculated for both rounds of water level measurements.

The depth to groundwater is between 2.8 and 9.6 feet bgs. The apparent horizontal gradient is low between PC-7 and PC-6 but appears to increase closer to the Cove as suggested by the steeper gradient in the vicinity of PC-2 and PC-1. Sediments at PC-2 were generally finer grained than encountered at other water table well locations at the study site. Appreciable organic sediment was also incorporated with the mineral sediments at this boring location. In addition, the nearby topographic relief is greater in this area, which may also impact horizontal groundwater gradients. Gradients between wells PC-7 and PC-6, and PC-2 and PC-1 are estimated at 0.003 and 0.011 respectively for Round 1 and 0.009 and 0.003 for Round 2.

Vertical gradients between adjacent screens are generally upward above a depth of 43 ft. bgs (-30 ft. msl) and mixed below this depth with a strong downward gradient between 70 and 80 ft. bgs. A medium to coarse sand zone underlain by a layer of finer sand, silt and organics encountered at 57 feet bgs could impact vertical groundwater flow and suggest preferential flow in that zone.

### Estimated Groundwater Velocity – Barnstable

Groundwater velocities were estimated based on sediment characteristics identified within the screened interval of the water table wells and with the horizontal groundwater gradients measured during this round of water level measurement. Table 8 summarizes estimated velocities at all sites. For Barnstable, two velocities were calculated due to differing sediment characteristics and hydraulic gradients between the upper and lower study area. The estimated groundwater velocity varies between 1.5 and 4.5 feet per day with the higher velocity in the upper Prince Avenue area between PC-7 and PC-4.

**Table 8 – Summary of Groundwater Velocity Estimates at ISC Sites**

| | Barnstable | | Mashpee | Falmouth | Dennis | Orleans | |
|---|---|---|---|---|---|---|---|
| **Hydraulic Conductivity at water table, K (ft/day)** | Very fine to medium silty sand – PC-1 area | Medium sand PC-4 area | Fine to medium sand | Fine to medium sand | Medium to coarse sand | Fine to coarse sand with silt and clay – LP-4 area | Fine to coarse sand with silt and clay – LP-2 area |
| | 40 | 300 | 250 | 250 | 300 | 10 | 10 |
| **Porosity, n (-)** | 0.3 | 0.2 | 0.25 | 0.25 | 0.3 | 0.3 | 0.3 |
| **Horizontal gradient, i (ft/ft)** | 0.0109 | 0.003 | 0.003 | 0.0013 | 0.009 | 0.013 | 0.036 |
| **Estimated horizontal groundwater velocity, V (ft/day)** | 1.5 | 4.5 | 3.0 | 1.4 | 9.0 | 0.4 | 1.2 |

## Water Quality Data Summary – Barnstable

*Water Table Wells* - Field-measured and laboratory-analyzed constituents for this first round of sampling are listed in Table 9 for two-inch water table wells. Laboratory-measured pH at water table wells ranged from 5.5 to 6.0. Field-measured specific conductance was between 110 and 142 with an outlying value of 263 µS/cm at PC-7. Field-measured DO varied significantly between wells with the highest DO at 8.14 mg/L in PC-7 and a low of 0.75 at PC-2. DO values were higher in Round 2 but generally followed the same pattern.

Nitrate-N concentrations varied significantly between wells with the lowest concentration at 0.1 mg/L at PC-2 and the highest value at 2.5 mg/L at PC-6. Ammonia-N was detected at PC-1 and PC-6 at low concentrations and nitrite-N was detected at PC-2 and PC-6 also at low concentrations. Nitrate dominated the nitrogen species and formed most of the measured total-N at all wells other than PC-2. At PC-2, the high concentration of TKN (the sum of organic nitrogen and ammonia nitrogen) and low concentration of ammonia-N, imply a predominant organic-N component. Dissolved metals were generally lowest at wells with the higher dissolved oxygen concentrations. Chloride was highest at PC-7.

Figure 8 illustrates the concentration of selected water quality parameters at water table wells. The lowest nitrate concentrations correspond with lower DO and higher sulfate concentrations. Based on information from the town and local residents, some wetland deposits were encountered during Prince Cove marina repairs and the organic sediments encountered between the surface and 8.5 feet at PC-2 are consistent with this observation. The elevated dissolved iron and low DO

and nitrate at PC-2 appear to reflect the geochemical influence of these organic deposits and suggest potential denitrification
. Nitrate and DO concentrations are higher and dissolved iron lower at PC-4, PC-6, and PC-7 where organic deposits are not present. Additionally, the highest concentration of field tested nitrate-N detected during core advancement was 5 to 15 feet below the water table (Appendix D). Consequently, these shallow water table wells may not represent the maximum nitrate-N concentration in subsurface at that well location.

*Piezometer Cluster* - Differences in constituent concentrations with depth at the piezometer cluster location are illustrated in Table 10 and Figure 9. These small-diameter wells are located adjacent to PC-4. Laboratory-measured pH is between 5.7 and 6.5 and is lower in shallow piezometers. Specific conductance values are generally low at 78 to 144 µS/cm. Dissolved oxygen is highest in shallow piezometers PCZ-13 to PCZ-50. DO drops below 1 mg/L in the deepest piezometers - PCZ-60 to PCZ-88.5.

Figure 9 illustrates the concentrations of several key parameters with depth. Piezometer screen depths have been converted to elevation for this illustration. Groundwater sample elevations begin nearly at sea level and extend to 80 feet below mean sea level (msl). Nitrate concentrations in the shallow piezometers are similar between shallow piezometers (1.4 to 2.3 mg/L) but drop significantly below 60 feet. No nitrate was detected at PCZ-60. Nitrite-N and ammonia-N were generally very low and tentatively identified or below detection limits.

In general, the lowest nitrate concentrations correspond with the lowest DO concentrations as well. Refer to Round 2 DO for the most accurate site measurements. Consistent with this geochemistry, dissolved iron is highest in the lower zones of investigation below 60 feet bgs where dissolved oxygen is least. Vertical gradients are also generally upward within this zone of elevated nitrate.

The typical redox sequence is first for there to be aerobic respiration of organic matter, then denitrification of nitrate, followed by reduction of manganese to create dissolved manganese, followed by reduction of iron to form dissolved iron, and reduction of sulfate to sulfide (Hemond and Fechner-Levy, 2000). The concentrations indicated in Table 10 and Figure 9 indicates a redox level consistent with iron reduction, but not sulfate reduction (i.e., slightly negative redox potential consistent with that measured at PCZ-70, -80, and -88.5). Alkalinity, which is raised by aerobic degradation of organic matter (Wiedemeier et al., 1999) is also elevated at depth and is consistent with the hypothesized redox sequence. Thus, the water at depth appears to have contained organic matter that was biodegraded, consuming oxygen, nitrate, oxidized manganese, and oxidized iron in the process.

Chloride tracks similarly to nitrate in concentration profile. Both likely reflect anthropogenic inputs: nitrate from on-site septic systems and chloride from on-site

septic systems as well as road-salt application. Metcalf and Eddy (2003) report typical chloride concentrations in wastewater to be from 30 to 90 mg/L, which could explain the observed chloride concentration of 10 to 30 mg/L seen in most samples, but probably not the higher reading of 46.5 mg/L in PC-7. Road salt may be a more significant influence on this well than the others.

### Discharge to Adjacent Surface Water – Barnstable

The groundwater flow directions estimated from elevations at water table wells suggest flow towards Prince Cove and the Marstons Mill River salt marsh. Vertical gradients also suggest that at least the upper 43 feet of the saturated zone discharge upwards towards surface water. This coincides with the zone of highest nitrate concentration as well, which suggests the majority of nitrate-contaminated groundwater may eventually discharge to surface water. Some denitrification could be happening in the marsh deposits that border the Cove as suggested by the low nitrate concentration at PC-2 where organic deposits and corresponding low DO and nitrate-N were observed.

### Summary – Barnstable

In summary:

- Subsurface sediments encountered were medium to coarse sand underlain by fine to medium sands. A four-foot-thick layer of fine sand with silt and clay was also encountered at depth, which appears to impact vertical flow.
- A significant thickness of organic fine to medium sand thought to be marsh deposits was encountered at shallow depth at PC-2.
- Depth to groundwater is 3 to 10 ft. bgs.
- Vertical hydraulic gradients indicate upward flow potential to -30 ft. msl with both upward and downward gradients between deeper piezometers.
- Shallow groundwater likely discharges to the salt marsh and Prince Cove.
- Groundwater velocities are estimated at 1.5 to 4.5 ft/day.
- The highest nitrate-N concentration detected in a water table well was 2.5 mg/L at PC-6.
- Nitrate concentrations are greatest in the zone between -0 and -40 feet msl and drop off significantly below these elevations. In this zone concentrations of nitrate-N were detected between 1.4 and 2.3 mg/L.
- Low nitrate-N and reducing conditions were encountered below -40 ft. msl.
- Chloride follows a similar concentration profile to nitrate and is likely indicative of septic system influences.
- Nitrate concentrations are not as high near the water table than as at 10 to 40 feet below the water table, likely due to the introduction of uncontaminated rainfall recharge from the surface.
- At PC-2, marsh deposits were encountered in the subsurface and the concentration of nitrate-N at this well was 0.1 mg/L and evidence of reducing conditions (low DO and redox potential) are exhibited. These are similar to

conditions in a wetland setting and support the potential for denitrification to occur.

## Mashpee – Timber Landing Road

Wells installed for this ISC are TL-1, TL-2, TL-3, TL-4, TL-5, TL-6, and TL-7 and are screened across or just below the water table. The suffix on each of the ten piezometers installed for the ISC—TLZ-14 through TLZ-100—indicates the total depth of the well and each piezometer is completed with a one-foot screen at the bottom of the well. These piezometers were installed adjacent to water table well TL-4.

### Subsurface Sediments – Mashpee

Sediments encountered between the surface and about 45 feet bgs typically consisted of fine to medium or medium to coarse sand. Between 45 and 60 feet bgs sediments consisted of fine to medium sand with sections of fine sand and silt (51.9 to 58.5 ft. bgs). Between 60 feet bgs and the end of the core at 100 feet bgs, sediments typically consisted of fine to medium sand with minor gravel and cobbles. Sediments to about 20 feet bgs were consistently tan and orange. Between 20 and 51.9 feet both grey and tan/orange zones of sand were encountered, but transitioned to primarily grey colored sediment below 51.9 feet bgs.

### Summary of Water Level Data – Mashpee

Water table wells are located in seven locations along the woods road in the Timber Landing conservation area. Figure 10 shows the water level elevations at each well and an estimate of the water table surface and flow direction based on these measured levels and their relationship to the Mashpee River. Table 4 lists the measured water levels, water level elevations and horizontal and vertical gradients calculated for both rounds of water level measurements.

The depth to groundwater is between 4.7 and 27.1 feet bgs with much of this variation due to differing land-surface elevations. Elevation of the water table varies from 4.3 ft. msl at TL-7, the most upland well, to 1.2 ft. msl at TL-4, the well nearest the tidal inlet in the adjacent Mashpee River salt marsh. The apparent horizontal gradient is moderate (0.003) between TL-7 and TL-4 and between TL-2 and TL-4 (0.003). The surface topography and multiple small wetlands suggest complex water table elevation contours. The water table surface approximated for Figure 10 does not incorporate these complexities due to the limited water table data available. Estimated groundwater elevation contours (Figure 10) and groundwater flow directions show that groundwater flows from the uplands towards the low area at TL-6, TL-5, and TL-4. It is inferred that from there,

groundwater flows towards the tidal stream and salt marsh and to the Mashpee River beyond.

Based on this round of water level measurements, vertical gradients are upward between the shallowest piezometers, TLZ-31 and TLZ-22, i.e. from -18 ft. msl to -9.5 ft. msl and are flat or slightly downward at the water table. Gradients are downward for the next 30 feet of the section to -47 ft. msl then turn strongly upward from TLZ-70 to TLZ-60. The convergence of flow towards the elevation range between -47 ft. msl and -57 ft. msl indicates a likely preferential flow zone in the coarser sediments at TLZ-70 compared to the fine sand and silt encountered at from -39 to -46 ft. msl just above TLZ-60. Gradients vary between strongly upward, and strongly downward between the deepest piezometers TLZ-90 and TLZ-100 at an elevation of -87 ft. msl. These patterns likely reflect the localized presence of coarser sediments that create conditions of preferential flow.

### Estimated Groundwater Velocity – Mashpee

Groundwater velocities were estimated based on sediment characteristics identified within the screened interval of the water table wells and with the horizontal groundwater gradients measured during this round of water level measurement. Table 8 summarizes estimated velocities at all sites. The groundwater velocity was estimated at 3.0 ft/day between TL-7 and TL-4 and TL-2 to TL-4, as subsurface sediment characteristics and measured horizontal gradients between these two sets of wells are generally the same.

### Water Quality Data Summary – Mashpee

*Water Table Wells* - Field-measured and laboratory-analyzed constituents for this both rounds of sampling are listed in Table 11 for two-inch water table wells. Dissolved oxygen (DO) in mg/L and nitrate-N are highlighted in blue and green respectively for ease of table review. Figure 11 illustrates the concentration of selected water quality parameters at water table wells.

Laboratory-measured pH at water table wells ranged from 5.1 to 6.0 with one anomalously low pH of 3.6 at well TL-5 in Round 1. This pH was measured at 4.5 during Round 2 but another anomalously low pH of 3.0 at TL-6 suggests these low pH values may be valid. Field-measured pH at these two wells was 4.2 to 4.7 for both rounds.

Field-measured specific conductance was between 80 and 129 µS/cm. Field-measured DO varied significantly between wells with the highest DO at 8.41 mg/L in TL-7 and a low of 0.29 at TL-6. The high DO at TL-7 may have been partly due to the mechanical pumping method used for well purging during Round 1. During Round 2, the well was pumped with a submersible pump and DO was measured

using the flow cell with a resulting value of 5.03 mg/L. This is likely a more reliable value.

Nitrate varied significantly between wells with the lowest concentration at 0.021 mg/L at TL-6 and the highest level at 2.4 mg/L at TL-3 (Figure 11). Ammonia-N was detected at all wells at low concentrations as was nitrite-N. TKN (a combination of ammonia-N and organic N) was higher than ammonia-N concentrations at all wells. There appears to be a significant organic N fraction at TL-6 and TL-7. Dissolved iron and manganese were highest at TL-7 and lowest at TL-3. The high iron and manganese concentrations at TL-7 are inconsistent with the high DO concentration; further suggesting that concentration measurement was compromised by the mechanical sampling method in Round 1. During Round 2 when a submersible pump was used for purging, iron and manganese were significantly lower. Dissolved boron was highest at TL-4 at 0.0369 mg/L and lowest at TL-1 at 0.010 mg/L. Arsenic was below detection limits in all water table wells.

*Piezometer Cluster* - Results of two rounds of water quality sampling are listed in Table 12. Figures 12, 13, and 14 illustrate the concentrations of several key parameters with depth. Piezometer screen depths have been converted to elevation for these illustrations. Sample intervals begin just below sea level and extend to 87 ft. msl.

The lowest nitrate concentrations were found at TLZ-22 (9.5 ft. msl) with 0.052 mg/L and TLZ-100 with 0.027 mg/L. The greatest nitrate concentrations were detected at TLZ-31 (18.5 ft. msl) and TLZ-40 (27 ft. msl) with 2.1 mg/L and 2.7 mg/L, respectively. Nitrite-N and ammonia-N were generally very low and tentatively identified or below detection limits.

Laboratory-measured pH is between 5.5 and 7.2 and is lower in shallow piezometers. Specific conductance values were generally low at 83 to 186 µS/cm, peaking at TLZ-40 (-27 ft. msl) and generally decreasing with depth. As seen in Figure 12, dissolved oxygen is highest in piezometers TLZ-31, TLZ-40, and TLZ-90 in Round 1 sampling. For Round 2, DO is higher than round 1 in shallow piezometers. However the DO at TLZ-90 was lower at 0.8 mg/L but higher at TLZ-80 at 4.0 mg/L. DO drops below 1 mg/L at TLZ-100 (86.8 ft. msl). Dissolved organic carbon (DOC) and nitrate follow the same general pattern as dissolved oxygen.

Figure 13 shows that chloride increases with depth to a peak at -27 ft. msl (TLZ-40) and then generally decreases with depth. Sulfate is highest at -10 ft. msl but sulfate concentrations otherwise generally increase with depth. Dissolved iron concentrations are very low until TLZ-50 (-40 ft. msl) with the highest concentration at TL-90 at -77 ft. msl. Alkalinity generally trends higher with depth. As seen in Figure 14, dissolved boron is highest at -9.5 msl but remains lower at depth. Arsenic concentrations are below detection limits at all depths.

Overall, the water quality data appear to indicate anthropogenic influence in shallow groundwater above elevation -37 ft. msl. Elevated boron, orthophosphate, and sulfate at elevation -10 ft. msl, as well as near-zero dissolved iron suggest a zone influenced by nearby on-site wastewater disposal. Slightly deeper, elevated chloride, and elevated nitrate, total nitrogen, and dissolved organic carbon at -27 ft. msl also suggest anthropogenic influences from road salt and on-site wastewater disposal respectively.

### Discharge to Adjacent Surface Water – Mashpee

Groundwater discharge to local surface water is upward to an elevation of -18.5 ft. msl but trends to downward vertical flow to -57 ft. msl where it again turns upward. This suggests that the local flow system discharges towards the Mashpee River and adjacent marsh but intermediate and regional flow likely discharges farther downgradient. The upper zone of discharge coincides with the higher nitrate concentrations suggesting that locally anthropogenically influenced groundwater also discharges to local surface water bodies.

### Summary – Mashpee

In summary:

- Sediments encountered were primarily fine to medium and medium to coarse sand. A six-foot-thick zone of fine sand and silt was encountered between -39 and -47 ft. msl.
- The depth to water was between 5 and 27 ft. bgs depending on the topographic setting of the well.
- Vertical gradients suggest upward flow between -9.5 and -18 ft. msl and are variable below that depth.
- The estimated groundwater velocity is 3.0 ft/day.
- The highest nitrate-N concentration detected in the water table wells during this round was 2.4 mg/L at water table well TL-3.
- Nitrate-N concentrations are greatest in the zone between -18 and -27 ft. msl at concentrations of 2.1 and 2.7 mg/L respectively and are below 1 mg/L at all other depths. Reducing conditions were present where nitrate-N falls below 1 mg/L.
- Dissolved oxygen concentrations, dissolved organic carbon, and nitrate seem to track similarly with depth.
- Chloride concentrations increase with depth until reaching a peak at -27 ft. msl and then decline suggesting a near-surface anthropogenic source.
- Sulfate and alkalinity generally increase with depth to approximately -80 feet msl. Sulfate and boron have concentration peaks at -9.5 ft. msl.
- From these preliminary data, anthropogenic influences appear to impact water quality above an elevation of -37 ft. msl.

- Local discharge to the Mashpee River is suggested by vertical gradients and some denitrification may be occurring in shallow zones influenced by reducing conditions in adjacent wetlands (TL-6).
- Long groundwater residence times may be the largest influence on water chemistry below -37 ft. msl throughout the study depth.

### Falmouth – Sailfish Drive

Wells installed for this ISC are SF-1, SF-2, SF-3, SF-4, SF-5S, and SF-6 and are screened across or just below the water table. Well SF-5D was installed approximately 15 feet below the water table adjacent to SF-5S. In addition, a set of depth-nested piezometers was also installed adjacent to water table well SF-2. The deep continuous sediment core was also completed at SF-2.

The suffix on each of the nine piezometers installed for the ISC, SFZ-19 through SFZ-77, indicates the total depth of the well in feet. Each piezometer is completed with a one-foot screen at the bottom of the well. The well locations are shown on Figure 4. A detailed piezometer location map is included in Appendix B.

### Subsurface Sediments – Falmouth

Sediments encountered between the surface and 20-25 feet bgs (-3 to -6 ft. msl) typically consist of fine to medium or medium to coarse sand. A zone of silty fine to medium sand with some clay was encountered (16 feet thick at SF-2) immediately below this unit to -18 ft. msl. Sediments coarsened below silty sand and were described as fine to coarse sand with cobbles and fine gravel to 75 ft. bgs (-57 ft. msl). At the very bottom of the continuous core, a coarse sand and gravel was encountered that prevented further penetration by the Geoprobe rig. Sediments were generally tan to brown with orange and red oxidized zones composed of coarse sand to 40 ft. bgs. Below this sediments were grey but a red brown layer of fine to coarse sand was encountered at SF-2 from 61.9 to 63.4 ft. bgs (-43.5 to – 45 ft. msl). At SF-6, the upgradient well, organic inclusions were noted from 12 to 20 feet bgs.

### Water Level Data – Falmouth

Water table wells are located in five locations along Sailfish Drive and one location on Tarpon Drive. Figure 15 shows the water level elevations at each well on March 22, 2016 and provides an estimate of the water table surface elevation and flow direction based on these measured levels and their relationship to Bourne's Pond. Table 5 lists the measured depths to water, water level elevations, and horizontal and vertical gradients calculated for three rounds of water level measurements. Although there is currently no data available on how tide change may influence water levels at the Sailfish site, we did note that the tide was near high at the time of water level measurements on all three measurement dates.

The depth to groundwater is between 17 and 26 feet bgs. The apparent horizontal groundwater gradient is low and between SF-6 and SF-2 is estimated at 0.0013. Subsurface materials below the water table include a zone of silty sand with some clay near the water table at some wells, but fine to coarse sand was the predominant sediment type encountered throughout the study section.

Based on this round of water levels, vertical gradients between adjacent screens are nearly flat or downward between sea level and -15 feet msl, suggesting shallow recharge and horizontal discharge to Bourne's Pond. However, gradients are upward or strongly upward below this depth, consistent with predominately medium to coarse sand found below this zone. However, the May 2016 vertical gradients suggest downward flow between the mid-range piezometers. The presence of a lower permeability silty zone from sea level to about -25 feet msl, underlain by the more hydraulically conductive materials may contribute to the observed distribution of upward gradients. A downward gradient between adjacent piezometers was observed below -40 feet msl. A zone of coarse sand and gravel was encountered below -50 feet msl, which may also be a zone of preferential groundwater flow.

### Estimated Groundwater Velocity – Falmouth

Groundwater velocities were estimated based on sediment characteristics identified within the screened interval of the water table wells and with the horizontal groundwater gradients measured during sampling rounds. The estimated groundwater velocity is 1.4 feet/day in the shallow water table zone (Table 8). Sediments coarsen with depth suggesting increased velocity in lower zones. This combined with the measured positive gradients suggest local groundwater discharge from shallow and intermediate groundwater zones to nearby Bourne's Pond.

### Water Quality Data Summary – Falmouth

*Water Table Wells* - Field-measured and laboratory-analyzed constituents from the both rounds of sampling are listed in Table 13. Laboratory-measured pH at water table wells ranged from 4.7 to 6.4. Field-measured specific conductance (SC) was measured between 50.7 and 146 µS/cm. Field-measured DO varied between wells with the highest DO at 9.6 mg/L in SF-5D and a low of 3.32 mg/L at SF-2 in Round 1. Round 2 measurements recorded higher DO overall.

Figure 16 shows the concentration of selected constituents at water table wells. Nitrate-N varied between wells with the lowest concentration at 0.52 mg/L at SF-4 and the highest at 3.1 mg/L at SF-5D. Nitrate was also below 1 mg/L at SF-6 for both rounds. Nitrite-N was not detected at wells, but ammonia-N was detected at

several wells at low concentrations. DOC was found at relatively high concentrations especially at SF-4 where it exceeds 3 mg/L. Dissolved metals concentrations were low at water table wells and at Well SF-5D consistent with the aerobic conditions observed in all wells. Chloride concentrations are greatest at SF-1.

Well SF-4 reveals a different chemistry than the other wells, with significantly higher alkalinity, lower acidity, and the lowest level of nitrate and highest level of DOC of any of the wells. This pattern may point to higher levels of organic matter and greater levels of microbiological activity at this well. There is however nothing apparent with respect to the location of this well within the surrounding neighborhood (Figure 4) that would suggest it should be unusual.

*Piezometer Cluster* - Differences in constituent concentrations with depth at the piezometer cluster location are illustrated in Table 14 and Figures 17, 18 and 19. These small-diameter wells are located adjacent to SF-2. Laboratory-measured pH is between 4.7 (SF-26) and 7.8 (SF-77). The pH at the remaining piezometers is 5.4 to 5.7. Thus, all of the wells are acidic with the exception of the single deepest well. SC values are in the range of 103 at the shallowest piezometer to 314 µS/cm at the deepest piezometer. Dissolved oxygen is relatively high at all depths at 6.5 to 9 mg/L.

Figure 17 illustrates the concentrations of nitrate, dissolved organic carbon (DOC), dissolved iron, and dissolved oxygen versus the elevation of the piezometer screen. Groundwater sample elevations begin nearly at sea level (the elevation of the water table at this location is approximately 1.0 ft. msl) and extend to -60 ft. msl. Nitrate-N increases from 0.72 close to the water table to 8.9 mg/L just 7 feet below the water table. Nitrate-N concentrations then drop to 4.3 mg/L 14 feet below the water table and stay within the range of 1.7 to 3.0 to the bottom of the study depth as shown in this figure. DO concentrations also vary with depth but do not track nitrate concentrations exactly. DOC is at its highest concentration (1.3 mg/L) at the surface and drops to less than 1 mg/L below this depth. This is in contrast to the water table wells where DOC was as high as 3.0 mg/L.

Figures 18 and 19 illustrate variations in selected water quality constituents with depth. Note that concentration units in Figure 19 have been modified as noted from those reported in Table 14 in order to compare them on the same graph. Figures 19 and 20 reveal likely anthropogenic influence between elevations of roughly -5 feet msl and -40 feet msl. Several constituents are potentially related to anthropogenic influences. Nitrogen compounds and especially nitrate are associated with septic system discharges as are dissolved solids and chlorides. Chlorides are also introduced by road deicing.

Boron is found in many cleaning products and has been linked to septic system discharge in several studies (MPCA, 1999 and Burgess, 2008). Although dissolved

boron is found at low concentrations, it increases from 0.015 in the shallowest piezometer to 0.0425 before dropping back down to below 0.02 mg/L below -32 ft. msl. Thus the zone between roughly -5 and -30 ft. msl shows in situ boron with a signature of potential septic influence. Specific conductance is elevated at -8 feet msl and again at -27 and -32 feet msl (Figure 18), the latter overlapping a zone of elevated chloride between -22 and -39 feet msl. These various indicators point to anthropogenic influence on groundwater quality between about -5 feet msl and -40 feet msl, with the shallower portion likely influenced by more local sources and the deeper portion by more distance sources, however the relatively high DO and nitrate to the depth of investigation suggest manmade influence throughout the flow system.

Anomalously higher alkalinity is seen in the deepest piezometer with a concentration of 86.4 mg/L in contrast to concentrations less than 10 mg/L at other depths (Figure 19). The pH of 7.8 measured at this depth indicates slightly basic groundwater. This portion of the aquifer also exhibits weaker upward gradients (Table 5) suggesting lower rates of discharge to Bourne's Pond than the shallower depths. One possible explanation for this differing chemistry is that this is older and slower-moving groundwater with chemistry reflecting longer contact times between aquifer solids and groundwater and perhaps less affected by acid rain.

### Discharge to Adjacent Surface Water – Falmouth

Groundwater discharge to local surface water is suggested to an elevation of -39 ft. msl based on slightly downward gradients at shallowest depths and upward gradients above -40 ft. msl. This suggests that the local flow system discharges towards Bourne's Pond but intermediate and regional flow may discharge downgradient. On a portion of the nitrate impacted water discharges to Bourne's Pond with the remainder discharging further downgradient to adjacent ponds or the Nantucket Sound. Little or no salt marsh is present along the immediate shoreline but the tidal creek and marsh south of Sailfish Drive may provide some denitrification of local groundwater discharge to this surface water feature.

### Summary – Falmouth

In summary,

- Subsurface sediments are predominately fine to medium or medium to coarse sands with a unit of silty fine sand at depth. A coarse sand and gravel was encountered at the bottom of the study interval approximately 78 ft. bgs.
- The water table lies between 17 and 26 feet bgs.
- The horizontal groundwater gradient is low and groundwater velocity was estimated at 1.4 ft/day. The impact of tidal change on upland groundwater levels was not evaluated for this study. The water levels were measured at

or near high tide so horizontal gradients may differ somewhat at lower tide levels.

- Nitrate-N concentrations are significantly elevated within the first 20 feet of the saturated zone (up to 8.9 mg/L), and remain elevated between 1.7 and 3 mg/L to the full depth of investigation. No significant reducing zone was encountered.
- Anthropogenic influences are apparent in groundwater above an elevation of -40 feet msl but may alter groundwater quality to 77 ft. bgs based on DO and still elevated nitrate at this depth.
- Groundwater at approximately -60 feet msl shows distinctly different chemistry than the shallower water, perhaps a reflection of older, slower-moving groundwater at this depth.
- Shallow groundwater likely discharges to local surface water based on upward gradients above – 40 ft. msl but deeper zones likely discharge downgradient of the pond.

### Dennis – Vinland Drive

Wells installed for this ISC are VL-1, VL-2, VL-3, VL-4, VL-5, and VL-6 and are screened across or just below the water table. Six piezometers were also installed adjacent to VL-2 and parallel to Vinland Drive. The suffix on each of the piezometers installed for the ISC - VLZ-44 through VLZ-66 - indicates the total depth of the well in feet. Each piezometer is completed with a one-foot screen at the bottom of the well. The well locations are shown in Figure 5.

#### Subsurface Sediments – Dennis

Sediments encountered at the Vinland Road site are primarily made up of medium to coarse sand and silt and clay units. Gravel was noted in the shallow medium to coarse sand zones. A one-to-two-foot-thick zone of silty clay with some sand was encountered about 46 feet bgs corresponding to -3 to -7 ft. msl depending on boring location. Below this finer zone, banded medium to coarse sand continued to 66 feet where a substantial clay layer was encountered. The deep core was completed to 80 feet and clay was encountered from 66 to 80 ft. bgs. Sediment was generally grey with bands of red and red-orange oxidized zones. The clay was a medium to dark grey color, and increased in density with depth.

#### Summary of Water Level Data – Dennis

Water table wells are located at five locations along Vinland Drive and at one location on Thorwald Drive. Figure 20 shows the water level elevations at each well on March 31 and provides an estimate of the water table surface elevation and flow direction based on these measured levels and their relationship to Kelley's Bay. Groundwater flows generally northeast to southwest towards Kelley's Bay.

Table 6 lists the measured depths to water, water level elevations, and horizontal and vertical gradients calculated for both rounds of water level measurements. The depth to groundwater is between 35 to 41 feet bgs. The apparent horizontal groundwater gradient between VL-6 and VL-1 is estimated at 0.010.

Based on measured water levels, vertical gradients between adjacent screens are upward to elevation -11 ft. msl and are downward or flat between -11 and -21 ft. msl. This suggests discharge of groundwater towards Kelley's Bay through most of the study depth.

### Estimated Groundwater Velocity – Dennis

Groundwater velocities were estimated based on sediment characteristics identified within the screened interval of the water table wells and the horizontal groundwater gradients measured during water level measurement rounds. The estimated groundwater velocity is 9.0 ft. per day in the shallow water table zone. Sediments are generally medium to coarse sand throughout the study zone with a silt/clay lens at -4 to -6 ft. msl. Medium to coarse banded sands were encountered below this depth, which could suggest zones of preferential flow in the coarse sediment bands.

### Water Quality Data Summary – Dennis

*Water Table Wells* - Field-measured and laboratory-analyzed constituents for both rounds of sampling are listed in Table 15 for two-inch wells. DO in mg/L and nitrate-N is highlighted in blue and green respectively for ease of table review.

Laboratory-measured pH at water table wells ranged from 4.4 to 5.8. Field-measured specific conductance (SC) was measured between 165 and 303 µS/cm with the highest readings at VL-3 and VL-4. Field-measured DO was generally high, varying between 7.13 and 9.98 mg/L.

Figure 21 shows the concentrations of selected constituents at water table wells. . Nitrate-N was highest at VL-2, VL-3 and VL-4 at 4.4 to 6.2 mg/L with lower nitrate-N levels, 1.2 to 2.2 mg/L, at other water table wells. All levels are sufficiently elevated to be indicative of the presence of wastewater. Ammonia-N was detected at low concentrations at VL-3, VL-5 and VL-6 (ammonia-N was below detection limits at other water table wells) and nitrite-N was below detection limits at all wells. DOC concentrations were at or below 1 mg/L in all wells. Total Kjeldahl Nitrogen or TKN (the sum of organic nitrogen and ammonia nitrogen) was the highest at VL-4 and VL-6.

Dissolved iron was found to be moderately elevated at VL-3 at 6 mg/L in Round 1 but less than 1 mg/L at all other wells. Round 2 dissolved iron was below detection limits, which might indicate some, sampling inconsistencies. Sulfate concentrations were between 10 and 16 mg/L at all wells. Chloride is elevated in VL-2 and VL-4 compared to other wells with concentrations of 72.2 and 56.6 mg/L respectively.

*Piezometer Cluster* - Differences in constituent concentrations with depth at the piezometer cluster location are illustrated in Table 16 and Figures 22 through 24. These one-inch-diameter wells are located adjacent to VL-2. Laboratory-measured pH varies between 4.3 and 5.8 (Round 2) throughout the study depth. Specific conductance (SC) values are highest at the shallowest piezometer (381 µS/cm) and generally decline with depth. Dissolved oxygen concentrations are 4.2 to 7.2 mg/L with the lowest DO at VLZ-48 (-3.3 ft. msl). This piezometer is completed just above the shallow clay lens and appears slightly reduced based on redox potential.

Figure 22 illustrates the concentrations of nitrate, DOC, and DO versus the elevation of the piezometer screen. Groundwater sample elevations begin just above sea level (the elevation of the water table at this location is approximately 1 ft. msl) and extend to about -21 ft. msl. Nitrate-N concentrations are 2.4 to 4.3 mg/L with the highest concentrations at approximately 1, -7 and -11 ft. msl. DO concentrations vary similarly.

Chloride Figure 23 is highest (88.9 mg/L) in the shallowest piezometer at about 1 ft. msl, a pattern consistent with the measured SC. The shallowness of this elevated concentration suggests a nearby source—most likely road salt or possibly septic system influence. Total alkalinity and sulfate peak just below the surface at -3 ft. msl at VLZ-48.

Figure 24 illustrates the relationship between nitrate-N, dissolved iron, and dissolved manganese. The 5/6/16 dissolved iron data was used in this illustration due to possible problems with field filtration using the mechanical Waterra pump during round 1. As shown in Figure 24, the highest dissolved iron concentration (0.9 mg/L) is found at approximately -7 ft. msl and dissolved manganese (0.46 mg/L) is most elevated at about -3 ft. msl.

### Apparent groundwater discharge to surface water – Dennis

Groundwater discharge to Kelley's Bay is suggested to an elevation of -21 ft. msl based on upward gradients in this zone. A thin clay layer within the medium to coarse sand which predominates the shallow sediments is likely discontinuous and does not impede discharge. There is no boundary marsh at the water's edge in the immediate area of the site.

### Summary – Dennis

In summary:

- Subsurface materials are largely medium to coarse sands with a one-to-two-foot-thick intermediate clay lens. A substantial clay layer was detected at about 66 ft. bgs.
- The depth to groundwater was approximately 35 to 41 ft. bgs.
- The estimated groundwater velocity is 9.0 ft/day.
- Nitrate-N concentrations are found between 1.2 to 6.2 mg/L at water table wells.
- Nitrate-N concentrations at piezometers were between 2.4 to 4.3 mg/L with the greatest concentration at the shallow piezometer. No significant reducing zone was encountered.
- Elevated chloride and specific conductance in water table wells and the shallow piezometers suggests anthropogenic influences from road salt and/or septic systems.
- The shallow clay lens appears to act as a partial confining unit based on strong upward gradients between piezometers.
- Groundwater within the shallow zone studied (to approximately -21 ft. msl) appears to discharge to local surface water based on strong upward gradient potential. The shallow clay layer is likely discontinuous and does not prevent migration of nitrate to surface water. No boundary marsh is present at the water's edge at Kelley's Bay.
- The deeper clay encountered appears to bound anthropogenic influences to a 20-foot interval between the water table and the lower clay unit.

## Orleans – Lonnie's Pond

Wells installed for this ISC are LP-2, LP-3, LP-4, LP-5, and LP-6 and are screened across or just below the water table. Ten piezometers were also installed adjacent to LP-4 and next to each side of the town-landing road. The suffix on each of the piezometers installed for the ISC, LPZ-10 through LPZ-90, indicates the total depth of the well in feet. Because land-surface elevation varies between the piezometers, the relationship between depth and elevation varies somewhat from well to well. Each piezometer is completed with a one-foot screen at the bottom of the well.

### Subsurface Sediments – Orleans

Sediments encountered at the Lonnie's Pond site were silty fine to medium sands with zones of coarse sand and gravel and clay. Several zones of organic inclusions were also detected at several wells between elevation 15 and -9 ft. msl. Below -60 ft. msl a medium sand was also encountered which was present to the bottom of the

continuous core at 90 ft. bgs (-79 ft. msl). Sediments were generally light brown and tan in the shallow subsurface and transitioned to grey sediments below -28 ft. msl. Multiple zones of coarse orange and orange-red sand and gravel were also encountered above -28 ft. msl. Sediments encountered at LP-6, the upgradient well on Monument Road were generally coarser than those encountered adjacent to the pond.

### Summary of Water Level Data – Orleans

Water table wells are located in four locations along Herring Brook Way and at one location on Monument Road. Figure 25 shows the water level elevations at each well on March 31 and provides an estimate of the water table surface elevation and flow direction based on these measured levels and their relationship to Lonnie's Pond. An active cranberry bog occupies an area on the west side of Monument Road just upgradient from LP-6. Crystal Lake, a freshwater pond, lies just to the northwest of Lonnie's Pond.

Table 7 lists the measured depths to water, water level elevations, and horizontal and vertical gradients calculated for both rounds of water level measurements. The depth to groundwater was between 3 and 26 feet bgs. The apparent horizontal groundwater gradient between LP-6 and LP-4 is estimated at 0.013. The gradient is somewhat steeper between LP-2 and LP-3 at 0.036.

Based on measured water levels, vertical gradients between adjacent screens are strongly upward to elevation -17 ft. msl and between -42 and -27 ft. msl. Downward gradients were found between -27 and -17 ft. msl as well as between -49and -42 ft. msl with upward gradients between the deepest piezometers (-79 and -70 ft. msl).

### Estimated Groundwater Velocity - Orleans

Groundwater velocities were estimated based on sediment characteristics identified within the screened interval of the water table wells and the horizontal groundwater gradients measured during water level measurement rounds. The estimated groundwater velocity is 0.4 to 1.2 ft. per day in the shallow water table zone using the two gradients measured at the study site (Table 8). Sediments in the shallow zone are generally silty fine to medium sand with deeper clay lenses and a deep medium sand zone. Flow in this deeper zone may have a greater groundwater velocity than that of shallow more fine-grained sediments.

### Water Quality Data Summary – Orleans

*Water Table Wells* - Field-measured and laboratory-analyzed constituents are listed in Table 17 for two-inch wells. DO in mg/L and nitrate-N is highlighted in blue and green respectively for ease of table review.

Laboratory-measured pH at water table wells ranged from 5.6 to 6.0. Field-measured specific conductance (SC) was measured between 217 and 1572 µS/cm with the highest readings at LP-2 and LP-6. Field-measured DO was generally high, varying between 7.3 mg/L at LP-4 and 9.9 mg/L at LP-2, but with one exceptionally low measurement of 1.6 mg/L at LP-5.

Figure 26 shows the concentration of selected constituents at water table wells. Nitrate-N was generally low with the lowest concentration at 0.41 mg/L at LP-6 and the highest at 1.3 mg/L at LP-4 and LP-6. Nitrite-N was very low or not detected at wells, but ammonia-N was detected at three wells at low concentrations. Total Kjeldahl Nitrogen or TKN (the sum of organic nitrogen and ammonia nitrogen) was also low, with the highest concentration of 0.7 mg/L found at LP-2 and LP-3. Dissolved organic carbon (DOC) was also found at higher concentrations than observed at most of the other Cape Cod sites sampled in this program, especially at LP-2 and LP-5 at 3.4 and 2.5 mg/L respectively. Dissolved iron was found to be high at LP-2 but relatively low at other wells. Sulfate concentrations were highest at LP-3 and LP-4 between 10 and 16 mg/L.

*Piezometer Cluster* - Differences in constituent concentrations with depth at the piezometer cluster location are illustrated in Table 18 and Figures 27 through 30. These one-inch diameter wells are located adjacent to LP-4. Laboratory-measured pH varies between 5.4 and 6.6 throughout the section. SC values are at the lowest at the shallowest piezometer (149.7 µS/cm) and highest at 1021 µS/cm at LPZ-29 Dissolved oxygen dips below 1 mg/l at LPZ-39 and at the deepest piezometers – LPZ-71, -80, and -90.

Figure 27 illustrates the concentrations of nitrate, dissolved organic carbon (DOC), dissolved iron, and dissolved oxygen versus the elevation of the piezometer screen. Groundwater sample elevations begin just above sea level (the elevation of the water table at this location is approximately 4 ft. msl) and extend to about -90 ft. msl. Nitrate varies with depth, but is highest at elevations 1, -17, and -43 ft. msl. DO concentrations vary similarly and iron is also high at -43 ft. msl and between -61 and -79 ft. msl. Chloride and specific conductance are elevated at -17 ft. msl and shallower and at -43 ft. msl, pointing to anthropogenic influence. The shallowness suggests nearby sources.

The high dissolved iron concentration at -70 and -79 ft. msl coincides with low DO and low redox potential, as would be expected, as well as higher pH. The chemistry at this depth may reflect the fact that this is older water rather than having been influenced by anthropogenic factors. The high dissolved iron at -43 ft. msl is not consistent with DO or redox readings at that piezometer. However, specific conductance and chloride are also elevated at -43 ft. msl, suggesting this zone is influenced by upgradient anthropogenic sources. DOC is highest at the shallowest piezometer and then increases at -60 to -70 ft. msl.

Figure 28 shows the concentrations of sulfate, chloride, and alkalinity at the piezometer cluster. Like nitrate and DO shown in Figure 27, chloride is highest at -17 (307 mg/L) and -43 ft. msl (173 mg/L). Alkalinity is relatively low but peaks at -60 ft. msl in this section. Sulfate is found at a concentration of 14 mg/L or less throughout the section.

Figure 29 illustrates variations in dissolved manganese, SC, nitrate-N, and dissolved arsenic with depth. Note that concentration units have been modified for SC in order to compare SC on the same graph with the other constituents. Nitrate and SC track closely and manganese is elevated in lower piezometers in the section. Dissolved arsenic was below detection limits throughout most of the section but increases somewhat between -60 and -80 ft. msl. Redox potential (Figure 30) tracks inversely with dissolved iron, with generally oxidizing conditions noted above -50 ft. msl, but with somewhat lower potential at sea level and then again between -28 and -43 ft. msl. Reducing conditions are indicated below -50 ft. msl.

### Apparent groundwater discharge to surface water – Orleans

Groundwater discharge to Lonnie's Pond is suggested to an elevation of -17 ft. msl based on upward gradients in this zone. There is a narrow band of salt marsh at the water's edge along Lonnie's Pond in the immediate area of the site.

### Summary – Orleans

In summary,

- Subsurface sediments were composed of very silty fine to medium sands with zones of coarse sand and gravel and clay. A medium sand free of fines was encountered at depth.
- Organic sediments were encountered at LP-5 located at the lowest elevation and adjacent to the pond.
- Horizontal groundwater gradients were relatively high, but groundwater velocities were estimated between 0.4 and 1.2 ft/day.
- Nitrate-N concentrations are found below 2 mg/L in all wells, both in the spatially distributed water table wells and the depth-distributed piezometers.
- Reducing conditions were encountered in shallow zones and at depth.
- A significant reducing zone was encountered below -50 ft. msl and the geochemistry generally differs above and below this level.
- Higher concentrations of nitrate, chloride, and SC in zones between 1 and -17 ft. msl and around -43 ft. msl suggest anthropogenic sources and may represent a combination of road salt, septic system discharge, and possibly cranberry bog operational influences.
- The deeper water may be older water rather than having been altered by anthropogenic influences.

- Groundwater likely discharges to Lonnie's Pond, as suggested by upward gradients above -17 ft. msl. Some natural denitrification may occur where organic sediments are present in the subsurface. The boundary marsh at the water's edge is narrow but may contribute to local denitrification.

## Summary and Discussion of ISC Area-wide and Site Hydrogeologic Characteristics

Each study site presented a range of subsurface conditions and apparent influences on water quality and is summarized below. The field data collection and analysis completed for the initial site characterization provided adequate information for this initial assessment work and allowed for valuable comparison of site information to determine which sites could be suitable for pilot PRB studies. Table 20 provides a summary of site characteristics at the five ISC sites.

In general sediments were fine to coarse sands with intervals of finer materials. The western sites (Falmouth, Mashpee, and Barnstable) sediment characteristics and sequences were most similar. Greater thicknesses of finer materials were encountered in Dennis and Orleans. At Dennis a significant thickness of clay and silt was encountered beneath a shallow saturated zone of medium to coarse sand, bounding the site hydrologically. Orleans sediments were estimated to have the lowest hydraulic conductivity overall due to silt and clay in shallow sediments.

Water levels at the Barnstable, Mashpee, and Orleans sites were shallow compared to Falmouth and Dennis, with Dennis having the greatest depth to water. Highly oxidized zones of sand and gravel were encountered across all sites. These zones were often much coarser than the surrounding sediment. Organic sediments were encountered at several sites especially at shallow wells close to the edge of the nearby water bodies (Orleans, Barnstable, Falmouth). Estimated groundwater velocities were greatest at Dennis and lowest at Orleans.

The greatest concentrations of nitrate in wells completed for these investigations were at Dennis and Falmouth. However field testing of nitrate during boring advancement and testing of the piezometer clusters showed that the greatest concentrations of nitrate are at some locations well below the water table. Since many of the wells installed were shallow water table wells with short 5-foot screens, those wells may have missed some of the higher nitrate concentrations. Thus, the areal distribution of nitrate at some sites may be underestimated (Falmouth, Dennis, Barnstable). Even at wells where shallow reducing conditions have lowered nitrate concentrations, deeper zones may still contain elevated nitrate.

The greatest depth of investigation for the projects was 100 feet at Mashpee. ISCs at other sites were terminated at shallower depths due to difficult drilling conditions

for the Geoprobe (Falmouth) or significant thickness of low conductivity materials (Dennis). At Barnstable, Mashpee, and Orleans, reducing conditions coupled with low nitrate concentrations were encountered at depth, which helped to limit the depth of nitrate impacts. At Dennis the significant depth to water and the thick underlying clay unit limited nitrate impacts to a short depth interval below the water table. The thickness of zones affected by nitrate concentrations greater than 1 mg/L varied from approximately 20 feet at Mashpee and Dennis to over 60 feet at Falmouth. The saltwater/freshwater interface was not encountered at any of the five ISC sites.

At several wells where organic sediments were encountered close to the water table, nitrate concentrations were low compared to other shallow wells (Orleans, Barnstable, Falmouth). Many sites are adjacent to or flow towards bounding salt marshes. The reducing conditions typical at these marshes may provide some natural denitrification of groundwater discharge but may also force discharging groundwater horizontally beneath finer marsh sediments towards the coves/ponds where there are sediments with higher hydraulic conductivity.

**Table 20 – Summary of ISC Site Characteristics, Cape Cod, Massachusetts**

| Characteristic | Barnstable - Prince Cove | Mashpee - Timber Landing | Falmouth - Sailfish Drive | Dennis - Vinland Drive | Orleans - Lonnie's Pond |
|---|---|---|---|---|---|
| Depth to Water (ft. bgs) | 3 to 10 | 5 to 27 | 17 to 26 | 35 to 41 | 3 to 26 |
| Estimated hydraulic Conductivity of nitrate-bearing zones (ft/day) | 40 to 300 | 250 | 250 | 300 | 10 |
| Confining zones (ft bls) | 57-61 | none | none | 48-51 and 66 to? | multiple |
| Estimated groundwater velocity (ft/day) | 1.5 to 4.5 | 3 | 1.4 | 9 | 0.4 to 1.2 |
| Highest nitrate-N concentration measured during ISC study (mg/L) | 2.5 | 2.7 | 8.9 | 6.2 | 1.8 |
| Shallow reducing zones? | Yes | Yes | No | No | Yes |
| Reducing zones at depth in study interval | Yes | No | No | No | Yes |
| Interval of nitrate-N greater than 1.0 mg/L (feet) | 42 | 20 | 64 | 22 | 30 |

# Estimates of Mass Flux of Nitrate-Nitrogen

## Introduction

Appendix E includes the spreadsheets used to estimate the mass flux of nitrate at each of the ISC sites. The method of mass flux estimation is described in a previous section. The study interval was divided first into multiple water quality intervals each of which was assigned the nitrate concentration from the corresponding piezometer. Where more than one stratigraphic unit was encountered in the water quality interval, it was further subdivided to represent differing K values. The estimated K values for the saturated study intervals are included in Appendix E.

For all sites, the sediment characteristics observed in the deep continuous core, Round 1 horizontal hydraulic gradients, and Round 1 nitrate concentrations measured at the piezometers were used to estimate flux.

Specific site considerations are described in the following sections. A summary table of calculated mass fluxes is presented in Table 21.

**Table 21 – Estimated Mass Flux of Nitrate-N at ISC Sites**

| ISC site/Scenario | Total saturated thickness (feet) | $NO_3$-N flux over total depth (grams/day/m) | Treatment zone saturated thickness* (feet) | NO3-N flux over treatment zone (grams/day/m) |
|---|---|---|---|---|
| **Barnstable - A** | 80.6 | 34.6 | 45.1 | 26.8 |
| **Barnstable - B** | 80.6 | 8.2 | 45.1 | 7.5 |
| **Mashpee** | 88.2 | 6.6 | 18 | 4.2 |
| **Falmouth** | 59.6 | 5.6 | 55 | 5.5 |
| **Dennis** | 23.9 | 19.4 | 23.9 | 19.4 |
| **Orleans** | 82 | 8.3 | 57.5 | 7.4 |

* Treatment zone - Zone where adjacent water quality interval $NO_3$-N concentration greater than or equal to 1.0 mg/L

### Barnstable – Prince Cove

Fluxes of Nitrate-N at the Prince Avenue site in Barnstable were estimated using two different scenarios corresponding to the two horizontal hydraulic gradients estimated at the site: 0.011 and 0.003. At Barnstable the greatest mass flux appears to be at the PC-43 and PC-50 depth intervals where K was assigned the value 350 ft/day and the nitrate-N concentration is 2.3 mg/L. Using the gradient of 0.011 estimated in the PC-2 to PC-1 area, the mass flux is 34.6 g/day over the entire saturated thickness of 80.6 feet. The interval where concentrations in adjacent piezometers exceed 1 mg/L is considered the likely treatment zone. At Barnstable this zone is 45.6 feet thick. The mass flux in this zone with the 0.011 gradient is estimated at 26.8 g/day. Using the gentler gradient measured between PC-7 and PC-4, 0.003, the corresponding mass flux is calculated at 8.3 g/day (total saturated thickness), and 7.5 g/day over the treatment depth.

### Mashpee – Timber Landing Road

At Mashpee, the gradient was measured at different locations on the groundwater flow map but resulted in the same gradient of 0.003. The greatest mass flux is in the interval between 26.5 and 44.5 ft. bgs. Another interval in which nitrate is 1 mg/L or greater is the 74.5 to 84.5 ft. bgs water quality interval. It is assumed that a treatment scheme would likely concentrate on the shallower zone, so the treatment interval calculated is 18 feet thick with a nitrate-N mass flux of 4.3 g/day. If the entire depth is considered (88.5 feet), nitrate-N mass flux totals 6.5 g/day.

### Falmouth – Sailfish Drive

At Sailfish Drive, the treatment zone is estimated to extend from the water table to 55 feet below. The nitrate-nitrogen concentration falls below 1 mg/L only at the shallow piezometer and remains greater than 1 mg/L to the depth of investigation of 77 feet. The zones of greatest contribution to mass flux are at 26 feet bgs and 67 feet bgs. Due to the low gradient, the treatment zone mass flux and the total mass flux of nitrate-N are calculated as being fairly low at 5.5 and 5.6 g/day respectively.

### Dennis – Vinland Drive

The Vinland Drive site has a relatively thin treatment zone of 23.9 feet. The depth to groundwater is nearly 40 feet and the thick clay unit at 66 ft bgs that underlies the medium to coarse sand at the site bounds the treatment zone to this depth. Additionally, nitrate-N is greater than 1 mg/L throughout the saturated zone, the

hydraulic gradient is fairly high, and the hydraulic conductivity of the saturated zone is also high. This results in a mass flux of nitrate-N in the treatment and saturated zone over the study depth of 19.4 g/day.

### Orleans – Lonnie's Pond

The proposed site on Herring Brook Way near Lonnie's Pond is unique in that several piezometers installed at the location of the continuous core had nitrate-N concentrations that were lower than 1 mg/L within the larger zone of elevated nitrate. At this location then, the treatment zone thickness was 57.5 feet. The total saturated zone over the study depth is 82 feet. The greatest mass flux contribution occurs over the LPZ-29 interval. The total treatment zone nitrate-N mass flux is calculated at 7.4 g/day and over the saturated interval the mass flux is estimated at 8.3 g/day.

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CAPE COD PERMEABLE REACTIVE BARRIER
INITIAL HYDROGEOLOGIC SITE CHARACTERIZATION RESULTS AND EVALUATION OF SITE SUITABILITY FOR PERMEABLE REACTIVE BARRIER INSTALLATION

# Report Tables

## Tables included in this section:
## (All other tables within body of report)

| Table 3 - Water Levels and Hydraulic Gradients - PRB ISC Site - Barnstable, MA | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Well | Top of PVC Casing (ft msl) | Depth to Water (ft) 3/7/16 | Water Surface Elevation (ft msl) 3/7/16 | Horizontal Gradients 3/7/16 | | Depth to Water (ft) 4/18/16 | Water Surface Elevation (ft msl) 4/18/16 | Horizontal Gradients 4/18/16 | |
| PC-1 | 11.63 | 9.62 | 2.01 | **PC-2 to PC-1** | | 9.00 | 2.63 | **PC-2 to PC-1** | |
| PC-2 | 7.12 | 2.83 | 4.29 | 0.011 | | 2.52 | 4.60 | 0.009 | |
| PC-4 | 12.46 | 8.80 | 3.66 | | | 8.56 | 3.90 | | |
| PC-6 | 10.87 | 5.32 | 5.55 | **PC-7 to PC-6** | | 5.10 | 5.77 | **PC-7 to PC-6** | |
| PC-7 | 12.98 | 6.18 | 6.80 | 0.003 | | 5.86 | 7.12 | 0.003 | |
| | | | | **Vertical Gradients between adjacent screens** | | | | **Vertical Gradients between adjacent screens** | |
| PCZ-13 | 12.04 | 8.38 | 3.66 | | | 8.35 | 3.69 | | |
| PCZ-23 | 12.05 | 8.38 | 3.67 | 0.001 | slightly upward | 8.31 | 3.74 | 0.005 | slightly upward |
| PCZ-30 | 12.23 | 7.82 | 4.41 | 0.106 | strongly upward | 7.89 | 4.34 | 0.086 | strongly upward |
| PCZ-35 | 12.23 | 7.74 | 4.49 | 0.016 | upward | 7.81 | 4.42 | 0.016 | upward |
| PCZ-43 | 12.33 | 7.43 | 4.90 | 0.051 | strongly upward | 7.50 | 4.83 | 0.051 | strongly upward |
| PCZ-50 | 12.62 | 7.91 | 4.71 | -0.027 | downward | 8.45 | 4.17 | -0.094 | strongly downward |
| PCZ-60 | 12.63 | 7.82 | 4.81 | 0.010 | slightly upward | 7.98 | 4.65 | 0.048 | upward |
| PCZ-70 | 12.50 | 8.69 | 3.81 | -0.100 | strongly downward | 7.75 | 4.75 | 0.010 | upward |
| PCZ-80 | 12.31 | 9.02 | 3.29 | -0.052 | strongly downward | 8.74 | 3.57 | -0.118 | strong downward |
| PCZ-88.5 | 12.26 | 8.82 | 3.44 | 0.018 | upward | 8.75 | 3.51 | -0.007 | slightly downward |

elevated nitrate zone

**Vertical gradient rankings**
0.05 or greater - strongly upward
0.009 to 0.049- upward
less than 0.009 - slightly upward

-0.05 or greater - strongly downward
-0.009 to 0.049- downward
less than- 0.009 - slightly downward

| Table 4- Water Levels and Hydraulic Gradients - PRB ISC Site - Mashpee, MA | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Well | Top of PVC Casing (ft msl)* | Depth to Water (ft) 3/14/16 | Water Surface Elevation (ft msl) 3/14/16 | Horizontal Gradients 3/14/16 | | Depth to Water (ft) 4/28/16 | Water Surface Elevation (ft msl) 4/28/16 | Horizontal Gradients 4/28/16 | |
| TL-1 | 19.27 | 17.00 | 2.27 | **TL-7 to TL-4** | | 16.38 | 2.89 | **TL-7 to TL-4** | |
| TL-2 | 25.17 | 22.65 | 2.52 | 0.003 | | 22.12 | 3.05 | 0.003 | |
| TL-3 | 10.96 | 9.11 | 1.85 | | | 8.95 | 2.01 | | |
| TL-4 | 12.43 | 11.26 | 1.17 | **TL-2 to TL-4** | | 11.23 | 1.20 | **TL-2 to TL-4** | |
| TL-5 | 13.64 | 12.41 | 1.23 | 0.003 | | 12.33 | 1.31 | 0.005 | |
| TL-6 | 6.23 | 4.66 | 1.57 | | | 4.80 | 1.43 | | |
| TL-7 | 31.33 | 27.07 | 4.26 | | | 26.80 | 4.53 | | |
| | | | | **Vertical Gradients between adjacent screens** | | | | **Vertical Gradients between adjacent screens** | |
| TLZ-14 | 12.57 | 11.41 | 1.16 | | | 11.35 | 1.22 | | |
| TLZ-22 | 12.38 | 11.21 | 1.17 | 0.001 | flat | 11.22 | 1.16 | -0.007 | slightly downward |
| TLZ-31 | 12.36 | 11.15 | 1.21 | 0.004 | upward | 11.17 | 1.19 | 0.003 | slightly upward |
| TLZ-40 | 12.51 | 11.35 | 1.16 | -0.006 | slightly downward | 11.36 | 1.15 | -0.004 | slightly downward |
| TLZ-50 | 12.64 | 11.72 | 0.92 | -0.024 | downward | 11.57 | 1.07 | -0.008 | slightly downward |
| TLZ-60 | 12.94 | 12.19 | 0.75 | -0.017 | downward | 11.91 | 1.03 | -0.004 | slightly downward |
| TLZ-70 | 13.10 | 9.77 | 3.33 | 0.258 | strongly upward | 8.79 | 4.31 | 0.328 | strongly upward |
| TLZ-80 | 13.25 | 9.57 | 3.68 | 0.035 | upward | 9.03 | 4.22 | -0.009 | slightly downward |
| TLZ-90 | 13.47 | 9.97 | 3.50 | -0.018 | downward | 9.05 | 4.42 | 0.020 | upward |
| TLZ-100 | 13.31 | 9.40 | 3.91 | 0.041 | upward | 9.00 | 4.31 | -0.011 | downward |

elevated nitrate zone

* Surveyed by CEI, benchmark elevation based on Cape Cod Commission two-foot elevation contours for the project area.

**Vertical gradient rankings**
0.05 or greater - strongly upward
0.009 to 0.049- upward
less than 0.009 - slightly upward

-0.05 or greater - strongly downward
-0.009 to 0.049- downward
less than- 0.009 - slightly downward

**Table 5 - Water Levels and Hydraulic Gradients - PRB ISC Site - Falmouth, MA (Sailfish Drive)**

| Well | Top of PVC Casing (ft. msl) | Depth to Water (ft) 3/22/16 | Water Surface Elevation (ft msl) 3/22/16 | Horizontal Gradients 3/22/16 | | Depth to Water (ft) 4/6/16 | Water Surface Elevation (ft msl) 4/6/16 | Horizontal Gradients 4/6/16 | | Depth to Water (ft) 5/5/16 | Water Surface Elevation (ft msl) 5/5/16 | Horizontal Gradients 5/5/16 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SF-1 | 19.32 | 18.24 | 1.08 | **SF-6 to SF-2** | | 18.42 | 0.90 | **SF-6 to SF-2** | | 18.01 | 1.31 | **SF-6 to SF-2** | |
| SF-2 | 17.84 | 16.83 | 1.01 | 0.0014 | | 17.01 | 0.83 | 0.0013 | | 16.55 | 1.29 | 0.0010 | |
| SF-3 | 23.62 | 22.52 | 1.10 | | | 22.70 | 0.92 | | | 22.17 | 1.45 | | |
| SF-4 | 23.04 | 21.75 | 1.29 | | | 21.94 | 1.1 | | | 21.46 | 1.58 | | |
| SF-5S | 26.11 | 24.60 | 1.51 | | | 24.82 | 1.29 | | | 24.38 | 1.73 | | |
| SF-5D | 26.42 | 24.98 | 1.44 | | | 25.22 | 1.2 | | | 24.75 | 1.67 | | |
| SF-6 | 26.97 | 25.43 | 1.54 | | | 25.65 | 1.32 | | | 25.31 | 1.66 | | |
| | | | | **Vertical Gradients between adjacent screens** | | | | **Vertical Gradients between adjacent screens** | | | | **Vertical Gradients between adjacent screens** | |
| SFZ-19 | 18.50 | 17.52 | 0.98 | | | 17.71 | 0.79 | | | 17.15 | 1.35 | | |
| SFZ-26 | 18.39 | 17.4 | 0.99 | 0.001 | slightly upward | 17.61 | 0.78 | -0.001 | slightly downward | 17.05 | 1.34 | -0.001 | slightly downward |
| SFZ-33 | 18.26 | 17.29 | 0.97 | -0.003 | slightly downward | 17.67 | 0.59 | -0.027 | downward | 16.92 | 1.34 | 0.000 | flat |
| SFZ-40 | 18.19 | 17.19 | 1.00 | 0.004 | slightly upward | 17.23 | 0.96 | 0.053 | strongly upward | 16.96 | 1.23 | -0.016 | downward |
| SFZ-45 | 18.10 | 17.09 | 1.01 | 0.002 | slightly upward | 17.12 | 0.98 | 0.004 | slightly upward | 16.93 | 1.17 | -0.012 | downward |
| SFZ-50 | 18.04 | 16.98 | 1.06 | 0.010 | upward | 17.06 | 0.98 | 0.000 | flat | 16.60 | 1.44 | 0.054 | strongly upward |
| SFZ-57 | 18.05 | 17.02 | 1.03 | 0.007 | slightly upward | 17.05 | 1 | 0.000 | flat | 16.59 | 1.46 | 0.039 | upward |
| SFZ-67 | 18.07 | 17.05 | 1.02 | -0.001 | slightly downward | 17.12 | 0.95 | -0.005 | slightly downward | 16.59 | 1.48 | 0.002 | slightly upward |
| SFZ-77 | 17.95 | 18.42 | -0.47 | -0.149 | strongly downward | 17.01 | 0.94 | -0.001 | slightly downward | 16.50 | 1.45 | -0.003 | slightly downward |

elevated nitrate zone

**Vertical gradient rankings**
0.05 or greater - strongly upward
0.009 to 0.049- upward
less than 0.009 - slightly upward

-0.05 or greater - strongly downward
-0.009 to 0.049- downward
less than- 0.009 - slightly downward

| Table 6 - Water Levels and Hydraulic Gradients - PRB ISC Site - Dennis, MA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Well** | **Top of PVC Casing (ft msl)** | **Depth to Water (ft) 3/31/16** | **Water Surface Elevation (ft msl) 3/31/16** | **Horizontal Gradient 3/31/16** | | **Depth to Water (ft) 5/6/16** | **Water Surface Elevation (ft msl) 5/6/16** | **Horizontal Gradient 5/6/16** | |
| VL-1 | 40.03 | 36.48 | 3.55 | | | 33.98 | 6.05 | | |
| VL-2 | 44.68 | 40.40 | 4.28 | **VL-6 to VL-3** | | 40.05 | 4.63 | **VL-6 to VL-3** | |
| VL-3 | 44.01 | 39.77 | 4.24 | 0.010 | | 39.38 | 4.63 | 0.010 | |
| VL-4 | 43.16 | 38.86 | 4.30 | | | 38.40 | 4.76 | | |
| VL-5 | 40.22 | 35.40 | 4.82 | | | 34.98 | 5.24 | | |
| VL-6 | 43.41 | 35.82 | 7.59 | | | 35.33 | 8.08 | | |
| | | | | **Vertical gradient between adjacent screens** | | | | **Vertical gradient between adjacent screens** | |
| VLZ-44 | 44.70 | 40.40 | 4.30 | | | 40.02 | 4.68 | | |
| VLZ-48 | 44.71 | 40.35 | 4.36 | 0.015 | upward | 40.03 | 4.68 | 0 | flat |
| VLZ-52 | 44.67 | 37.81 | 6.86 | 0.625 | strongly upward | 37.27 | 7.40 | 0.68 | strongly upward |
| VLZ-56 | 44.63 | 37.64 | 6.99 | 0.0325 | upward | 37.12 | 7.51 | 0.0275 | upward |
| VLZ-61 | 44.62 | 37.72 | 6.90 | 0 | flat | 37.12 | 7.50 | -0.004 | slightly downward |
| VLZ-66 | 44.72 | 37.82 | 6.90 | 0 | flat | 37.24 | 7.48 | -0.004 | slightly downward |

elevated nitrate zone

**Vertical gradient rankings**

0.05 or greater - strongly upward
0.009 to 0.049- upward
less than 0.009 - slightly upward

-0.05 or greater - strongly downward
-0.009 to 0.049- downward
less than- 0.009 - slightly downward

| Table 7 - Water Levels and Hydraulic Gradients - PRB ISC Site - Orleans, MA | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Well** | **Top of PVC Casing (ft msl) *** | **Depth to Water (ft) 3/31/16** | **Water Surface Elevation (ft msl) 3/31/16** | **Horizontal Gradients 3/31/16** | | **Depth to Water (ft) 5/9/16** | **Water Surface Elevation (ft msl) 5/9/16** | **Horizontal Gradients 5/9/16** | |
| LP-2 | 22.13 | 14.42 | 7.71 | **LP-2 to LP-3** | | 14.11 | 8.02 | **LP-2 to LP-3** | |
| LP-3 | 15.08 | 11.64 | 3.44 | 0.036 | | 11.33 | 3.75 | 0.036 | |
| LP-4 | 11.09 | 7.49 | 3.60 | | | 7.19 | 3.90 | | |
| LP-5 | 8.00 | 2.97 | 5.03 | **LP-6 to LP-4** | | 3.13 | 4.87 | **LP-6 to LP-4** | |
| LP-6 | 32.05 | 25.70 | 6.35 | 0.013 | | 25.22 | 6.83 | 0.013 | |
| | | | | **Vertical Gradients between adjacent screens** | | | | **Vertical Gradients between adjacent screens** | |
| LPZ-10 | 11.27 | 7.51 | 3.76 | | | 8.90 | 2.37 | | |
| LPZ-15 | 11.49 | 7.35 | 4.14 | 0.076 | strongly upward | 7.35 | 4.14 | 0.354 | strongly upward |
| LPZ-21 | 11.59 | 7.12 | 4.47 | 0.055 | strongly upward | 7.10 | 4.49 | 0.058 | strongly upward |
| LPZ-29 | 11.61 | 6.63 | 4.98 | 0.064 | strongly upward | 6.51 | 5.10 | 0.076 | strongly upward |
| LPZ-39 | 11.57 | 8.02 | 3.55 | -0.143 | strongly downward | 8.91 | 2.66 | -0.244 | strongly downward |
| LPZ-53 | 9.87 | 4.62 | 5.25 | 0.121 | strongly upward | 4.55 | 5.32 | 0.190 | strongly upward |
| LPZ-61 | 9.99 | 6.10 | 3.89 | -0.170 | strongly downward | 6.15 | 3.84 | -0.185 | upward |
| LPZ-71 | 9.90 | 4.40 | 5.50 | 0.161 | strongly upward | 4.00 | 5.90 | 0.206 | strongly upward |
| LPZ-80 | 9.95 | 4.35 | 5.60 | 0.011 | upward | 3.85 | 6.10 | 0.022 | upward |
| LPZ-90 | 10.92 | 5.28 | 5.64 | 0.004 | slightly upward | 4.68 | 6.24 | 0.014 | upward |

elevated nitrate zone

* Surveyed by CEI, benchmark elevation based on Cape Cod Commission two-foot elevation contours for the project area.

**Vertical gradient rankings**
0.05 or greater - strongly upward
0.009 to 0.049- upward
less than 0.009 - slightly upward

-0.05 or greater - strongly downward
-0.009 to 0.049- downward
less than- 0.009 - slightly downward

**Table 9 - Measured Water Quality Concentrations for Barnstable - Prince Cove ISC site Water Table Wells**

| Sample ID/Location | PC-1 | | | | PC-2 | | | | PC-4 | | | | PC-6 | | | | PC-7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/8/20 | | 4/19/20 | | 3/8/20 | | 4/19/20 | | 3/8/20 | | 4/19/20 | | 3/9/20 | | 4/19/20 | | 3/9/20 | | 4/19/20 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 5.71 | | 5.47 | | 5.46 | | 5.07 | | 4.97 | R | 5.53 | | 5.67 | | 5.54 | | 4.3 | R | 5.50 | |
| Tempurature (°C) | 9.7 | | 10.9 | | 7.6 | | 9.4 | | 9.5 | | 10.6 | | 9.1 | | 9.7 | | 8.8 | | 9.2 | |
| Dissolved Oxygen(DO; mg/L) | 1.69 | | 4.11 | | 0.75 | | 4.14 | | 5.43 | | 5.84 | | 3.93 | | 5.76 | | 8.14 | | 8.76 | |
| Specific Conductance (uS/cm) | 110 | | 113.8 | | 128 | | 149.5 | | 117 | | 109.9 | | 142 | | 150.1 | | 263 | | 238 | |
| Redox Potential (ORP; mV) | 123.5 | | 216.2 | | 22 | | 135.6 | | -121.1 | R | 211.1 | | 160.3 | | 218.2 | | -80.6 | R | 251.3 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 6.0 | | 6.1 | | 5.5 | | 5.5 | | 6.0 | | 6 | | 5.7 | | 5.9 | | 5.7 | | 6 | |
| Nitrate as N (mg/L) | 0.64 | | 0.97 | | 0.1 | | 0.086 | J | 1.4 | | 1.6 | | 2.5 | | 2.6 | | 1.7 | | 1.8 | |
| Nitrite as N (mg/L) | <0.001 | | <0.010 | | 0.010 | J | <0.05 | E | <0.001 | | <0.05 | | 0.012 | J | <0.010 | | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | 0.067 | J | 0.03 | J | <0.021 | | 0.045 | J,E | <0.021 | | 0.04 | J | 0.043 | J | <0.075 | | 0.045 | J | <0.028 | |
| Total Kjeidahl Nitrogen (TKN) (mg/L) | 0.16 | J | 0.123 | J | 0.423 | | 0.127 | J,E | <0.093 | | 0.089 | J | 0.230 | J | <0.3 | | 0.151 | J | <0.066 | |
| Total Nitrogen (mg/L) | 0.64 | | 0.97 | | 0.52 | | <0.30 | | 1.4 | | 1.6 | | 2.5 | | 2.6 | | 1.7 | | 1.8 | |
| Orthophosphate (mg/L) | 0.002 | J | <0.001 | | 0.003 | J | <0.001 | | 0.009 | | 0.005 | | 0.004 | J | <0.001 | | 0.006 | | <0.001 | |
| Total Alkalinity (mg CaCO3/L) | 10.6 | | 9.9 | | 3.4 | | 3.7 | | 8.40 | | 8.8 | | 8.6 | | 8.6 | | 14.4 | | 13.8 | |
| Chloride (mg/L) | 23.4 | | 20.5 | | 28.7 | | 32.2 | | 20.2 | | 19.2 | | 20.6 | | 28.9 | | 46.5 | | 51.8 | |
| Sulfate (mg/L) | 10.7 | | 7.66 | | 16.1 | | 16 | | 8.38 | | 8.8 | | 10.1 | | 10.7 | | 8.52 | | 8.92 | |
| Dissolved Iron (mg/L) | 0.075 | | <0.020 | | 1.3 | | 0.89 | E | <0.020 | | <0.20 | | 0.15 | | <0.020 | | <0.020 | | <0.020 | |
| Dissolved Manganese (mg/L) | 0.075 | | 0.0331 | | 0.133 | | 0.138 | | 0.0151 | | 0.0106 | | 0.0135 | | 0.0155 | | 0.248 | | 0.0294 | |
| Dissolved Boron (mg/L) | 0.0446 | | 0.0464 | | 0.0175 | J | 0.0162 | J | 0.0207 | J | 0.0256 | J | 0.0159 | J | 0.0194 | J | 0.018 | J | 0.0156 | J |
| Dissovled Arsenic (mg/L) | 0.0022 | J | <0.0020 | | <0.0020 | | <0.0020 | | 0.0026 | J | <0.0020 | | 0.0027 | J | <0.0020 | | <0.0020 | | 0.0023 | J |
| Dissovled Organic Carbon (mg/L) | 1.2 | | 1.3 | | 1.6 | | 1.2 | | 1 | | 0.77 | J | 0.9 | J | 0.7 | J | 2.2 | | 0.77 | J |

Notes:

J - Data indicates a presence of a compound thatmeets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shading indicates data that should not be relied upon due to QA/QC concerns

**Table 10 - Measured Water Quality Concentrations for Barnstable - Prince Cove ISC Site - Piezometer Groundwater Data**

| Sample ID/Location | PCZ-13 | | | | PCZ-23 | | | | PCZ-30 | | | | PCZ-35 | | | | PCZ-43 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/9/20 | | 4/19/20 | | 3/9/20 | | 4/19/20 | | 3/9/20 | | 4/19/20 | | 3/9/20 | | 4/19/20 | | 3/8/20 | | 4/20/20 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 4.89 | R | 5.49 | | 4.98 | R | 5.48 | | 4.76 | R | 5.43 | | 4.17 | R | 5.49 | | 5.42 | R | 5.50 | |
| Tempurature (°C) | 9.99 | | 10.3 | | 10.47 | | 10.5 | | 10.4 | | 10.4 | | 10.27 | | 10.3 | | 10 | | 10.4 | |
| Dissolved Oxygen(DO; mg/L) | 7.95 | | 9.72 | | 6.26 | | 6.70 | | 6.63 | | 7.92 | | 6.35 | | 7.38 | | 7.71 | | 7.28 | |
| Specific Conductance (uS/cm) | 98 | | 85.4 | | 125 | | 111.6 | | 124 | | 113.3 | | 125 | | 110.2 | | 123 | | 112.3 | |
| Redox Potential (ORP; mV) | -111.3 | R | 253.4 | | -147.9 | R | 258.4 | | -130.8 | R | 249.7 | | -94.8 | R | 258 | | -120 | R | 207.8 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 5.8 | | 5.9 | | 5.8 | | 5.8 | | 5.8 | | 5.8 | | 5.7 | | 5.8 | | 6.1 | | 5.8 | |
| Nitrate as N (mg/L) | 1.4 | | 1.3 | | 2.3 | | 2.4 | | 2.2 | | 2.2 | | 2.3 | | 2.4 | | 2.3 | | 2.6 | |
| Nitrite as N (mg/L) | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | 0.022 | J | <0.028 | | 0.061 | J,E | <0.028 | | 0.066 | J | <0.028 | | <0.021 | | 0.066 | J | 0.025 | J | <0.028 | |
| Total Kjeidahl Nitrogen (TKN) (mg/L) | 0.170 | J | 0.131 | J | 0.127 | J | 0.076 | J | 0.142 | J | <0.066 | | 0.113 | J | <0.066 | | 0.095 | J | <0.066 | |
| Total Nitrogen (mg/L) | 1.4 | | 1.3 | | 2.3 | | 2.4 | | 2.2 | | 2.2 | | 2.3 | | 2.4 | | 2.3 | E | 2.6 | |
| Orthophosphate (mg/L) | 0.013 | | 0.013 | | 0.012 | | 0.010 | | 0.01 | | 0.009 | | 0.006 | | 0.007 | | 0.005 | | 0.002 | J |
| Total Alkalinity (mg CaCO3/L) | 8.5 | | 8.5 | | 9.5 | | 9.3 | | 8.8 | | 8.7 | | 9.30 | | 8.7 | | 12.4 | | 9.9 | |
| Chloride (mg/L) | 14.6 | | 14.6 | | 19.9 | | 19 | | 19.9 | | 20.7 | | 19.8 | | 19.4 | | 19.9 | | 18.7 | |
| Sulfate (mg/L) | 5.23 | | 5.73 | | 4.52 | | 5.16 | | 4.29 | | 4.86 | | 4.31 | | 4.81 | | 4.94 | | 5.69 | |
| Dissolved Iron (mg/L) | 0.021 | J | <0.020 | | < 0.020 | | <0.020 | | 0.046 | J | <0.020 | | 0.10 | | 0.044 | J | 1.5 | | 0.078 | |
| Dissolved Manganese (mg/L) | 0.0052 | J | 0.0027 | J | < 0.0020 | | 0.0024 | J | <0.0020 | | <0.0020 | | 0.0098 | J | 0.0026 | J | 0.0348 | | 0.0057 | J |
| Dissolved Boron (mg/L) | 0.0115 | J | 0.011 | J | 0.0304 | | 0.0318 | | 0.0226 | J | 0.0206 | J | 0.0269 | J | 0.0248 | J | 0.0283 | J | 0.0286 | J |
| Dissovled Arsenic (mg/L) | 0.0025 | J | 0.002 | J | < 0.0020 | | 0.002 | J | 0.0028 | J | 0.0023 | J | 0.0027 | J | <0.0020 | | 0.0031 | J,E | 0.0031 | J |
| Dissovled Organic Carbon (mg/L) | 0.46 | J | 0.96 | J | 0.56 | J | 0.58 | J | 0.65 | J | 0.55 | J | 0.89 | J | 0.53 | J | 0.52 | J | 0.54 | J |

Notes:

J - Data indicates a presence of a compound that meets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shading indicates data that should not be relied upon due to QA/QC concerns

**Table 10 - Measured Water Quality Concentrations for Barnstable - Prince Cove ISC Site - Piezometer Groundwater Data**

| Sample ID/Location | PCZ-50 | | | | PCZ-60 | | | | PCZ-70 | | | | PCZ-80 | | | | PCZ-88.5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/8/20 | | 4/20/20 | | 3/9/20 | | 4/20/20 | | 3/9/20 | | 4/20/20 | | 3/8/20 | | 4/20/20 | | 3/8/20 | | 4/20/20 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 5.05 | R | 5.65 | | 6.17 | | 6.41 | | 6.51 | | 6.75 | | 6.88 | | 6.48 | | 6.52 | | 6.16 | |
| Tempurature (°C) | 10.2 | | 10.5 | | 9.91 | | 10.5 | | 10.05 | | 10.5 | | 9.47 | | 10.85 | | 9.69 | | 10.63 | |
| Dissolved Oxygen(DO; mg/L) | 4.21 | | 7.29 | | 0.92 | | 0.74 | | 0.14 | | 0.64 | | 0.84 | | 1.57 | | 0.29 | | 0.41 | |
| Specific Conductance (uS/cm) | 124 | | 122.4 | | 144 | | 123.8 | | NM | | 109.0 | | 86 | | 96 | | 78 | | 85 | |
| Redox Potential (ORP; mV) | -117.4 | R | 210.4 | | 3.9 | | -18.7 | | -52.5 | | -59.5 | | -63.8 | | -27.5 | | -20.7 | | 8.2 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 6.3 | | 6 | | 6.1 | | 6.6 | | 6.2 | | 6.8 | | 6.5 | | 6.8 | | 6.4 | | 6.6 | |
| Nitrate as N (mg/L) | 2 | | 2.8 | | <0.019 | | <0.019 | | 0.021 | J | 0.028 | J | 0.058 | J | 0.02 | J | 0.025 | J | <0.019 | |
| Nitrite as N (mg/L) | 0.02 | | <0.010 | | 0.014 | J | <0.010 | | <0.010 | | <0.010 | | 0.030 | J | <0.010 | | 0.03 | J | <0.010 | |
| Ammonia as N (mg/L) | <0.021 | | <0.028 | | 0.043 | J | 0.042 | J | 0.066 | J | 0.054 | J | 0.063 | J | 0.053 | J | 0.025 | J | <0.028 | |
| Total Kjeidahl Nitrogen (TKN) (mg/L) | <0.093 | | 0.086 | J,E | 0.261 | J | 0.14 | J | 0.135 | | 0.156 | J | 0.182 | J | 0.146 | J | 0.204 | J | 0.085 | J |
| Total Nitrogen (mg/L) | 2 | | 2.8 | | <0.30 | | <0.30 | | <0.30 | | <0.30 | | <0.30 | | <0.30 | | <0.30 | | <0.30 | |
| Orthophosphate (mg/L) | 0.006 | | 0.005 | E | 0.002 | J | 0.14 | | 0.002 | | 0.138 | | 0.005 | | 0.065 | | 0.009 | | 0.05 | |
| Total Alkalinity (mg CaCO3/L) | 14.5 | | 11.6 | E | 18.1 | | 23.4 | | 15.8 | | 24.8 | | 17.4 | | 20.3 | | 13.4 | | 15.7 | |
| Chloride (mg/L) | 19.7 | | 19.7 | | 17.6 | | 16.7 | | 11.7 | | 13.1 | | 10.7 | | 10.3 | | 10.2 | | 9.98 | |
| Sulfate (mg/L) | 6.20 | | 6.28 | | 13.6 | | 14.2 | | 9.53 | | 11.1 | | 9.41 | | 9.66 | | 9.84 | | 10.2 | |
| Dissolved Iron (mg/L) | 0.64 | | 0.09 | | 8.0 | | 7.1 | | 6.3 | | 7 | | 11 | | 4.8 | | 7.6 | | 3.2 | |
| Dissolved Manganese (mg/L) | 0.0702 | | 0.0158 | | 0.197 | | 0.149 | | 0.158 | | 0.162 | | 0.245 | | 0.122 | | 0.105 | | 0.0501 | |
| Dissolved Boron (mg/L) | 0.0211 | J | 0.0253 | J | 0.0169 | J | 0.0147 | J | 0.0081 | J | 0.008 | J | 0.0085 | J | 0.0074 | J | 0.0106 | J | 0.0077 | J |
| Dissovled Arsenic (mg/L) | 0.0042 | J | 0.002 | J | 0.0045 | J | 0.0037 | J | 0.0061 | | 0.0063 | | 0.0101 | | 0.0053 | | <0.0020 | | 0.003 | J |
| Dissovled Organic Carbon (mg/L) | 1.2 | | 0.45 | J | 1.1 | | 0.49 | J | 0.43 | | 0.52 | J | 3.2 | | 0.82 | J | 0.46 | J | 0.46 | J |

Notes:

J - Data indicates a presence of a compound that meets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shading indicates data that should not be relied upon due to QA/QC concerns

**Table 11 - Measured Water Quality Concentrations Mashpee 2-inch Monitoring Well Groundwater**

| Sample ID/Location | TL-1 | | | | TL-2 | | | | TL-3 | | | | TL-4 | | | | TL- 5 | | | | TL-6 | | | | TL-7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/16/16 | | 4/28/16 | | 3/16/16 | | 4/28/16 | | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/28/16 | | 3/16/16 | | 4/28/16 | | 3/16/16 | | 4/28/16 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 1.70 | R | 4.95 | | 4.51 | | 4.76 | | 4.88 | | 5.12 | | 4.85 | | 5.05 | | 4.74 | | 4.44 | | 4.2 | | 4.25 | | 8.04 | R | 4.80 | |
| Temperature (°C) | 10.28 | | 9.9 | | 10.56 | | 10.7 | | 9.2 | | 9.5 | | 8.93 | | 9.4 | | 9.23 | | 10.42 | | 7.22 | | 9.28 | | 8.65 | | 11.5 | |
| Dissolved Oxygen(DO; mg/L) | 2.64 | | 10.88 | E | 5.33 | | 4.89 | | 3.63 | | 4.64 | | 2.21 | | 2.1 | | 1.45 | | 1.38 | | 0.29 | | 0.22 | | 8.41 | R | 5.03 | |
| Conductivity (uS/cm) | 101 | | 90.1 | | 92 | | 85.5 | | 129 | | 136.2 | | 117 | | 103.6 | | 106 | | 114 | | 80 | | 60 | | 127 | | 127 | |
| Redox Potential (ORP; mV) | 34.9 | R | 371.3 | | -104.3 | R | 380.5 | | -109.6 | R | 362.4 | | -127.2 | R | 356.0 | | 186.3 | | 200.0 | | 118.0 | | 78.3 | | 154 | R | 187 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 5.1 | | 4.8 | | 5.2 | | 4.8 | | 5.3 | | 5.0 | | 6.0 | | 5.0 | | 3.6 | | 4.5 | | 5.5 | | 3.00 | | 5.6 | | 4.7 | |
| Nitrate as N (mg/L) | 0.11 | | 0.25 | | 0.16 | | 0.29 | | 2.4 | | 2.2 | | 1.0 | | 0.66 | | 1.2 | | 0.98 | | 0.021 | J | <0.019 | | 1.2 | | 0.73 | |
| Nitrite as N (mg/L) | <0.010 | | <0.010 | | <0.010 | | 0.035 | J | 0.018 | J | <0.010 | | 0.020 | | <0.010 | | 0.014 | J | 0.012 | J | <0.010 | | <0.010 | | 0.014 | J | <0.010 | |
| Ammonia as N (mg/L) | <0.021 | | <0.028 | E | <0.021 | | 0.048 | J | <0.021 | | <0.028 | | 0.029 | J | <0.028 | | 0.030 | J | 0.138 | | 0.053 | J | 0.029 | J | 0.029 | J | <0.028 | |
| Total Kjeidahl Nitrogen (TKN) (mg/L) | 0.166 | J | 0.578 | E | 0.204 | J,E | 0.295 | J | <0.093 | | 0.116 | J | 0.105 | J | 0.324 | | 0.215 | J | 1.19 | | 0.364 | | 0.340 | | 0.904 | | 0.192 | J |
| Total Nitrogen (mg/L) | <0.30 | | 0.83 | E | <0.30 | | <0.30 | | 2.4 | | 2.2 | | 1.0 | | 0.98 | | 1.2 | | 2.2 | | 0.36 | | 0.34 | | 2.1 | | 0.73 | |
| Orthophosphate (mg/L) | 0.002 | J | 0.005 | | 0.002 | J | 0.005 | | 0.002 | J | 0.004 | J | 0.002 | J | 0.003 | J | 0.004 | J | 0.005 | | 0.009 | | 0.010 | | 0.002 | J | 0.005 | |
| Total Alkalinity | 3.20 | | 2.80 | | 2.80 | | 2.50 | | 5.80 | | 5.40 | | 9.40 | | 4.00 | | 2.60 | | 2.40 | | 3.90 | | 3.00 | | 5.40 | | 3.40 | |
| Chloride (mg/L) | 17.8 | | 14.5 | | 16.4 | | 17.4 | | 26.2 | | 24.5 | | 23.8 | | 19.4 | | 19.7 | | 20.3 | | 15.3 | | 11.9 | | 18.8 | | 25.0 | |
| Sulfate (mg/L) | 11.2 | | 11.7 | | 9.41 | | 7.36 | | 8.58 | | 7.48 | | 8.03 | | 8.91 | | 35.4 | | 10.5 | | 5.69 | | 4.15 | | 14.3 | | 10.4 | |
| Dissolved Iron (mg/L) | 0.18 | | <0.020 | | 0.29 | | 0.059 | | 0.081 | | 0.10 | | 1.0 | | <0.020 | | 0.14 | | 0.36 | | 2.6 | | 1.0 | | 14 | | <0.020 | |
| Dissolved Manganese (mg/L) | 0.165 | | 0.114 | | 0.285 | | 0.135 | | 0.0381 | | 0.0433 | | 0.0631 | | 0.0266 | | 0.135 | | 0.101 | | 0.106 | | 0.0570 | | 0.508 | | 0.0536 | |
| Dissolved Boron (mg/L) | 0.010 | J | <0.0070 | | 0.0123 | J | 0.0119 | J | 0.0270 | J | 0.0234 | J | 0.0369 | | 0.0315 | | 0.0158 | J | 0.0131 | J | 0.0191 | J | 0.016 | J | 0.0218 | J | 0.0149 | J |
| Dissolved Arsenic (mg/L) | <0.0020 | | <0.0020 | E | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | 0.0022 | J | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | 0.0027 | J | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 1.2 | | 1.4 | E | 1.1 | | 1.1 | | 0.92 | J | 0.78 | | 1.5 | | 1.8 | | 4.0 | | 1.2 | | 5.7 | | 3.7 | | 2.5 | | 1.1 | |

Notes:
J - Data indicates a presence of a compound thatmeets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.
R - Suspected error in field pH and ORP measurements
NS - Not Sampled / NM -Not Measured
E - Exceeds RPD of 20% with duplicate sample
Grey shaded cells indicate data that should not be relied upon based on QA/QC

**Table 12 - Measured Water Quality Concentrations at Mashpee-Timber Landing ISC site - Piezometer Groundwater Data**

| Sample ID/Location | TLZ-14 | | | | TLZ-22 | | | | TLZ-31 | | | | TLZ-40 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/27/16 | |
| Field Measurements | | | | | | | | | | | | | | | | |
| pH (SU) | 4.88 | | 5.73 | | 5.21 | | 5.46 | | 5.72 | | 5.74 | | 5.85 | | 5.66 | |
| Temperature (°C) | 8.76 | | 9.4 | | 10.00 | | 10.2 | | 9.74 | | 10.8 | | 9.74 | | 10.9 | |
| Dissolved Oxygen(DO; mg/L) | 1.17 | | 4.91 | | 0.23 | | 3.55 | | 4.27 | | 7.21 | | 5.61 | | 6.32 | |
| Conductivity (uS/cm) | 83 | | 67.4 | | 135 | | 143.0 | | 157 | | 165.1 | | 186 | | 204.1 | |
| Redox Potential (ORP; mV) | -135.6 | | 409.0 | | -181.9 | | 260.0 | | 138.5 | | 291.2 | | 123.5 | | 313.7 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | |
| pH (SU) | 5.5 | | 5.2 | | 6.0 | | 5.3 | | 6.0 | | 5.6 | | 5.7 | | 5.6 | |
| Nitrate as N (mg/L) | 0.17 | | 0.034 | J | 0.052 | J | 0.16 | | 2.1 | | 2.0 | | 2.7 | | 3.0 | |
| Nitrite as N (mg/L) | 0.012 | J | <0.010 | | 0.014 | J | <0.010 | | <0.010 | | 0.013 | J | 0.021 | J | <0.010 | |
| Ammonia as N (mg/L) | 0.026 | J | 0.050 | J | 0.036 | J | 0.172 | | 0.039 | J | 0.174 | | 0.031 | J | 0.110 | E |
| Total Kjeidahl Nitrogen (TKN) (mg/L) | 0.193 | J | 0.213 | J | 0.174 | J | 0.135 | J | <0.093 | | 0.078 | J | <0.093 | | 0.093 | J,E |
| Total Nitrogen (mg/L) | <0.093 | | <0.30 | | <0.30 | | <0.30 | | 2.1 | | 2.0 | | 2.7 | | 3.0 | |
| Orthophosphate (mg/L) | 0.003 | J | 0.012 | | 0.007 | | 0.013 | | 0.0030 | J | 0.014 | | 0.002 | J | 0.012 | |
| Total Alkalinity (mg CaCO3/L) | 5.2 | | 3.70 | | 10.0 | | 10.1 | | 10.7 | | 10.0 | | 9.70 | | 8.20 | |
| Chloride (mg/L) | 16.8 | | 12.9 | | 27.3 | | 25.2 | | 33.1 | | 32.3 | | 42.8 | | 43.2 | |
| Sulfate (mg/L) | 7.47 | | 5.30 | | 14.7 | | 15.0 | | 6.59 | | 6.72 | | 4.52 | | 4.53 | |
| Dissolved Iron (mg/L) | 0.22 | | 0.031 | J | 0.13 | | 0.19 | | 0.030 | J | 0.061 | | 0.06 | | <0.020 | E |
| Dissolved Manganese (mg/L) | 0.0492 | | 0.0230 | J | 0.0197 | | 0.0164 | | 0.0052 | J | 0.0022 | J | 0.214 | | 0.0332 | |
| Dissolved Boron (mg/L) | 0.0214 | J | 0.0167 | J | 0.0332 | | 0.0373 | | 0.0103 | J | 0.0094 | J | 0.0099 | J | 0.0104 | J |
| Dissolved Arsenic (mg/L) | <0.0020 | | 0.0047 | J | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 2.0 | | 1.8 | | 1.4 | | 1.1 | | 0.52 | J | 0.41 | J | 5.5 | | 0.4 | J |

Notes:

J - Data indicates a presence of a compound that meets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shaded cells indicate data that should not be relied upon based on QA/QC

**Table 12 - Measured Water Quality Concentrations at Mashpee-Timber Landing ISC site - Piezometer Groundwater Data**

| Sample ID/Location | TLZ-50 | | | | TLZ-60 | | | | TLZ-70 | | | | TLZ-80 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/27/16 | |
| Field Measurements | | | | | | | | | | | | | | | | |
| pH (SU) | 6.26 | | 5.81 | | 6.03 | | 5.83 | | 5.30 | | 5.70 | | 5.95 | | 5.28 | |
| Temperature (°C) | 9.65 | | 11.0 | | 10.01 | | 11.0 | | 10.42 | | 10.9 | | 9.84 | | 10.96 | |
| Dissolved Oxygen(DO; mg/L) | 2.14 | | 2.43 | | 2.27 | | 2.19 | | 1.80 | | 3.48 | | 1.37 | | 4.03 | |
| Conductivity (uS/cm) | 138 | | 124.1 | | 125 | | 116.2 | | 125 | | 129.4 | | 123 | | 113 | |
| Redox Potential (ORP; mV) | 44.3 | | 224.4 | | 55.7 | | 168.4 | | -94.3 | | 262.1 | | 74.0 | | 140.0 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | |
| pH (SU) | 6.4 | | 5.8 | | 6.5 | | 5.8 | | 6.5 | | 5.6 | | 6.7 | | 5.7 | |
| Nitrate as N (mg/L) | 0.62 | | 0.83 | | 0.48 | | 0.44 | | 0.8 | | 0.91 | | 0.99 | | 1.3 | |
| Nitrite as N (mg/L) | 0.023 | J | 0.013 | J | <0.010 | | <0.010 | | 0.014 | J | <0.010 | | 0.014 | J | <0.010 | |
| Ammonia as N (mg/L) | 0.028 | J | 0.089 | | 0.024 | J,E | 0.039 | J | 0.033 | J | 0.079 | | 0.024 | J | 0.030 | J |
| Total Kjeidahl Nitrogen (TKN) (mg/L) | 0.134 | J | <0.066 | | 0.127 | J | 0.172 | J | 0.096 | J | 0.131 | J | 0.093 | J | <0.066 | |
| Total Nitrogen (mg/L) | 0.62 | | 0.83 | | 0.48 | | 0.44 | | 0.8 | | 1.0 | | 0.99 | | 1.3 | |
| Orthophosphate (mg/L) | 0.002 | J | 0.016 | | 0.003 | J,E | 0.018 | | 0.004 | J | 0.019 | | 0.002 | J | 0.013 | |
| Total Alkalinity (mg CaCO3/L) | 18.6 | | 14.8 | | 16.4 | | 12.4 | | 13.9 | | 10.1 | | 18.8 | | 14.1 | |
| Chloride (mg/L) | 24.7 | | 19.3 | | 23.5 | | 22.6 | | 24.3 | | 23.4 | | 17.2 | | 14.5 | |
| Sulfate (mg/L) | 8.95 | | 9.75 | | 7.52 | | 7.65 | | 8.58 | | 8.24 | | 11.4 | | 11.3 | |
| Dissolved Iron (mg/L) | 2.6 | | 0.39 | | 2.8 | | 0.41 | | 1.4 | | 0.088 | | 2.4 | | 0.026 | J |
| Dissolved Manganese (mg/L) | 0.595 | | 0.116 | | 0.395 | | 0.235 | | 0.110 | | 0.0135 | | 0.973 | | 0.0702 | |
| Dissolved Boron (mg/L) | 0.0104 | J | 0.0104 | J | 0.0108 | J | 0.0101 | J | 0.0125 | J | 0.0099 | J | 0.0104 | J | 0.0092 | J |
| Dissolved Arsenic (mg/L) | <0.0020 | | 0.003 | J | <0.0020 | | 0.0025 | J | <0.0020 | | <.0020 | | <0.0020 | | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 0.59 | J | 0.47 | J | 0.94 | J,E | 0.45 | J | 0.43 | | 0.43 | | 0.57 | | 0.46 | |

Notes:

J - Data indicates a presence of a compound that meets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shaded cells indicate data that should not be relied upon based on QA/QC

**Table 12 - Measured Water Quality Concentrations at Mashpee-Timber Landing ISC site - Piezometer Groundwater Data**

| Sample ID/Location | TLZ-90 | | | | TLZ-100 | | | |
|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/15/16 | | 4/27/16 | | 3/15/16 | | 4/28/16 | |
| Field Measurements | | | | | | | | |
| pH (SU) | 5.38 | | 5.17 | | 5.65 | | 5.32 | |
| Temperature (°C) | 9.35 | | 10.85 | | 9.78 | | 10.85 | |
| Dissolved Oxygen(DO; mg/L) | 4.67 | | 0.76 | | 0.40 | | 0.39 | |
| Conductivity (uS/cm) | 122 | | 115 | | 107 | | 110 | |
| Redox Potential (ORP; mV) | -53.4 | | 112.6 | | 90.9 | | 104.8 | |
| Laboratory Analyses | | | | | | | | |
| pH (SU) | 6.9 | | 5.7 | | 7.2 | | 5.4 | |
| Nitrate as N (mg/L) | 0.36 | | 0.55 | | 0.027 | J | 0.030 | J |
| Nitrite as N (mg/L) | 0.016 | | <0.010 | | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | <0.021 | | 0.057 | J | <0.021 | | 0.047 | J |
| Total Kjeidahl Nitrogen (TKN) (mg/L) | 0.132 | J | 0.079 | J | 0.196 | J | 0.148 | J |
| Total Nitrogen (mg/L) | 0.36 | | 0.55 | | <0.30 | | <0.30 | |
| Orthophosphate (mg/L) | 0.002 | J | 0.025 | | 0.009 | | 0.015 | |
| Total Alkalinity (mg CaCO3/L) | 25.4 | | 17.6 | | 15 | | 13.7 | |
| Chloride (mg/L) | 14.1 | | 14.2 | | 14.2 | | 13.2 | |
| Sulfate (mg/L) | 15.3 | | 13.5 | | 14.8 | | 15.9 | |
| Dissolved Iron (mg/L) | 3.1 | | 0.19 | | 0.41 | | 0.37 | |
| Dissolved Manganese (mg/L) | 0.369 | | 0.0238 | | 0.23 | | 0.180 | |
| Dissolved Boron (mg/L) | 0.0096 | J | 0.0082 | J | 0.0123 | J | <0.0070 | |
| Dissolved Arsenic (mg/L) | <0.0020 | | 0.0025 | J | <0.0020 | | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 0.73 | J | 0.53 | J | 0.94 | J | 0.90 | J |

Notes:

J - Data indicates a presence of a compound that meets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shaded cells indicate data that should not be relied upon based on QA/QC

**Table 13 - Measured Water Quaiity Concentrations at Falmouth Sailfish ISC Site - Water Table Wells**

| Sample ID/Location | SF-1 | | | | SF-2 | | | | SF-3 | | | | SF-4 | | | | SF-5S | | | | SF-5D | | | | SF-6 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/24/20 | | 5/6/20 | | 3/24/20 | | 5/6/20 | | 3/24/20 | | 5/6/20 | | 3/24/20 | | 5/6/20 | | 3/24/20 | | 5/7/20 | | 3/24/20 | | 5/6/20 | | 3/24/20 | | 5/6/20 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | NM | R | 4.92 | | 5.01 | | 4.67 | | NM | R | 4.67 | | NM | R | 6.49 | | 4.86 | | 5.14 | | 5.72 | | 5.45 | | NM | R | 4.72 | |
| Temperature (°C) | 10.5 | | 14.48 | | 10.9 | | 12.84 | | 11.4 | | 10.6 | | 11.5 | | 10.7 | | 13.8 | | 14.4 | | 12.1 | | 10.38 | | 11.4 | | 11.06 | |
| Dissolved Oxygen (DO; mg/L) | 7.86 | | 6.48 | | 3.32 | | 3.89 | | 6.65 | | 9.76 | | 6.78 | | 9.92 | | 7.09 | | 9.10 | | 9.60 | | 9.47 | | 5.59 | | 7.42 | |
| Specific Conductance (uS/cm) | 128 | | 177 | | 86.7 | | 95 | | 108 | | 108.0 | | 146 | | 134.4 | | 50.7 | | 116.3 | | 94.5 | | 120 | | 94 | | 102 | |
| Redox Potential (ORP; mV) | 355.6 | R | 138 | | 299.0 | | 208 | | 271.8 | R | 313.8 | | 238.9 | R | 126.0 | | 290.0 | | 369.3 | | 174.6 | | 155.1 | | 259.8 | R | 212 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 4.9 | | 5.3 | | 5.2 | | 5 | | 4.9 | | 4.5 | | 6.4 | | 6.3 | | 4.7 | | 4.4 | | 5.8 | | 5.9 | | 5.4 | | 5 | |
| Nitrate as N (mg/L) | 3.0 | | 3.8 | | 2.3 | | 1.6 | | 2.5 | | 3.4 | | 0.52 | | 0.5 | | 2.8 | | 2.2 | | 3.1 | | 2.4 | | 0.72 | | 0.59 | |
| Nitrite as N (mg/L) | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.019 | | <0.010 | | <0.019 | | <0.010 | | <0.010 | | <0.010 | J | <0.010 | | <0.010 | | <0.010 | | 0.016 | J |
| Ammonia as N (mg/L) | 0.029 | J,E | 0.215 | | <0.021 | | 0.064 | J | 0.06 | J | 0.034 | J,E | <0.021 | | <0.021 | | 0.025 | J | 0.051 | J | <0.021 | | 0.038 | J | 0.024 | J | <0.021 | |
| Total Kjeldahl Nitrogen (TKN) (mg/L) | <0.093 | | 0.224 | J | <0.093 | | 0.094 | J | <0.093 | | <0.3 | E | 0.208 | J | 0.268 | J | 0.335 | | 0.081 | J | <0.093 | | 0.118 | J | 0.101 | J | 0.169 | J |
| Total Nitrogen (mg/L) | 3.0 | | 3.8 | | 2.3 | | 1.6 | | 2.5 | | 3.4 | | 0.5 | | 0.5 | | 3.1 | | 2.2 | | 3.1 | | 2.4 | | 0.72 | | 0.59 | |
| Orthophosphate (mg/L) | 0.002 | J | 0.003 | J | 0.005 | | 0.006 | | 0.002 | J | 0.004 | J,E | 0.003 | J | 0.005 | | 0.002 | J | 0.006 | | 0.002 | J | 0.004 | J | 0.002 | J | 0.004 | J |
| Total Alkalinity (mg/L CaCO3) | 2.20 | | 3.9 | | 3.90 | | 3.9 | | 4.10 | | 2.3 | | 45.9 | | 41.3 | | 3.10 | | 2.1 | | 9.90 | | 9.0 | | 5.10 | | 4.4 | |
| Chloride (mg/L) | 29.7 | | 28.6 | | 12.8 | | 12.9 | | 20.1 | | 15.8 | | 16.4 | | 13.6 | | 15.4 | | 11.4 | | 13.4 | | 16.6 | | 20.2 | | 14.7 | |
| Sulfate (mg/L) | 10.2 | | 9.94 | | 10.7 | | 8.65 | | 12.8 | | 12.4 | | 13.2 | | 11.2 | | 16.0 | | 16.1 | | 6.86 | | 6.64 | | 10.8 | | 11.4 | |
| Dissolved Iron (mg/L) | 0.040 | J | 0.25 | | <0.020 | | 0.039 | J | 0.74 | | 0.36 | E | <0.020 | | 0.062 | | 0.12 | | 0.026 | J,E | 0.091 | | 0.22 | | 0.21 | | <0.020 | |
| Dissolved Manganese (mg/L) | 0.249 | | 0.397 | | 0.0478 | | 0.0546 | | 0.503 | | 0.12 | | 0.0100 | | 0.078 | | 0.302 | | 0.0746 | | 0.0526 | | 0.049 | | 0.310 | | 0.0594 | |
| Dissolved Boron (mg/L) | 0.015 | J | 0.0205 | J | 0.0147 | J | 0.012 | J | 0.0228 | J | 0.0172 | J | <0.0070 | | <0.0070 | | 0.0086 | J | <0.0070 | | 0.0079 | | 0.0105 | J | 0.0147 | J | 0.0117 | J |
| Dissolved Arsenic (mg/L) | 0.0024 | J | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | 0.002 | J | <0.0020 | | <0.0020 | | 0.0020 | J | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 1.1 | | 0.55 | J | 0.98 | J | 0.88 | J | 1.6 | | 1.4 | | 3.3 | | 2 | | 1.1 | | 1.3 | | 0.7 | J | 0.76 | J | 1.7 | | 1.7 | |

Notes:

J - Data indicates a presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shaded cell data should not be relied upon based on QA/QC review

**Table 14 - Measured Water Quality Concentrations - Falmouth-Sailfish ISC Site Piezometer Groundwater Data**

| Sample ID/Location | SFZ-19 | | | | SFZ-26 | | | | SFZ-33 | | | | SFZ-40 | | | | SFZ-45 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Screen bottom elevation (ft msl) | -0.5 | | | | -7.6 | | | | -14.7 | | | | -21.8 | | | | -26.9 | | | |
| Sampling Date | 3/23/16 | | 5/6/16 | | 3/23/16 | | 5/6/16 | | 3/23/16 | | 5/6/16 | | 3/23/16 | | 5/6/16 | | 3/23/16 | | 5/6/16 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 4.92 | | 4.11 | | NM | R | 4.29 | | 5.12 | | 5.10 | | 4.88 | | 5.12 | | NM | R | 5.22 | |
| Temperature (°C) | 11.0 | | 11.06 | | 11.10 | | 11.54 | | 11.7 | | 11.74 | | 11.5 | | 11.9 | | 10.92 | | 11.85 | |
| Dissolved Oxygen (DO; mg/L) | 7.16 | | 5.21 | | 6.5 | | 6.53 | | 7.53 | | 6.28 | | 8.89 | | 8.53 | | 7.22 | | 7.58 | |
| Specific Conductance (uS/cm) | 103.3 | | 188 | | 213 | | 173 | | 121.2 | | 140 | | 132.2 | | 123 | | 218 | | 175 | |
| Redox Potential (ORP; mV) | 285 | | 212 | | -70.1 | R | 206 | | 121.9 | | 164 | | 244.4 | | 280 | | -41.7 | R | 159.9 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 5.4 | | 5 | | 4.7 | | 4.5 | | 5.5 | | 5.3 | | 5.5 | | 5.2 | | 5.5 | | 5.4 | |
| Nitrate as N (mg/L) | 0.72 | | 0.59 | | 8.9 | | 7 | | 4.3 | | 4.3 | | 2.4 | | 3 | | 3.0 | | 2.8 | |
| Nitrite as N (mg/L) | <0.010 | | <0.010 | | <0.010 | | <0.05 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | <0.021 | | 0.043 | J | 0.023 | J,E | 0.05 | J | 0.035 | J | 0.04 | J | <0.021 | | 0.124 | | <0.021 | | 0.049 | J |
| Total Kjeldahl Nitrogen (TKN) (mg/L) | 0.102 | J | 0.282 | J | <0.186 | | <0.132 | | <0.093 | | 0.215 | J | <0.093 | | 0.14 | J | <0.093 | | 0.15 | J |
| Total Nitrogen (mg/L) | 0.72 | | 0.59 | | 8.9 | | 7 | | 4.3 | | 4.3 | | 2.4 | | 3 | | 3.0 | | 2.8 | |
| Orthophosphate (mg/L) | 0.041 | | 0.033 | | 0.004 | J | 0.004 | J | 0.00 | J | 0.004 | J | 0.007 | | <0.001 | | 0.006 | | <0.001 | |
| Total Alkalinity (mg/L CaCO3) | 5.30 | | 4.1 | | 2.60 | | 2.4 | | 6.40 | | 3.8 | | 4.80 | | 4.1 | | 3.30 | | 5.9 | |
| Chloride (mg/L) | 20.2 | | 39.1 | | 19.8 | | 19.1 | | 19.0 | | 19.9 | | 26.5 | | 23.4 | | 31.0 | | 30.2 | |
| Sulfate (mg/L) | 9.31 | | 10 | | 12.3 | | 10.4 | | 9.81 | | 8.4 | | 10.2 | | 11.5 | | 13.9 | | 13.2 | |
| Dissolved Iron (mg/L) | <0.020 | | <0.020 | | <0.020 | | 0.05 | | 0.120 | | 0.026 | J | 0.0417 | | 0.022 | J | 0.021 | J | <0.020 | |
| Dissolved Manganese (mg/L) | 0.0237 | | 0.0418 | | 0.317 | | 0.287 | | 0.108 | | 0.0663 | | 0.0338 | | 0.0284 | | 0.0189 | | 0.016 | |
| Dissolved Boron (mg/L) | 0.015 | J | 0.0102 | J | 0.0310 | | 0.0249 | J | 0.0425 | | 0.0366 | | 0.0417 | | 0.0394 | | 0.0419 | | 0.0368 | |
| Dissolved Arsenic (mg/L) | <0.0020 | | <0.0020 | | 0.0021 | J,E | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 1.3 | | 1.4 | | 0.76 | J | 0.68 | J | 0.58 | J | 0.59 | J | 0.84 | J | 0.61 | J | 0.61 | J | 0.6 | J |

Notes:

J - Data indicates a presence of a compound thatmeets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shaded cell data should not be relied upon based on QA/QC review

**Table 14 - Measured Water Quality Concentrations - Falmouth-Sailfish ISC Site Piezometer Groundwater Data**

| Sample ID/Location | SFZ-50 | | | | SFZ-57 | | | | SFZ-67 | | | | SFZ-77 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Screen bottom elevation (ft msl) | -32.0 | | | | -39.0 | | | | -48.9 | | | | -59.6 | | | |
| Sampling Date | 3/23/16 | | 5/6/16 | | 3/23/16 | | 5/6/16 | | 3/23/16 | | 5/6/16 | | 3/23/16 | | 5/6/16 | |
| Field Measurements | | | | | | | | | | | | | | | | |
| pH (SU) | NM | R | 5.14 | | 5.3 | | 5.12 | | 5.29 | | 5.42 | | NM | R | 7.79 | |
| Temperature (°C) | 11.0 | | 11.8 | | 11.3 | | 11.84 | | 11 | | 11.8 | | 10.65 | | 11.87 | |
| Dissolved Oxygen (DO; mg/L) | 7.76 | | 8.88 | | 9.02 | | 8.0 | | 8.69 | | 8.55 | | 6.55 | | 7.53 | |
| Specific Conductance (uS/cm) | 243 | | 161 | | 139.1 | | 154 | | 112.6 | | 110 | | 314 | | 246 | |
| Redox Potential (ORP; mV) | -126.3 | R | 267 | | 160.0 | | 157.1 | | 172.2 | | 218.1 | | -153.1 | R | 42.9 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | |
| pH (SU) | 5.5 | | 5.5 | | 5.7 | | 5.4 | | 5.7 | | 5.6 | | 7.8 | | 7.7 | |
| Nitrate as N (mg/L) | 1.7 | | 1.6 | | 2.6 | | 2.6 | | 2.9 | | 3.1 | | 1.7 | | 1.6 | |
| Nitrite as N (mg/L) | <0.010 | | <0.010 | | <0.010 | | 0.017 | J,E | 0.012 | J | <0.010 | | 0.014 | J | <0.010 | |
| Ammonia as N (mg/L) | 0.031 | J | 0.068 | J | 0.025 | J | 0.035 | J | 0.026 | J | 0.241 | | 0.072 | J | 0.080 | |
| Total Kjeldahl Nitrogen (TKN) (mg/L) | <0.093 | | 0.358 | | <0.093 | | 0.087 | J | <0.093 | | 0.15 | J | <0.093 | | 0.228 | J |
| Total Nitrogen (mg/L) | 1.7 | | 2 | | 2.6 | | 2.6 | | 2.9 | | 3.1 | | 1.7 | | 1.6 | |
| Orthophosphate (mg/L) | 0.002 | J | <0.001 | | 0.004 | J | <0.001 | | 0.006 | | <0.001 | | 0.034 | | 0.037 | |
| Total Alkalinity (mg/L CaCO3) | 6.10 | | <2.0 | | 7.50 | | 6.1 | | 7.90 | | 7 | | 86.4 | | 82.8 | |
| Chloride (mg/L) | 43.0 | | 41 | | 28.1 | | 27.7 | | 17.5 | | 18.5 | | 15.8 | | 14.9 | |
| Sulfate (mg/L) | 9.57 | | 8.88 | | 9.94 | | 9.13 | | 11.5 | | 10.3 | | 15.5 | | 14.4 | |
| Dissolved Iron (mg/L) | 0.3 | | 0.049 | J | 0.27 | | 0.042 | J | 0.11 | | 0.041 | J | <0.020 | | <0.020 | |
| Dissolved Manganese (mg/L) | 0.146 | | 0.128 | | 0.0224 | | 0.0112 | | 0.0281 | | 0.0106 | | 0.0252 | | 0.0098 | J |
| Dissolved Boron (mg/L) | 0.0174 | J | 0.0135 | J | 0.0165 | J | 0.0149 | J | 0.0200 | J | 0.0178 | J | 0.0209 | J | 0.0194 | J |
| Dissolved Arsenic (mg/L) | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | 0.0028 | J |
| Dissolved Organic Carbon (mg/L) | 0.68 | J | 0.91 | J | 0.6 | J | 0.49 | J | 0.50 | J | 0.48 | J | 0.66 | J | 0.51 | J |

Notes:

J - Data indicates a presence of a compound thatmeets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey shaded cell data should not be relied upon based on QA/QC review

**Table 15 - Measured Water Quality Concentrations at Dennis-Vinland Drive Site - Water Table Wells**

| Sample ID/Location | VL-1 | | | | VL-2 | | | | VL-3 | | | | VL-4 | | | | VL-5 | | | | VL-6 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 4/2/20 | | 5/7/20 | | 4/1/20 | | 5/7/20 | | 4/2/20 | | 5/7/20 | | 4/2/20 | | 5/7/20 | | 4/2/20 | | 5/7/20 | | 4/2/20 | | 5/7/20 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 4.56 | | 5.42 | | 4.82 | | 5.00 | | 4.49 | | 5.15 | | 4.43 | | 5.51 | | 4.67 | | 6.04 | | 5.23 | | 6.11 | |
| Temperature (°C) | 12.3 | | 15.1 | | 11.9 | | 12.9 | | 12.3 | | 12.2 | | 12.2 | | 13.5 | | 11.7 | | 12.9 | | 12.4 | | 14.2 | |
| Dissolved Oxygen (DO; mg/L) | 8.66 | | 9.39 | | 29.4 | R | 9.31 | | 9.11 | | 10.0 | | 7.13 | | 7.31 | | 9.77 | | 9.79 | | 9.98 | | 10.25 | |
| Specific Conductance (uS/cm) | 218.2 | | 199.9 | | 277 | | 286.0 | | 280.3 | | 323.0 | | 302.7 | | 277.9 | | 165.8 | | 90.2 | | 179.2 | | 131.1 | |
| Redox Potential (ORP; mV) | 307.5 | | 346.6 | | 255.8 | | 312.4 | | 258.8 | | 345.0 | | 297.6 | | 336.1 | | 297.3 | | 290.4 | | 224.6 | | 285.1 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 4.4 | | 4.3 | | 5.0 | | 4.5 | | 4.6 | | 4.4 | | 4.6 | | 4.4 | | 5.0 | | 5.0 | | 5.8 | | 4.9 | |
| Nitrate as N (mg/L) | 2.2 | | 2.6 | | 4.4 | | 4.5 | | 5.8 | | 7.1 | | 6.2 | | 7.4 | | 1.9 | | 1.0 | | 1.2 | | 0.41 | |
| Nitrite as N (mg/L) | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | 0.014 | J |
| Ammonia as N (mg/L) | <0.028 | | 0.037 | J | <0.028 | | <0.028 | | 0.032 | JE | <0.028 | | <0.028 | | 0.047 | J | 0.035 | J | <0.028 | | 0.089 | | <0.028 | |
| Total Kjeldahl Nitrogen (TKN) (mg/L) | 0.308 | | 0.083 | J | 0.392 | | <0.3 | | 0.351 | JE | <0.132 | E | 2.41 | | 0.164 | J | 0.384 | | 0.098 | J | 4.36 | | 0.169 | J |
| Total Nitrogen (mg/L) | 2.5 | | 2.6 | | 4.8 | | 4.5 | | 5.8 | | 7.1 | | 8.6 | | 7.4 | | 2.3 | | 1 | | 5.6 | | 0.41 | |
| Orthophosphate (mg/L) | 0.007 | | 0.008 | | 0.005 | | 0.008 | | 0.011 | E | 0.007 | | 0.006 | | 0.007 | | 0.006 | | 0.009 | | 0.005 | | 0.007 | |
| Total Alkalinity (mg/L CaCO3) | 2.20 | | 2.2 | | 3.50 | | 2.9 | | 2.90 | | 2.5 | | 3.60 | | 2.4 | | 4.10 | | 5.9 | | 12.30 | | 4.8 | |
| Chloride (mg/L) | 41.4 | | 34.3 | | 72.2 | | 40.9 | | 56.0 | | 42.8 | | 56.6 | | 43 | | 29.6 | | 15.5 | | 32.3 | | 20.1 | |
| Sulfate (mg/L) | 14.1 | | 10.2 | | 11.1 | | 10.6 | | 13.6 | | 11.8 | | 11.9 | | 11.7 | | 10.6 | | 4.49 | | 15.6 | | 13.6 | |
| Dissolved Iron (mg/L) | 0.39 | | 0.042 | J | 1.3 | | <0.020 | | 6.0 | E | <0.020 | | 1.7 | | <0.020 | | 0.12 | | 0.023 | J | 0.15 | | <0.020 | |
| Dissolved Manganese (mg/L) | 0.0277 | | 0.0263 | | 0.0717 | | 0.0429 | | 0.0871 | E | 0.0449 | | 0.0637 | | 0.0497 | | 0.0204 | | 0.013 | | 0.0321 | | 0.0157 | |
| Dissolved Boron (mg/L) | 0.0188 | J | 0.0174 | J | 0.0369 | | 0.0328 | | 0.0343 | | 0.0286 | | 0.0237 | J | 0.018 | J | 0.0198 | J | 0.0112 | J | 0.0134 | J | 0.0101 | J |
| Dissolved Arsenic (mg/L) | <0.0020 | | <0.0020 | | 0.0033 | J | <0.0020 | | 0.0073 | E | <0.0020 | | 0.0033 | J | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 0.72 | J | 1.1 | | 0.95 | J | 0.79 | J | 1.0 | J | 0.97 | J | 0.86 | J | 0.84 | J | 0.89 | J | 1.2 | | 0.79 | J | 1.1 | |

Notes:

J - Data indicates a presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field DO measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

Grey cell means data questionable and should not be relied upon

**Table 16 - Measured Water Quality Concentration**
**at Dennis-Vinland Road Site - Piezometer**
**Groundwater Data**

| **Sample ID/Location** | **VLZ-44** | | | | **VLZ-48** | | | | **VLZ-52** | | | | **VLZ-56** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Screen bottom elevation (ft msl)** | **0.7** | | | | **-3.3** | | | | **-7.3** | | | | **-11.4** | | | |
| Sampling Date | 4/2/20 | | 5/6/2016* | | 4/2/20 | | 5/7/20 | | 4/2/20 | | 5/7/20 | | 4/2/20 | | 5/7/20 | |
| Field Measurements | | | | | | | | | | | | | | | | |
| pH (SU) | 4.67 | | 5.00 | | 5.80 | | 5.65 | | 5.65 | | 5.33 | | 5.43 | | 5.19 | |
| Temperature (°C) | 11.7 | | 12.9 | | 11.6 | | 11.83 | | 12.3 | | 11.87 | | 12.1 | | 11.64 | |
| Dissolved Oxygen (DO; mg/L) | 7.09 | | 9.31 | | 4.23 | | 4.12 | | 6.28 | | 4.70 | | 6.52 | | 6.15 | |
| Specific Conductance (uS/cm) | 381 | | 286.0 | | 235 | | 219 | | 205.8 | | 185 | | 211.8 | | 188 | |
| Redox Potential (ORP; mV) | 300.8 | | 312.4 | | 126.6 | | 99.9 | | 220.2 | | 137 | | 212 | | 152 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | |
| pH (SU) | 4.8 | | NS | | 5.9 | | 5.5 | | 5.8 | | 5.3 | | 5.4 | | 5.2 | |
| Nitrate as N (mg/L) | 4.3 | | NS | | 2.4 | | 2.5 | | 4.0 | | 3.9 | | 4.2 | | 3.9 | |
| Nitrite as N (mg/L) | <0.010 | | NS | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | <0.028 | | NS | | 0.029 | J | 0.036 | J | 0.031 | J | <0.028 | | <0.028 | | <0.028 | |
| Total Kjeldahl Nitrogen (TKN) (mg/L) | <0.066 | | NS | | <0.066 | | 0.35 | | 1.09 | | 0.66 | | <0.066 | | 0.288 | J |
| Total Nitrogen (mg/L) | 4.3 | | NS | | 2.4 | | 2.8 | | 5.1 | | 3.9 | | 4.2 | | 3.9 | |
| Orthophosphate (mg/L) | 0.005 | | NS | | 0.006 | | 0.006 | | 0.02 | | 0.019 | | 0.008 | | 0.009 | |
| Total Alkalinity (mg/L CaCO3) | 2.50 | | NS | | 14.4 | | 14.2 | | 10.0 | | 9 | | 6.70 | | 6.8 | |
| Chloride (mg/L) | 88.9 | | NS | | 34.3 | | 36.2 | | 31.5 | | 30.1 | | 33.3 | | 31.9 | |
| Sulfate (mg/L) | 11.6 | | NS | | 18.1 | | 16.3 | | 11.3 | | 10.7 | | 10.8 | | 10.3 | |
| Dissolved Iron (mg/L) | 0.19 | | NS | | 0.93 | | 0.51 | | 3.6 | | 0.9 | | 0.038 | J | 0.69 | |
| Dissolved Manganese (mg/L) | 0.0636 | | NS | | 0.466 | | 0.419 | | 0.108 | | 0.104 | | 0.0105 | | 0.0263 | |
| Dissolved Boron (mg/L) | 0.0415 | | NS | | 0.0250 | J | 0.0202 | J | 0.0306 | | 0.0271 | J | 0.0329 | | 0.029 | J |
| Dissolved Arsenic (mg/L) | 0.0031 | J | NS | | <0.0020 | | <0.0020 | | 0.0052 | | 0.0027 | J | 0.0025 | J | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | 0.72 | J | NS | | 0.57 | J | 0.57 | J | 0.68 | J | 0.69 | J | 0.68 | J | 0.75 | J |

Notes:

J - Data indicates a presence of a compound thatmeets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

*NS - low water level did not permit collection of a groundwater sample

Grey cell means data questionable and shoule not be relied upon

**Table 16 - Measured Water Quality Concentration at Dennis-Vinland Road Site - Piezometer Groundwater Data**

| Sample ID/Location | VLZ-61 | | | | VLZ-66 | | | |
|---|---|---|---|---|---|---|---|---|
| Screen bottom elevation (ft msl) | -16.4 | | | | -21.3 | | | |
| Sampling Date | 4/1/20 | | 5/7/20 | | 4/1/20 | | 5/7/20 | |
| Field Measurements | | | | | | | | |
| pH (SU) | 4.94 | | 5.02 | | 5.35 | | 5.37 | |
| Temperature (°C) | 10.6 | | 11.55 | | 11.3 | | 11.13 | |
| Dissolved Oxygen (DO; mg/L) | 7.24 | | 6.5 | | 6.52 | | 7.07 | |
| Specific Conductance (uS/cm) | 169 | | 179 | | 188.6 | | 197 | |
| Redox Potential (ORP; mV) | 212 | | 142 | | 234.2 | | 94 | |
| Laboratory Analyses | | | | | | | | |
| pH (SU) | 5.4 | | 5.1 | | 5.5 | | 5.3 | |
| Nitrate as N (mg/L) | 2.8 | | 3.2 | | 3.2 | | 3.2 | |
| Nitrite as N (mg/L) | <0.010 | | <0.010 | | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | <0.028 | E | <0.028 | | 0.030 | J | 0.031 | J |
| Total Kjeldahl Nitrogen (TKN) (mg/L) | <0.066 | E | 0.203 | J | <0.066 | | 0.074 | J |
| Total Nitrogen (mg/L) | 2.8 | | 3.2 | | 3.2 | | 3.2 | |
| Orthophosphate (mg/L) | 0.004 | JE | 0.012 | | 0.008 | | 0.013 | |
| Total Alkalinity (mg/L CaCO3) | 5.40 | | 4.7 | | 7.20 | | 8.4 | |
| Chloride (mg/L) | 31.9 | | 32.2 | | 36.8 | | 33.8 | |
| Sulfate (mg/L) | 12.0 | | 9.42 | | 12.6 | | 11.8 | |
| Dissolved Iron (mg/L) | 0.13 | E | 0.022 | J | 0.14 | | 0.67 | |
| Dissolved Manganese (mg/L) | 0.0275 | | 0.0209 | | 0.0141 | | 0.0464 | |
| Dissolved Boron (mg/L) | 0.0325 | | 0.0283 | J | 0.0366 | | 0.0306 | |
| Dissolved Arsenic (mg/L) | 0.0024 | J | <0.0020 | | <0.0020 | | 0.002 | |
| Dissolved Organic Carbon (mg/L) | 0.49 | JE | 0.69 | J | 0.55 | J | 0.66 | J |

Notes:

J - Data indicates a presence of a compound thatmeets the identification criteria.The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM -Not Measured

E - Exceeds RPD of 20% with duplicate sample

*NS - low water level did not permit collection of a groundwater sampl

Grey cell means data questionable and shoule not be relied upon

**Table 17 - Measured Water Quality Concentrations- Orleans-**
**Lonnie's Pond - Water Table Wells**

| Sample ID/Location | LP-2 | | | | LP-3 | | | | LP-4 | | | | LP-5 | | | | LP-6 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Date | 3/31/20 | | 5/9/2016* | | 4/1/20 | | 5/10/20 | | 3/31/20 | | 5/10/20 | | 4/1/20 | | 5/10/20 | | 4/1/20 | | 5/10/20 | |
| Field Measurements | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 5.69 | | 5.53 | | 5.87 | | 5.77 | | 5.28 | | 5.60 | | 5.04 | | 5.74 | | 5.21 | | 5.86 | |
| Temperature (°C) | 12.0 | | 19.1 | | 10.4 | | 17.3 | | 8.6 | | 14.8 | | 7.3 | | 14.1 | | 10.7 | | 14.2 | |
| Dissolved Oxygen (DO; mg/L) | 9.93 | | 5.48 | | 8.29 | | 5.93 | | 7.3 | | 5.76 | | 1.6 | | 1.09 | | 9.50 | | 10.55 | |
| Specific Conductance (uS/cm) | 1572 | | 2233 | | 312.7 | | 333.7 | | 217 | | 196.5 | | 765 | | 263.8 | | 1426 | | 1003 | |
| Redox Potential (ORP; mV) | 102.8 | | 179.5 | | 158.7 | | 171.6 | | 233.7 | | 207.3 | | 192.4 | | 147.7 | | 267.9 | | 131.8 | E |
| Laboratory Analyses | | | | | | | | | | | | | | | | | | | | |
| pH (SU) | 5.9 | | 5.6 | | 6.0 | | 5.7 | | 5.6 | | 5.2 | | 5.6 | | 5.5 | | 5.6 | | 5.6 | |
| Nitrate as N (mg/L) | 0.77 | | 1.3 | | 1.2 | | 0.9 | | 1.3 | | 0.81 | | 0.41 | | 0.74 | | 1.3 | | 1.4 | |
| Nitrite as N (mg/L) | 0.025 | J | 0.016 | J | <0.010 | | 0.015 | J | <0.010 | | <0.010 | | <0.010 | | 0.015 | J | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | 0.098 | J | 0.059 | J | 0.053 | JBE | <0.028 | | <0.028 | | <0.028 | | 0.034 | JB | 0.061 | J | <0.028 | | 0.057 | J,E |
| Total Kjeldahl Nitrogen (TKN; mg/L) | 0.703 | | 2.09 | | 0.700 | E | 0.31 | | 0.136 | J | 0.193 | J | 0.244 | J | 0.815 | | 0.112 | J | 0.258 | J |
| Total Nitrogen (mg/L) | 1.5 | | 3.4 | | 1.9 | E | 1.2 | | 1.3 | | 0.81 | | 0.41 | | 1.6 | | 1.3 | | 1.4 | |
| Orthophosphate (mg/L) | 0.006 | | 0.008 | | 0.004 | JE | 0.005 | | 0.006 | | 0.005 | | 0.004 | J | 0.009 | | 0.004 | J | 0.006 | |
| Total Alkalinity (mg/L CaCO3) | 32.5 | | 22.8 | | 18.3 | | 20.6 | | 11.3 | | 10.9 | | 16.6 | | 15.7 | | 5.40 | | 8.6 | |
| Chloride (mg/L) | 511 | | 624 | | 75.1 | | 71.4 | | 42.6 | | 36.3 | | 234 | | 51.6 | | 444 | | 263 | |
| Sulfate (mg/L) | 5.75 | | 4.6 | | 12.6 | | 12.5 | | 16.3 | | 14.1 | | 7.53 | | 7.22 | | 3.08 | | 2.83 | |
| Dissolved Iron (mg/L) | 5.3 | | 0.33 | | 0.25 | E | 0.65 | | 0.083 | | 0.068 | | 0.44 | | 0.21 | | 0.14 | | 1.1 | E |
| Dissolved Manganese (mg/L) | 0.724 | | 0.221 | | 0.210 | | 0.112 | | 0.0518 | | 0.0265 | | 0.408 | | 0.115 | | 0.499 | | 1.15 | E |
| Dissolved Boron (mg/L) | 0.0119 | J | 0.0134 | J | 0.0143 | J | 0.0165 | J | 0.0151 | J | 0.0156 | J | 0.0213 | J | 0.0214 | J | 0.0085 | J | 0.0103 | J |
| Dissolved Arsenic (mg/L) | <0.0020 | | 0.002 | J | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | <0.0020 | | 0.005 | U | <0.0020 | | 0.0021 | J,E |
| Dissolved Organic Carbon (mg/L) | 3.4 | J | 2.1 | J | 1.1 | | 1.5 | | 0.85 | | 0.94 | J | 2.5 | | | | 1.2 | J | 0.99 | J |

Notes:

B - The analyte was detected above the reporting limit in the associated method blank. Flag only applies to associated field samples that have detectable concentrations of the analyte at less than ten times (10x) the concentration found in the blank.

J - Data indicates a presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM - Not Measured

E - Exceeds RPD of 20% with duplicate sample

*Round 2 LP-2 well kept going dry & clogged

Grey shaded cell data should not be relied upon based on QA/QC review

**Table 18- Measured Water Quality Concentrations at Orleans-Lonnie's Pond ISC Site - Piezometer Groundwater Data**

| Sample ID/Location | LPZ-10 | | | | LPZ-15 | | | | LPZ-21 | | | | LPZ-29 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Screen bottom elevation (ft msl) | 1.3 | | | | -3.5 | | | | -9.4 | | | | -17.4 | | | |
| Sampling Date | 3/31/20 | | 5/9/16 | | 3/31/20 | | 5/10/20 | | 3/31/20 | | 5/10/20 | | 3/31/20 | | 5/11/20 | |
| Field Measurements | | | | | | | | | | | | | | | | |
| pH (SU) | 5.90 | | NS | | 4.20 | | 5.39 | | 5.3 | | 5.51 | | 5.19 | | 5.29 | |
| Temperature (°C) | 13.5 | | NS | | 10.1 | | 10.8 | | 10.0 | | 10.90 | | 10.7 | | 11.68 | |
| Dissolved Oxygen (DO; mg/L) | 7.91 | | NS | | 4.23 | | 7.17 | | 3.74 | | 3.86 | | 5.90 | | 6.96 | |
| Specific Conductance (uS/cm) | 149.7 | | NS | | 219.1 | | 230.4 | | 581 | | 572.3 | | 1021 | | 1086 | |
| Redox Potential (ORP; mV) | 55.1 | | NS | | 181.0 | | 298.7 | | 226.8 | | 275.9 | | 149.5 | | 53.0 | |
| Laboratory Analyses | | | | | | | | | | | | | | | | |
| pH (SU) | 6.6 | | NS | | 5.4 | | 5.5 | | 5.6 | | 5.5 | | 5.4 | | 5.2 | |
| Nitrate as N (mg/L) | 1.6 | | NS | | 0.48 | | 0.78 | | 1.3 | | 1.5 | | 1.8 | | 2 | |
| Nitrite as N (mg/L) | 0.023 | J | NS | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | | <0.010 | |
| Ammonia as N (mg/L) | NA | | NS | | 0.044 | J | <0.028 | | <0.028 | | 0.054 | J | <0.028 | | 0.071 | J,E |
| Total Kjeldahl Nitrogen (TKN; mg/L) | NA | | NS | | 0.147 | J | 0.159 | J | <0.066 | | <0.066 | | 0.097 | J | <0.066 | E |
| Total Nitrogen (mg/L) | NA | | NS | | 0.48 | | 0.78 | | 1.3 | | 1.5 | | 1.8 | | 2.0 | |
| Orthophosphate (mg/L) | <0.001 | | NS | | 0.008 | | 0.011 | | 0.025 | | 0.027 | | 0.019 | | 0.023 | |
| Total Alkalinity (mg/L CaCO3) | NA | | NS | | 10.2 | | 11.5 | | 15.8 | | 17.5 | | 8.40 | | 8.6 | |
| Chloride (mg/L) | 56.4 | | NS | | 46.1 | | 47.4 | | 144 | | 122 | | 307 | | 284 | |
| Sulfate (mg/L) | 13.3 | | NS | | 12.8 | | 12.1 | | 8.11 | | 7.12 | | 7.19 | | 6.33 | |
| Dissolved Iron (mg/L) | NA | | NS | | 0.038 | J | <0.020 | | 0.037 | J | <0.020 | | 0.053 | E | <0.020 | E |
| Dissolved Manganese (mg/L) | NA | | NS | | 0.0190 | | 0.0148 | | 0.0423 | | 0.0392 | | 0.0407 | | 0.0449 | |
| Dissolved Boron (mg/L) | NA | | NS | | 0.0163 | J | 0.015 | J | 0.0317 | | 0.0314 | | 0.0278 | JE | 0.0264 | J |
| Dissolved Arsenic (mg/L) | NA | | NS | | <0.0020 | | <0.0020 | | 0.0020 | J | <0.0020 | | <0.0020 | J | <0.0020 | |
| Dissolved Organic Carbon (mg/L) | NA | | NS | | 1.0 | | 0.91 | J | 0.48 | | 0.92 | J | 0.61 | JE | 0.94 | J |

Notes:

B - The analyte was detected above the reporting limit in the associated method blank. Flag only applies to associated field samples that have detectable concentrations of the analyte at less than ten times (10x) the concentration found in the blank.

J - Data indicates a presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM - Not Measured

E - Exceeds RPD of 20% with duplicate sample

NA-Not analyzed

Grey shaded cell data should not be relied upon based on QA/QC review

**Table 18- Measured Water Quality Concentrations at Orleans-Lonnie's Pond ISC Site - Piezometer Groundwater Data**

| Sample ID/Location | LPZ-39 | | | | LPZ-53 | | | | LPZ-61 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Screen bottom elevation (ft msl) | -27.4 | | | | -43.1 | | | | -50.0 | | | |
| Sampling Date | 3/31/20 | | 5/11/20 | | 4/1/20 | | 5/11/20 | | 4/1/20 | | 5/11/20 | |
| Field Measurements | | | | | | | | | | | | |
| pH (SU) | 5.68 | | 5.92 | | 5.99 | | 5.60 | | 5.9 | | 5.91 | |
| Temperature (°C) | 11.0 | | 14.57 | | 11.4 | | 12.6 | | 10.8 | | 13.44 | |
| Dissolved Oxygen (DO; mg/L) | 0.93 | | 4.75 | | 3.96 | | 4.96 | | 2.18 | | 1.57 | |
| Specific Conductance (uS/cm) | 309 | | 330 | | 620.5 | | 673 | | 387 | | 417 | |
| Redox Potential (ORP; mV) | 41.1 | | 46.2 | | 83.2 | | 166.6 | | -225.4 | | -32.9 | |
| Laboratory Analyses | | | | | | | | | | | | |
| pH (SU) | 6.0 | | NA | | 5.8 | | 5.6 | | 6.0 | | 6.0 | |
| Nitrate as N (mg/L) | 0.44 | | NA | | 1.8 | | 1.8 | | 1.0 | | 1 | |
| Nitrite as N (mg/L) | 0.016 | J | NA | | 0.021 | J | <0.010 | | 0.017 | J | <0.010 | |
| Ammonia as N (mg/L) | 0.196 | | <0.020 | | 0.053 | JB | 0.038 | J | <0.028 | | <0.028 | |
| Total Kjeldahl Nitrogen (TKN; mg/L) | 0.347 | | 0.3 | | 0.145 | J | <0.066 | | 0.114 | J | <0.066 | |
| Total Nitrogen (mg/L) | 0.79 | | 0.83 | | 1.8 | | 1.8 | | 1.0 | | 1 | |
| Orthophosphate (mg/L) | 0.031 | | NA | | 0.005 | | 0.005 | | 0.024 | | 0.035 | |
| Total Alkalinity (mg/L CaCO3) | 23.9 | | NA | | 22.9 | | 14.7 | | 29.7 | | 26.9 | |
| Chloride (mg/L) | 66.3 | | NA | | 173 | | 143 | | 93.9 | | 78.7 | |
| Sulfate (mg/L) | 2.3 | | NA | | 5.50 | | 4.46 | | 4.22 | | 2.39 | |
| Dissolved Iron (mg/L) | 0.78 | | 0.60 | | 4.3 | | 0.57 | | 1.3 | | 0.33 | |
| Dissolved Manganese (mg/L) | 0.248 | | 0.164 | | 0.334 | | 0.122 | | 0.488 | | 0.169 | |
| Dissolved Boron (mg/L) | 0.0407 | | 0.0339 | | 0.0326 | | 0.0326 | | 0.0336 | | 0.0345 | |
| Dissolved Arsenic (mg/L) | <0.0020 | | 0.0023 | J | <0.0020 | | <0.0020 | | <0.0020 | | 0.0021 | J |
| Dissolved Organic Carbon (mg/L) | 0.69 | | 1.2 | | 0.69 | J | 0.65 | J | 0.96 | J | 0.84 | J |

Notes:

B - The analyte was detected above the reporting limit in the associated method blank. Flag only applies to associated field samples that have detectable concentrations of the analyte at less than ten times (10x) the concentration found in the blank.

J - Data indicates a presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

NS - Not Sampled / NM - Not Measured

E - Exceeds RPD of 20% with duplicate sample

NA-Not analyzed

Grey shaded cell data should not be relied upon based on QA/QC review

**Table 18- Measured Water Quality Concentrations at Orleans-Lonnie's Pond ISC Site - Piezometer Groundwater Data**

| Sample ID/Location | LPZ-71 | | | | LPZ-80 | | | | LPZ-90 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Screen bottom elevation (ft msl) | -61.1 | | | | -70.1 | | | | -79.1 | | | |
| Sampling Date | 3/31/20 | | 5/11/20 | | 3/31/20 | | 5/11/20 | | 3/31/20 | | 5/11/20 | |
| Field Measurements | | | | | | | | | | | | |
| pH (SU) | 6.77 | | 6.82 | | 7.29 | | 6.65 | | 7.09 | | 6.68 | |
| Temperature (°C) | 10.0 | | 12.4 | | 11.1 | | 12.0 | | 11.2 | | 12.0 | |
| Dissolved Oxygen (DO; mg/L) | 0.65 | | 0.39 | | 0.23 | | 0.36 | | 0.22 | | 0.36 | |
| Specific Conductance (uS/cm) | 223 | | 221.9 | | 161.7 | | 175.1 | | 172.3 | | 184.6 | |
| Redox Potential (ORP; mV) | -136.7 | | -128.4 | | -197.8 | | -103.9 | | -184.7 | | -101.3 | |
| Laboratory Analyses | | | | | | | | | | | | |
| pH (SU) | 6.4 | | 6.2 | | 6.4 | | 6.4 | | 6.3 | | 6.4 | |
| Nitrate as N (mg/L) | 0.11 | | 0.059 | J | 0.069 | J | 0.04 | J | 0.051 | J | 0.035 | J |
| Nitrite as N (mg/L) | 0.027 | J | 0.024 | J | 0.017 | J | 0.017 | J | <0.010 | | 0.014 | J |
| Ammonia as N (mg/L) | 0.110 | | 0.077 | | 0.060 | J | 0.041 | J | 0.117 | | 0.098 | |
| Total Kjeldahl Nitrogen (TKN; mg/L) | 0.199 | J | 0.177 | J | 0.105 | J | 0.098 | J | 1.42 | | 0.149 | J |
| Total Nitrogen (mg/L) | <0.30 | | <0.30 | | <0.30 | | <0.30 | | 1.4 | | <0.30 | |
| Orthophosphate (mg/L) | <0.001 | | 0.003 | J | 0.682 | | 0.721 | | 0.002 | J | 0.085 | |
| Total Alkalinity (mg/L CaCO3) | 43.9 | | 38.2 | | 32.4 | | 29 | | 30.2 | | 30 | |
| Chloride (mg/L) | 27.1 | | 25 | | 25.7 | | 24.2 | | 26.8 | | 25 | |
| Sulfate (mg/L) | 10.3 | | 8.42 | | 8.28 | | 7.7 | | 11.4 | | 10.5 | |
| Dissolved Iron (mg/L) | 0.0279 | | 30 | | 14 | | 13 | | 12 | | 12 | |
| Dissolved Manganese (mg/L) | 0.198 | | 0.186 | | 0.126 | | 0.116 | | 0.359 | | 0.331 | |
| Dissolved Boron (mg/L) | 0.0258 | J | 0.026 | J | 0.0218 | J | 0.0221 | J | 0.0231 | J | 0.0223 | J |
| Dissolved Arsenic (mg/L) | 0.0279 | | 0.022 | | 0.0071 | | 0.0036 | J | 0.0185 | | 0.0163 | |
| Dissolved Organic Carbon (mg/L) | 1.7 | | 1.8 | | 1.8 | | 0.99 | J | 0.66 | | 0.82 | J |

Notes:

B - The analyte was detected above the reporting limit in the associated method blank. Flag only applies to associated field samples that have detectable concentrations of the analyte at less than ten times (10x) the concentration found in the blank.

J - Data indicates a presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

R - Suspected error in field pH and ORP measurements

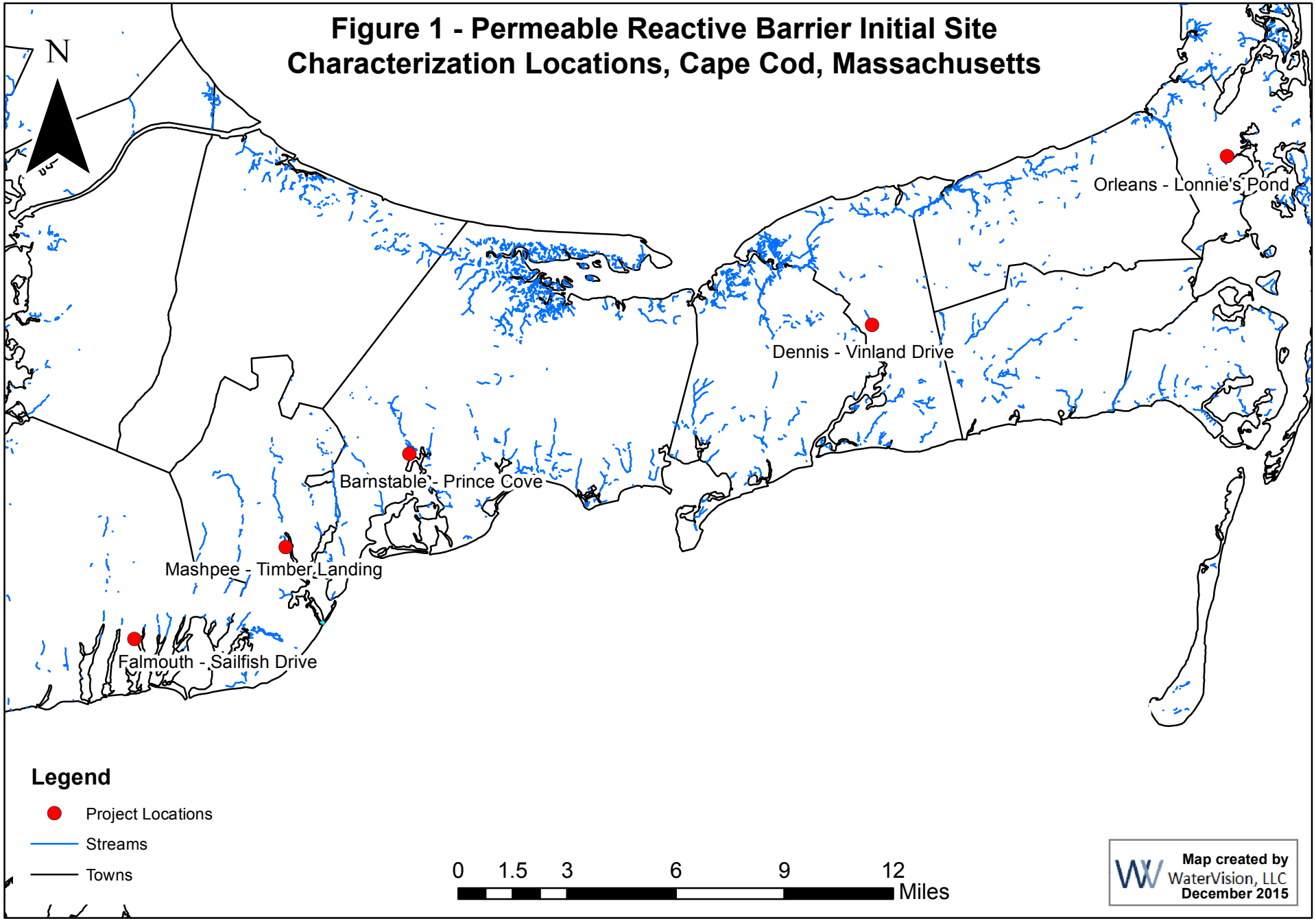
NS - Not Sampled / NM - Not Measured

E - Exceeds RPD of 20% with duplicate sample

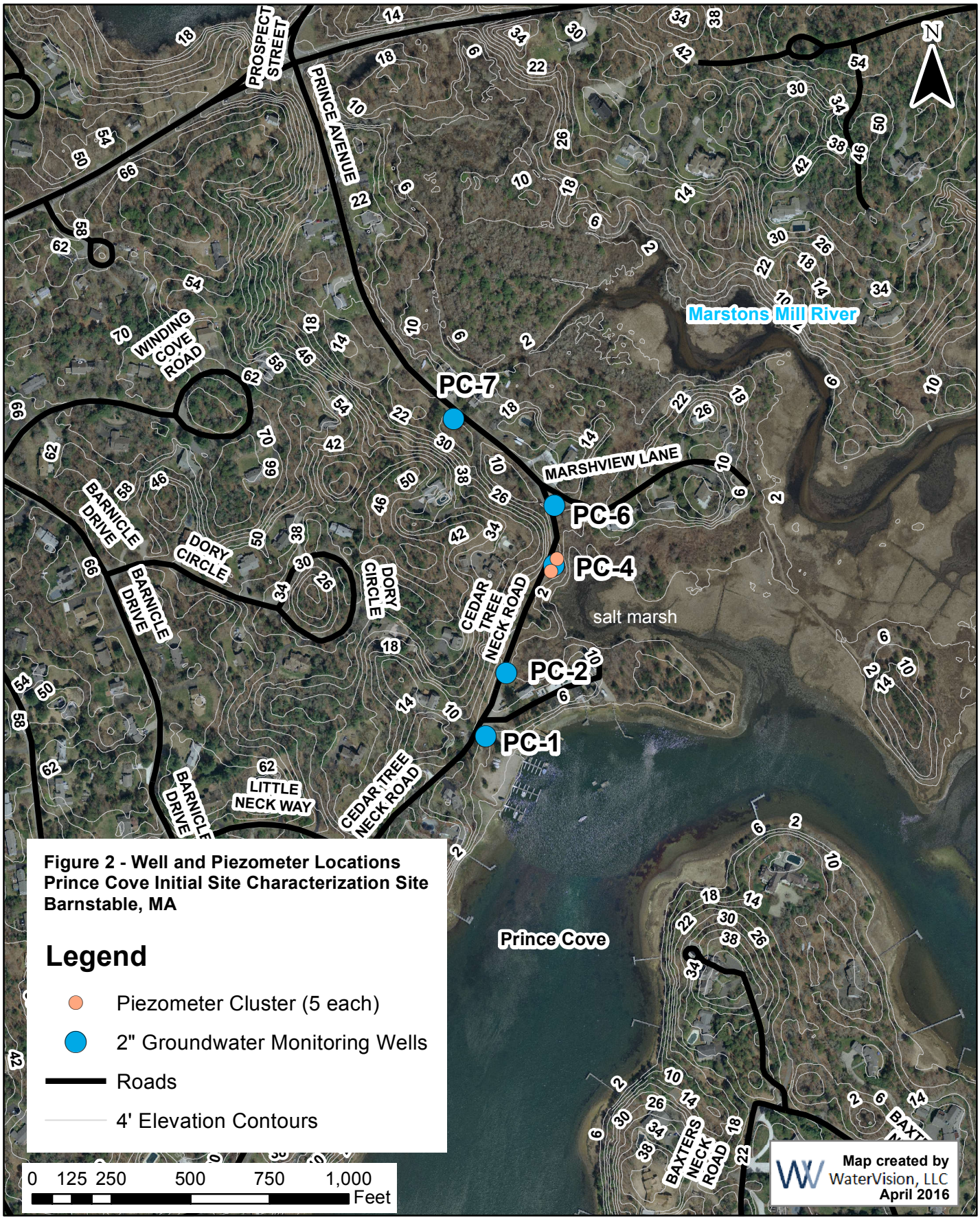
NA-Not analyzed

Grey shaded cell data should not be relied upon based on QA/QC review

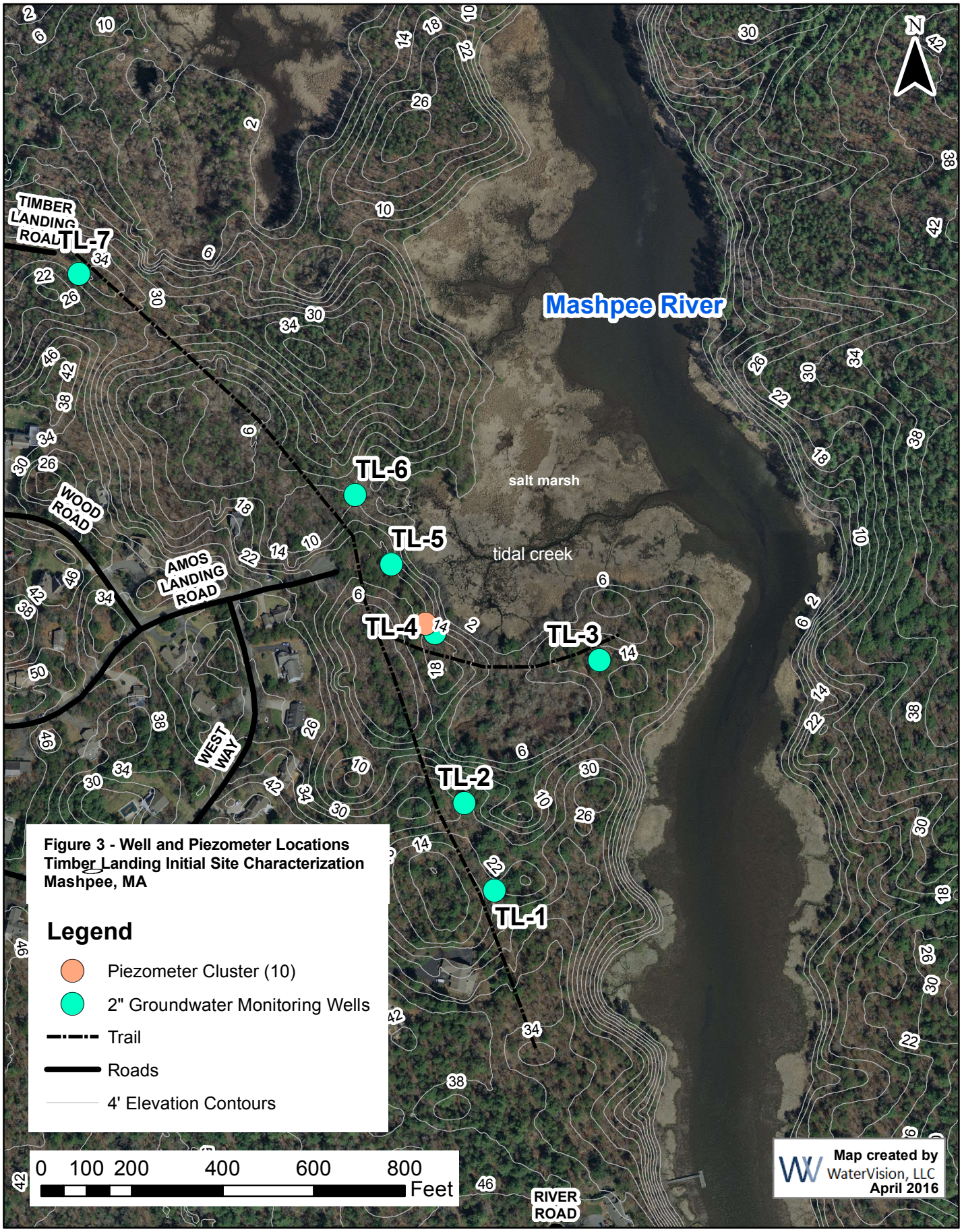
# Figure 1 - Permeable Reactive Barrier Initial Site Characterization Locations, Cape Cod, Massachusetts



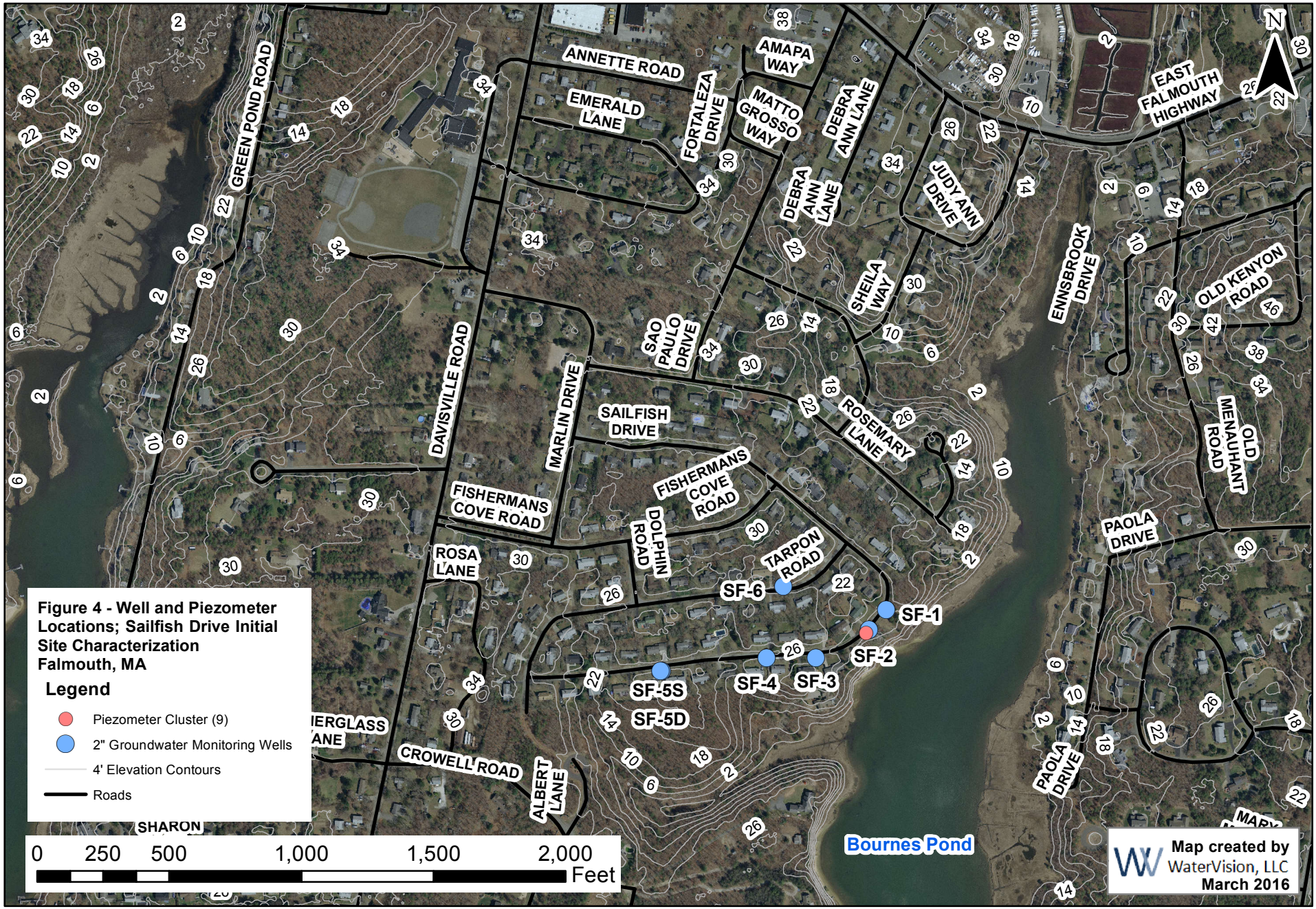

Sources: Town boundaries from Mass GIS, Streams from MassDEP Hydrography.




Sources: Aerial photography 2013-2014 and Roads from Mass GIS, Parcel Boundaries from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezometer Cluster locations from WaterVision LLC. Elevation contours from Cape Cod Commission.

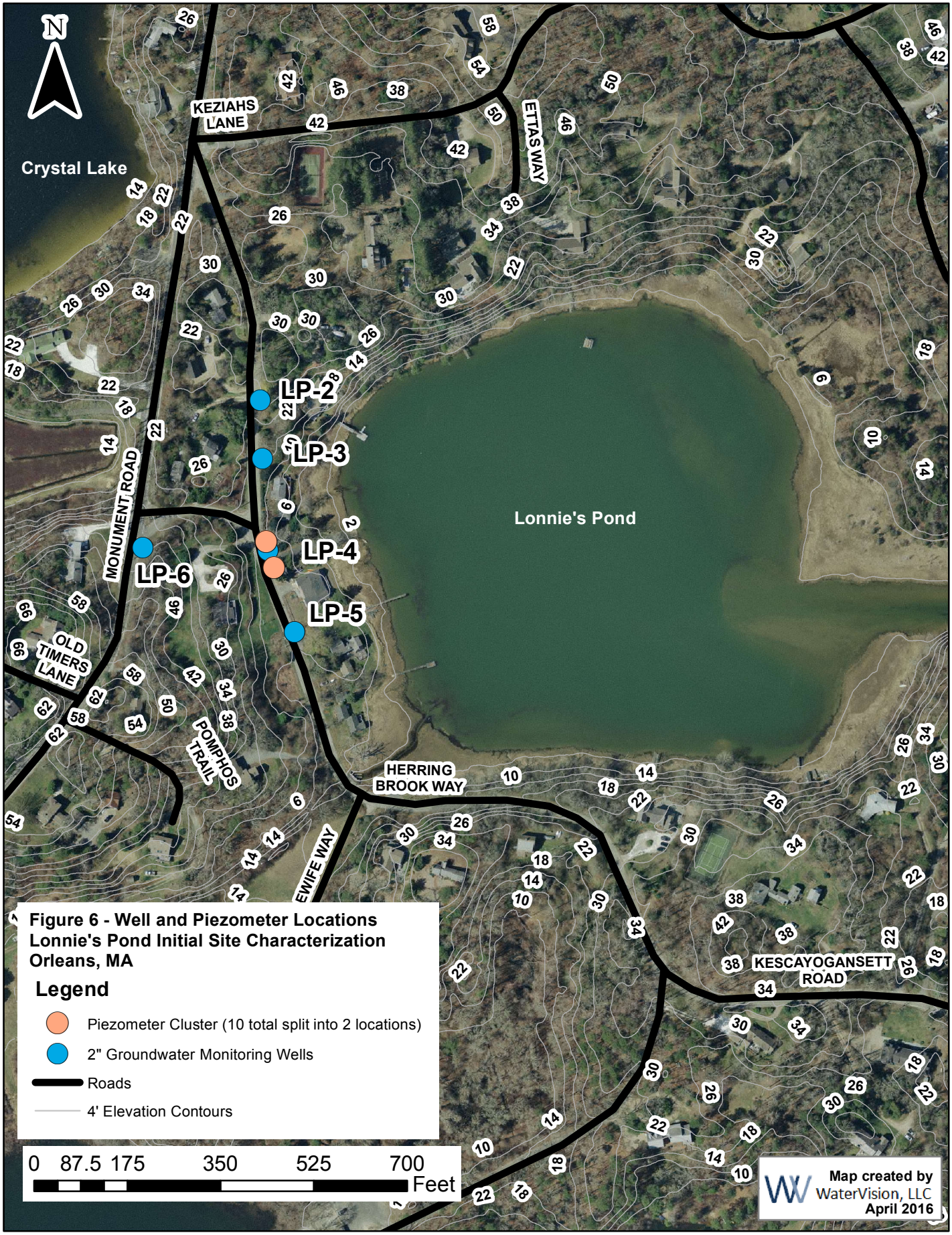



Sources: Aerial photography 2013-2014 and Roads from Mass GIS, surveyed Groundwater Monitoring Well and Piezometer Cluster locations from WaterVision LLC. Elevation contours from the Cape Cod Commission.

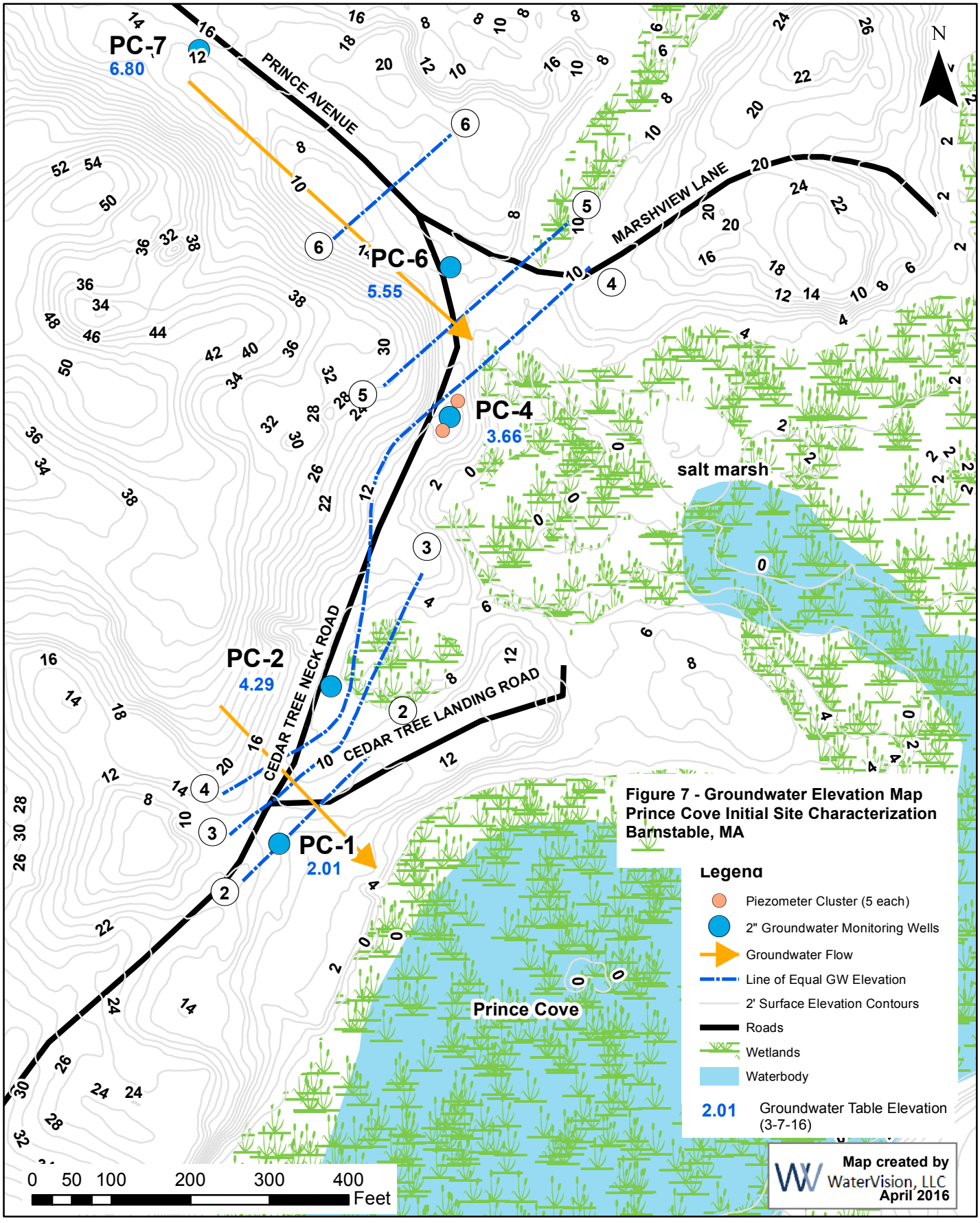



Sources: Aerial photography 2013-2014 and Roads from Mass GIS,
Parcel Boundaries from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezometer locations from WaterVision LLC. Elevation contours from the Cape Cod Commission.

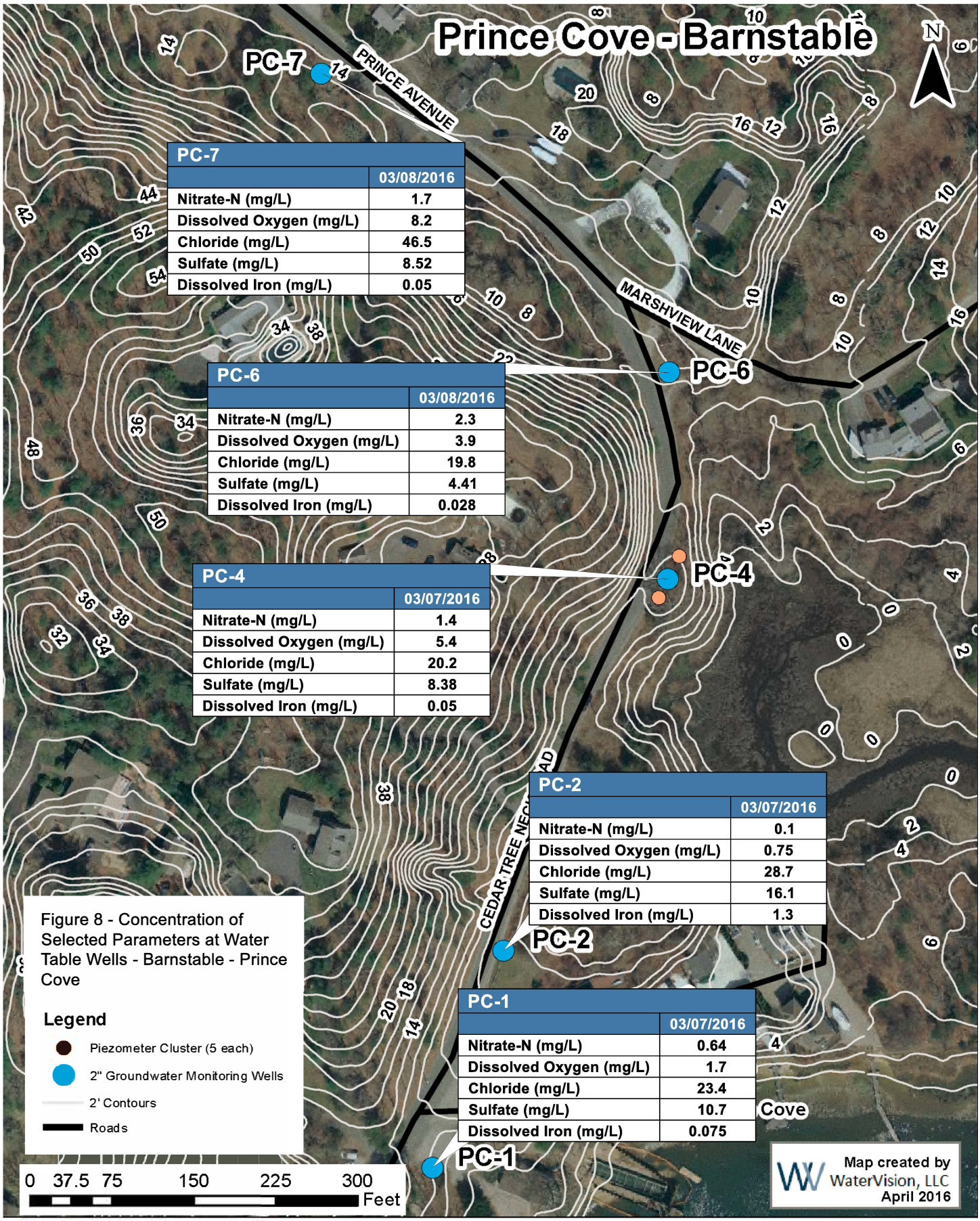

Sources: Aerial photography 2013-2014 and Roads from Mass GIS, Surface elevation contours from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezometer locations from WaterVision LLC.




Sources: Aerial photography 2013-2014 and Roads from Mass GIS, Elevation contours from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezomenter locations from WaterVision LLC.

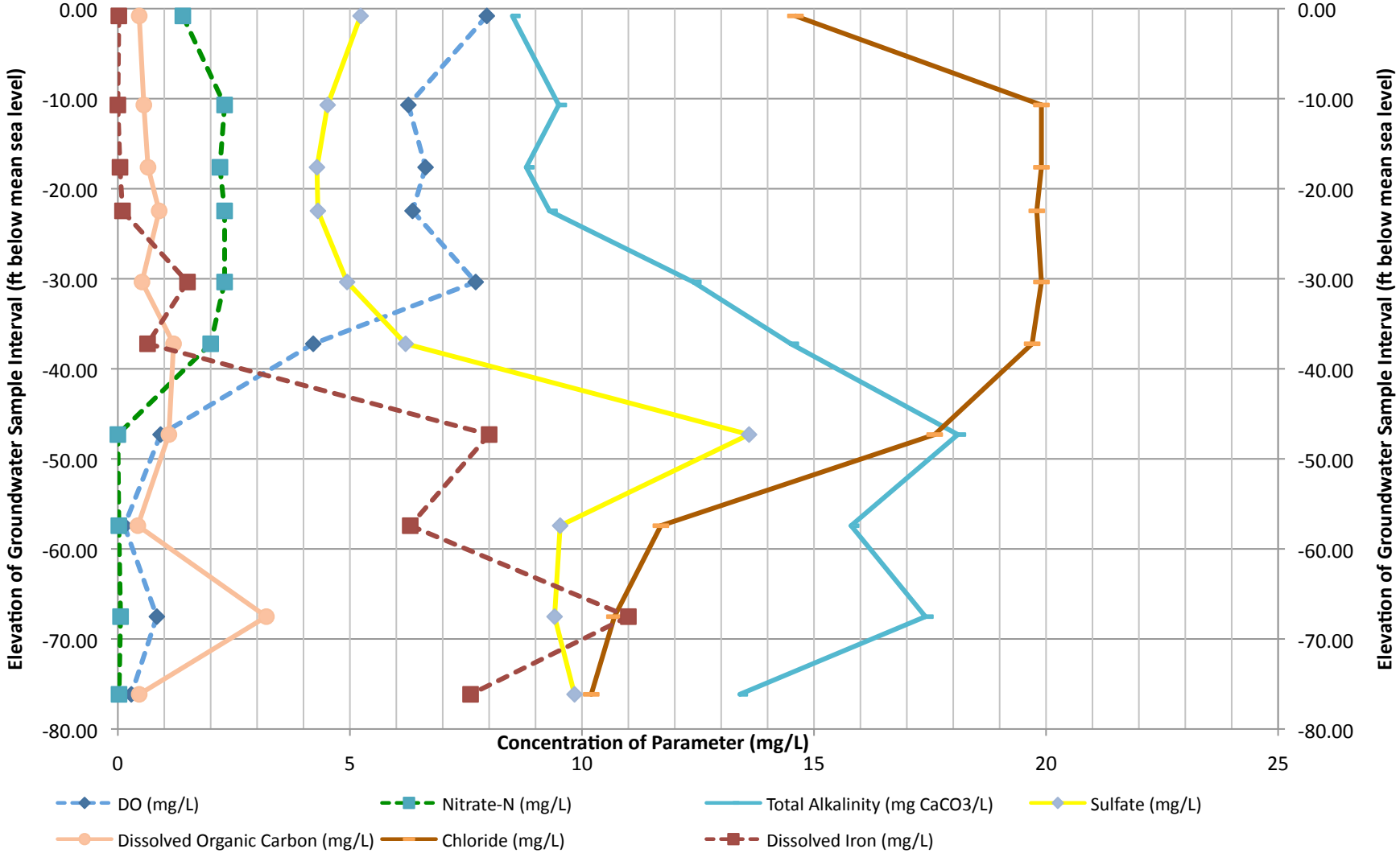


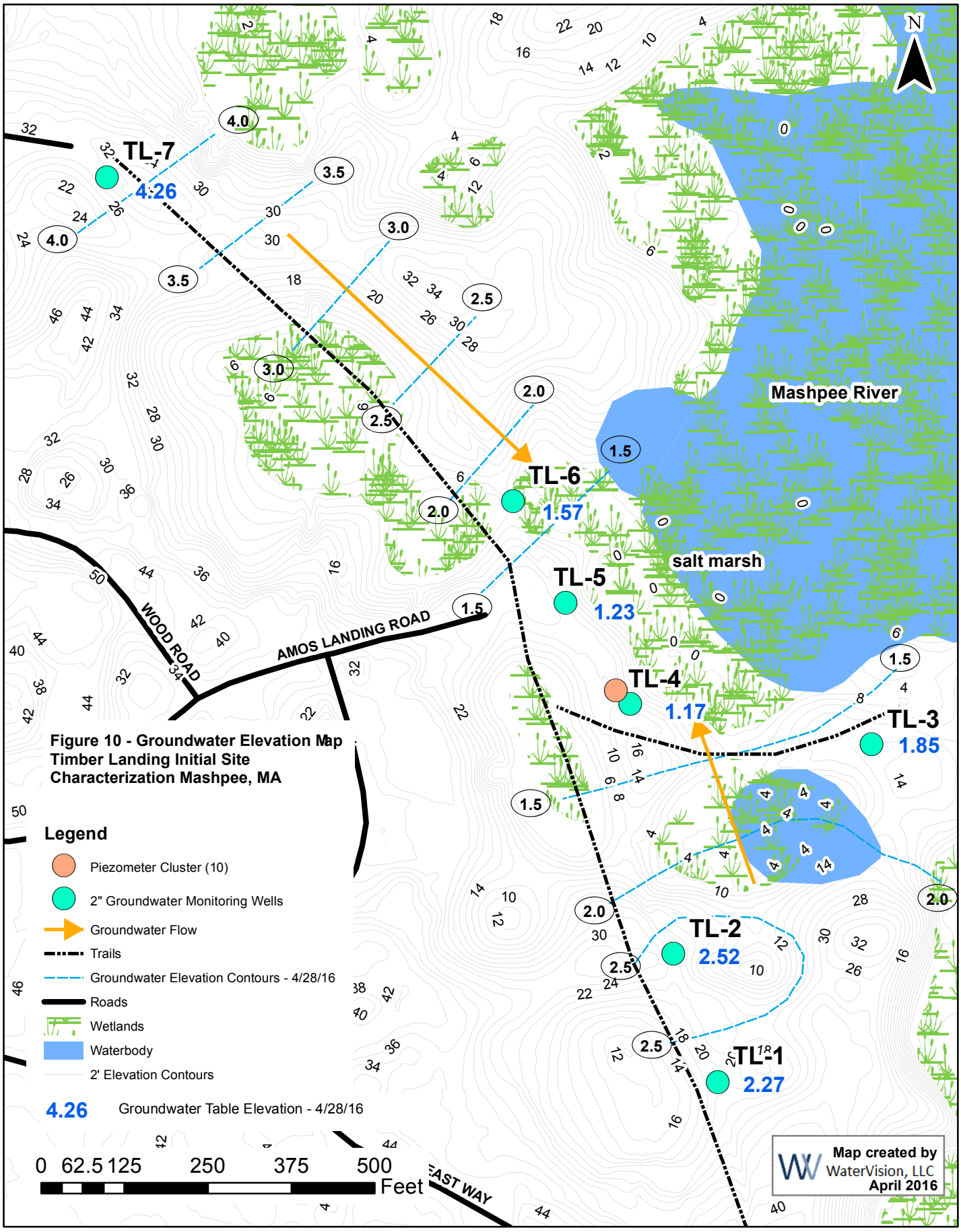

Sources: Roads from Mass GIS. Surveyed Groundwater Monitoring Well and Piezometer Cluster locations and groundwater table elevations and contours from WaterVision LLC. Wetlands and waterbodies from MassDEP. Elevation Contours from Cape Cod Commission.



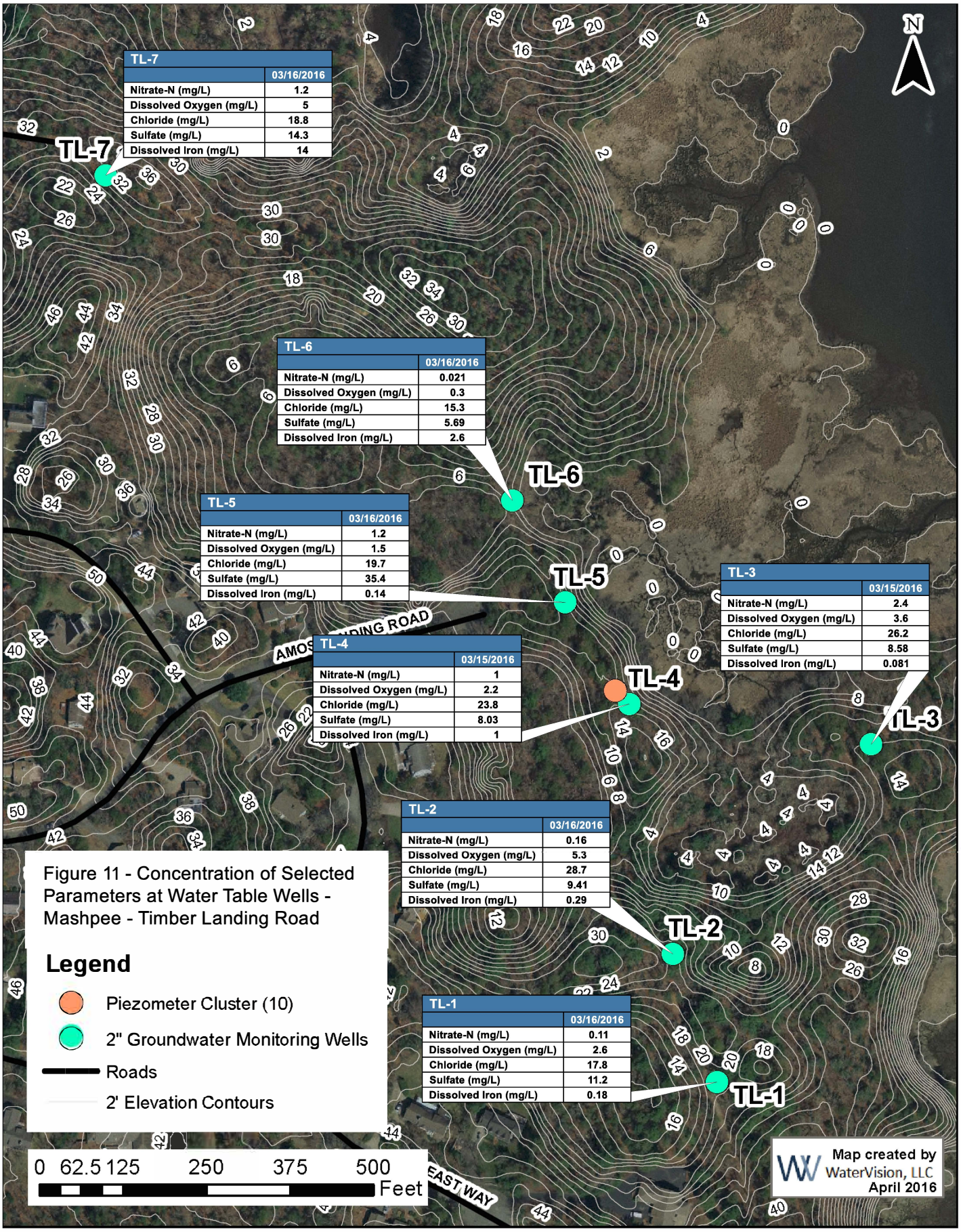

Sources: Aerial photography 2013 - 2014 and Roads from Mass GIS, Parcel Boundaries from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezometer Cluster locations from WaterVision LLC. 2 foot contours from Cape Cod Commission.

**Figure 9 - Variation of Water Quality Parameters with Elevation, ISC Site - Barnstable - March 2016**






Sources: Roads from Mass GIS, surveyed Groundwater Monitoring Well and Piezometer Cluster locations from WaterVision LLC. Wetlands and waterbodies from MassDEP. 2' surface elevation contours from Cape Cod Commission.




Sources: Aerial photography 2013 - 2014 and Roads from Mass GIS, surveyed Groundwater Monitoring Well and Piezometer Cluster locations from WaterVision LLC. 2 foot surface elevation contours from the Cape Cod Commission.

**Figure 12 - Variation of Dissolved Oxygen, Nitrate-N, dissolved Manganese, and Dissolved Organic Carbon with Elevation, ISC Site - Mashpee, MA - March 2016**

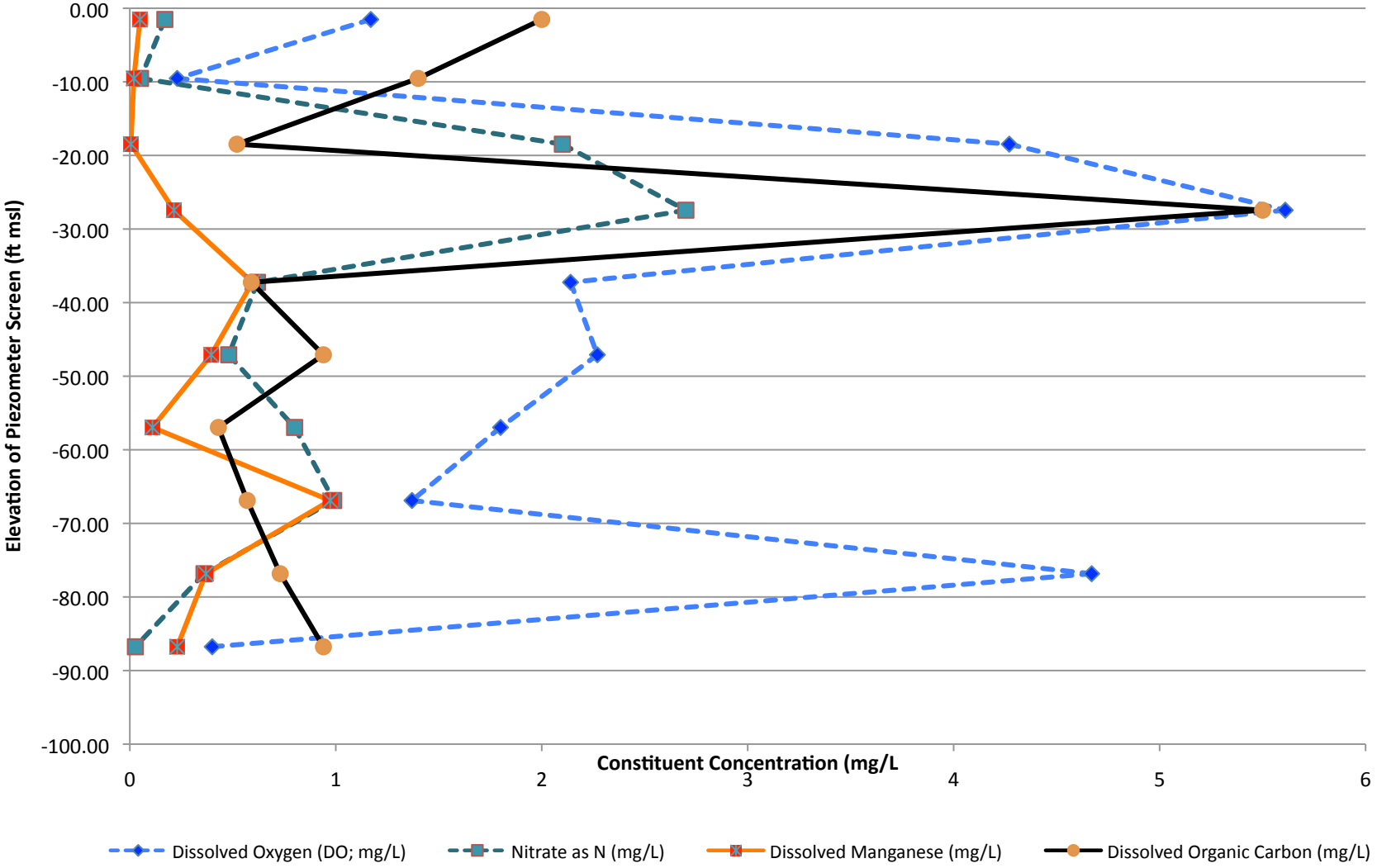


**Figure 13 - Variation of Nitrate-N, Dissolved Iron, Chloride, Sulfate and Total Alkalinity with Elevation, ISC Site - Mashpee, MA - March 2016**

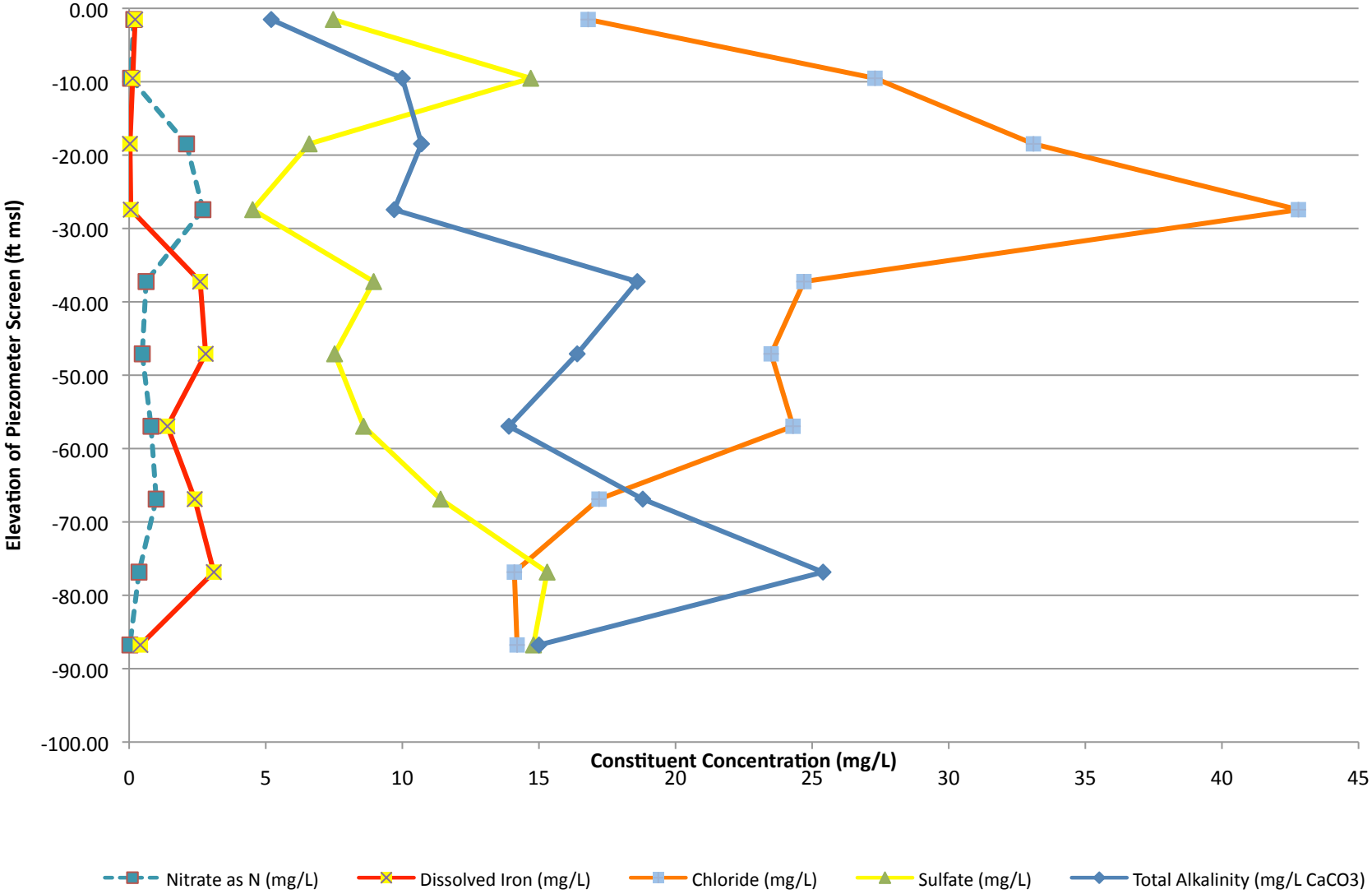
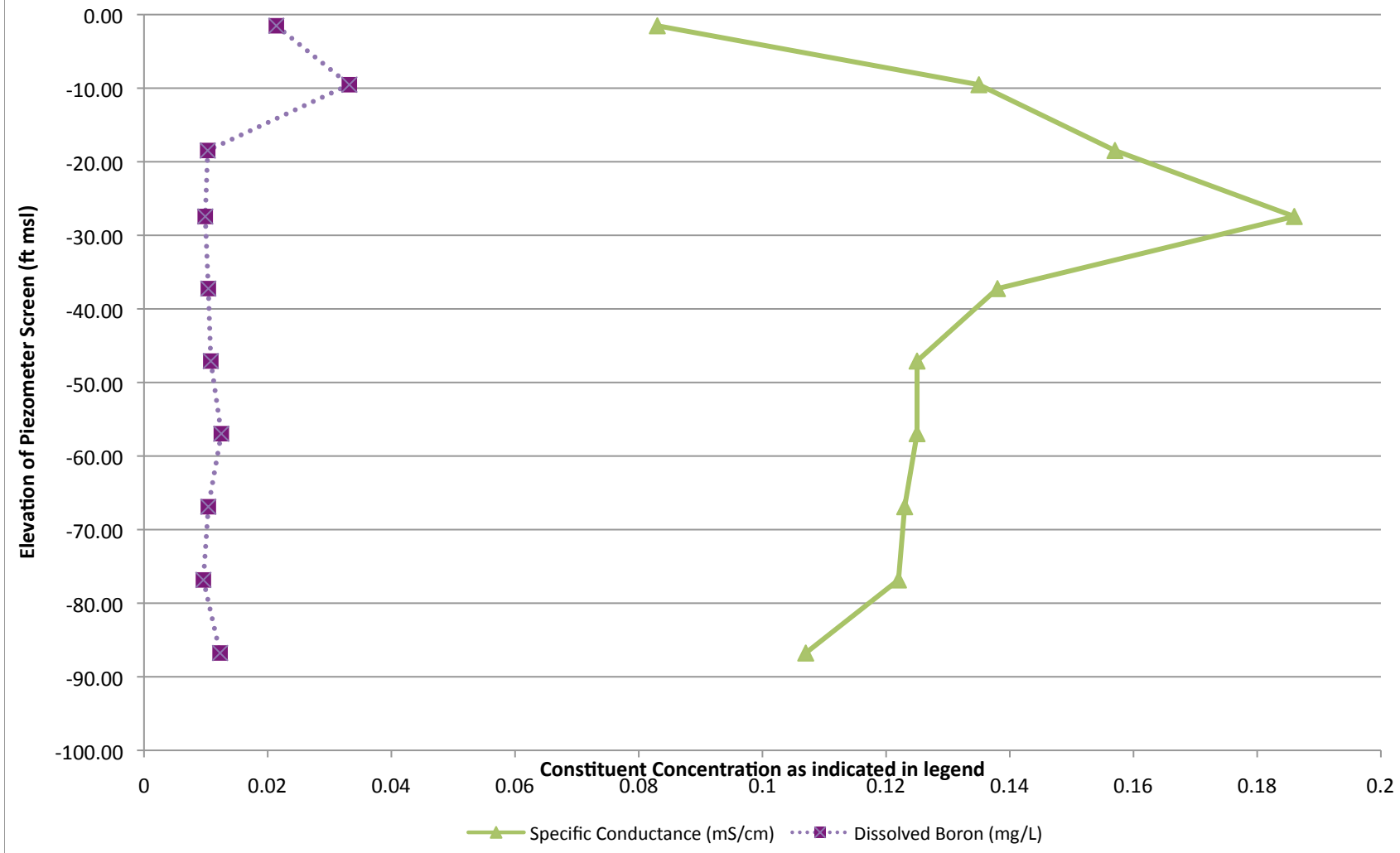


**Figure 14 - Variation of Water Quality Parameters with Elevation, ISC Site - Mashpee, MA - March 2016**



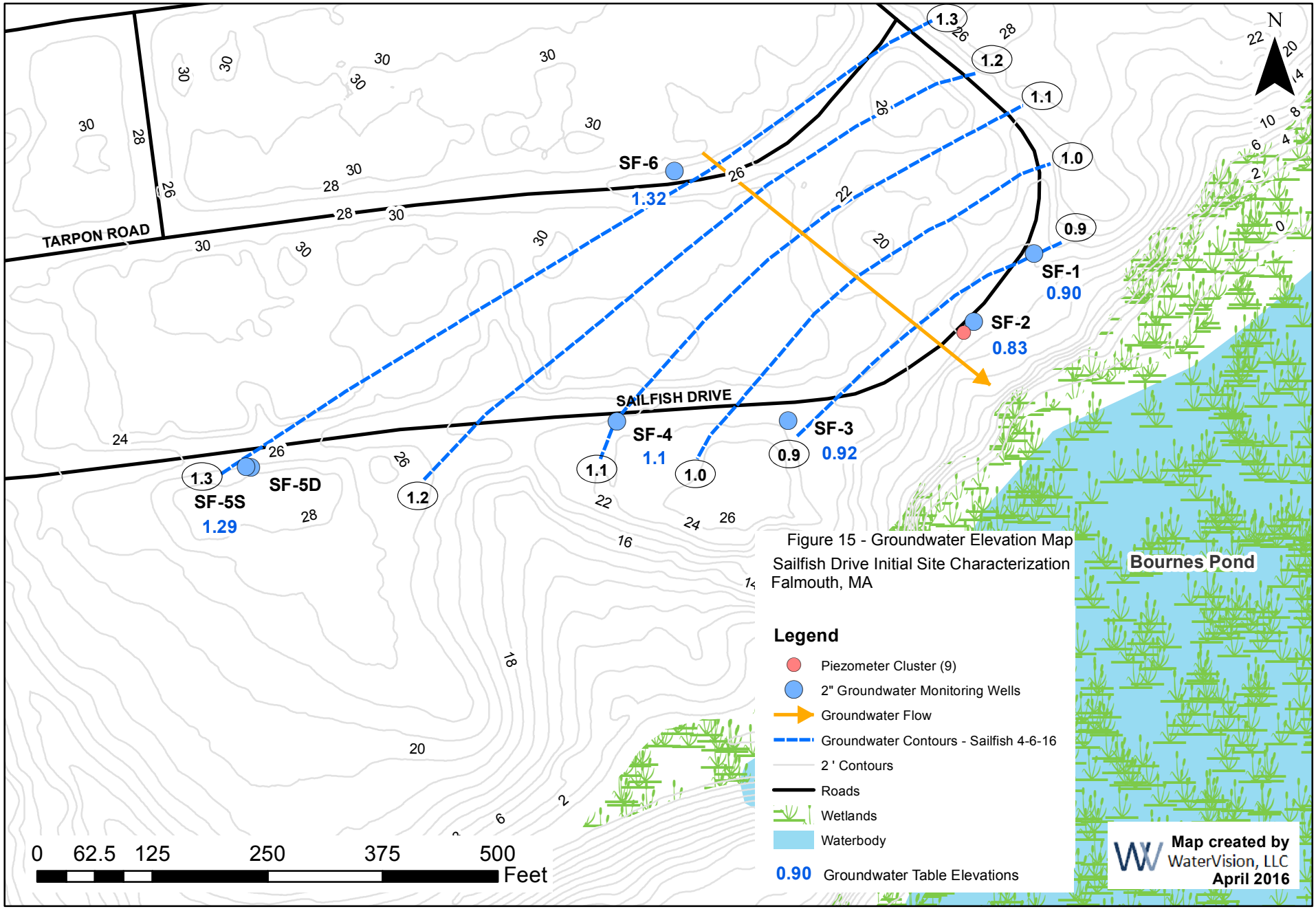
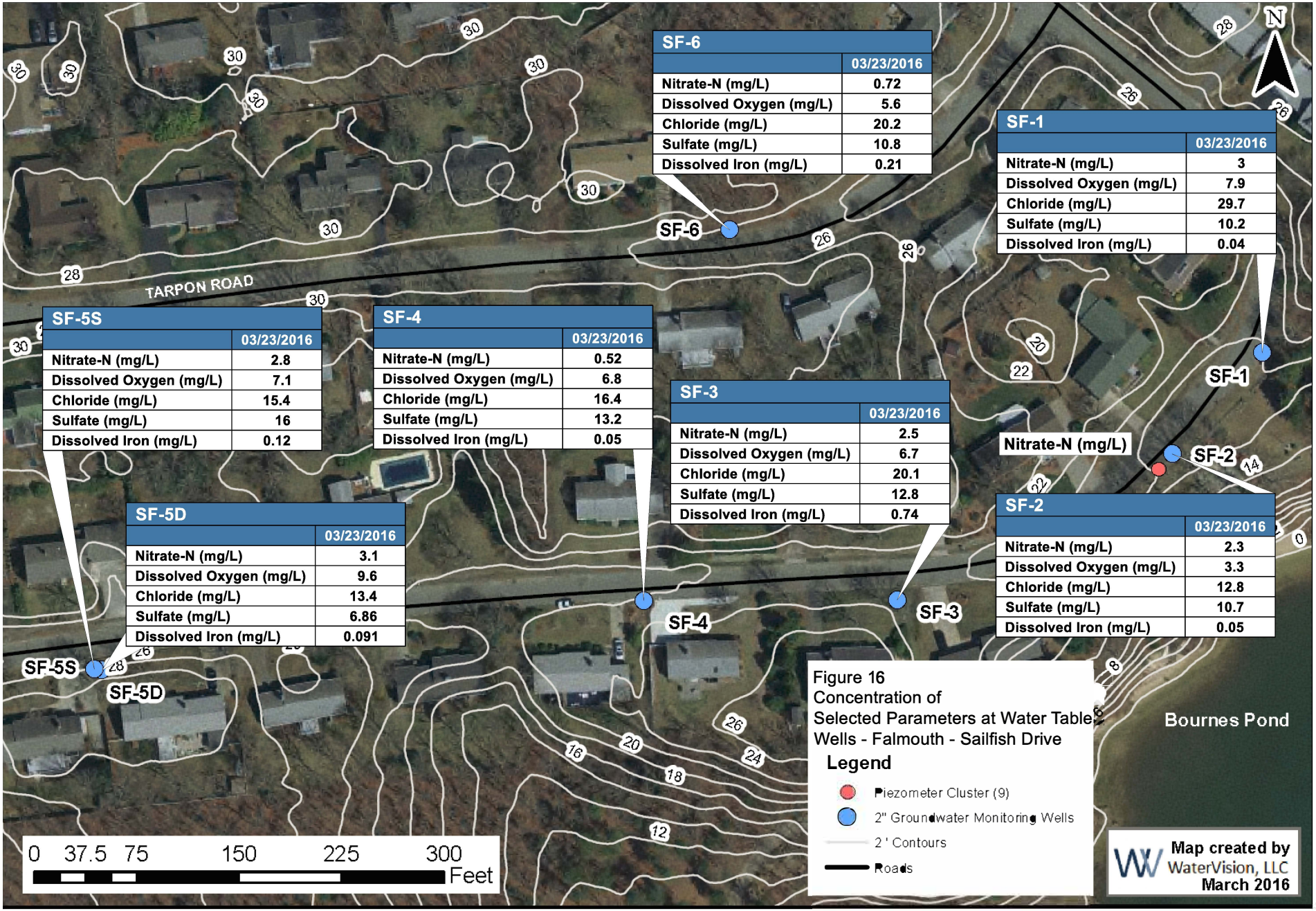


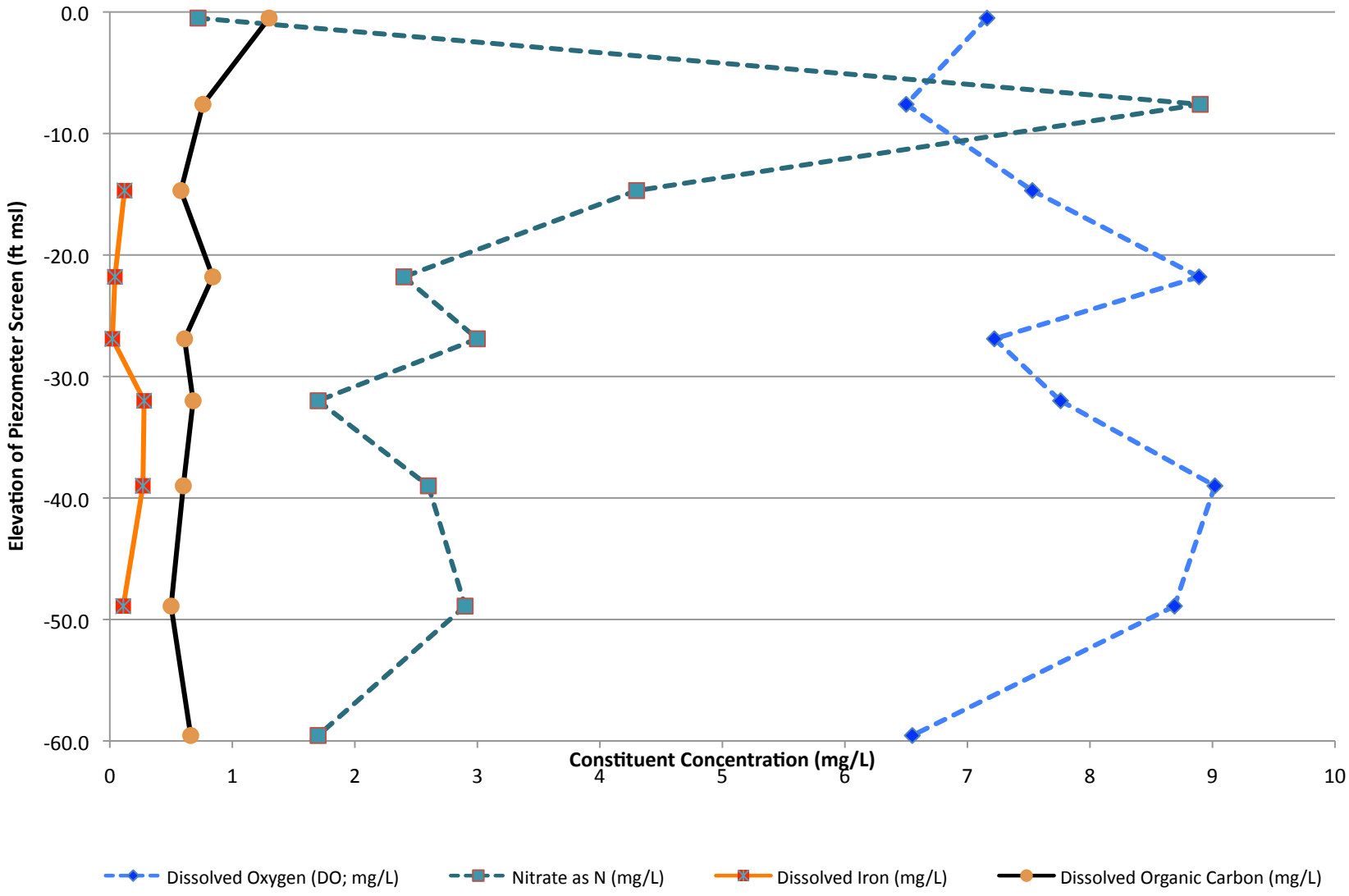

Figure 15 - Groundwater Elevation Map
Sailfish Drive Initial Site Characterization
Falmouth, MA

Sources: Roads from Mass GIS, Surveyed Groundwater Monitoring Well and Piezometer locations and groundwater table elevations (4/6/16) from WaterVision LLC. 2 foot surface elevation contours from the Cape Cod Commission.




Sources: Aerial photography 2013 - 2014 and Roads from Mass GIS, Parcel Boundaries from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezometer locations from WaterVision LLC. 2 foot elevation contours from the Cape Cod Commission.

**Figure 17 - Variation of Nitrate-N, Dissolved Oxygen, Dissolved Iron, and Dissolved Organic Carbon with Elevation, ISC Site - Falmouth, MA -Sailfish Site - March 2016**



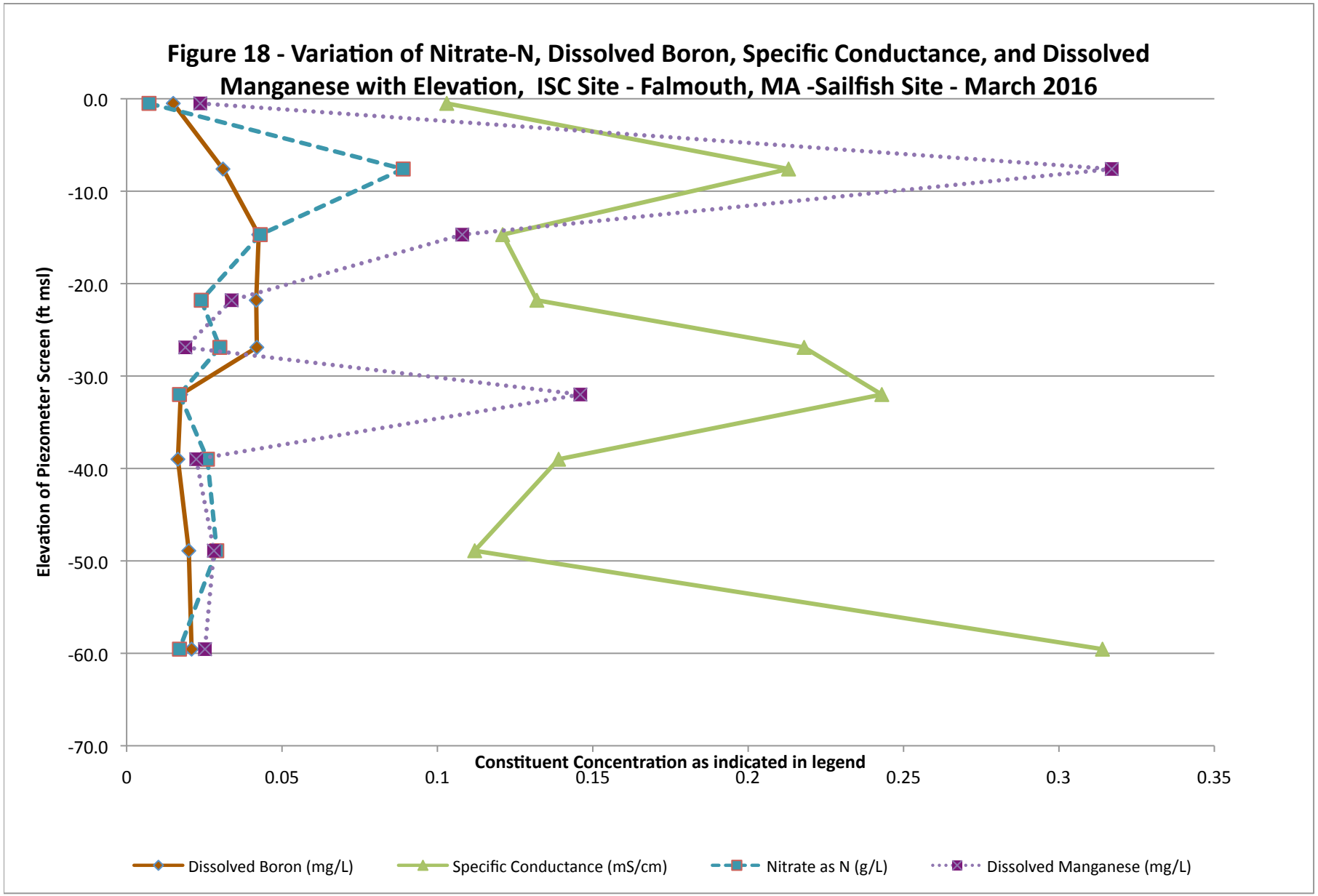
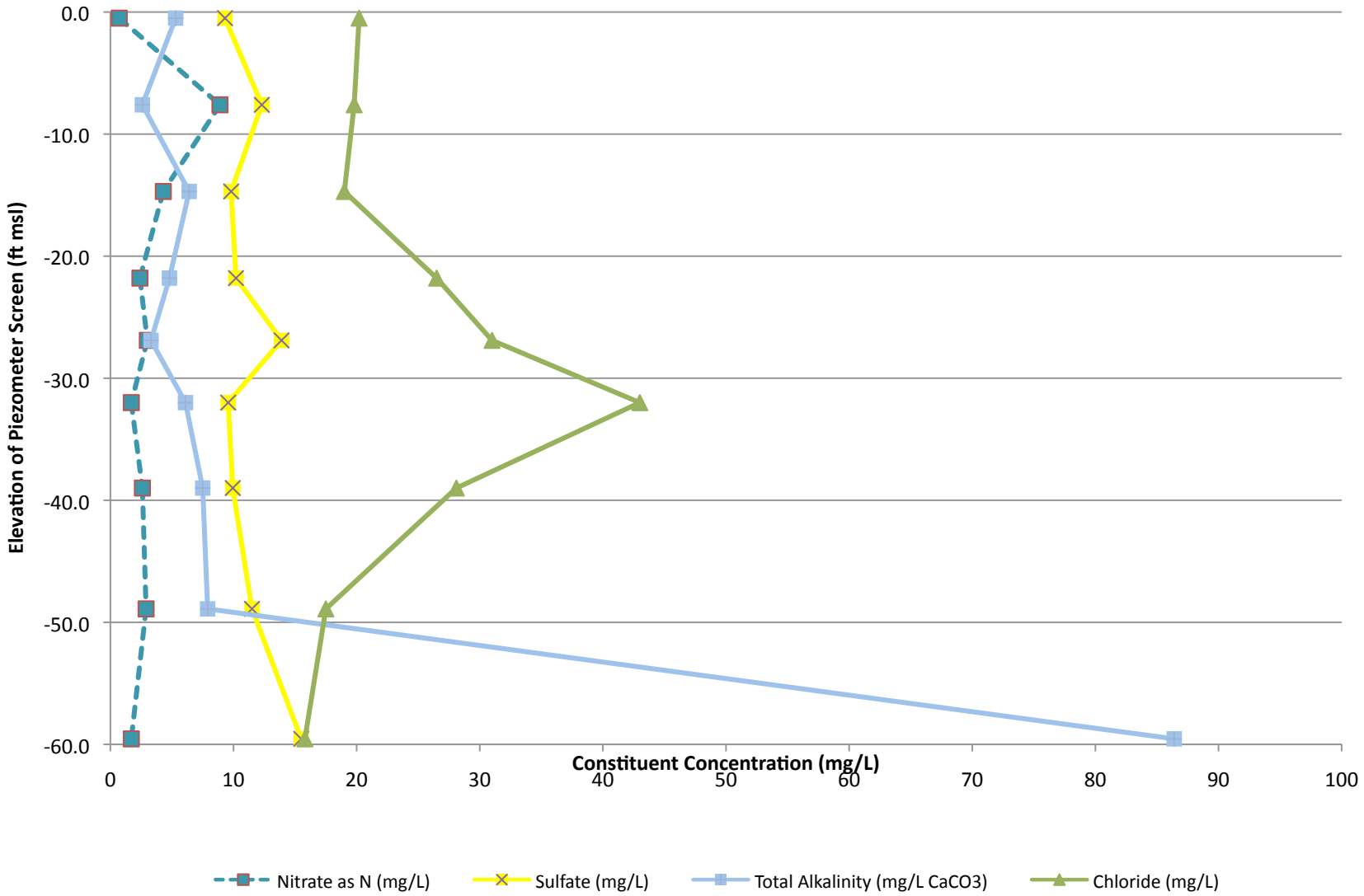
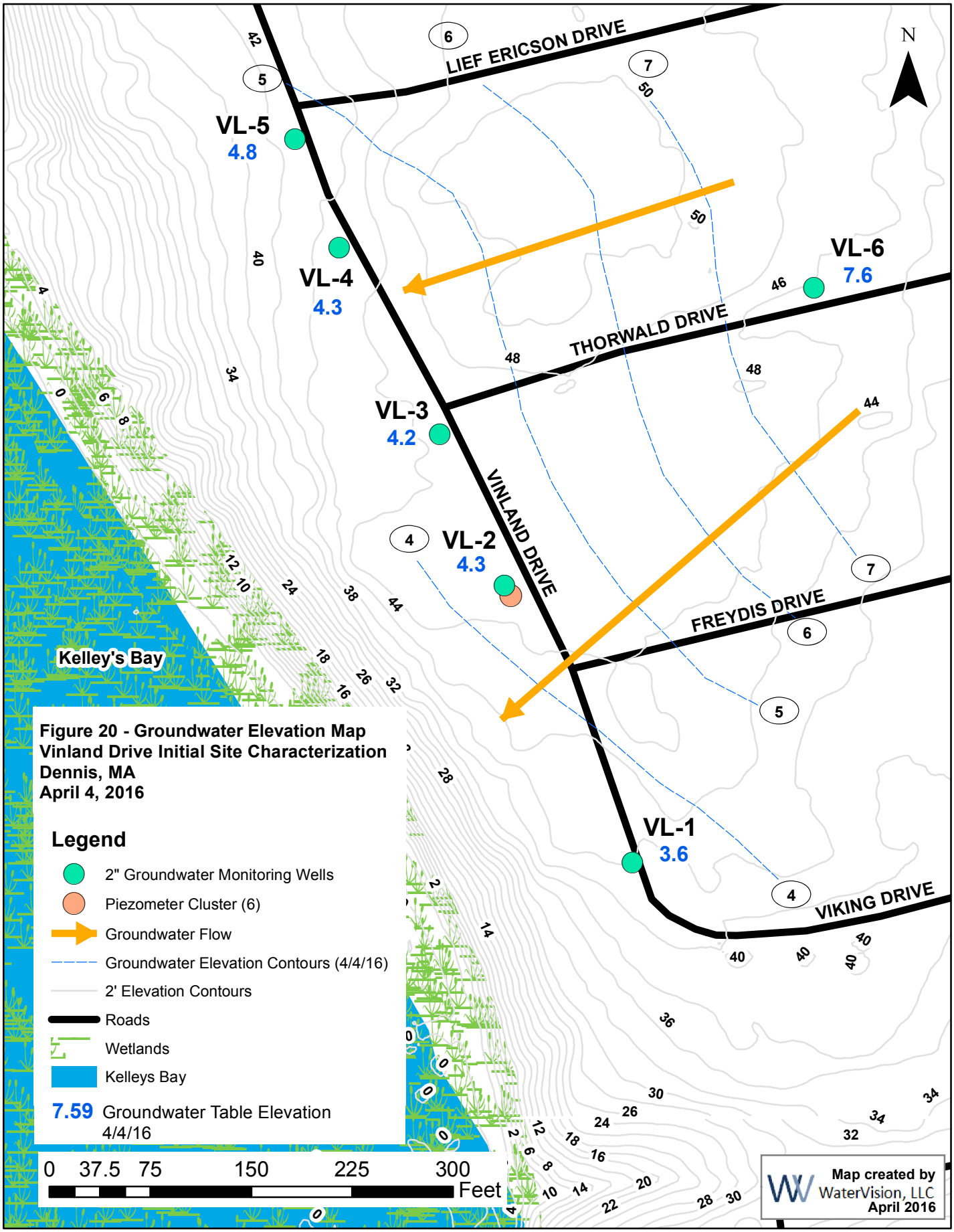


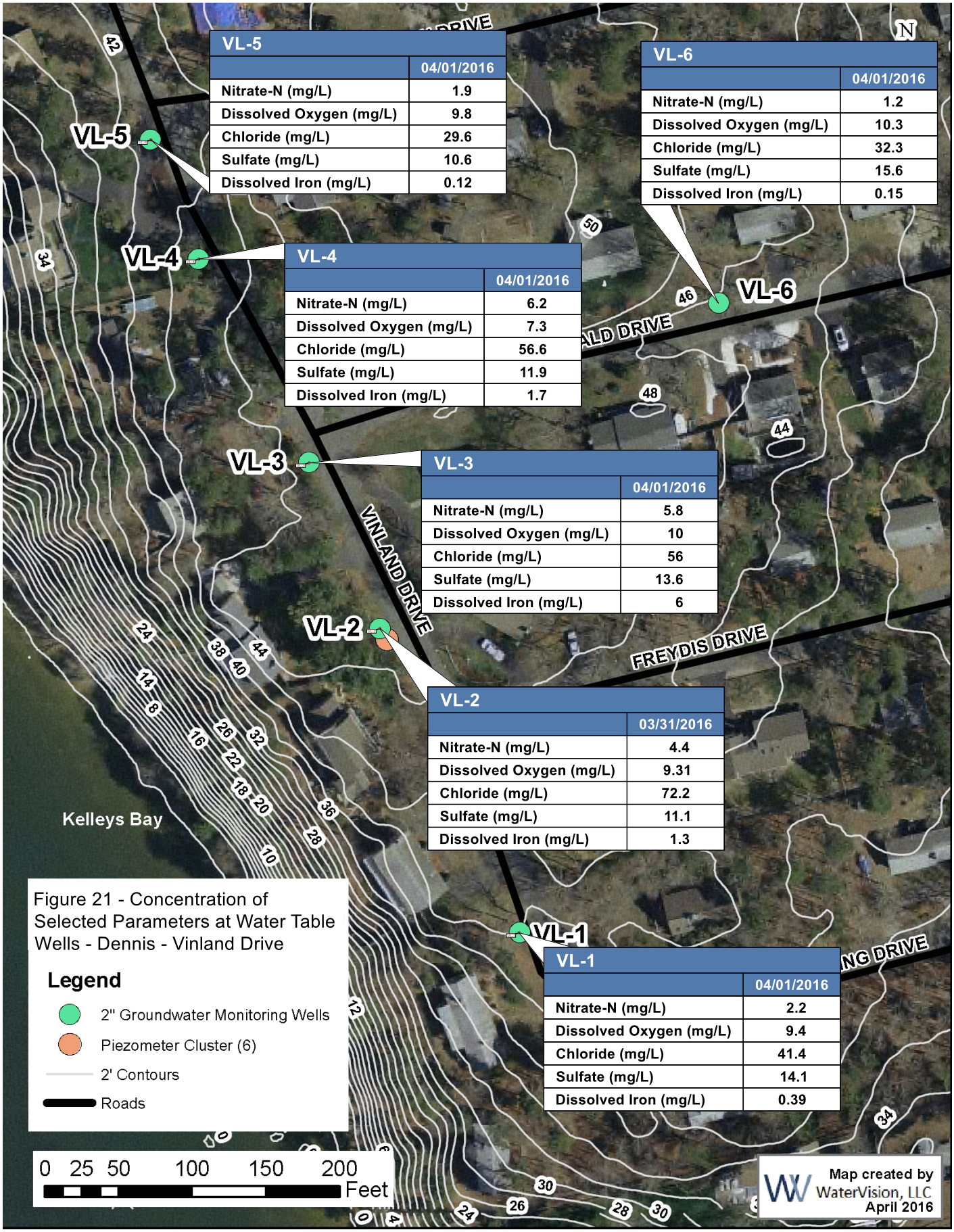
Figure 18 - Variation of Nitrate-N, Dissolved Boron, Specific Conductance, and Dissolved Manganese with Elevation, ISC Site - Falmouth, MA -Sailfish Site - March 2016
Elevation of Piezometer Screen (ft msl)
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
Constituent Concentration as indicated in legend
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Dissolved Boron (mg/L)
Specific Conductance (mS/cm)
Nitrate as N (g/L)
Dissolved Manganese (mg/L)

**Figure 19 - Variation of Nitrate-N, Sulfate, Alkalinity and Chloride with Elevation ISC Site - Falmouth, MA -Sailfish Site - March 2016**






Sources: Roads from Mass GIS, 2 foot surface elevation contours from Cape Cod Commission,
Surveyed Groundwater Monitoring Well and Piezometer locations from WaterVision LLC.
Wetlands and waterbodies from MassDEP.




| VL-5 | 04/01/2016 |
|---|---|
| Nitrate-N (mg/L) | 1.9 |
| Dissolved Oxygen (mg/L) | 9.8 |
| Chloride (mg/L) | 29.6 |
| Sulfate (mg/L) | 10.6 |
| Dissolved Iron (mg/L) | 0.12 |

| VL-6 | 04/01/2016 |
|---|---|
| Nitrate-N (mg/L) | 1.2 |
| Dissolved Oxygen (mg/L) | 10.3 |
| Chloride (mg/L) | 32.3 |
| Sulfate (mg/L) | 15.6 |
| Dissolved Iron (mg/L) | 0.15 |

| VL-4 | 04/01/2016 |
|---|---|
| Nitrate-N (mg/L) | 6.2 |
| Dissolved Oxygen (mg/L) | 7.3 |
| Chloride (mg/L) | 56.6 |
| Sulfate (mg/L) | 11.9 |
| Dissolved Iron (mg/L) | 1.7 |

| VL-3 | 04/01/2016 |
|---|---|
| Nitrate-N (mg/L) | 5.8 |
| Dissolved Oxygen (mg/L) | 10 |
| Chloride (mg/L) | 56 |
| Sulfate (mg/L) | 13.6 |
| Dissolved Iron (mg/L) | 6 |

| VL-2 | 03/31/2016 |
|---|---|
| Nitrate-N (mg/L) | 4.4 |
| Dissolved Oxygen (mg/L) | 9.31 |
| Chloride (mg/L) | 72.2 |
| Sulfate (mg/L) | 11.1 |
| Dissolved Iron (mg/L) | 1.3 |

| VL-1 | 04/01/2016 |
|---|---|
| Nitrate-N (mg/L) | 2.2 |
| Dissolved Oxygen (mg/L) | 9.4 |
| Chloride (mg/L) | 41.4 |
| Sulfate (mg/L) | 14.1 |
| Dissolved Iron (mg/L) | 0.39 |

Sources: Aerial photography 2013 - 2014 and Roads from Mass GIS, Parcel Boundaries from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezometer locations from WaterVision LLC. 2 foot elevation contours from the Cape Cod Commission.

**Figure 22 - Variation of Nitrate, Dissolved Oxygen*, and Dissolved Organic Carbon with Depth - ISC Site - Dennis, MA, March 2016**

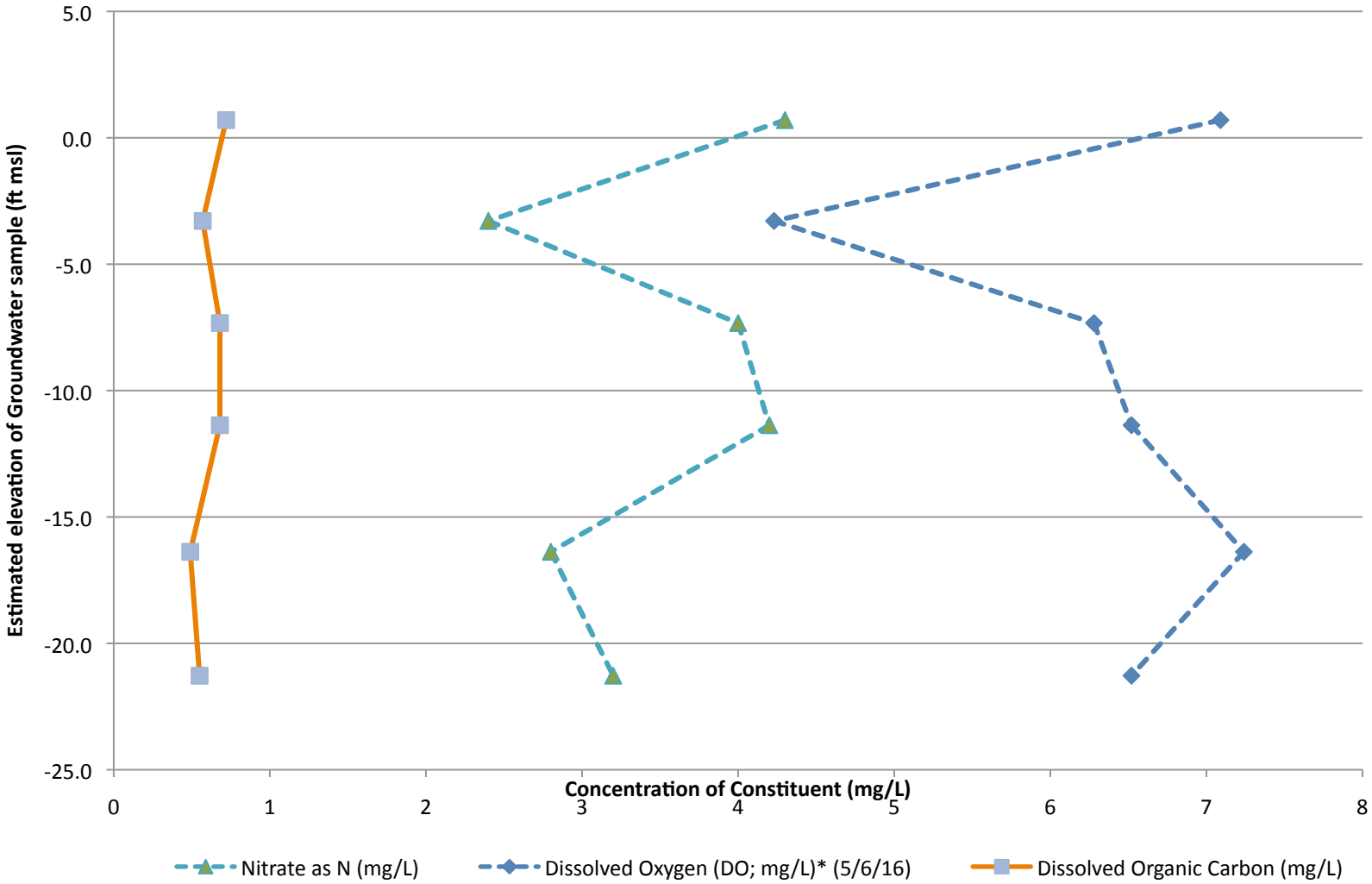
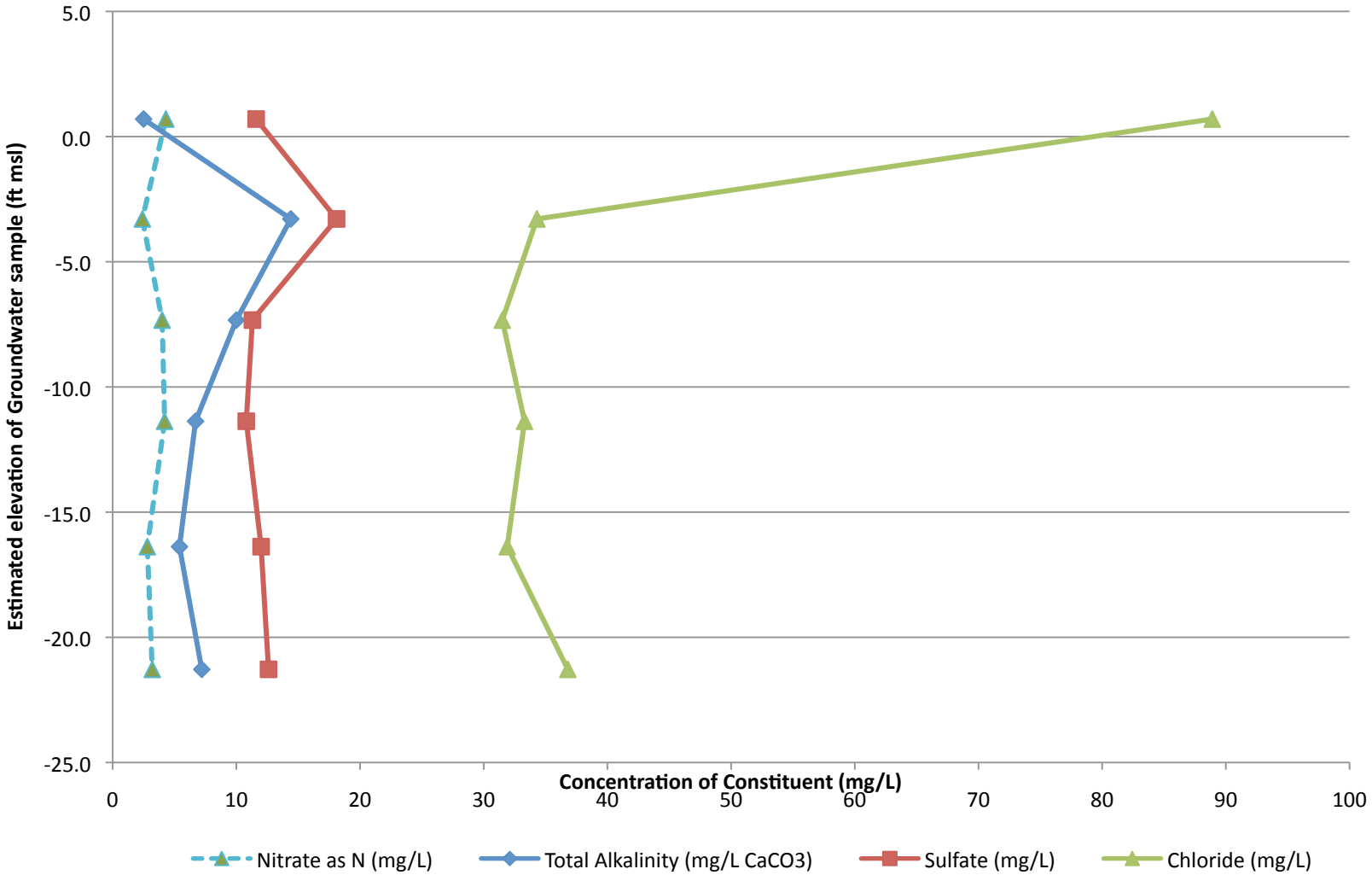


**Figure 23- Variation of Nitrate, Alkalinity, Sulfate, and Chloride with Elevation - ISC Site - Dennis, MA, March 2016**



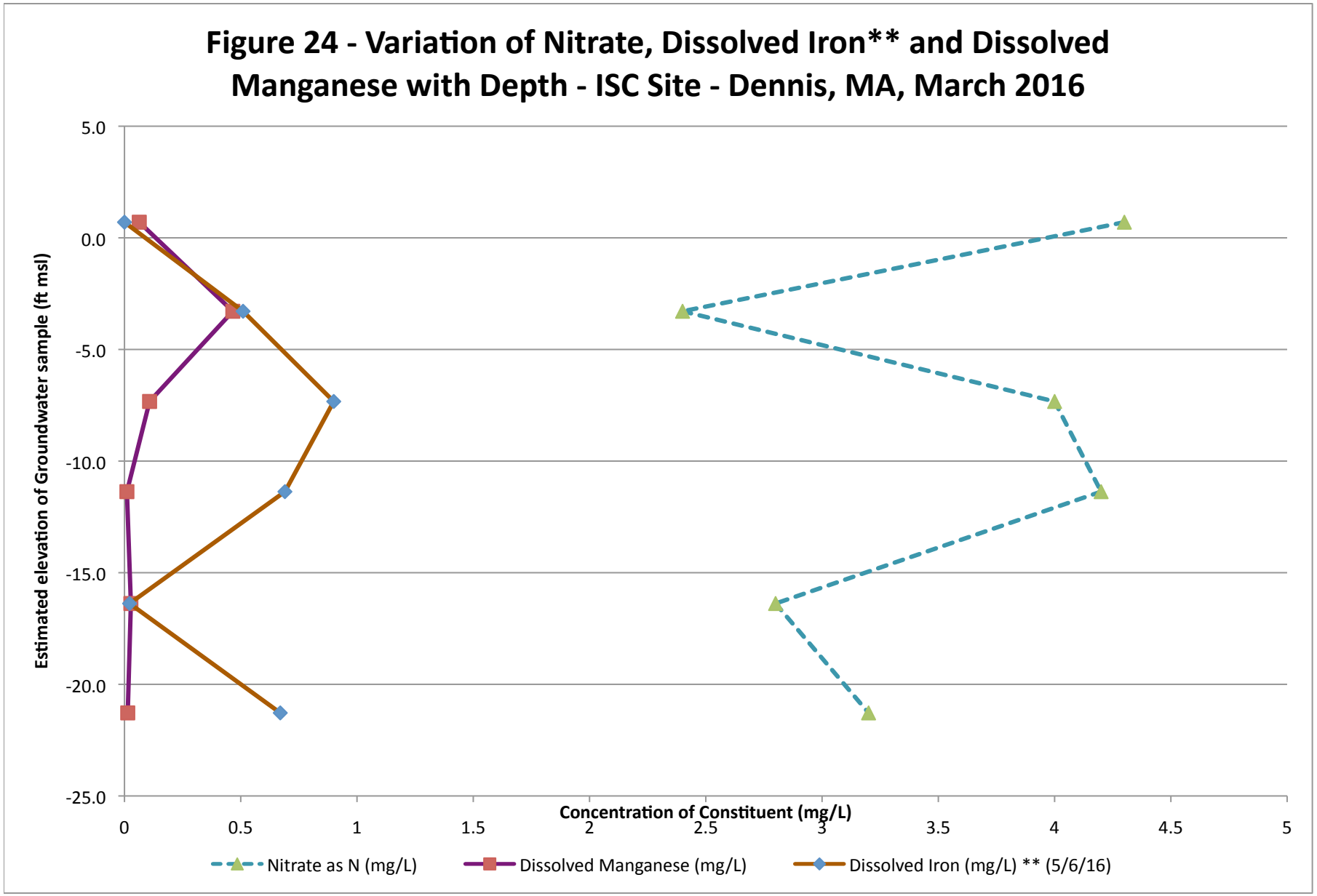


Figure 24 - Variation of Nitrate, Dissolved Iron** and Dissolved Manganese with Depth - ISC Site - Dennis, MA, March 2016
Estimated elevation of Groundwater sample (ft msl)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Concentration of Constituent (mg/L)
Nitrate as N (mg/L)
Dissolved Manganese (mg/L)
Dissolved Iron (mg/L) ** (5/6/16)

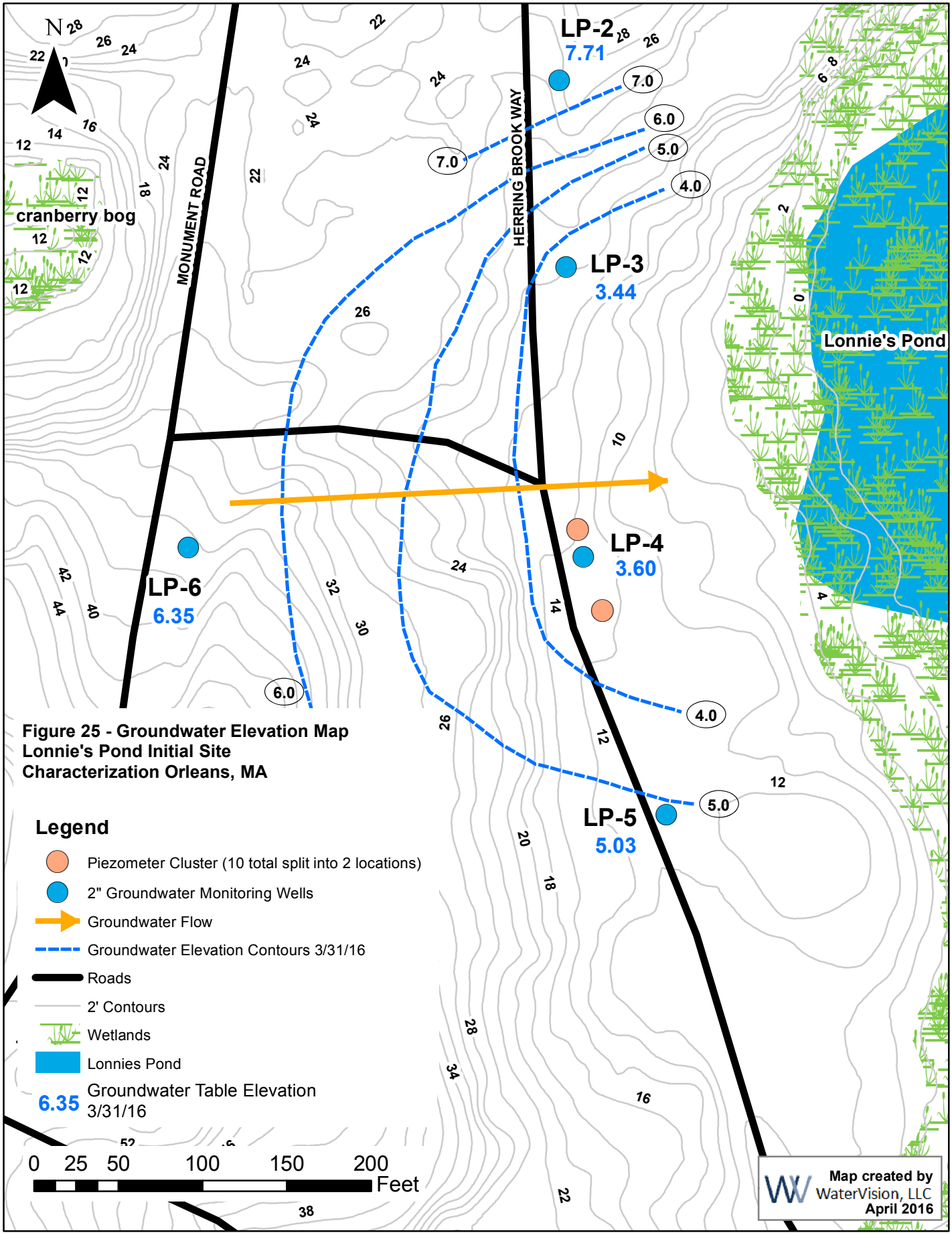
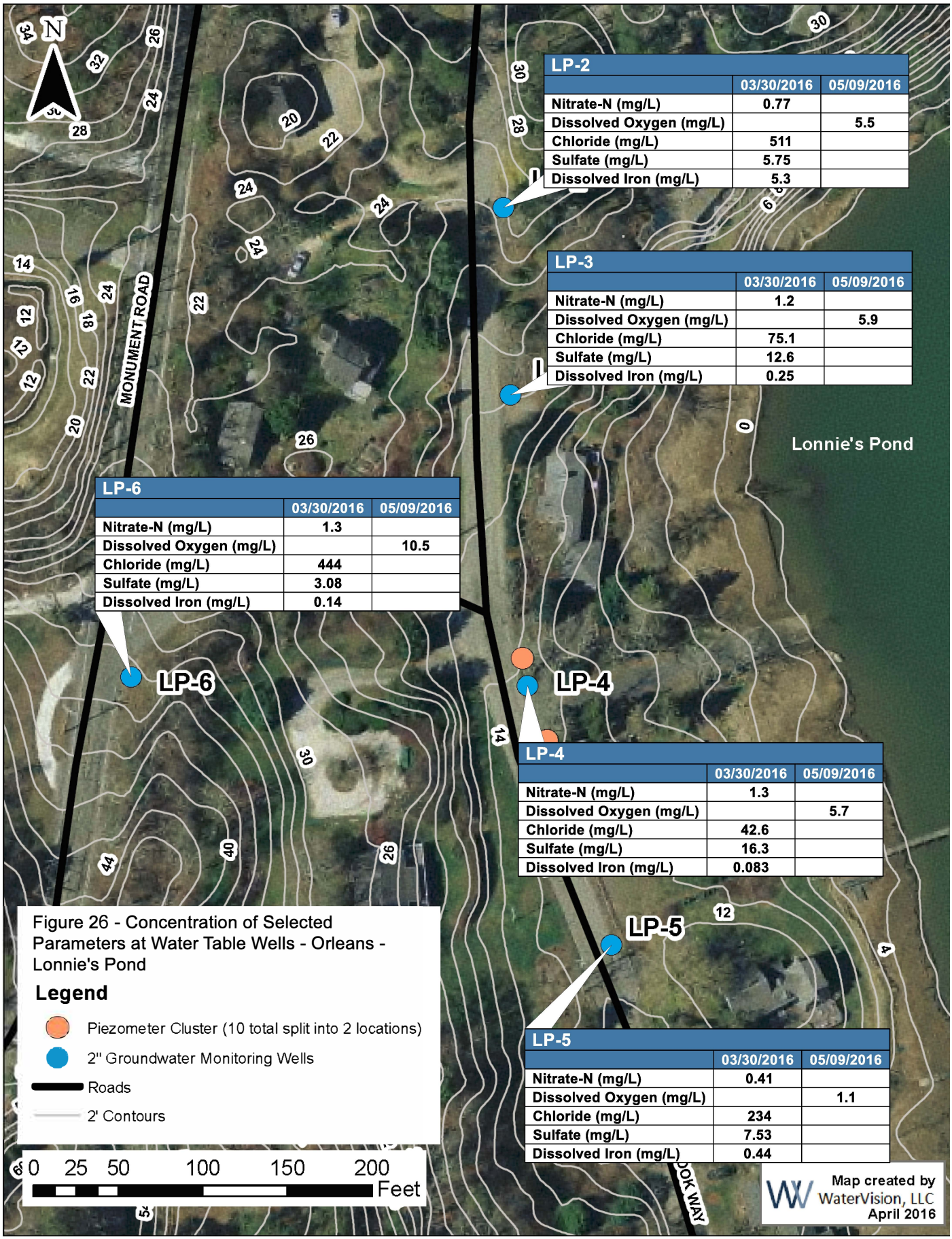



**Figure 25 - Groundwater Elevation Map**
**Lonnie's Pond Initial Site Characterization Orleans, MA**

Sources: Roads from Mass GIS, 2 foot surface elevation contours from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezomenter locations from WaterVision LLC. Wetlands and waterbodies from MassDEP.




| LP-2 | 03/30/2016 | 05/09/2016 |
|---|---|---|
| Nitrate-N (mg/L) | 0.77 | |
| Dissolved Oxygen (mg/L) | | 5.5 |
| Chloride (mg/L) | 511 | |
| Sulfate (mg/L) | 5.75 | |
| Dissolved Iron (mg/L) | 5.3 | |

| LP-3 | 03/30/2016 | 05/09/2016 |
|---|---|---|
| Nitrate-N (mg/L) | 1.2 | |
| Dissolved Oxygen (mg/L) | | 5.9 |
| Chloride (mg/L) | 75.1 | |
| Sulfate (mg/L) | 12.6 | |
| Dissolved Iron (mg/L) | 0.25 | |

| LP-6 | 03/30/2016 | 05/09/2016 |
|---|---|---|
| Nitrate-N (mg/L) | 1.3 | |
| Dissolved Oxygen (mg/L) | | 10.5 |
| Chloride (mg/L) | 444 | |
| Sulfate (mg/L) | 3.08 | |
| Dissolved Iron (mg/L) | 0.14 | |

| LP-4 | 03/30/2016 | 05/09/2016 |
|---|---|---|
| Nitrate-N (mg/L) | 1.3 | |
| Dissolved Oxygen (mg/L) | | 5.7 |
| Chloride (mg/L) | 42.6 | |
| Sulfate (mg/L) | 16.3 | |
| Dissolved Iron (mg/L) | 0.083 | |

| LP-5 | 03/30/2016 | 05/09/2016 |
|---|---|---|
| Nitrate-N (mg/L) | 0.41 | |
| Dissolved Oxygen (mg/L) | | 1.1 |
| Chloride (mg/L) | 234 | |
| Sulfate (mg/L) | 7.53 | |
| Dissolved Iron (mg/L) | 0.44 | |

Sources: Aerial photography 2013 - 2014 and Roads from Mass GIS, Parcel Boundaries from Cape Cod Commission, Surveyed Groundwater Monitoring Well and Piezometer locations from WaterVision LLC. 2 foot elevation contours from the Cape Cod Commission.

**Figure 27 - Variation of Nitrate-N, Dissolved Oxygen, Dissolved Organic Carbon and Dissolved Iron with Elevation, ISC Site - Orleans, MA March 2016**

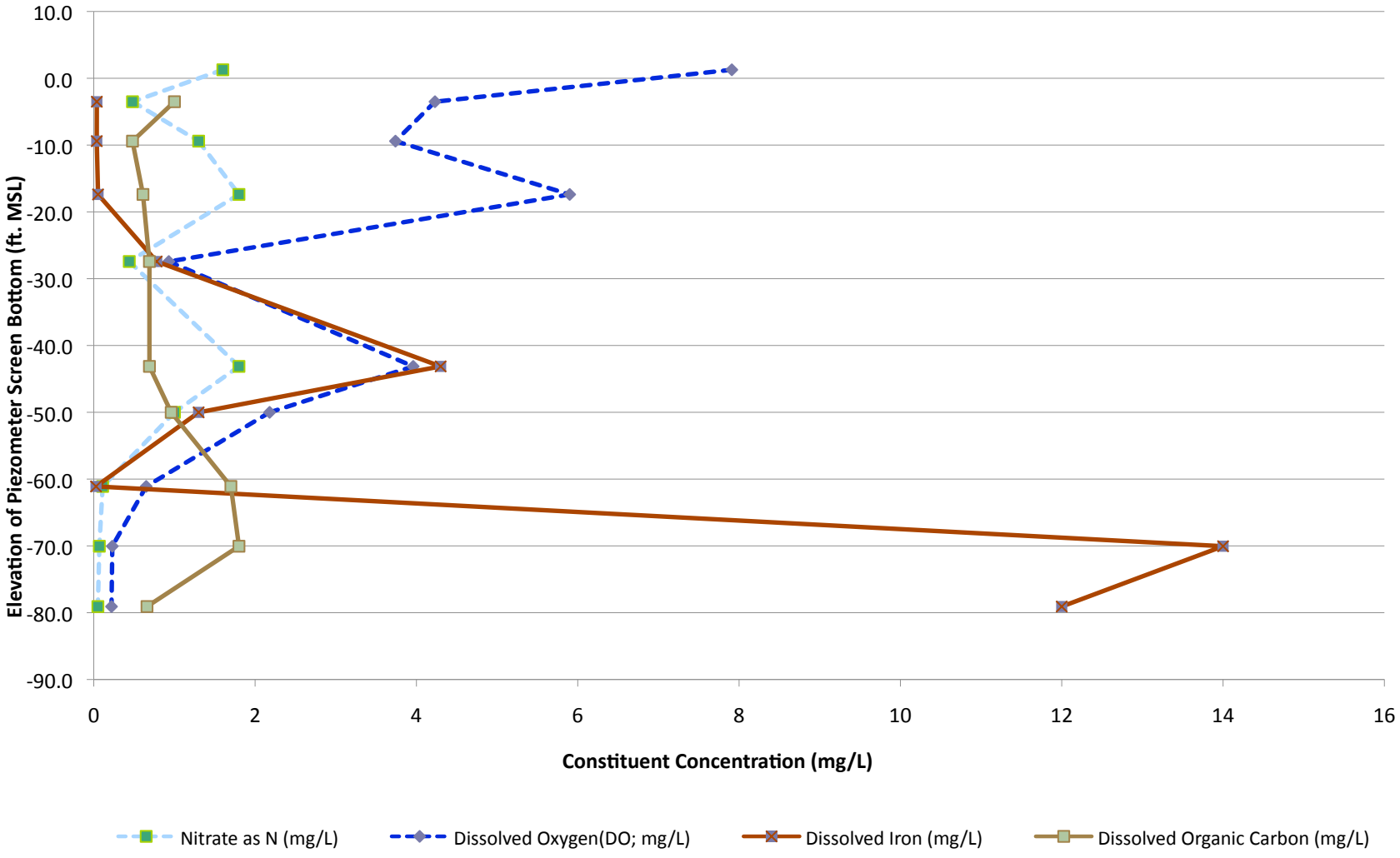


**Figure 28 - Variation of Sulfate, Alkalinity and Chloride Concentrations with Elevation, ISC Site - Orleans, MA March 2016**

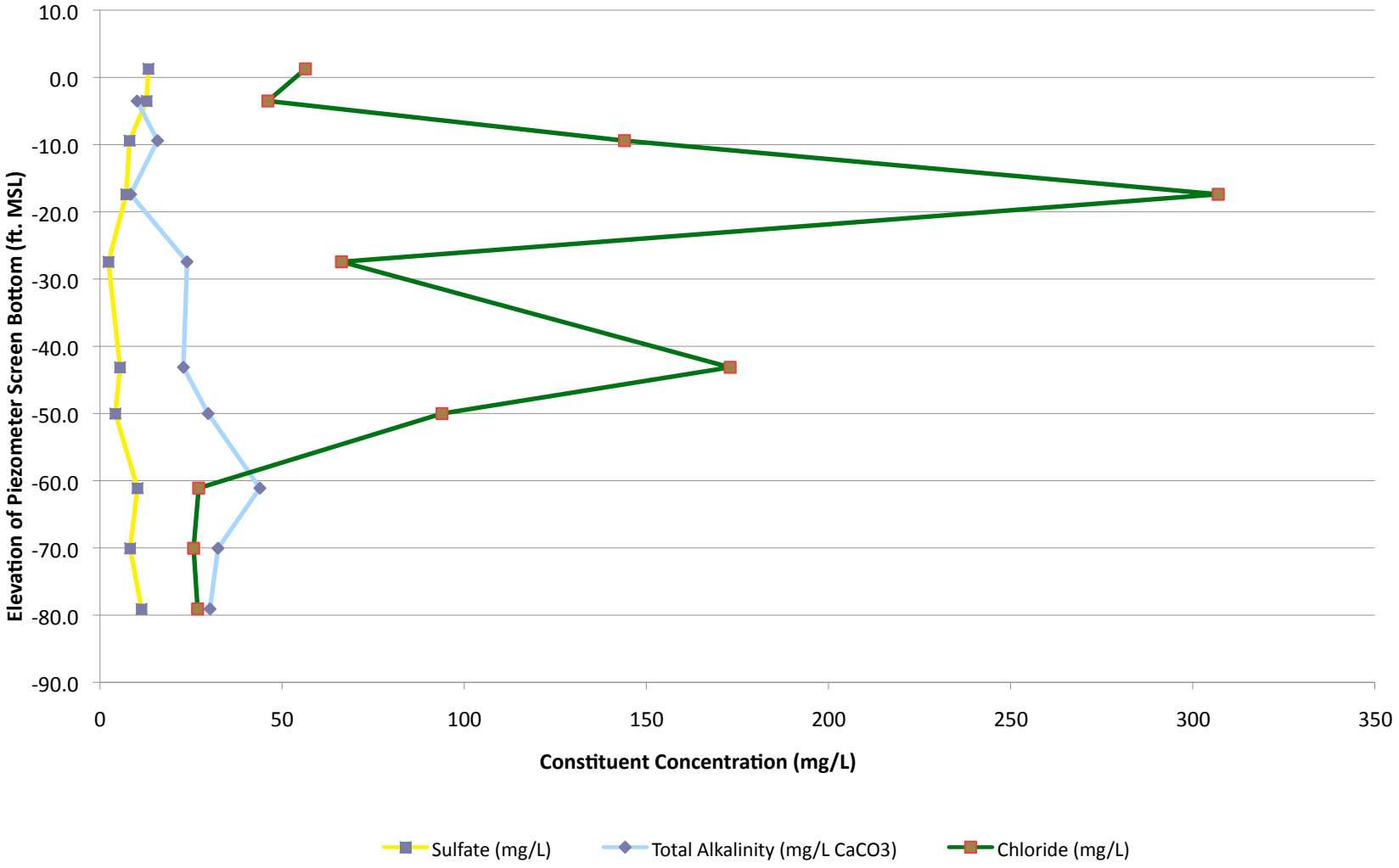
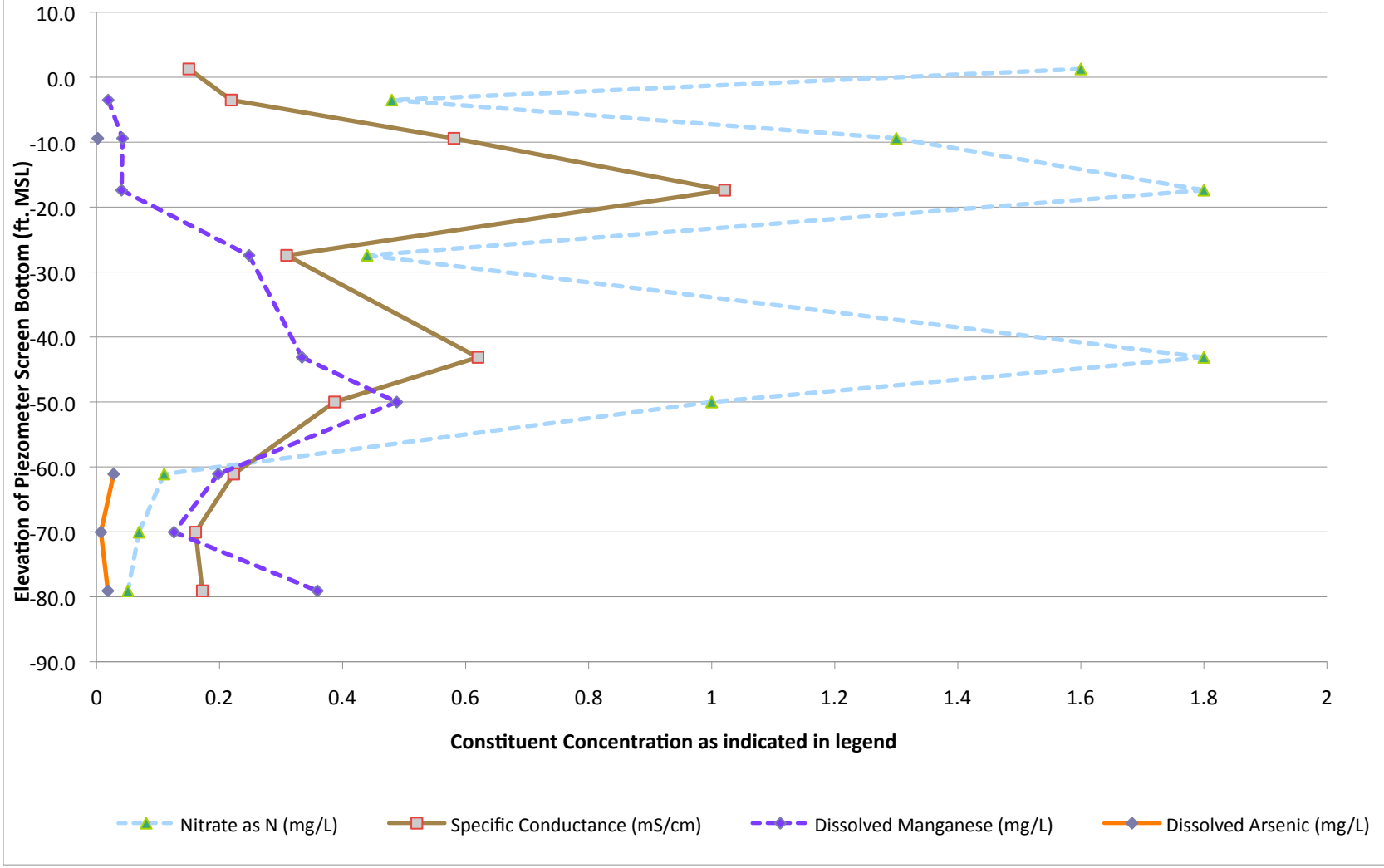


**Figure 29 - Variations in Specific Conductance, Nitrate-N, Dissolved Manganese and Arsenic with Elevation, ISC Site - Orleans, MA March 2016**



## Figure 30 - Variations in Redox Potential with Elevation, ISC Site - Orleans, MA March 2016