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 Michael Domenica, PE, Program Manager
CC	Betsy Shreve, AICP, AECOM Project Director James Begley, LSP, MT Environmental AECOM PRB Team
Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 10.1.B.2 – NT Demonstration Projects** **Technical Memorandum for Landfill Field Investigation Phase 1 Report- Draft**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	April 27, 2017

Approvals	Date	Signature / Initials
George Meservey, Orleans, MA Director of Planning & Community Development		
Michael Domenica, PE, Water Resources Associates, Program Manager		

1. Introduction

This Phase 1 Technical Memorandum provides updated information regarding assessment activities implemented in January and February 2017 at the Orleans Municipal Landfill and former septage lagoons (the landfill) and assessment results. A Phase 2 Technical Memorandum will be prepared with 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 recommended actions to address nitrogen flux and 1,4-dioxane in the groundwater. 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. The assessment work was implemented to investigate the flux of nitrogen compounds in groundwater emanating from the landfill and migrating toward Town Cove. In addition to assessing the nature and extent of nitrogen in groundwater, the assessment was also included an evaluation of the solvent 1,4-dioxane in groundwater. 1,4-dioxane had been recently identified in groundwater at concentrations greater than the current Massachusetts regulatory limit of 0.0003 mg/L.

2. Orleans Landfill Site Description and Background

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 in part on 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. Landfill drainage and transfer station stormwater are infiltrated along a drainage swale located over the former septage disposal area. 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). 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). The 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, and the difference in total nitrogen and nitrate concentrations, in deep groundwater as 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. Prior to this investigation 1,4-dioxane had 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. Landfill Groundwater Monitoring Well Network

A. The following groundwater monitoring wells were in place prior to this assessment; monitoring well locations are shown on Figure 2:

- 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 2016 nitrogen and 1,4-dioxane analyses from the landfill monitoring program and the results of the current assessment to date are included in Table 1.

4. Initial Conceptual Site Model Prior to the Current Assessment

A. Conceptual Site Model

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 Transport

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 degrade 1,4-dioxane).

Regional groundwater contour maps prepared by the United States Geological Survey (USGS) with the 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). Based on the location of the landfill near the high point of the watershed it is anticipated that groundwater at the landfill will move deeper into the aquifer as it migrates in the downgradient direction due to accretion of infiltrating precipitation.

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.

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 0.003 to the north 0.0006 to the northwest respectively. 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 by Coastal Engineering at 0.30 from soil samples collected during soil boring installation. Based on these data, they 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, and 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 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. MW-5S has shown a fairly steady elevated concentration of nitrate.

Landfill groundwater monitoring data also included 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 was 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 1). Groundwater conditions at MW-2D appear to be anoxic while the shallow well MW-2S at this location is screened in aerobic groundwater.

The source and extent of 1,4-dioxane is 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. Initial Conceptual Site Model Summary

The CSM 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. In this report the mass flux of nitrogen in groundwater migrating from the landfill toward Town Cove is defined as the mass that passes through a cross sectional area located immediately downgradient of the landfill and affected by the landfill over a period of time. Based on information available prior to this investigation, the area with elevated nitrogen concentrations at the landfill appeared to extend up to 800 feet cross-gradient (between MW-1 to the west and MW-3/MW-5 to the east). Elevated nitrogen concentrations were also known to 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. The location of septage disposal may have changed over time. 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.

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.

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.

5. Phase 1 Assessment

A. The Phase 1 Assessment plans included actions 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.

B. Completed Phase 1 assessment activities include:

- An evaluation of 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;
- Assessment of the the concentration of nitrogen compounds and 1,4-dioxane in landfill stormwater and groundwater at recharge locations;
- Groundwater sampling of selected pre-existing groundwater monitoring wells for nitrogen and 1,4-dioxane analyses;

- Installation and sampling of new groundwater monitoring wells placed near potential contaminant source areas and adjacent, upgradient, crossgradient, and downgradient of MW-2S(84-94) and MW-2D(124-134), including some with multi-level screen intervals. Note that values in parentheses have been added to show the depth of the screen in feet below ground surface;
- Groundwater monitoring including measuring groundwater elevations based on surveyed top of well casing elevations and depth to groundwater, collection of groundwater field parameters, and collection of groundwater samples for laboratory analyses including 1,4-dioxane, nitrogen compounds, and other parameters in groundwater;
- An evaluation of groundwater hydrogeology and groundwater flow in the vicinity of the landfill based on data collected;
- Collection and analyses of 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 nutrients and organic material; and
- Installation of new monitoring wells downgradient of the landfill closer to Town Cove as necessary (monitoring well locations 11, and 12). The monitoring wells will be sampled and groundwater samples will be analyzed for total nitrogen, nitrate, and 1,4-dioxane.

Source area and nearfield downgradient monitoring well locations are shown on Figure 2. Downgradient watershed sampling locations are shown on Figure 3.

6. Results of Phase 1 Assessment

A. Evaluation Landfill Cap Drainage Design, Stormwater Management Systems and Associated Potential Sources of Nitrogen and 1,4-Dioxane to Groundwater Including the Former Septage Lagoons

1) General

The landfill cap and associated drainage system was installed in 2005 to contain the solid waste and prevent continued infiltration of precipitation. The landfill cap system and transfer station stormwater management system are shown in Figure 4. According to the Massachusetts Department of Environmental Protection, the final cover system includes a subgrade of compacted soil materials on top of waste which is overlain by:

- A gas venting layer consisting of a minimum thickness of six inches of soil with a minimum saturated hydraulic conductivity of $1.2x10^{-3}$ centimeters per second, overlain by
- A low permeability layer consisting of a 40 mil textured high-density polyethylene geomembrane, flexible membrane liner, overlain by
- A drainage layer consisting of soil with a minimum thickness of twelve inches and a minimum saturated hydraulic conductivity of $1.2x10^{-2}$ cm/sec with a perforated pipe subdrain system constructed within the drainage soil, overlain by
- A vegetative support layer comprised of a minimum thickness of twelve inches of soil, with a vegetative cover seed mix.

The cover system was completed with a minimum top slope of 5% and side-slopes no greater than 3:1. Stormwater runoff controls were constructed to maintain the integrity of the final cover, prevent ponding of water on areas of the final cover, and to control stormwater runoff to prevent off-site impacts. The stormwater control system includes a perimeter swale around the entire landfill and a 108,000 cubic foot (808,000 gallon) capacity retention basin located in the northeast corner of the site. The retention basin includes a sediment forebay and was designed to fully control the twenty-five year storm event prior to discharge through an emergency spillway.

Drainage pipes were installed across the side slope to collect stormwater accumulated within the sand drainage layer. Side slope pipes connect to a header installed down the side slopes leading to stone riprap lined perimeter swales. Pre-cast catchbasins were installed in the paved areas at the transfer station to direct stormwater runoff to the riprap swale leading to the stormwater detention basin (MassDEP October, 2013).

Sources of nitrogen associated with the stormwater management and landfill cap system include general transfer station runoff and the potential mobilization of nitrogen from the former septage lagoon area by infiltrating stormwater and landfill cover drainage water in the unlined riprap swale located to the north of the landfill cap. A sample of general transfer station runoff was collected from Stormdrain-1 located adjacent to the Gift Shop building (Figure 2). Stormwater test results are included in Table 2. Laboratory results for the stormwater sample indicated mainly the presence of organic nitrogen with total nitrogen measured at 4.5 mg/L, nitrate-nitrogen at 0.42 mg/L, and ammonia-nitrogen measured at 0.67 mg/L. The stormwater was also analyzed for the presence of 1,4-dioxane and it was not detected (<0.25 µg/L).

A soil boring was completed at the location of monitoring well MW-7 installed adjacent to the northwest end of the unlined riprap swale on January 18^{th} and 19^{th}, 2017. Soil sampling results indicated the presence of soil with a high nitrogen and organic content with septage odor at approximately 12 feet below ground surface. Test results for soil samples collected at 12-13 ft., 13.5-14.5 ft., 15-17 ft., 42-44 ft. and 57-58 ft. below ground surface indicated high concentrations of nitrogen and organic material were limited to the 12-13 ft. range. The concentration of total nitrogen in this residual material was measured at 1,440 mg/kg or 0.14 percent (Table 3). Visual observations at depths less than 12 feet indicated the presence of relatively clean sand.

2) Results of Evaluation

Transfer station stormwater is a source of nitrogen that is infiltrated to groundwater without treatment. Stormwater does not appear to be a source of 1,4-dioxane. A concentration of 4.5 mg/L total nitrogen was measured in the surface water runoff sample collected although the stormwater nitrogen concentration is likely to be highly variable. The section of the unlined riprap perimeter swale to the north of the landfill cap receives runoff from the landfill cap drainage layer on the north and west sides of the landfill as well as stormwater from the transfer station catch basins. This section of swale is located above the former septage lagoons. Based on landfill drawings and observation, landfill drainage and stormwater infiltrates through the swale and does not flow east to the retention basin except during significant storm events. This results in a significant recharge to groundwater through the residual organic material with a high concentration of total nitrogen in the septage lagoon area and potentially a high mass loading to groundwater.

B. Assessment of Nitrogen and 1,4-Dioxane in Runoff from Composting Operations

1) General

The landfill composting operation processes yard waste that includes leaves, brush, garden, and landscape trimmings. Generally yard waste includes green waste and brown waste. Green waste is primarily fresh plant material such as grass clippings and garden waste that contains appreciable amounts of nitrogen, phosphorus, and mineral nutrients. Brown waste includes dry leaves, hay, and brush that contains primarily carbon, with a high carbon/nitrate (C/N) ratio (Chatterjee et. al., 2013).

Compost operations include the maintenance of aerated windrows of yard waste in an area to the north of the capped landfill on both paved and unpaved surface. An assessment of the concentration of nitrogen compounds in stormwater originating from an area of paved surface that includes yard waste composting operations was completed. Samples of runoff from the paved composting area were collected for nitrogen analyses at Stormdrain-2, located in the paved area near the east end of the riprap swale (Figure 2). The results of analyses were compared to general transfer Station runoff samples that were collected from Stormdrain -1 located adjacent to the Gift Shop. The results of stormwater analyses are included in Table 2 and a comparison of nitrogen compound concentrations in the stormwater samples is presented in Chart 1. The stormwater originating from the compost pile area was also analyzed for the presence of 1,4-dioxane and it was not detected (<0.25 µg/L)

2) Results of Evaluation

Significantly higher nitrogen concentrations were detected in the sample from the Stormdrain-2 location, which is more associated with the composting operation than general transfer station runoff. Total nitrogen concentrations from transfer station and composting area stormwater runoff were 4.5 mg/L and 27.1 mg/L respectively. A comparison of the test results is included in Chart 1. These data indicate composting operations are a likely significant source of nitrogen to groundwater. The compost is located on both paved and unpaved surfaces and a portion of the leachate from compost directly infiltrates to groundwater through sandy soil, while a portion is recharged to groundwater through the stormwater management system. Stormwater originating from the compost area does not appear to be a source of 1,4-dioxane.

C. Groundwater Assessment

1) General

Phase 1 groundwater monitoring wells, including single and multi-screen wells, were installed on the landfill property and in public roadways immediately downgradient of the landfill property to assess the nearfield horizontal and vertical extent of groundwater contamination. Monitoring well locations and screen depth were selected based on previously available assessment data and available information regarding the direction of groundwater flow. The objective was to install new monitoring wells in potential source areas (e,g, septage lagoons) to estimate the extent of existing nitrate sources, in deeper groundwater at locations of known shallower contamination (nitrogen compounds and 1,4-dioxane in groundwater) to assess vertical distribution, and cross gradient from wells with known contamination to determine the lateral extent of contaminants. The monitoring wells were installed at selected locations with the intention of installing additional monitoring wells in Phase 2 once initial analyses were complete and a clearer picture of the extent of contaminants was available. In addition, monitoring well locations were selected to assess the extent of groundwater contamination around existing monitoring wells MW-2S(84-94) and MW-2D(124-134), where the highest concentrations of nitrogen compounds and 1,4-dioxane had been previously detected. Monitoring wells installed during Phase 1 included:

- MW-2(140-150) adjacent to and deeper than MW-2S(84-94) and MW-2D(124-134),
- MW-7S(55-65), MW-7D(115-125) upgradient of MW-2S(84-94) and MW-2D(124-134), adjacent to the north side of the capped landfill and the drainage swale over the septage lagoons,
- MW-8(36-46) located cross gradient of MW-2S(84-94) and MW-2D(124-134), to the east and downgradient of the east side of the landfill on Giddiah Hill Road,
- MW-9(92-102), located cross gradient to the west of MW-2S(84-94) and MW-2D(124-134), adjacent to Lots Hollow Road, and
- MW-10(85-95) located downgradient of MW-2S(84-94) and MW-2D(124-134), on Finlay Road (Figure 2).

The values in parentheses are the depth of the screen interval in feet below ground surface that have been added to well designations to clarify the vertical location of screen intervals. The depth to groundwater at monitoring wells varies depending on location. Surveyed top of casing elevations and well construction details including screen elevations are included in Table 4. During the field effort MW-1D(99-109) was reconstructed to repair a bent and obstructed well casing. All new monitoring wells are 2-inch PVC wells with 10 foot screens installed with hollow stem auger drilling by Desmond Well Drilling Inc. using a CME-75rig mounted on a GMC 7500.

The new and selected previously existing monitoring wells were developed by pumping and sampled using the US EPA low flow methodology between February 6 and February 8, 2017 for field parameters, nitrogen compounds and selected anions, elements, dissolved organic carbon (DOC), and 1,4-dioxane. The results of these analyses are included in Table 1).

Water table elevations were recorded prior to purging wells for sampling and are recorded in Table 5. Groundwater elevations indicate flow to the northeast as indicated on Figure 2. Variations in groundwater elevation at cluster well locations also indicate the potential for a steep vertical gradient.

2) Results of Evaluation

Groundwater data indicates the presence of a two layer nitrogen plume emanating from the landfill and transfer station property. Shallow groundwater is contaminated with nitrate-nitrogen to a depth of approximately 20 feet below the water table. Ammonia-nitrogen is the dominant form of nitrogen in deeper groundwater. The maximum concentration of nitrate observed in February 2017 groundwater samples was 20.2 mg/L detected in MW-9(92-102), located cross gradient to the west of MW-2S(84-94) (Figure 2). A concentration of 18.8 mg/L was measured at MW-2S(84-94). The maximum concentration of ammonia observed in February 2017 groundwater samples was 12.7 mg/L measured at MW-5D(124-134) located east of MW-2D(124-134). A concentration of 11.9 mg/L ammonia was measured at MW-2D(124-134).

Based on the Phase 1 assessment additional monitoring wells are necessary to refine the Conceptual Site Model and assess the flux of nitrogen from the landfill.

7. Phase 2 Assessment Plan and Status

The following Phase 2 monitoring wells have been installed and are currently being sampled to fill data gaps: MW-2(161-171), MW-5(140-150), MW-7(90-100), MW-8(84-94), MW-13(74-84). Locations of Phase 2 monitoring wells are shown on Figure 5. Two deep screened monitoring wells MW-11(91-101) and MW-12(97-97) were also installed in the watershed between the landfill and Town Cove (see Figure 3). Selected monitoring wells sampled in Phase 1 are being resampled in Phase 2 to confirm results of analyses.

The additional data collected during Phase 2 will be used to confirm the nearfield nature and extent of groundwater contamination and assess sources of groundwater contamination.

8. References

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

Chatterjee, N., M. Flury, C. Hinman, C. G. Cogger, 2013, Chemical and Physical Characteristics of Compost Leachates-A Review . Washington State University.

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 Orleans Landfill Groundwater Analyses

Sample ID	**MW-1S (56-66)**			**MW-1D(99-109)**		**MW-2S (84-94)**			
Top of Screen Elevation (ft)	27.30			-15.70		17.30			
Bottom of Screen Elevation (ft)	17.30			-25.70		7.30			
Sampling Date	9/15/2016[1]	2/8/2017	3/29/2017	2/8/2017	3/29/2017	2/26/2016	9/15/2016[1]	02/06/2017	3/28/2017[2]
Field Measurements									
pH (SU)	5.5	5.3	4.7	5.6	4.9	4.9	5.2	4.8	4.5
Temperature (^{o}C)	-	14.1	13.4	13.7	12.6	13.2	-	16.0	15.0
Dissolved Oxygen (DO; mg/L)	-	3.0	1.1	4.2	4.4	1.4	-	1.6	0.8
Dissolved Oxygen (DO; %)	-	-	10.5	-	38.6	-	-	16.2	7.5
Redox Potential (ORP; mV)	-	120.2	149.8	138.3	143.4	193.6	-	129.8	144.7
Specific Conductivity (µS/cm)[c]	-	137.0	127.0	172.0	173.0	942.0	-	751.0	777.0
Laboratory Analyses									
Nitrogen									
Nitrate as N (mg/L)	**8.8**	**3.6**	**2.56**	**3.28**	**4.12**	**24.7**	**22.0**	**18.8**	**1.05**
Nitrite as N (mg/L)	<0.050	<0.01	<0.01	<0.01	<0.01	<0.01	<0.050	**0.0**	<0.01
Ammonia (mg/L)	<0.050	<0.1	**0.11**	**0.51**	**0.43**	**0.25**	<0.050	**0.14**	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	**0.71**	**1.24**	-	**1.21**	-	-	**1.30**	**2.13**	**2.29**
Total Nitrogen (mg/L)	**9.5**	**4.8**	**4.26**	**4.5**	**4.86**	**27.1**	**23.0**	**21.0**	**3.34**
Alkalinity									
Total Alkalinity (mg/L)	-	-	-	-	-	-	**10**	-	-
Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-
Anions									
Chloride (mg/L)	**18.0**	**13.2**	**15**	**32.5**	**30.7**	**131.0**	**110.0**	**88.8**	**94.8**
Sulfate (mg/L)	**6.1**	**6.7**	**5.4**	**8.7**	**8.2**	**66.0**	**91.0**	**77.0**	**81**
Elements									
Dissolved Iron (mg/L)	<0.12	<0.1	<0.1	<0.1	<0.1	**0.1**	<0.12	<0.1	<0.1
Dissolved Manganese (mg/L)	**0.19**	**0.37**	**0.454**	**0.08**	**0.059**	**0.60**	**0.62**	**0.55**	**0.528**
Boron (mg/L)	-	-	-	-	-	**0.22**	-	**0.28**	-
Organic Compounds									
1,4-Dioxane	-	-	-	-	-	-	-	<0.25	-
DOC (mg/L)	-	-	-	-	-	**9.5**	-	**9.5**	-
Methane	-	-	-	-	-	-	-	-	-

Notes:

Bold - detected above the Minimum Detection Limit

1. Data From Barnstable County Landfill Monitoring
2. Data for TKN and Total Nitrogen was re-run and results reported on April 24, 2017.

E. Data point appears to be in error (124-134)-Well screen depth below land surface

Table 1 Orleans Landfill Groundwater Analyses

Sample ID	**MW-2D (124-134)**					**MW-2(140-150)**		**MW-3S (50-60)**		
Top of Screen Elevation (ft)	-22.40					-38.70		18.60		
Bottom of Screen Elevation (ft)	-32.40					-48.70		8.60		
Sampling Date	2/26/2016	9/15/2016[1]	02/06/2017	02/06/2017(DUP)	3/28/2017[2]	02/06/2017	3/28/2017	9/15/2016[1]	2/8/2017	3/29/2017
Field Measurements										
pH (SU)	4.7	6.4	6.0	6.0	5.6	6.0	6.3	5.9	5.25	4.41
Temperature (^{o}C)	12.4	-	15.5	15.5	15.1	15.2	16.9	-	15.07	13.85
Dissolved Oxygen (DO; mg/L)	0.8	-	0.1	0.1	0.0	0.1	0.2	-	4.45	4.22
Dissolved Oxygen (DO; %)	-	-	0.6	0.6	0.2	0.8	2.2	-	-	42.1
Redox Potential (ORP; mV)	144.9	-	54.5	54.5	106.0	65.1	97.7	-	100.8	170.8
Specific Conductivity (µS/cm)[c]	886.0	-	800.0	800.0	828.0	637.0	6341.0	-	918	2139
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	**9.26**	**0.50**	**0.208**	**0.18**	**2.32**	<0.03	<0.03	**4.7**	**0.601**	**0.299**
Nitrite as N (mg/L)	**0.065**	<0.050	**0.014**	<0.01	<0.01	<0.01	<0.01	<0.050	<0.01	<0.01
Ammonia (mg/L)	**0.34**	**10.0**	**11.5**	**11.2**	**10.9**	**11.9**	**11.2**	<0.050	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	**12.00**	**13.70**	**14.70**	**12.13**	**12.80**	-	**0.73**	**0.61**	-
Total Nitrogen (mg/L)	**11.1**	**13.0**	**13.9**	**14.8**	**14.45**	**12.8**	**17.2**	**5.4**	**1.2**	**0.75**
Alkalinity										
Total Alkalinity (mg/L)	-	**210**	-	-	-	-	-	-	-	-
Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-	-
Anions										
Chloride (mg/L)	**152.0**	**120.0**	**97.7**	**99.2**	**134**	**49.0**	**46.1**	**74.0**	**324.0**	**774**
Sulfate (mg/L)	**51.6**	**40.0**	**52.5**	**52.0**	**51**	**62.0**	**63.5**	**8.8**	5.0	<5
Elements										
Dissolved Iron (mg/L)	<0.1	**0.3**	<0.1	**0.11**	**0.107**	**0.11**	**0.908**	<0.12	<0.1	**1.27**
Dissolved Manganese (mg/L)	**1.10**	**4.50**	**5.12**	**5.10**	**4.48**	**5.46**	**5.12**	**0.03**	**0.18**	**0.669**
Boron (mg/L)	**0.16**	-	**0.26**	**0.25**	-	**0.28**	-	-	<0.05	-
Organic Compounds								-	-	
1,4-Dioxane	-	-	**1.84**	**1.7**	-	**2.05**	-	-	-	-
DOC (mg/L)	**4.5**	-	**7.2**	**8.6**	-	**7.0**	-	-	-	-
Methane	-	-	-	-	-	-	-	-	-	-

Notes:

Bold - detected above the Minimum Detection Limit

1. Data From Barnstable County Landfill Monitoring
2. Data for TKN and Total Nitrogen was re-run and results reported on April 24, 2017.

E. Data point appears to be in error

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

Table 1 Orleans Landfill Groundwater Analyses

Sample ID	**MW-3D (84-94)**			**MW-5S (78-88)**				**MW-5D (124-134)**			
Top of Screen Elevation (ft)	-15.20			24.10				-22.00			
Bottom of Screen Elevation (ft)	-25.20			14.10				-32.00			
Sampling Date	9/15/2016[1]	2/8/2017	3/29/2017	2/26/2016	9/15/2016[1]	2/6/2017	3/29/2017	2/26/2016	9/15/2016[1]	2/6/2017	3/29/2017
Field Measurements											
pH (SU)	6.2	6.12	5.63	5.7	6.1	5.5	5.1	6.1	6.3	5.9	5.6
Temperature (^{o}C)	**-**	13.99	12.87	13.5	**-**	14.0	14.2	13.5	**-**	13.9	13.8
Dissolved Oxygen (DO; mg/L)	**-**	0.11	0.02	5.0	**-**	2.4	1.9	2.4	**-**	0.2	0.0
Dissolved Oxygen (DO; %)	**-**	**-**	0.2	**-**	**-**	23.2	18.6	**-**	**-**	1.9	0.0
Redox Potential (ORP; mV)	**-**	-56.1	-29.6	169.7	**-**	58.3	139.3	87.5	**-**	29.4	89.8
Specific Conductivity (µS/cm)[c]	**-**	632	709	477.0	**-**	523.0	494.0	437.0	**-**	441.0	445.0
Laboratory Analyses											
Nitrogen											
Nitrate as N (mg/L)	<0.01	<0.03	<0.03	**0.03**	**9.4**	**17.3**	**18.6**	**11.4**	<0.01	**0.05**	**0.058**
Nitrite as N (mg/L)	<0.050	**0.014**	**0.043**	<0.050	<0.050	<0.01	<0.01	<0.050	<0.050	<0.01	<0.01
Ammonia (mg/L)	**4.6**	**-**	**4.36**	**0.10**	**0.10**	**0.12**	<0.1	**15.3**	**16.0**	**12.7**	**14**
Total Kjeldahl Nitrogen (TKN) (mg/L)	**5.60**	**5.75**	**-**	**-**	<0.50	**2.19**	**-**	**-**	**14.00**	**13.90**	**-**
Total Nitrogen (mg/L)	**5.6**	**5.8**	**5.35**	**1.8**	**0.1E**	**19.5**	**18.9**	**26.8**	**16.0**	**13.9**	**16**
Alkalinity											
Total Alkalinity (mg/L)	**-**	**-**	**-**	**-**	**48**	**-**	**-**	**-**	**96**	**-**	**-**
Bicarbonate Alkalinity (mg/L)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Anions											
Chloride (mg/L)	**170.0**	**159.0**	**147**	**53.1**	**54.0**	**63.5**	**64.4**	**61.2**	**60.0**	**66.1**	**70.1**
Sulfate (mg/L)	**17.0**	**14.1**	**18.1**	**27.9**	**26.0**	**55.0**	**49**	**45.2**	**22.0**	**24.0**	**23.8**
Elements											
Dissolved Iron (mg/L)	**38.0**	**34.6**	**34.5**	**-**	<0.12	**0.10**	**0.12**	**-**	**0.61**	**0.62**	**0.608**
Dissolved Manganese (mg/L)	**3.00**	**2.66**	**2.78**	**-**	**0.06**	**0.11**	**0.075**	**-**	**0.62**	**0.52**	**0.584**
Boron (mg/L)	**-**	<0.05	**-**	**-**	**-**	**0.11**	**-**	**-**	**-**	**0.06**	**-**
Organic Compounds	**-**	**-**									
1,4-Dioxane	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
DOC (mg/L)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Methane	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Notes:

Bold - detected above the Minimum Detection Limit

1. Data From Barnstable County Landfill Monitoring
2. Data for TKN and Total Nitrogen was re-run and results reported on April 24, 2017.

E. Data point appears to be in error

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

Table 1 Orleans Landfill Groundwater Analyses

Sample ID	**MW-E6-A (64-74)**			**MW-E6-B (54-64)**			**MW-6 (88-98)**	
Top of Screen Elevation (ft)	7.60			17.80			-15.80	
Bottom of Screen Elevation (ft)	-2.40			7.80			-25.80	
Sampling Date	2/10/2016	2/6/2017	3/28/2017	2/10/2016	2/6/2017	3/28/2017[2]	02/06/2017	3/28/2017[2]
Field Measurements								
pH (SU)	5.9	5.6	5.8	5.5	5.4	5.2	6.5	6.6
Temperature (^{o}C)	13.3	14.9	15.6	12.5	14.9	15.4	14.0	14.7
Dissolved Oxygen (DO; mg/L)	0.46	0.15	0.11	1.82	1.45	1.06	0.12	0.15
Dissolved Oxygen (DO; %)	**-**	1.5	1.1	**-**	14.5	10.5	1.2	1.5
Redox Potential (ORP; mV)	100.0	56.4	85.5	72.4	71.2	119.2	-82.1	-36.0
Specific Conductivity (µS/cm)[c]	672.0	1069.0	1186.0	847.0	743.0	793.0	900.0	991.0
Laboratory Analyses								
Nitrogen								
Nitrate as N (mg/L)	**11.6**	**7.2**	**2.61**	**20.8**	**16.3**	**8.27**	**0.1**	<0.03
Nitrite as N (mg/L)	<0.050	<0.01	<0.01	<0.050	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	**0.10**	<0.1	<0.1	**0.10**	**0.11**	<0.1	**0.12**	**22.6**
Total Kjeldahl Nitrogen (TKN) (mg/L)	**-**	**1.70**	**-**	**-**	**1.50**	**1.33**	**24.10**	**-**
Total Nitrogen (mg/L)	**12.6**	**8.9**	**3.94**	**21.2**	**17.8**	**9.60**	**24.2**	**24.99**
Alkalinity								
Total Alkalinity (mg/L)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Bicarbonate Alkalinity (mg/L)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Anions								
Chloride (mg/L)	**143.0**	**280.0**	**331**	**115.0**	**151.0**	**167**	**173.0**	**196**
Sulfate (mg/L)	**55.5**	**34.4**	**27.8**	**52.5**	**41.5**	**43.5**	**22.5**	**21.5**
Elements								
Dissolved Iron (mg/L)	**0.05**	**0.15**	**0.107**	**0.05**	**0.16**	<0.1	**18.40**	**13.5**
Dissolved Manganese (mg/L)	**0.02**	**0.05**	**0.05**	**0.02**	**0.04**	**0.026**	**2.49**	**2.39**
Boron (mg/L)	**0.14**	**0.10**	**-**	**0.14**	**0.11**	**-**	**0.24**	**-**
Organic Compounds								
1,4-Dioxane	**-**	<0.25	**-**	**-**	<0.25	**-**	**0.687**	**-**
DOC (mg/L)	**7.6**	**8.1**	**-**	**7.6**	**6.7**	**-**	8.8	**-**
Methane	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Notes:

Bold - detected above the Minimum Detection Limit

1. Data From Barnstable County Landfill Monitoring

2. Data for TKN and Total Nitrogen was re-run and results reported on April 24, 2017.

E. Data point appears to be in error (124-134)-Well screen depth below land surface

Table 1 Orleans Landfill Groundwater Analyses

Sample ID	**MW-7S(55-65)**			**MW-7D(115-125)**		**MW-8(36-46)**		**MW-9(92-102)**	
Top of Screen Elevation (ft)	14.80			-45.10		23.10		13.50	
Bottom of Screen Elevation (ft)	4.80			-55.10		13.10		9.00	
Sampling Date	02/06/2017	02/06/2017 (DUP)	3/28/2017	02/06/2017	3/28/2017[2]	2/8/2017	3/27/2017	2/8/2017	3/29/2017
Field Measurements									
pH (SU)	5.7	5.7	5.2	6.2	6.3	4.5	4.0	5.0	4.4
Temperature (^{o}C)	12.7	12.7	13.4	12.7	12.9	14.6	13.8	15.9	15.5
Dissolved Oxygen (DO; mg/L)	0.69	0.69	0.04	0.2	0.2	2.1	2.9	7.4	7.8
Dissolved Oxygen (DO; %)	6.5	6.5	0.4	1.9	2.2	20.5	28.5	-	76.1
Redox Potential (ORP; mV)	39.4	39.4	115.1	-64.1	2.0	175.6	179.8	139.1	185.6
Specific Conductivity (µS/cm)[c]	665.0	665.0	1229.0	510.0	482.0	397.0	351.0	297.0	327.0
Laboratory Analyses									
Nitrogen									
Nitrate as N (mg/L)	**8.7**	**12.8**	**4.96**	<0.03	<0.03	**5.5**	**3.83**	**20.2**	**6.37**
Nitrite as N (mg/L)	<0.01	<0.01	**0.012**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	**0.34**	**0.13**	**0.15**	**2.74**	**2.59**	**0.11**	**0.18**	**0.34**	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	**1.92**	**2.38**	-	**3.17**	-	**2.03**	-	**2.83**	-
Total Nitrogen (mg/L)	**10.6**	**15.2**	**8.67**	**3.2**	**3.20**	**7.6**	**4.84**	**23.0**	**6.65**
Alkalinity									
Total Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-
Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-
Anions									
Chloride (mg/L)	**127.0**	**124.0**	**369**	**55.3**	**57.2**	**55.1**	**66.4**	**65.5**	**60.8**
Sulfate (mg/L)	**29.6**	**33.6**	**15.5**	**36.2**	**34.2**	**37.8**	**24.3**	**15.5**	**34.6**
Elements									
Dissolved Iron (mg/L)	**0.34**	**0.27**	**0.216**	**18.30**	**17.5**	<0.1	<0.1	<0.1	<0.1
Dissolved Manganese (mg/L)	**0.02**	**0.02**	**0.031**	**3.21**	**2.72**	**0.10**	**0.301**	**0.49**	**0.052**
Boron (mg/L)	**0.08**	**0.08**	-	**0.14**	-	**0.09**	-	<0.05	-
Organic Compounds									
1,4-Dioxane	<0.25	-	-	**1.7**	-	<0.25	-	<0.25	-
DOC (mg/L)	-	-	-	-	-	**4.4**	-	**1.6**	-
Methane	-	-	<2	-	<2	-	-	-	-

Notes:

Bold - detected above the Minimum Detection Limit

1. Data From Barnstable County Landfill Monitoring

2. Data for TKN and Total Nitrogen was re-run and results reported on April 24, 2017.

E. Data point appears to be in error (124-134)-Well screen depth below land surface

Table 1 Orleans Landfill Groundwater Analyses

Sample ID	**MW-10(85-95)**	
Top of Screen Elevation (ft)	9.00	
Bottom of Screen Elevation (ft)	-1.00	
Sampling Date	2/8/2017	3/28/2017
Field Measurements		
pH (SU)	5.6	5.4
Temperature (^oC)	14.6	15.9
Dissolved Oxygen (DO; mg/L)	9.4	8.5
Dissolved Oxygen (DO; %)	-	81.5
Redox Potential (ORP; mV)	118.9	117.8
Specific Conductivity (µS/cm)[c]	175.0	176.0
Laboratory Analyses		
Nitrogen		
Nitrate as N (mg/L)	**2.4**	**2.5**
Nitrite as N (mg/L)	<0.01	<0.01
Ammonia (mg/L)	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	**0.85**	-
Total Nitrogen (mg/L)	**3.3**	**2.83**
Alkalinity		
Total Alkalinity (mg/L)	-	-
Bicarbonate Alkalinity (mg/L)	-	-
Anions		
Chloride (mg/L)	**42.9**	**39.1**
Sulfate (mg/L)	<5	**6.1**
Elements		
Dissolved Iron (mg/L)	<0.1	**0.375**
Dissolved Manganese (mg/L)	**0.07**	**0.028**
Boron (mg/L)	<0.05	-
Organic Compounds		
1,4-Dioxane	<0.25	-
DOC (mg/L)	<0.5	-
Methane	-	-

Notes:
Bold - detected above the Minimum Detection Limit
1. Data From Barnstable County Landfill Monitoring
2. Data for TKN and Total Nitrogen was re-run and results reported on April 24, 2017.
E. Data point appears to be in error (124-134)-Well screen depth below land surface

Table 2 Orleans Landfill Stormwater Analyses

Sample ID	**Stormwater 1**	**Stormwater 2**
Sample Description	Transfer Station Runoff	Compost Runoff
Sampling Date	2/8/2017	2/8/2017
Laboratory Analyses		
Nitrogen		
Nitrate as N (mg/L)	**0.424**	**10.5**
Nitrite as N (mg/L)	**0.026**	**0.15**
Ammonia (mg/L)	**0.67**	**2.92**
Total Kjeldahl Nitrogen (TKN) (mg/L)	**4.05**	**16.4**
Total Nitrogen (mg/L)	**4.5**	**27.1**
Anions		
Chloride (mg/L)	**455**	**188**
Sulfate (mg/L)	<5	**5.9**
Organic Compounds		
1,4-Dioxane	<0.25	<0.25
DOC (mg/L)	**39.6**	**175**

Notes:

Bold - detected above the Minimum Detection Limit

Table 3 Orleans Landfill Septage Lagoon Soil Analyses

Sample ID	**MW-7/12-13'**	**MW-7/13.5-14.5'**	**MW-7/15-17'**	**MW-7/42-44'**	**MW-7/57-58'**
Sampling Date	**01/18/2017**	**01/18/2017**	**01/19/2017**	**01/19/2017**	**01/19/2017**
Laboratory Analyses					
Nitrogen					
Nitrate/Nitrite as N	**0.32**	<0.25	<0.24	**0.76**	<0.23
Total Kjeldahl Nitrogen as N	**1440**	<93.2	**160**	<78	<86.7
Total Nitrogen	**1440**	<93.5	**160**	<78.2	<86.9
Other					
Total Volatile Solids	**4**	<1	<1	<1	<1

Notes:
Bold - detected above the Minimum Detection Limit

Table 4 Orleans Landfill Monitoring Well Construction Details

Location	Surface Elevation (ft)	TOC Elevation (ft)	Total Well Depth (ft bgs)	Screen Beginning Depth (ft bgs)	Screen End Depth (ft bgs)	Top Screen Elevation (ft)	Bottom Screen Elevation (ft)	Mid-Screen Elevation (ft)	Screen Length (ft)	Inst. Date	Address
MW-1S(56-66)	83.3	85.18	66.0	56.00	66.00	27.30	17.30	22.30	10.0	existing	Landfill
MW-1D(99-109)	83.3	85.11	109.0	99.00	109.00	-15.70	-25.70	-20.70	10.0	existing	Landfill
MW-2S(84-94)	101.3	101.49	94.0	84.00	94.00	17.30	7.30	12.30	10.0	existing	Landfill
MW-2D(124-134)	101.6	101.42	134.0	124.00	134.00	-22.40	-32.40	-27.40	10.0	existing	Landfill
MW-2(140-150) *	101.3	102.80	150.0	140.00	150.00	-38.70	-48.70	-43.70	10.0	1/18/2017	Landfill
MW-2 (161-171)	NA	NA	171.0	161.00	171.00	NA	NA	NA	10.0	March 2017	Landfill
MW-3S(50-60)	68.6	70.32	60.0	50.00	60.00	18.60	8.60	13.60	10.0	existing	Landfill
MW-3D(84-94)	68.8	69.74	94.0	84.00	94.00	-15.20	-25.20	-20.20	10.0	existing	Landfill
MW-5S(78-88)	102.1	103.91	88.0	78.00	88.00	24.10	14.10	19.10	10.0	existing	Powerline ROW
MW-5D(124-134)	102.0	103.89	134.0	124.00	134.00	-22.00	-32.00	-27.00	10.0	existing	Powerline ROW
MW-5 (140-150)	NA	NA	150.0	140.00	150.00	NA	NA	NA	10.0	March 2017	Powerline ROW
MW-6A(64-74)	71.6	71.22	74.0	64.00	74.00	7.60	-2.40	2.60	10.0	1/21/2016	Landfill
MW-6B(54-64)	71.8	71.40	64.0	54.00	64.00	17.80	7.80	12.80	10.0	1/21/2016	Landfill
MW-6C(52-62)	71.9	71.55	62.0	52.00	62.00	19.90	9.90	14.90	10.0	1/21/2016	Landfill
MW-E6(88-98) *	72.2	71.91	98.0	88.00	98.00	-15.80	-25.80	-20.80	10.0	1/17/2017	Landfill
MW-7S(55-65) *	69.8	71.64	65.0	55.00	65.00	14.80	4.80	9.80	10.0	1/19/2017	Landfill
MW-7D(115-125) *	69.9	71.66	125.0	115.00	125.00	-45.10	-55.10	-50.10	10.0	1/20/2017	Landfill
MW-7 (90-100)	NA	NA	100.0	90.00	100.00	NA	NA	NA	10.0	3/2/2017	Landfill
MW-8(36-46) *	59.1	58.80	46.0	36.00	46.00	23.10	13.10	18.10	10.0	1/25/2017	Giddiah Hill Road
MW-8 (84-94)	NA	NA	94.0	84.00	94.00	NA	NA	NA	10.0	3/1/2017	Giddiah Hill Road
MW-9(92-102) *	105.5	107.32	102.0	92.00	102.00	13.50	3.50	8.50	10.0	1/25/2017	Landfill
MW-10(85-95) *	94.0	93.69	95.0	85.00	95.00	9.00	-1.00	4.00	10.0	1/26/2017	Finlay Road
MW-13 (74-84)	NA	NA	84.0	74.0	84.0	NA	NA	NA	10.0	March 2017	Landfill
MW-11 (91-101)	NA	NA	101.0	91.0	101.0	NA	NA	NA	10.0	March 2017	Elementary School
MW-12-(87-97)	NA	NA	97.0	87.0	97.0	NA	NA	NA	10.0	March 2017	Snow Library

Notes: TOC = Top of Casing
bgs = below
ground surface
NA = Not
Available

All new wells constructed with 2-inch Schedule 40 PVC threaded flush joint casings, 10 ft screens with Schedule 40 PVC .010" 10 slot well screen

Table 5 Orleans Landfill Groundwater Elevations

Well ID	Location	TOC Elevation (ft)	Depth to Water (ft)				GW Elevation (ft)
			2/3/2017	2/6/2017	2/28/2017	03/27/2017-03/29/2017	
MW-1S(56-66)	Landfill	85	62	62	62	-	23
MW-1D(99-109)	Landfill	85	71	71	70	-	15
MW-2S(84-94)	Landfill	101	88	-	88	-	
MW-2D(124-134)	Landfill	101	88	88	88	-	13
MW-2(140-150) *	Landfill	103	90	-	90	89	NA
MW-2 (161-171)	Landfill	NA	NI	NI	NI	90	NA
MW-3S(50-60)	Landfill	70	54	55	55	-	15
MW-3D(84-94)	Landfill	70	55	55	55	-	15
MW-5S(78-88)	ROW	104	90	-	90	-	NA
MW-5D(124-134)	ROW	104	90	-	90	-	NA
MW-5 (140-150)	ROW	NA	NI	NI	NI	90	NA
MW-6A(64-74)	Landfill	71	56	56	56	-	15
MW-6B(54-64)	Landfill	71	56	56	56	-	15
MW-6C(52-62)	Landfill	72	NS	NS	NS	-	NS
MW-E6(88-98) *	Landfill	72	58	58	58	-	14
MW-7S(55-65) *	Landfill	72	67	57	56	56	15
MW-7D(115-125) *	Landfill	72	57	57	57	57	14
MW-7 (90-100)	Landfill	NA	NI	NI	NI	57	NA
MW-8(36-46) *	Giddiah Hill Rd	59	35	35	35	34	24
MW-8 (84-94)	Giddiah Hill Rd	NA	NI	NI	NI	43	NA
MW-9(92-102) *	Landfill	107	94	93	93	-	14
MW-10(85-95) *	Finlay Rd	94	81	82	81	-	12
MW-13 (74-84)	Landfill	NA	NI	NI	NI	44	NA
MW-11 (91-101)	Elementary School	NA	NI	NI	NI	38	NA
MW-12-(87-97)	Snow Library	NA	NI	NI	NI	36	NA

NS- no sampled
NI- not installed
NA- not available

This Page Intentionally Left Blank

Figures

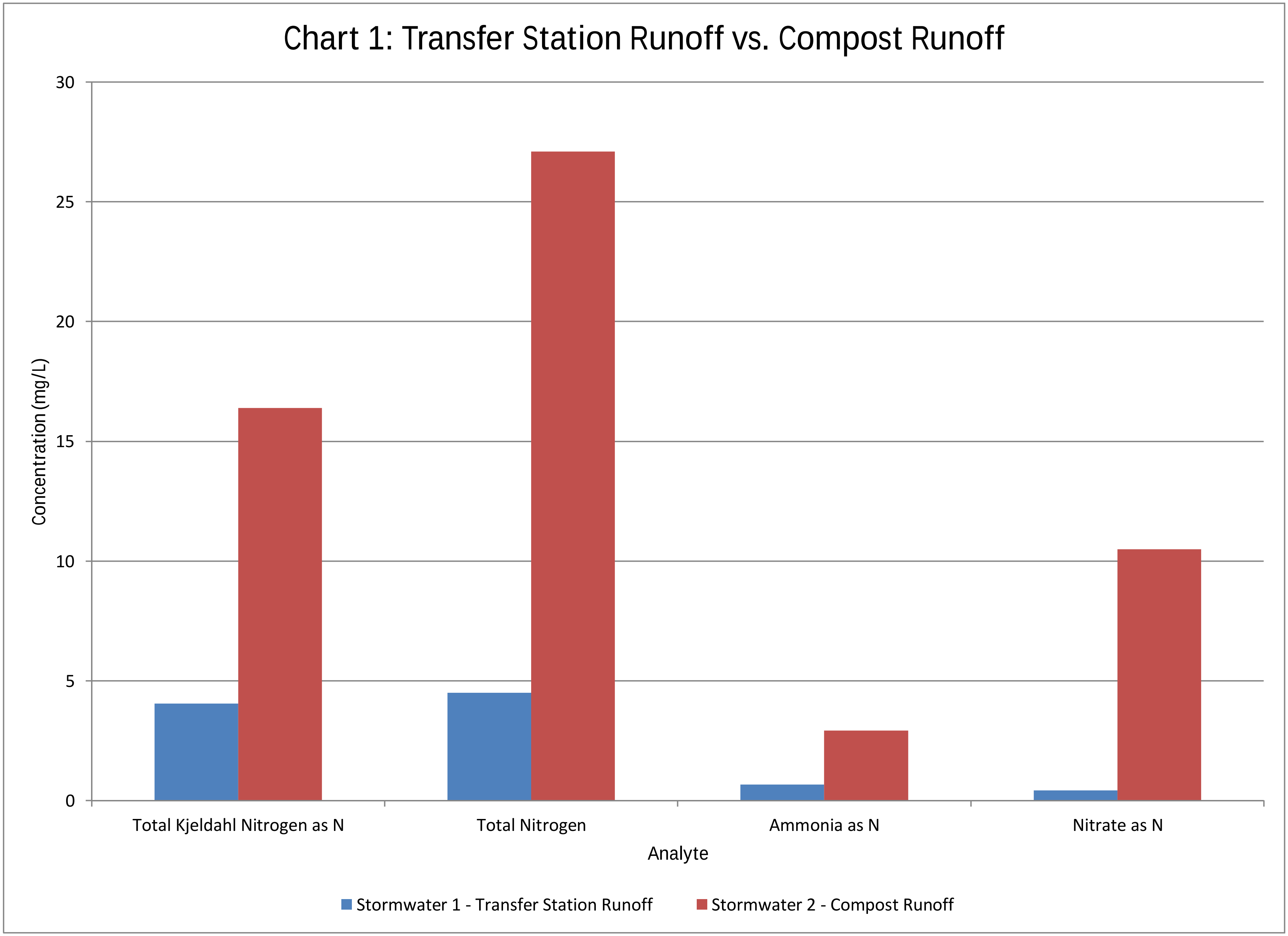


Chart 1: Transfer Station Runoff vs. Compost Runoff
30
25
20
15
10
5
0
Concentration (mg/L)
Total Kjeldahl Nitrogen as N
Total Nitrogen
Ammonia as N
Nitrate as N
Analyte
Stormwater 1 - Transfer Station Runoff
Stormwater 2 - Compost Runoff

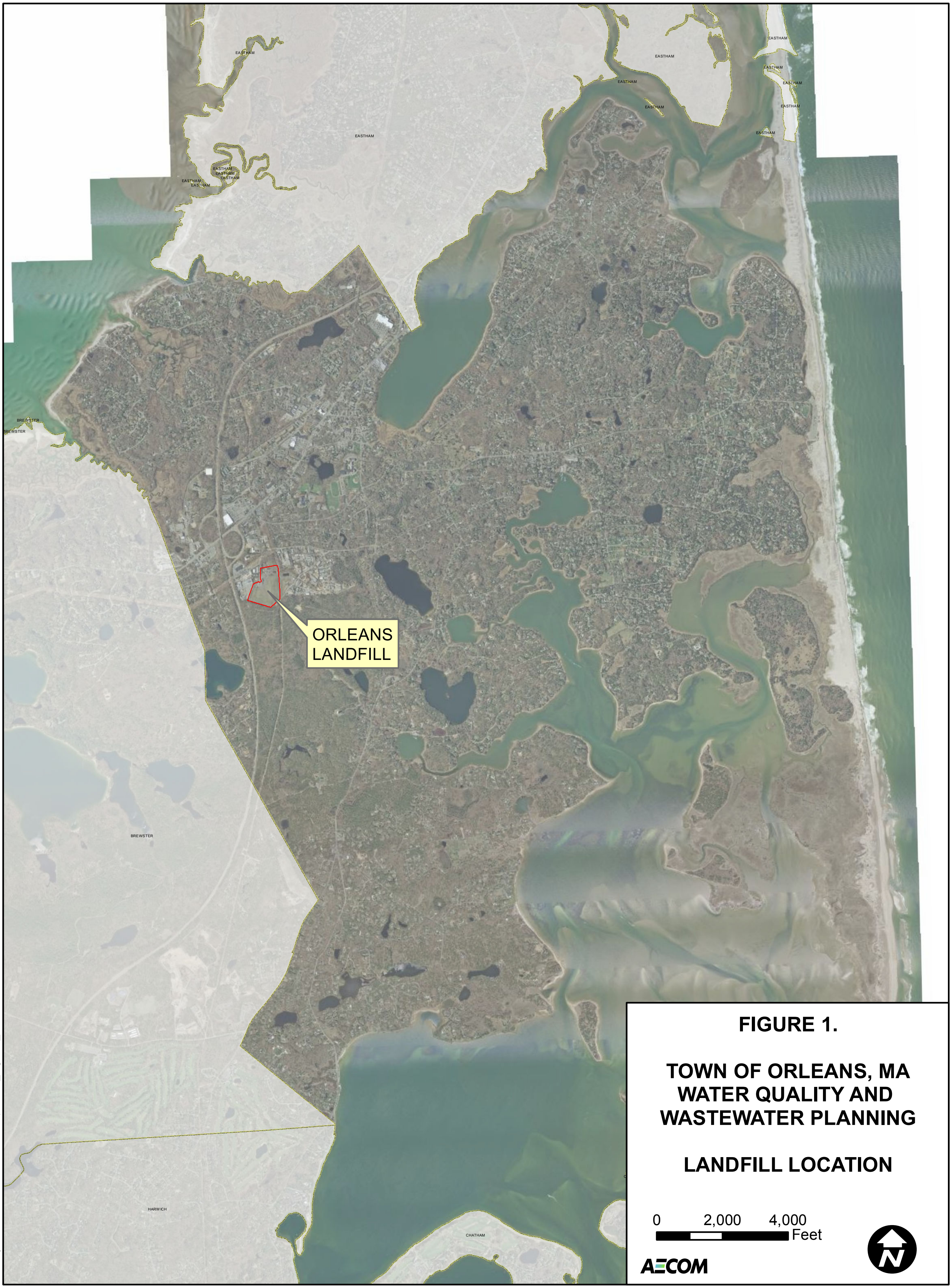


FIGURE 1.

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

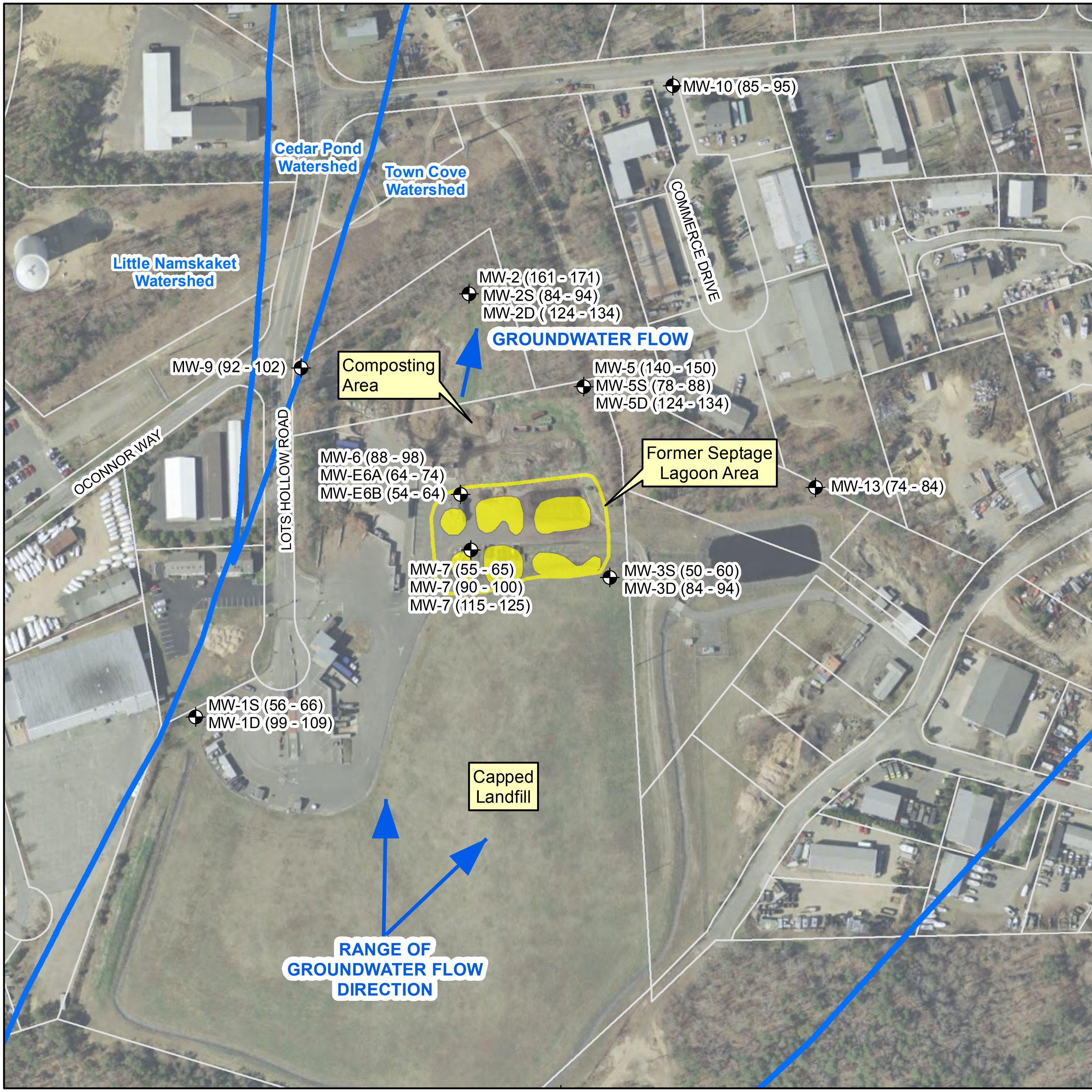


FIGURE 2.

TOWN OF ORLEANS, MA WATER QUALITY AND WASTEWATER PLANNING

TOWN LANDFILL MONITORING WELL LOCATIONS

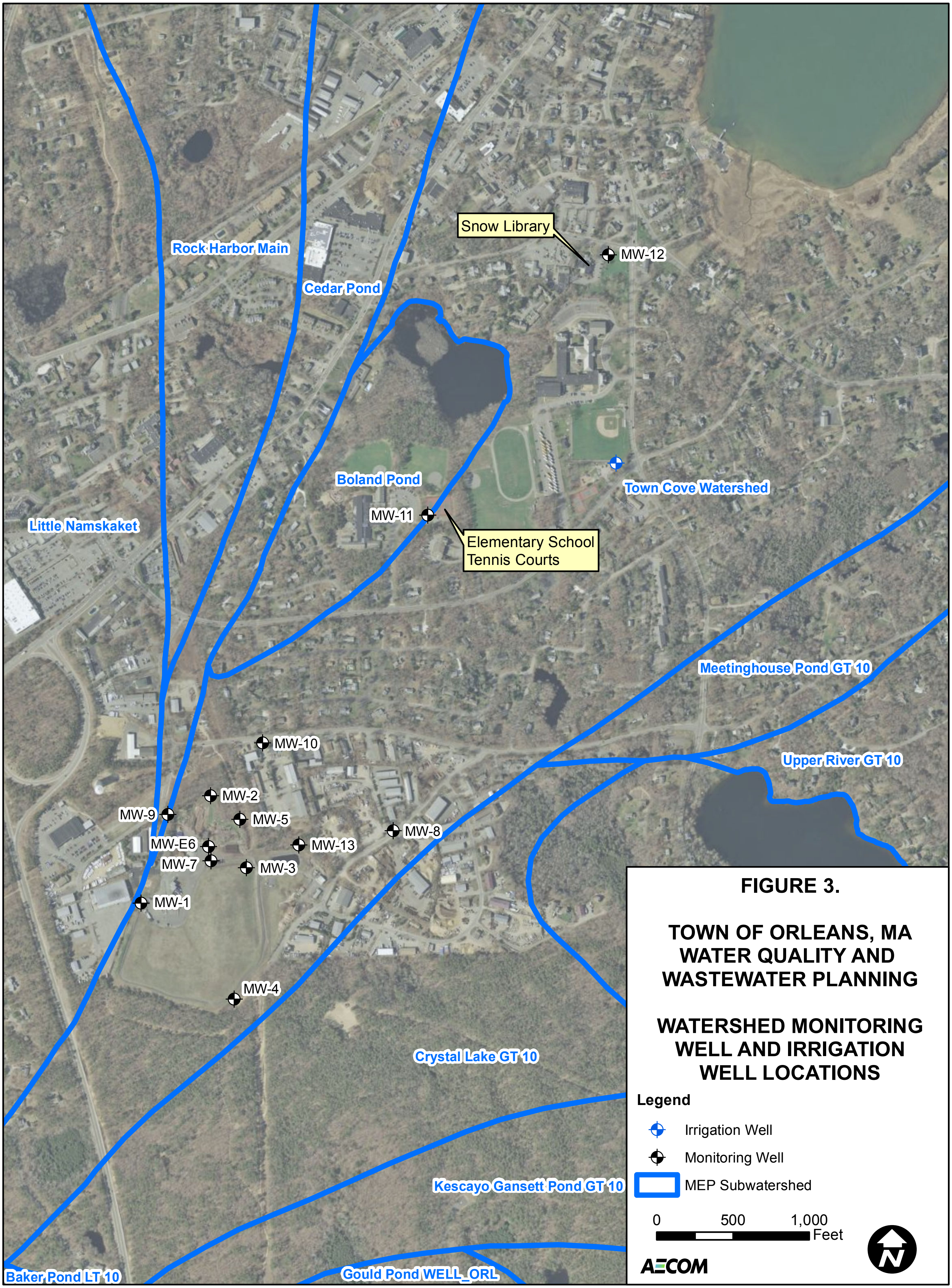
Legend

Monitoring Well (84-94) Screen-Depth Below Land Surface

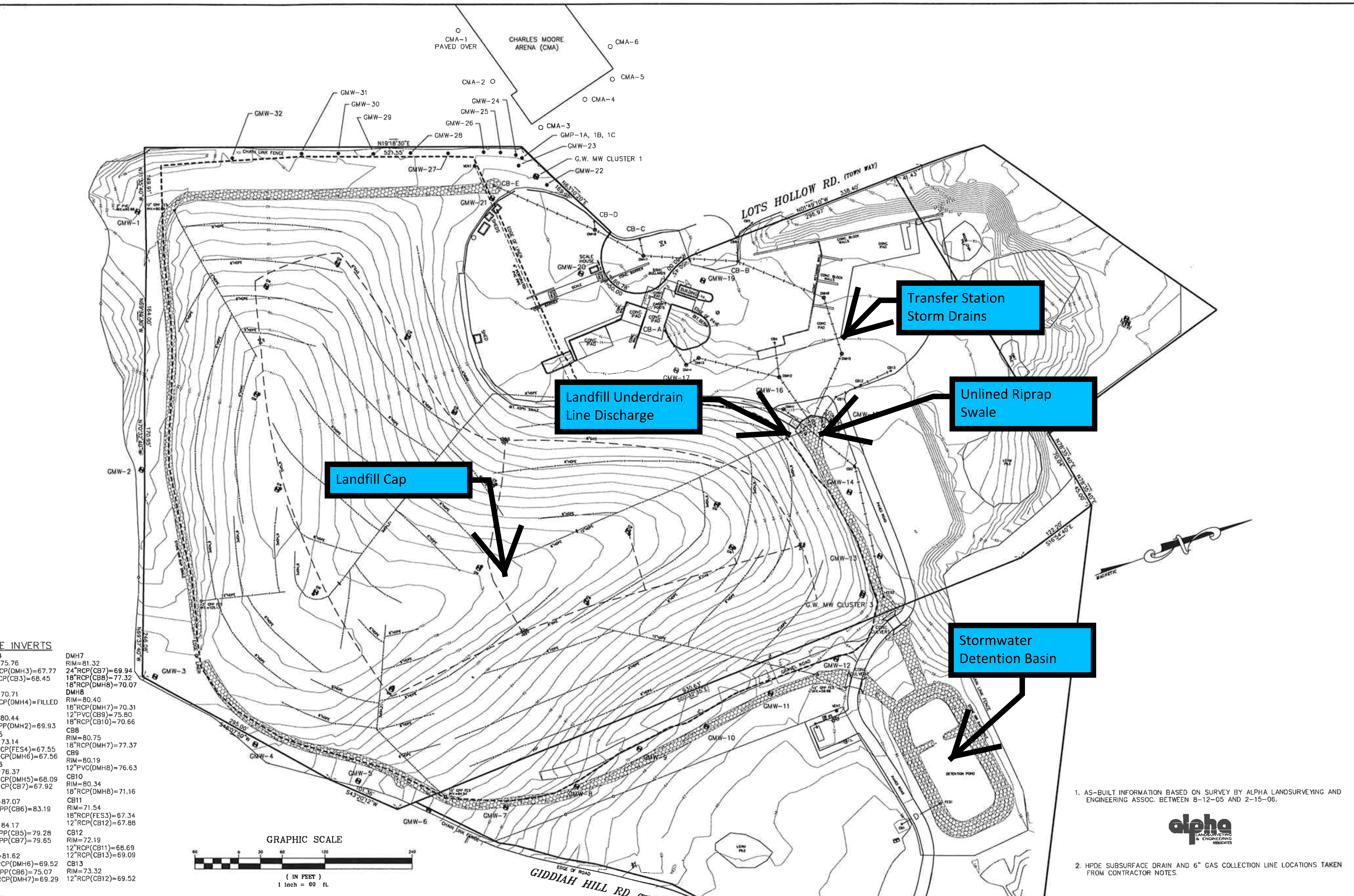
MEP Subwatershed

0 100 200 Feet

AECOM



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



STRUCTURE INVERTS

CB1
RIM=54.10
12"CPP(FES1)=FILLED
FES1
12"CPP(CB1)=49.02
FES2
18"RCP(CB2)=62.02
FES3
18"RCP(CB11)=66.80
FES4
36"RCP(DMH5)=66.67
FES5
18"RCP(DMH2)=66.43
CB2
RIM=69.37
18"RCP(FES2)=63.02
18"RCP(DMH1)=63.12
DMH1
RIM=71.95
18"RCP(CB2)=64.63
18"CPP(SWALE)=64.85
DMH2
RIM=73.41
18"RCP(FES5)=66.31
12"CPP(CB4)=67.69
18"RCP(DMH3)=66.36
DMH3
RIM=76.63
36"RCP(DMH4)=67.84
18"RCP(DMH2)=67.62

DMH4
RIM=75.76
36"RCP(DMH3)=67.77
12"RCP(CB3)=68.45
CB3
RIM=70.71
12"RCP(DMH4)=FILLED
CB4
RIM=80.44
12"CPP(DMH2)=69.93
DMH5
RIM=73.14
36"RCP(FES4)=67.55
36"RCP(DMH6)=67.56
DMH6
RIM=76.37
36"RCP(DMH5)=68.09
36"RCP(CB7)=67.92
CB5
RIM=87.07
12"CPP(CB6)=83.19
CB6
RIM=84.17
12"CPP(CB5)=79.28
12"CPP(CB7)=79.65
CB7
RIM=81.62
36"RCP(DMH6)=69.52
12"CPP(CB6)=75.07
24"RCP(DMH7)=69.29

DMH7
RIM=81.32
24"RCP(CB7)=69.94
18"RCP(CB8)=77.32
18"RCP(DMH8)=70.07
DMH8
RIM=80.40
18"RCP(DMH7)=70.31
12"PVC(CB9)=75.80
18"RCP(CB10)=70.66
CB8
RIM=80.75
18"RCP(DMH7)=77.37
CB9
RIM=80.19
12"PVC(DMH8)=76.63
CB10
RIM=80.34
18"RCP(DMH8)=71.16
CB11
RIM=71.54
18"RCP(FES3)=67.34
12"RCP(CB12)=67.88
CB12
RIM=72.19
12"RCP(CB11)=68.69
12"RCP(CB13)=69.09
CB13
RIM=73.32
12"RCP(CB12)=69.52

GRAPHIC SCALE

(IN FEET)
1 inch = 60 ft.

1. AS-BUILT INFORMATION BASED ON SURVEY BY ALPHA LANDSURVEYING AND ENGINEERING ASSOC. BETWEEN 8-12-05 AND 2-15-06.

alpha LANDSURVEYING & ENGINEERING ASSOCIATES

2. HPDE SUBSURFACE DRAIN AND 6" GAS COLLECTION LINE LOCATIONS TAKEN FROM CONTRACTOR NOTES.

NOTES:

Underground facilities, structures, and utilities have been plotted from available surveys and records, and therefore their locations must be considered approximate only. There may be others, the existence of which is presently not known. Anyone using utility information and data provided herein shall "Call Dig-Safe" at 1-888-344-7233 seventy two (72) hours, 3 business days in advance to verify the location of utilities prior to start of construction.

ISSUE NO.						
3						
2						
1	RECORD DRAWING					
ISSUE NO.	DRAWN	DATE	CHECKED	DESIGNER	APPROVED	DATE

PROJECT SUPERVISOR — DEPARTMENT SUPERVISOR

ISSUE NO.						
7						
6						
5						
4						
ISSUE NO.	DRAWN	DATE	CHECKED	DESIGNER	APPROVED	DATE

Stearns & Wheler, LLC
Environmental Engineers and Scientists

TOWN OF ORLEANS
ORLEANS LANDFILL CLOSURE
ORLEANS LANDFILL RECORD DRAWING

JOB NO.	40235	CONTRACT		SHEET	1