Section 1
Introduction

1.1 Purpose and Background

This report, required under the North Carolina Solid Waste Management Rule .1635, assesses the corrective measures that were initiated during the assessment monitoring program and identifies potential corrective measures to meet the requirements set out in Rule .1636 at the North Wake Unlined Landfill.

The *North Wake Unlined Landfill Groundwater Assessment Report* was submitted to the Solid Waste Section (SWS) in February 2000 in accordance with Rule .1634. This report detailed the installation and sampling of several compliance monitoring and assessment monitoring wells and discussed the history of groundwater monitoring and assessment at the site. The report also recommended the use of monitored natural attenuation (MNA) as a corrective action for the site. Since December 2000, MNA parameter samples have been collected from monitoring wells MW-5, -6, -8, -9, -10, -24, and TB-1a in addition to the required Appendix I and detected Appendix II constituents (dichlorodifluoromethane, bis(2-ethylhexyl)phthalate, mercury, and pesticides and herbicides).

1.2 Site Characterization

The North Wake Unlined Landfill is located off of Deponie Road in Raleigh, Wake County, North Carolina. A site map is provided on **Figure 1-1**.

In November 1996, Wake County began disposal of municipal solid waste in the lined portion of the North Wake Landfill. A low permeability cap was installed to close the unlined landfill. This cap included the installation of a geosynthetic liner on the top of the landfill to further reduce infiltration. A methane gas recovery system was installed in the waste, and has been operational since November 1997.

Due to landfill gas migration beyond the limits of waste, a permanent landfill gas migration control system was installed along the western, northern and eastern perimeter of the landfill, inside the landfill property boundary. Construction of the permanent migration control system was completed and the system considered fully operational by November 2003. Continued monitoring and adjustments in applied vacuum on the perimeter system have resulted in the successful control of gas migration around the perimeter of the landfill. Temporary vacuum systems installed along the west and north sides of the landfill, starting in January 2002, were also used to control gas migration at known exceedence locations prior to installation of the permanent gas migration control system.

The permanent gas migration control system consists of a series of 78 gas extraction wells spaced at 25 to 50 feet apart along the western and northern perimeter of the landfill, together with a 1000 foot long, HDPE lined, vacuum cut-off trench along the eastern perimeter of the landfill. The wells and cut-off trench are connected to a buried 6-inch diameter HDPE vacuum header installed adjacent to each of the perimeter wells and cut-off trench along the west, north and east sides of the landfill. The vacuum gas recovery system in the waste, operated by DTE Biomass, serves as the vacuum source for the perimeter gas migration control system. Groundwater monitoring well and methane gas extraction well locations are provided on **Figure 1-1**.

At the request of the Solid Waste Section, additional groundwater assessment wells (MW-36/-36d) were installed to the north of MW-9 and MW-6/6d in order to assess for offsite contaminant migration. Both wells were installed in November 2008. Subsequent sampling determined that several VOC constituents were exceeding their respective NC2L values. In addition to the groundwater monitoring wells, two additional surface water sampling locations (SW-7 and SW-8) were added at Abbot's Creek, north of the landfill.

1.2.1 Geologic and Hydrogeologic Setting

1.2.1.1 Regional Geology

The geology of Wake County is made up of three different rock assemblages. The eastern portion of the county is underlain by a complex group of metamorphic rocks (gneiss, schists, and phyllites) of Late Precambrian or Paleozoic age, with mafic and granitic intrusions. Rocks of this group belong to the Raleigh Belt and the Carolina Slate Belt. The second group consists of stratified sedimentary rocks of Triassic age separated from the older rocks (Carolina Slate/Raleigh Belts) by the Jonesboro Fault. The third group consists of coastal plain sediments located primarily in the southeastern portion of the county (Parker, 1979). The North Wake Unlined Landfill is located within the Raleigh Belt of the metamorphic rock group.

The North Wake Unlined Landfill is situated over the Raleigh gneiss. West of the site and corresponding with the highest elevations in the vicinity, is the Falls Leucogneiss. Both of these rock occurrences demonstrate a southwest to northeast trend in outcrop. Immediately east of the site is the Gresham Lake pluton. During a January 1998 site reconnaissance, the Raleigh gneiss was observed to consist primarily of biotite gneiss and to a lesser degree hornblende gneiss. The gneiss demonstrates strong flow banding of compositional layers consisting of white, feldspar rich layers and quartz biotite layers. Granitoid orthogneiss was also observed within the north and south stream channels west of the site.

Although somewhat variable, the general strike of foliation in the Raleigh gneiss in the site vicinity is from southwest to northeast, as mapped by Horton and others (1992). The foliation dips to the east from approximately 35^{o} to 80^{o}.

Relatively small diabase dikes, several feet wide, have also been identified south of the site during construction of the North Wake Lined landfill. These dikes have been mapped and generally trend from south to north. Should these dikes extend into the proximity of the site, they would be approximately parallel to the west boundary of the unlined landfill at a distance of approximately 400 feet.

Also noted during previous site reconnaissance was an extremely quartz rich gneiss in both the north and south streams. This rock appeared to be resistant to erosion/weathering relative to the surrounding rock and formed the creek channels into a series of small waterfalls for distances of approximately 75 feet. These two outcrops may potentially represent a continuous, resistant rock layer that forms a subsurface bedrock ridge aligned with the regional structure.

1.2.1.2 Regional Hydrogeology

Groundwater in the vicinity of the site occurs in the saprolite horizon and within fractures of the crystalline bedrock. The transition zone between saprolite and unweathered rock is generally the zone in which most lateral groundwater flow occurs. This zone typically contains a lower percentage of clay, derived from the complete weathering of micaceous minerals and feldspar, and is made more permeable by cracking associated with shrinking and swelling of minerals by hydration.

Groundwater in saprolite is derived directly from infiltrating precipitation. Welby (1994), reports that an estimated 10 to 15 percent of the annual average precipitation of about 45 inches reaches the water table. Groundwater reaching the water table then flows laterally, primarily in the transition zone above crystalline rock, until it ultimately discharges at springs or as diffuse flow into surface water features. Alternately, groundwater may encounter fractures in the crystalline rock and serve to recharge these fracture systems.

Groundwater flow directions in saprolite and the transition zone are controlled primarily by topography with groundwater flow mirroring surface drainage patterns. However, the topography of the subsurface crystalline rock surface can cause deviations in the presumed groundwater flow directions as valleys and ridges on the rock surface can direct groundwater flow. Mineralogical heterogeneities in the saprolite/transition zone may result in contrasting permeability and influence groundwater flow directions. As seen at the North Wake lined landfill, diabase dikes can be less permeable than the surrounding materials and form groundwater flow barriers. Alternately, relic fractures in the saprolite/transition zones may represent preferential groundwater flow paths.

The occurrence and movement of groundwater in the unweathered bedrock is generally restricted to fractures as these materials have little primary porosity. The fractures are typically most numerous and have the largest openings near the top of the unweathered rock. The amount and location of groundwater in the crystalline rock varies greatly dependant on the depth, openness, and degree of connection between fractures. Large open fractures were not observed during the site reconnaissance. Upon inspection of fracture systems in the Benchmark quarry, all fractures in the crystalline bedrock were either mineralized or intruded. Although the quarry is currently being mined to elevations well below the elevation of the Neuse River, quarry representatives indicated that groundwater flow into the quarry has not been observed and during dry weather the excavation remains dry.

1.2.1.3 Site Geology

Site geology is based on previous well installation activities from the original groundwater assessment and the landfill gas perimeter recovery well installations. The subsurface geology at the site was highly variable. Generally, the site is covered by 4 to 6 inches of detritus, topsoil and rootmat. Underlying the topsoil is a layer of reddish brown silt/clay. This silt/clay was most commonly encountered up to depths of 7 to 17 feet below land surface (bls). The silt/clay was usually underlain by a light brown, fine sandy silt saprolite with varying amounts of mica. Occasionally, zones of silty sand saprolite as pegmatite or granite were encountered below the silt/clay. Generally, the silty sand or sandy silt saprolite graded into a partially weathered rock as silty sand saprolite with depth to top of bedrock. The depth to bedrock ranged from 15 to greater than 65 feet bls.

In some areas, a 4 to 6-inch cover of topsoil and rootmat was underlain by light to medium brown sandy silt alluvial deposits. This overburden varied from 5 to 15 feet in thickness. Below the alluvial layer, a layer of light brown sandy silt saprolite with varying amounts of mica was encountered.

Cuttings obtained during air-rotary drilling of some bedrock wells revealed bedrock which varied from schistose to granitic. Generally, the bedrock was highly weathered and fractured for the first 20 to 30 feet below auger refusal, however, one boring revealed highly fractured bedrock to depths of 90 feet bls.

1.2.1.4 Site Hydrogeology

The groundwater monitor wells installed surrounding the unlined landfill are generally completed to depths corresponding with the top of rock and are considered representative of the saprolite/transition zone. **Figure 1-2** presents a potentiometric contour map based on water level data obtained from the monitor wells during the March 2009 semi-annual sampling event. Water table elevations are provided in Appendix A on **Table 1**. The water table elevation contours indicate an easterly groundwater flow direction with minor flow towards the small creeks to the north and south, coincident with the site topography prior to landfill activities. The small perennial streams to the north and south appear to act as groundwater discharge features.

It is probable that groundwater elevations beneath the landfill have been higher than those indicated by the figure because of a mounding effect almost invariably occurring in unlined landfills. As a result, radial groundwater flow away from the landfill has occurred. Typically, such radial flow patterns dissipate within relatively short distances, beyond which the groundwater assumes a more typical flow direction. Installation of the impermeable cap, which occurred in late 1997, has likely caused a significant reduction in the mounding of groundwater within the landfill.

In situ horizontal hydraulic conductivity (slug) tests performed on monitoring wells MW-5, -6, -7, -8, -9, -10, -22, -23, and -24 indicated horizontal hydraulic conductivity ranges from 10.58 ft/day (3.73×10^{-3} cm/sec) in MW-6 to 0.07 ft/day (2.47×10^{-5} cm/sec) in MW-22. The average horizontal hydraulic conductivity for the wells across the site is approximately 2.38 ft/day (8.74×10^{-4} cm/sec).

Average linear velocity values are calculated for these wells during each semi-annual sampling event. Average linear velocity values for these wells from November 2005 to March 2009 are provided in Appendix A on **Table 2**. During the last groundwater sampling event in March 2009, linear velocity values ranged from 1.65 ft/day in MW-6 to 7.04×10^{-3} ft/day in MW-22.

1.2.2 Groundwater Quality

1.2.2.1 Required Appendix I and II Sampling

A summary of the site groundwater quality analytical results for Appendix II volatile organic compound (VOC) and metal constituents and other detected Appendix II constituents (bis(2-ethylhexyl)Phthalate, pesticides, herbicides) is provided in Appendix A on **Table 3**. In general, the occurrences of detected VOCs above respective North Carolina 2L Standards (NC2L) have been decreasing since beginning sampling activities.

Monitoring wells MW-5, -6, -7, -8, -9, and -10 have been sampled on a semi-annual basis since 1994. Monitoring wells MW-22, -23, and -24 have been sampled semi-annually since June 1997. Monitoring wells MW-23d, -27, -28, -28d, -29d, -30, -31, -31d, -32, -33, -34, -34d, -35, and TB-1a were installed as part of the groundwater assessment and have been sampled since May 1998. Some of these wells are sampled yearly (MW-27, -28, -28d, -33, -34, -34d, and -35), while the remaining wells are sampled semi-annually. Monitoring wells MW-6d, -8d, -10d, and TB-1a deep were installed in response to comments from the groundwater assessment and have been sampled semi-annually since June 2001. Monitoring well MW-27 was abandoned in November 2008. MW-27 had not been sampled since April 2004. Wells MW-36 and -36d were installed in November 2008 and will be sampled semi-annually. Well locations are provided on **Figure 1-1**. An isocontour map for total VOCs from the April 2009 sampling event is presented on **Figure 1-2**.

In almost all cases, groundwater quality has been improving since samples were first collected in 1994. VOCs in nearly all of the assessment monitoring wells have been below method detection limits. Only samples from TB-1a, MW-34, MW-34d, MW-36 and MW-36d have had detections above the laboratory reporting limits of VOCs other than chloroform since 1998. Recent sampling events have indicated that 1,4-dichlorobenzene, methylene chloride, tetrachloroethene, trichloroethene, and vinyl chloride have been detected in assessment wells MW-34, MW-36, and MW-36d at concentrations exceeding respective NC2L concentrations.

The monitoring wells in the south-west buffer area (MW-31, -31d, TB-1a, and TB-1a deep) have all had detections of chloroform above the North Carolina 2L Standard (NC2L). As chloroform has never been detected in the compliance monitoring wells, it is not likely that these chloroform detections are related to a release from the landfill.

Historical total VOC concentrations for select wells along the western and northern portions of the landfill are presented in Appendix B on **Figure 1** through **Figure 7**. Figures 1 through 7 show the historic VOC trends for MW-6, MW-9, MW-10, MW-23, MW-24, TB-1a, and MW-34 respectively. In some figures, there appears to be a decreasing trend in total detected VOC concentrations. However, these figures include the recent J value detections which were not reported before 2007. The recent increase of total detected VOC concentrations in TB-1a is due to chloroform detections, which are not likely related to a release from the landfill and have been declining in the most recent sampling events.

1.2.2.2 Monitored Natural Attenuation Sampling

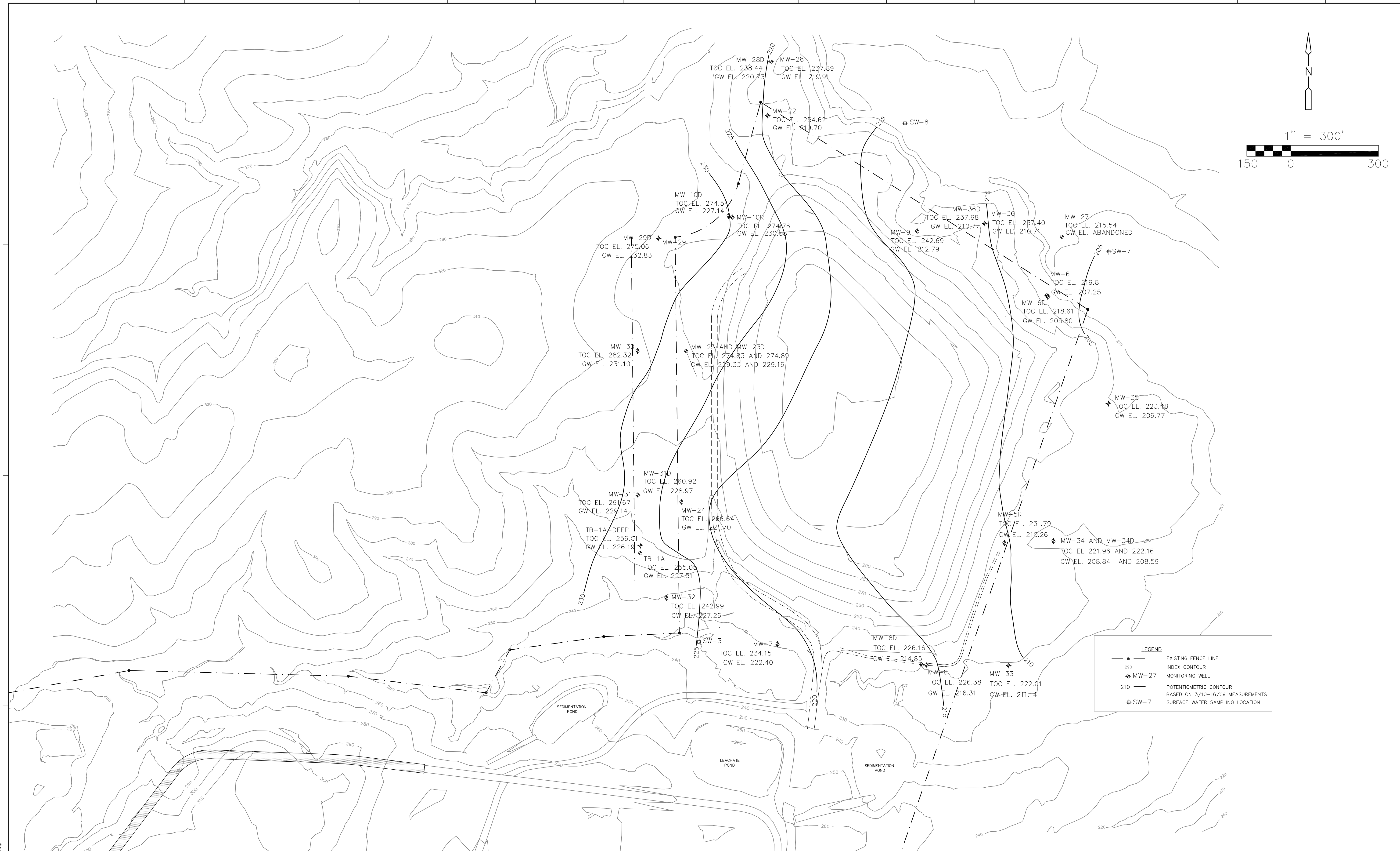
In addition to VOC and metal analyses, samples from the site shallow background monitoring well (MW-11) and monitoring wells MW-5, -6, -8, -9, -10, -24, and TB-1a are also analyzed for MNA parameters, which include: Dissolved oxygen, BOD, COD, chloride, nitrate, sulfate, sulfide, total organic carbon (TOC), carbon dioxide, ferrous iron, methane/ethane/ethane, volatile fatty acids, and dissolved hydrogen. A summary of the MNA parameter analytical results since inception of the program in December 2000 is presented in Appendix A on **Table 4**.

Detected concentrations of MNA parameters have varied from event to event, but occurrences of key parameters from certain wells are fairly consistent. In general, it appears that based on the concentrations of geochemical parameters from the select wells, environments are present which favor reductive dechlorination; notably, the concentrations of nitrate, ferrous iron, sulfate, and carbon dioxide. The following evidence indicates that one or more mechanisms of natural attenuation and/or reductive dechlorination may be occurring at the site:

- VOC concentrations in contaminated wells continue to decline (Figures 3 through 7 of Appendix B).
- The ratio of parent /daughter compounds continues to decrease over time.
- Nitrate, ferrous iron, sulfate, and carbon dioxide continue to be detected at concentrations favoring reductive dechlorination.
- Concentrations of cis-1,2-DCE continue to be greater than other DCE isomers trans-1,2-DCE and 1,1-DCE (neither trans-1,2-DCE or 1,1-DCE have been detected since 1995).

1.2.3 Surface Water Quality

Surface water samples for Metal and VOC constituents have been collected from sample locations SW-2 and SW-3 since 1995. Locations SW-7 and SW-8 were added in November 2009. These locations are monitored as part of the semi-annual sampling performed at the landfill. Several "J" value detections of VOCs have been reported in samples from each location, but generally appear to be random and infrequent. Several metals including barium, chromium, copper, lead, silver, vanadium and zinc have been detected at low levels in the surface water samples, and are most likely attributed to naturally occurring conditions. A summary of the surface water sampling data is provided in Appendix A on **Table 3**.



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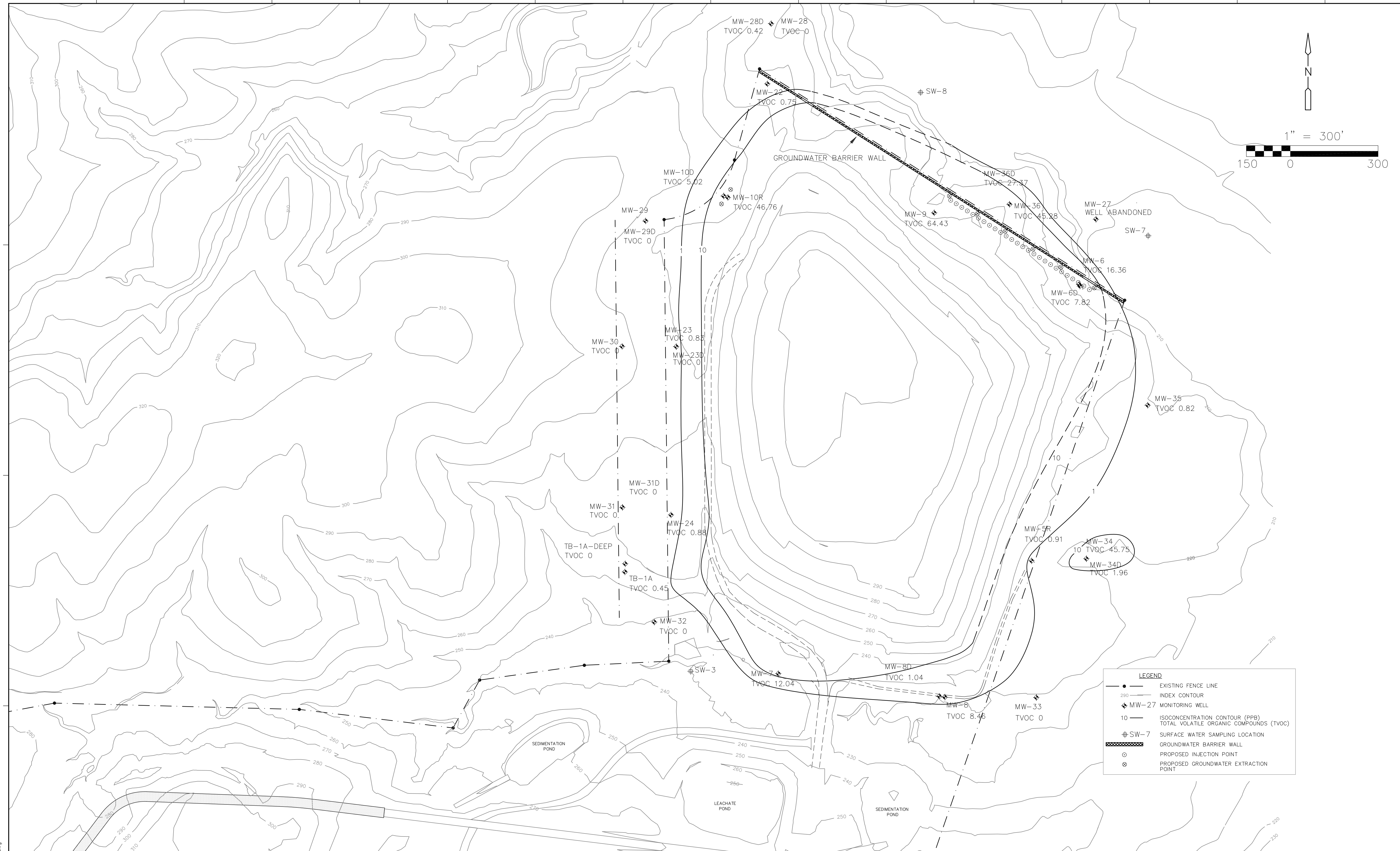
WAKE COUNTY
NORTH CAROLINA

NORTH WAKE UNLINED LANDFILL ASSESSMENT OF CORRECTIVE MEASURES

POTENTIOMETRIC CONTOUR MAP

PROJECT NO. 6172-71371
FILE NAME: NW-ACM1-1.dwg

FIGURE
1-1



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WAKE COUNTY
NORTH CAROLINA

NORTH WAKE UNLINED LANDFILL ASSESSMENT OF CORRECTIVE MEASURES

ISO CONTOUR MAP

PROJECT NO. 6172-71371
FILE NAME: NW-ACM1-2.dwg

FIGURE
1-2