AECOM
9 Jonathan Bourne Drive
Pocasset, MA 02559
www.aecom.com

508.833.6950 tel
508.833.6951 fax

# Memorandum

| | |
|---|---|
| To | George Meservey, Director of Planning & Community Development<br>Michael Domenica, PE, Program Manager |
| CC | Betsy Shreve, AICP, AECOM Project Director<br>James Begley, LSP, MT Environmental<br>AECOM PRB Team |
| Subject | **Town of Orleans, MA**<br>**Water Quality and Wastewater Planning**<br>**Task Number 10.1.B.2 – NT Demonstration Projects**<br>**Technical Memorandum for Landfill Field Investigation Plan - Final** |
| Project Number | 60476644 |
| From | Thomas Parece, P.E., AECOM Project Manager |
| Date | February 24, 2017 |

| Approvals | Date | Signature / Initials |
|---|---|---|
| George Meservey, Orleans, MA Director of Planning & Community Development | | |
| Michael Domenica, PE, Water Resources Associates, Program Manager | January 19, 2017 | M. Domenica (Draft) |

## 1. Introduction

A. The Orleans Municipal Landfill and former septage lagoons (the landfill) are located in the Town Cove/Nauset Marsh Estuarine System watershed. Nitrogen in groundwater in the vicinity of the landfill has the potential to migrate to Town Cove, affecting estuarine water quality. Assessment work is planned to investigate the flux of nitrogen compounds in groundwater emanating from the landfill and migrating toward Town Cove. In addition, landfill groundwater monitoring has recently identified the solvent 1,4-dioxane in groundwater at concentrations greater than the current Massachusetts regulatory limit of 0.0003 mg/L and action is required to assess associated risks. This work plan provides an overview of landfill conditions and planned assessment activities.

**2. Orleans Landfill Site Description**

A. The landfill consists of approximately 21 acres of Town-owned land located off Lots Hollow Road (Figure 1). The property includes a natural kettle hole that was used for solid waste disposal from the 1950s until 1991. The unlined solid waste fill area was closed and a 13-acre fill area was capped with a final cover system at a maximum elevation of approximately 110 feet above mean sea level (MSL) in 2005. The landfill property also includes an active solid waste transfer station and yard waste composting and stockpile area (Figure 2). The yard waste composting area is built on and is adjacent to land formerly used for septage waste disposal to lagoons. Six unlined septage lagoons, used between 1950 and 1989, were located just to the north of the capped solid waste area at an approximate elevation of 50 feet above MSL. The septage lagoons were filled and covered with sand and part of the area over the lagoons has been paved with asphalt (see Figure 2 and the Conceptual Site Model figure from the 2015 MT Environmental Restoration report on the landfill in Appendix A for the location of the lagoons). The landfill property is downgradient (and outside the Zone of Contribution) of the Town of Orleans public well located to the south. Adjacent properties also include commercial properties, the Charles Moore Ice Arena to the west and commercial/industrial properties to the north and east. Plans have been developed by Weston and Sampson for the construction of a new DPW facility on portions of the landfill property in 2017.

B. Nitrogen compounds (total nitrogen, nitrate, and ammonia) have been detected at significant concentrations in groundwater downgradient of the landfill and former septage lagoons. The highest nitrate concentrations have been observed since the landfill was capped in 2005. Long term monitoring of four monitoring wells (MW-1S, MW-2S, MW-2D, and MW-5S) indicates groundwater nitrate concentrations greater than the Massachusetts Maximum Contaminant Limit of 10 mg/L, with a maximum concentration of 40 mg/L observed at monitoring well 2S. Landfill monitoring wells were first tested for total nitrogen in May of 2015. Results of testing indicated that total nitrogen concentrations were significantly higher than nitrate concentrations in some of the deeper wells, while nitrate was approximately equal to total nitrogen in shallow wells (data not shown). 2015 sampling events did not quantify ammonia however, the significant difference between the concentration of total nitrogen and nitrate in some of the samples was likely due to the presence of ammonia. More recent data from groundwater analyses in 2016 confirmed the presence of ammonia in deep groundwater and are discussed in detail in Section 4 below.

C. Groundwater samples were first tested in May of 2015 for low-level concentrations of the solvent 1,4,-dioxane to comply with new MassDEP requirements. To date 1,4-dioxane has only been detected in monitoring well MW-2D, at concentrations ranging from 0.0014 mg/L to 0.0019 mg/L, four to six times the new Massachusetts regulatory limit of 0.0003 mg/L. The former Massachusetts regulatory limit was 0.3 mg/L.

**3. Current Landfill Groundwater Monitoring Well Network**

A. Existing groundwater monitoring well locations shown on Figure 2 are as follows:

- MW-1S and 1D on the west side of the landfill property;
- MW-2S and 2D to the north;
- MW-3S and 3D to the east;
- MW-4S and 4D to the south;
- MW-5S and 5D to the northeast; and
- MW-E6B and E6A to the north.

B. Four of the shallow landfill water table monitoring wells (MW-1S through MW-4S) were installed in 1992 as part of an assessment associated with the septage lagoon closure. Deeper screened monitoring wells (MW-1D, MW-2D, MW-3D, and MW-4D) were installed as part of the 1994 landfill Comprehensive Site Assessment, completing the well couplets at these locations. One additional couplet (MW-5S and MW-5D) was also installed in 1994. Monitoring well couplet MW-E6B and MW-E6A was installed by AECOM in 2016 for nitrogen assessment. The landfill monitoring wells have been routinely sampled twice a year for nitrate, dissolved iron and manganese, and volatile organic compounds. Total nitrogen and low level 1,4-dioxane were added to the sampling plan starting in May 2015. Results of recent 2016 nitrogen related analyses for landfill monitoring wells by Barnstable County Health Department and AECOM are included in Table 1 and results for 1,4-dioxane analyses are included in Table 2.

## 4. Conceptual Site Model

### A. General

A Conceptual Site Model (CSM) is a tool used to provide a framework of information to help understand and communicate what is known about a potential problem, visualize available information, identify gaps in data, and prioritize response actions. The following paragraphs provide a narrative version of the CSM for the landfill concerning nitrogen and 1,4-dioxane in groundwater.

### B. Potential Sources of Nitrogen in Groundwater

Municipal operations at the landfill, starting in the 1950s. Operations included operation of septage lagoons until 1989 and solid waste disposal until 1991. Current operations include a transfer station and stockpiling and composting of yard wastes. All these operations may have released nitrogen in the past or may be continuing to release nitrogen compounds to groundwater. The solid waste landfill was capped with an impermeable cover in 2005, reducing the infiltration of water through solid waste material. However, drainage structures constructed to manage runoff from the cap include an unlined rip rap swale that passes directly over part of the former septage lagoon area. The runoff from the landfill cap infiltrating through the former septage lagoons area may be intensifying the release of nitrogen compounds from residual material in the former septage lagoons. Leachate from compost operations and stormwater runoff from the transfer station is also infiltrated in the vicinity of the former septage lagoons.

### C. Potential Sources of 1,4-Dioxane in Groundwater

1,4-dioxane has been used in many products, including paint strippers, dyes, greases, varnishes and waxes. 1,4-dioxane is also found as an impurity in antifreeze and aircraft deicing fluids and in some consumer products including deodorants, shampoos and cosmetics (EPA, 2014). Groundwater contamination at the landfill has likely resulted from disposal of solvents and consumer products containing 1,4-dioxane in solid waste and/or in septage discharged to the former lagoons.

### D. Groundwater Flow and Potential Contaminant Transpor

Nitrogen compounds and 1,4-dioxane are soluble in groundwater and are generally transported with groundwater flow by advection with little retardation. There is a potential for natural attenuation of these groundwater contaminants under specific conditions. Under aerobic groundwater conditions ammonia may be converted to nitrate. In the presence of sufficient carbon, nitrate may be attenuated to nitrogen gas under anoxic denitrifying conditions. 1,4-dioxane is relatively resistant to biodegradation in groundwater but may be degraded by microorganisms under aerobic conditions in the presence of a suitable co-metabolic substrate (an alternative food/energy source that stimulates the production of enzymes that also fortuitously degrade 1,4-dioxane).

Regional groundwater contour maps prepared by the United States Geological Survey (USGS) and Cape Cod Commission and previous assessment reports associated with the landfill indicate groundwater flow to the north northwest, north, and northeast toward Town Cove (Walter et. al., 2004 and Coastal Engineering, 1999).

Boring logs for landfill monitoring wells show subsurface sediments that consist of glacial outwash sands and gravel with thin layers of more silty sand, silt and clay. The depth to groundwater varies significantly with location due to land surface elevation differences associated with the topography of the kettle hole. The approximate range for depth to groundwater at monitoring wells is 35 to 90 feet.

Groundwater elevation measurements, characterization of the aquifer sediments, and aquifer tests were used by Coastal Engineering to estimate groundwater velocity and flow direction in the vicinity of the landfill (Coastal Engineering, 1999). The hydraulic conductivity of aquifer materials was determined from aquifer testing at various locations. The hydraulic conductivity determined at shallow screen locations ranged from 5.6 feet/day at MW-1S to 70.88 feet/day at MW-2S. In general, a higher hydraulic conductivity indicates the potential for faster groundwater flow, depending on the gradient. The hydraulic conductivity determined at deeper screen locations ranged from 14.14 feet/day at MW-3D to 147.74 feet/day at MW-1D (Coastal Engineering, 1999). The methods used to test hydraulic conductivity provided information for the immediate vicinity of well screens; the average hydraulic conductivity is unknown due to the limited subsurface investigation conducted to date.

The slope of the potentiometric surface (the water table) derived from water elevation measurements was used to determine the hydraulic gradient and flow direction. According to the Comprehensive Site Assessment prepared for landfill closure by Coastal Engineering in 1999, there is the potential for divergent flow (groundwater flow in more than one direction) from the landfill area. The shallow screen wells indicated a consistent gradient of 0.012 to the northeast while deeper screen wells showed variation in flow direction including flow to the north and north northwest. Measurements indicated an average gradient of 0.0006 to the northwest and an average gradient of 0.003 to the north in the deeper screened wells. The 1990s data also indicated vertical gradients at all monitoring well couplets (downward at MW-1, MW-2, MW-3, and MW-4 and upward at MW-5). The variation in the vertical gradient and divergent groundwater flow direction could be the due to local mounding effects from stormwater, differences in sediment permeability, and the location of the landfill in a recharge area of the groundwater system. A downward vertical gradient indicates groundwater flow deeper into the aquifer. The porosity was estimated at 0.30 from soil samples collected during soil boring installation. Based on these data, Coastal Engineering calculated the horizontal groundwater velocity at a range of 0.029 feet/day to 2.84 feet/day.

The groundwater velocity estimate is highly variable from point to point depending on sediments present in the well screen interval, and velocity can be expected to vary along the long flow path from groundwater recharge to discharge. Slower flow is more likely in a silty sand layer as compared to groundwater in medium sand layers. Town Cove is located approximately 5,450 feet downgradient on a heading of 40 degrees northeast, consistent with the direction of shallow groundwater flow at the site. The travel time for groundwater from the landfill to Town Cove is unknown but has been estimated to range up to 50 years (USGS, 2004).

### E. Contaminant Assessment - Nitrogen in Groundwater

Landfill monitoring well nitrate data have been collected for more than 20 years between September 1994 and September 2016. The 1990s data (September 1994 through December 2000) were collected during assessments related to closure of the septage lagoons and solid waste landfill. A gap in data collection occurred during the landfill capping operations and semi-annual monitoring conducted by the Barnstable County Health Department was resumed starting in March 2005. More limited test data are available for MW-1D and MW-3S as they were sampled less frequently. These historical analyses have mainly included testing for nitrate-nitrogen alone. Nitrate-nitrogen analyses provide only a partial assessment of total nitrogen concentrations. Total nitrogen is the sum of Total Kjeldahl Nitrogen (ammonia and organic nitrogen) plus nitrate-nitrogen and nitrite-nitrogen.

Recent 2016 data collection has included groundwater analyses for additional nitrogen compounds. These data show the presence of ammonia in some of the deeper wells, including MW-2D, MW-3D and MW-5D. Ammonia and nitrate concentrations were variable at these deeper screened wells while the shallow wells showed nitrate as the dominant form of nitrogen (see Table 1).

A reference background nitrate concentration of 0.46 mg/L was previously reported for Cape Cod by the USGS (LeBlanc, 1984). Earlier data from Frimpter and Gay (1979), indicate uncontaminated groundwater may have less than 0.1 mg/L nitrate nitrogen. At the landfill, the lowest nitrate concentrations were observed in the upgradient deep screened monitoring well MW-4D located south of the landfill and were consistent with background Cape Cod groundwater. All other wells tested showed nitrate concentrations above background.

Four of the monitoring wells (MW-1S, MW-2S, MW-2D, and MW-5S) had nitrate concentrations above the Massachusetts Drinking Water Maximum Contaminant Level (MMCL) of 10 mg/L on one or more sampling dates. MW-5S has shown a consistent elevated nitrate concentration over the entire 20-year sampling period (pre- and post-landfill capping), with the nitrate concentration ranging from 6.6 mg/L to 22 mg/L. Other wells including MW-1S, MW-2S, MW-2D, and MW-4S showed a marked increase in nitrate concentration with renewed post-capping groundwater monitoring starting in March 2005 compared to the 1990s data. One shallow monitoring well, MW-2S, has shown a generally increasing, but highly variable, trend in nitrate concentration starting when post-capping groundwater sampling was resumed. The concentration of nitrate at MW-2S reached a maximum concentration of 40 mg/L in September 2009 and was reported at 34 mg/L in March of 2014 and 22 mg/L in September 2016. A Conceptual Site Model figure from the 2015 MT Environmental Restoration report on the landfill shows the upward trend in nitrate concentration at MW-2S and the fairly steady elevated concentration of nitrate at MW-5S (MTER, 2015)(Appendix A).

Available landfill groundwater monitoring data also includes limited measurements of dissolved oxygen that indicate oxygen levels are low in deeper groundwater. Shallow groundwater is generally aerobic (>1 - 2 mg/L dissolved oxygen). Biological attenuation of nitrate in groundwater by denitrification is inhibited under aerobic conditions. Attenuation of nitrate, at least in shallow groundwater, is unlikely during migration from the landfill to Town Cove. The significant thickness of the unsaturated zone above groundwater may be helping to maintain aerobic conditions in shallow groundwater, allowing for aeration of infiltrating precipitation and runoff. The depth to groundwater may also be limiting migration of organic carbon from below the former septage lagoons and from composting operations to groundwater while allowing for conversion of infiltrating ammonia in runoff to nitrate under aerobic conditions. Ammonia is generated during composting of high nitrogen materials such as fresh grass clippings. The breakdown of residual organic matter in the unsaturated zone below the former septage lagoons may also be a source of ammonia nitrogen.

There is also a potential the ammonia in deep groundwater comes from below the unlined landfill. The deeper groundwater is generally anoxic and therefore would not support the conversion of ammonia to nitrate.

Due to the limited number and location of monitoring wells, the extent of nitrogen compounds in groundwater both vertically and horizontally is unknown. Assessment of the horizontal and vertical extent of nitrogen compounds in groundwater immediately downgradient of the landfill and septage lagoons is necessary to determine the flux of nitrogen compounds from the landfill that may be discharging to Town Cove. Assessment is also necessary to confirm the sources of nitrogen compounds in groundwater and to facilitate evaluation of necessary response actions.

### F. Contaminant Assessment - 1,4-Dioxane in Groundwater

Landfill monitoring wells have been sampled three times for 1,4-dioxane since May 2015 and the compound has only been detected in monitoring well MW-2D (see Table 2). Groundwater conditions at MW-2D appear to be anaerobic while the shallow well MW-2S at this location is screened in aerobic groundwater.

Due to the wide spacing of monitoring wells and limited number of screens, the source and extent of 1,4-dioxane is presently unknown. Assessment of the horizontal and vertical extent of 1,4-dioxane in groundwater immediately downgradient of the landfill and septage lagoons is necessary to determine the potential watershed area that may be affected by contaminant migration and provide a basis for evaluation of risk management options.

### G. Conceptual Site Model Summary

The CSM for 1,4-dioxane in groundwater at the landfill shows that the compound has remained persistent in one monitoring well indicating a potentially ongoing source. Due to its physical characteristics, 1,4-dioxane has the potential to migrate long distances, affecting groundwater quality over a wide area that is currently undefined.

The CSM also indicates that there is the potential for groundwater with significant concentrations of nitrogen compounds at the landfill to contribute to the nitrogen load to Town Cove. The mass flux of nitrogen in groundwater migrating from the landfill toward Town Cove is the mass that passes through a defined cross sectional area affected by the landfill over a period of time. Based on current information, the area with elevated nitrogen concentrations at the landfill appears to extend at least 800 feet cross-gradient (between MW-1 to the west and MW-3/MW-5 to the east). Elevated nitrogen concentrations also extend to at least 40 feet below the water table. The full horizontal and vertical extent is unknown. These cross-section area and groundwater flow data indicate there may be a significant mass flux of nitrate from the landfill. Elevated concentrations of nitrate have been present in groundwater at the landfill for at least 22 years, a period of time extending at least to the start of regular groundwater monitoring in 1994.

Historical landfill and septage lagoon operations beginning around 1950 were likely sources of nitrogen to groundwater. With an estimated groundwater travel time of 50 years or less to Town Cove, it is likely that nitrogen from the landfill property may already be contributing nitrogen loading to Town Cove. Given current conditions and without corrective action, sources of nitrogen will continue to contribute a nitrogen load to the groundwater and to Town Cove over the long term.

Current yard waste composting operations may be a potential source of nitrogen leaching to groundwater. Current infiltration of Transfer Station stormwater and runoff from the top of the capped landfill through the former septage lagoon area may also be adding significant nitrogen to groundwater.

The infiltration of aerobic runoff may have converted a historical ammonia plume to a plume with nitrate as the dominant nitrogen compound in shallow groundwater while ammonia remains present in deeper anaerobic groundwater.

## 5. Assessment Plan

A. Assessment plans to define groundwater contaminant sources and the horizontal and vertical extent of nitrogen compounds and 1,4-dioxane in groundwater immediately downgradient of the landfill and septage lagoons are outlined below. An overview of proposed groundwater, stormwater, and soil sample parameters is included in Table 3.

B. Proposed assessment activities include:

- Evaluate the landfill cap drainage design and stormwater management systems in the vicinity of the transfer station and material composting areas to determine if runoff from the landfill surface or transfer station stormwater is recharging groundwater through the former septage lagoons;
- Assess the concentration of nitrogen compounds and 1,4-dioxane in landfill stormwater and in groundwater at the recharge location(s);
- Sample selected existing groundwater monitoring wells;
- Install and sample new groundwater monitoring wells placed in/near potential source areas (monitoring well locations 2, 6 and 7) (Figure 2);
- Install and sample new groundwater monitoring wells along a line northwest to southeast immediately downgradient of the landfill (monitoring well locations 5, 8, 9, and 10) (Figure 2). Monitoring wells, including some with multi-level screen intervals, will be installed in a phased approach as necessary to assess the horizontal (cross-gradient) and vertical extent of 1,4-dioxane and nitrogen compounds in groundwater;

- Develop a layered project base map with landfill site features including stormwater systems, well locations, solid waste and septage lagoon areas, and features of the proposed new DPW facility;
- Assess groundwater hydrogeology and groundwater flow in the vicinity of the landfill by installing monitoring wells and collecting groundwater information;
- Identify private wells downgradient of the landfill and septage lagoons and collect groundwater samples for analyses of nitrate and 1,4-dioxane where appropriate;
- Collect and analyze sub-surface soil samples from the unsaturated zone at and below the former septage lagoon area for total nitrogen, nitrate and total volatile solids to quantify organic material;
- Install new monitoring wells downgradient of the landfill closer to Town Cove as necessary (monitoring well locations 11, 12, and 13). The monitoring wells will be sampled and groundwater samples will be analyzed for total nitrogen, nitrate, and 1,4-dioxane; and
- Perform groundwater sampling and analyses from selected existing monitoring wells and/or irrigation wells for total nitrogen, nitrate, and 1,4-dioxane to assist in the landfill groundwater contamination assessment.

Proposed source and downgradient monitoring well locations are shown on Figure 2. Proposed downgradient watershed sampling locations are shown on Figure 3. Results of the investigation will be presented in two Technical Memorandums which will include: (a) results of initial assessment with an update of the Conceptual Site Model; and (b) a summary of additional measures undertaken to fill data gaps, a risk evaluation to assess the need for corrective risk management actions, and both a feasibility evaluation to identify potential corrective actions and a conceptual design for actions to address nitrogen flux and 1,4-dioxane in the groundwater.

## 6. References

EPA January 2014, Technical Fact Sheet – 1,4-Dioxane EPA 505-F-14-011

Coastal Engineering Co. Inc, 1992, the Initial Site Assessment Report Orleans Municipal Sanitary Landfill.

Coastal Engineering Co. Inc, 1992, Supporting Documentation for Septage Lagoon Closure.

Coastal Engineering Co., Inc., 1999, Comprehensive Site Assessment Report Orleans Municipal Sanitary Landfill.

Frimpter, M.H., and Gay, F.B., 1979, Chemical quality of ground water on Cape Cod, Massachusetts: U.S. Geological Survey Water-Resources Investigations Report 79-65.

GHD, Inc. and Stearns & Wheler, LLC, 2005 through 2014, Orleans Municipal Landfill Semi-Annual Groundwater Monitoring Reports.

LeBlanc, D.R., 1984, Sewage plume in a sand and gravel aquifer, Cape Cod, Massachusetts: U.S. Geological Survey Water-Supply Paper 2218.

MT Environmental Restoration, April 2015, Orleans Landfill Nitrate Data Evaluation Report.

Stearns & Wheeler, LLC, 2006, Construction Certification Report, Town of Orleans Landfill Closure.

Walter, D.A., Masterson, J.P., and Hess, K.M., 2004, Ground-water recharge areas and travel times to pumped wells, ponds, streams, and coastal water bodies, Cape Cod, Massachusetts: U.S. Geological Survey Scientific Investigations Map I-2857, 1 sheet [http://pubs.usgs.gov/sim/2004/2857/].

Weston Inc., 1998, Site Inspection Prioritization Report.

This page intentionally left blank.

## Tables

# Table 1- Summary of Recent Groundwater Quality Orleans Landfill Work Plan

| **Sample ID** | **MW-1S (56-66)** | **MW-2S (84-94)** | | **MW-2D (124-134)** | | **MW-3S (50-60)** | **MW-3D (84-94)** | **MW-5S (78-88)** | | **MW-5D (124-134)** | | **MW-E6-A (64-74)** | **MW-E6-B (54-64)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | | | | | | | | | | | | | |
| Sampling Date | 9/15/2016[1] | 2/26/2016 | 9/15/2016[1] | 2/26/2016 | 9/15/2016[1] | 9/15/2016[1] | 9/15/2016[1] | 2/26/2016 | 9/15/2016[1] | 2/26/2016 | 9/15/2016[1] | 2/10/2016 | 2/10/2016 |
| Field Measurements | | | | | | | | | | | | | |
| pH (SU) | 5.5 | 4.9 | 5.2 | 4.7 | 6.4 | 5.9 | 6.2 | 5.7 | 6.1 | 6.1 | 6.3 | 5.9 | 5.5 |
| Temperature (°C) | - | 13.2 | - | 12.4 | - | - | - | 13.5 | - | 13.5 | - | 13.3 | 12.5 |
| Dissolved Oxygen (DO; mg/L) | - | 1.4 | - | 0.8 | - | - | - | 5.0 | - | 2.4 | - | 0.5 | 1.8 |
| Redox Potential (ORP; mV) | - | 193.6 | - | 144.9 | - | - | - | 169.7 | - | 87.5 | - | 100.0 | 72.4 |
| Specific Conductivity (µS/cm$^c$) | - | 942.0 | - | 886.0 | - | - | - | 477.0 | - | 437.0 | - | 672 | 847 |
| Laboratory Analyses | | | | | | | | | | | | | |
| Nitrogen | | | | | | | | | | | | | |
| Nitrate as N (mg/L) | **8.8** | **24.7** | **22.0** | **9.26** | **0.50** | **4.7** | <0.01 | **0.03** | **9.4** | **11.4** | <0.01 | **11.6** | **20.8** |
| Nitrite as N (mg/L) | <0.050 | <0.01 | <0.050 | **0.065** | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 |
| Ammonia (mg/L) | <0.050 | **0.3** | <0.050 | **0.34** | **10.0** | <0.050 | **4.6** | **0.1** | **0.1** | **15.3** | **16.0** | **0.1** | **0.1** |
| Total Kjeldahl Nitrogen (TKN) (mg/L) | **0.71** | - | **1.3** | - | **12** | **0.73** | **5.6** | - | <0.50 | - | **14.0** | - | - |
| Total Nitrogen (mg/L) | **9.5** | **27.1** | **23.0** | **11.1** | **13.0** | **5.4** | **5.6** | **1.8** | **0.1E** | **26.8** | **16.0** | **12.6** | **21.2** |
| Alkalinity | | | | | | | | | | | | | |
| Total Alkalinity (mg/L) | - | - | **10** | - | **210** | - | - | - | **48** | - | **96** | - | - |
| Bicarbonate Alkalinity (mg/L) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Anions | | | | | | | | | | | | | |
| Chloride (mg/L) | **18** | **131** | **110** | **152** | **120** | **74** | **170** | **53** | **54** | **61** | **60** | **143** | **115** |
| Sulfate (mg/L) | **6.1** | **66.0** | **91.0** | **51.6** | **40.0** | **8.8** | **17.0** | **27.9** | **26.0** | **45.2** | **22.0** | **55.5** | **52.5** |
| Elements | | | | | | | | | | | | | |
| Dissolved Iron (mg/L) | <0.12 | **0.1** | <0.12 | <0.1 | **0.3** | <0.12 | **38.0** | - | <0.12 | - | **0.6** | **0.1** | **0.1** |
| Dissolved Manganese (mg/L) | **0.2** | **0.6** | **0.6** | **1.1** | **4.5** | **0.0** | **3.0** | - | **0.1** | - | **0.6** | **0.0** | **0.0** |
| Boron (mg/L) | - | **0.2** | - | **0.156** | - | - | - | - | - | - | - | **0.1** | **0.1** |
| Dissolved Organic Carbon | | | | | | | | | | | | | |
| DOC (mg/L) | - | **9.5** | - | **4.51** | - | - | - | - | - | - | - | **7.6** | **7.6** |

Notes:
Bold - detected above the Minimum Detection Limit
1. Data From Barnstable County Landfill Monitoring
E. Data point appears to be in error
(124-134)-Well screen depth below land surface

# Table 2 - 1,4-Dioxane in Groundwater

| Sample ID | Date | Parameter | Concentration (mg/L) |
|---|---|---|---|
| MW-2D (124-134) | 5/15 | 1, 4-dioxane | 0.0019 |
| MW-2D (124-134) | 9/15 | 1, 4-dioxane | 0.0016 |
| MW-2D (124-134) | 3/16 | 1, 4-dioxane | 0.0014 |

Notes:

MA Standard 0.0003 mg/L

(124-134)-Well screen depth below land surface

# Table 3 - Proposed Groundwater, Stormwater, and Soil Sample Parameters

| | **Field Measurements** | | | | **Standard Analytical Plan** | | | | | | | **Optional Analyses** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample ID** | **pH, Conductivity, Temperature** | **D.O.** | **O.R.P.** | **Turbidity** | **Total Nitrogen** | **Ammonia Nitrogen** | **Nitrate Nitrogen** | **Nitrite Nitrogen** | **Dissolved Iron** | **Sulfate** | **1,4-dioxane** | **Dissolved Organic Carbon** | **Boron** | **Chloride** | **Total Kjeldahl Nitrogen** | **Total Volatile Solids** |
| Monitoring Well Groundwater | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | |
| Stormwater | x | x | x | x | x | x | x | x | | x | x | x | x | x | | |
| Soil (Septage Lagoon Area) | | | | | x | | x | x | | | | | | | x | x |

## Figures


**FIGURE 1.**

**TOWN OF ORLEANS, MA WATER QUALITY AND WASTEWATER PLANNING**

**LANDFILL LOCATION**

G:\Projects\MUNI\60476644ORL\Maps\PRB_Figure1_Landfill.mxd

G:\Projects\MUNI\60476644ORL\Maps\PRB_Figure2_Landfillv2.mxd

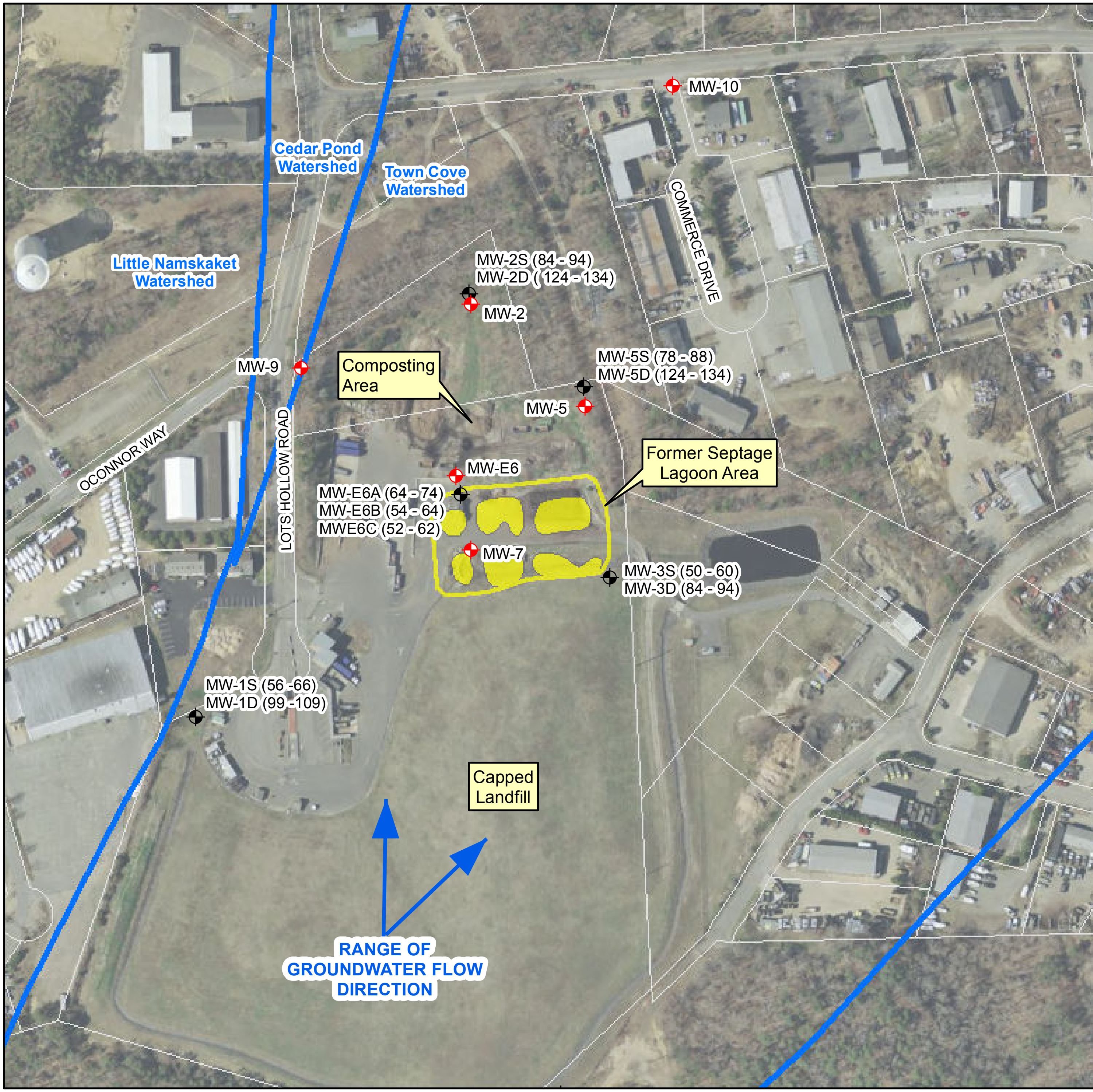



**FIGURE 2.**

**TOWN OF ORLEANS, MA WATER QUALITY AND WASTEWATER PLANNING**

**PROPOSED SAMPLING PLAN AT TOWN LANDFILL**

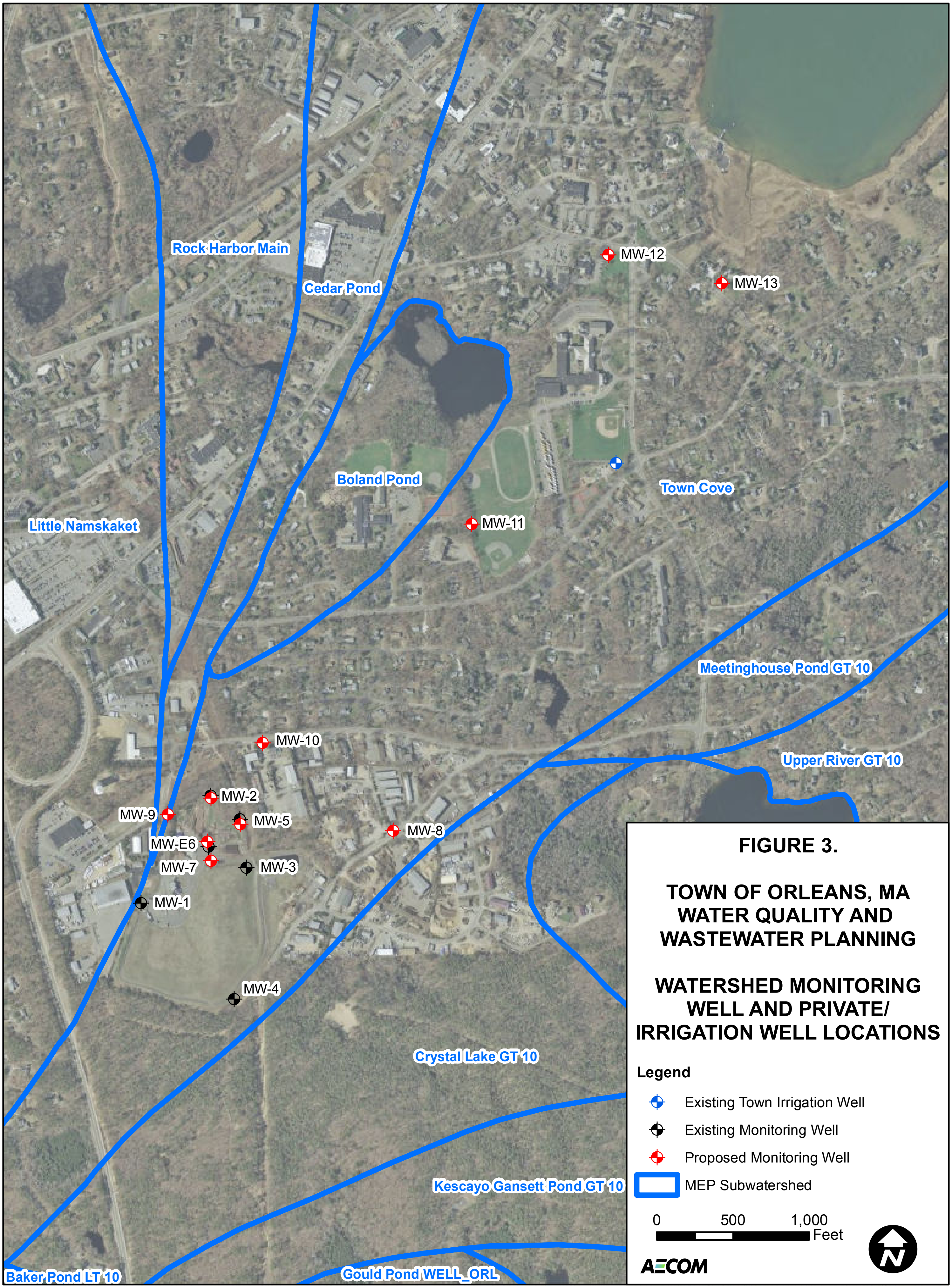
**Legend**

- Existing Monitoring Well
- Proposed Monitoring Well
- MEP Subwatershed

Note:
Monitoring wells are labeled with well screen intervals as feet below surface.

0 100 200 Feet

AECOM



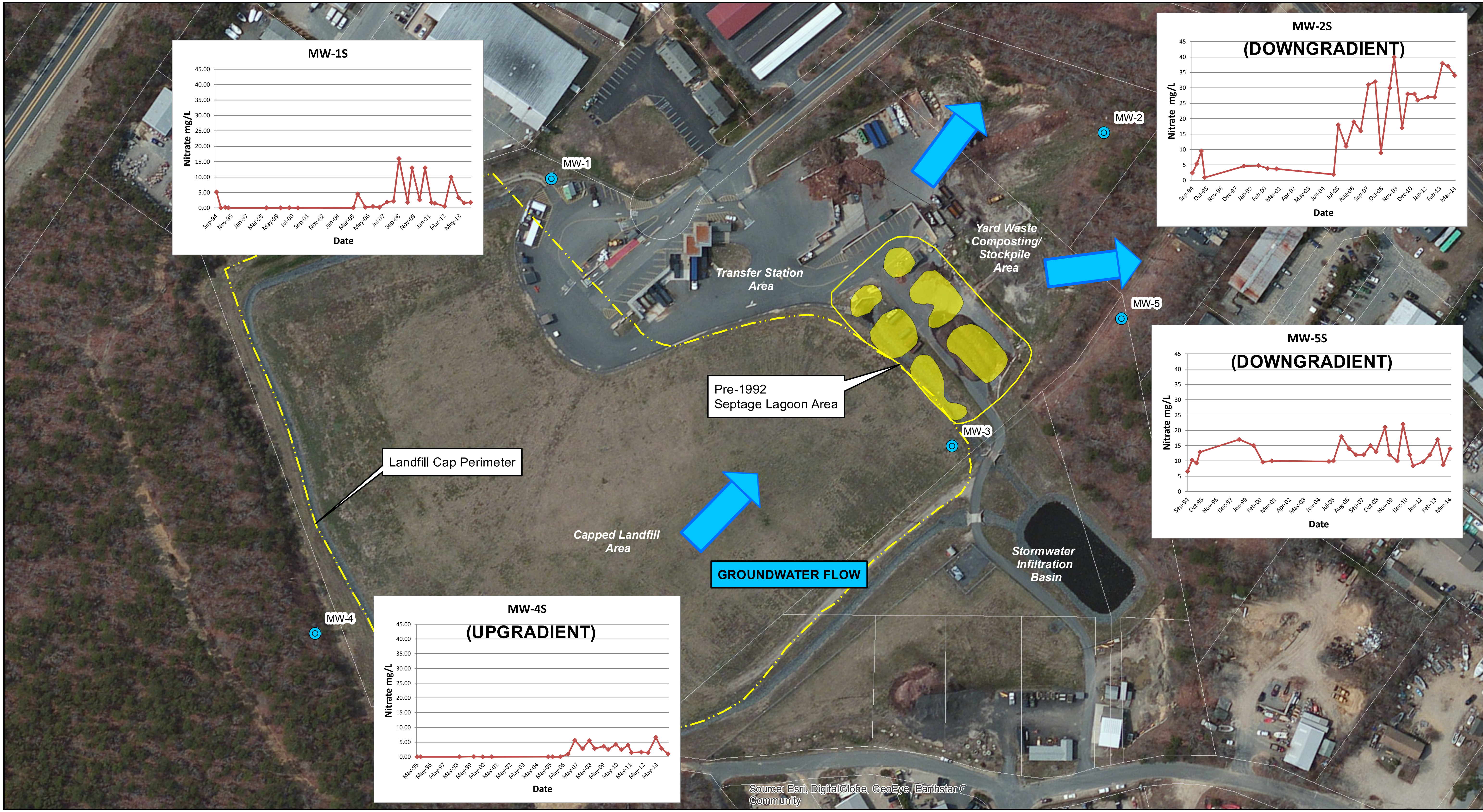

# FIGURE 3.

## TOWN OF ORLEANS, MA WATER QUALITY AND WASTEWATER PLANNING

## WATERSHED MONITORING WELL AND PRIVATE/ IRRIGATION WELL LOCATIONS

G:\Projects\MUNI\60476644ORL\Maps\PRB_Figure3_Landfill.mxd

**Appendix A**




Paper Size ANSI B

0 70 140 280 Feet

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

LEGEND

Monitoring Well

GHD

M T Environmental Restoration

Making Sense Out of Science
Molecular Translations, Inc.

Town of Orleans, Massachusetts
Landfill Monitoring

Conceptual Site Model Plan

| | |
|---|---|
| Job Number | 86-14842 |
| Revision | A |
| Date | 08 Apr 2015 |

Figure 3

G:\86\14842\GIS\Maps\MXD_Deliverables\2015 FILES\Figure 3- Existing Site Septage.mxd



Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:jjobrien

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