EA Engineering, Science, and Technology, Inc.

TECHNICAL MEMORANDUM

EA Project No. 62196.08

Topic: **Remediation Feasibility Memorandum**

Potential Remediation Alternatives

Gude Landfill, Montgomery County, Maryland

Date: **11 January 2011**

1.0 INTRODUCTION

1.1 Purpose

The Remediation Feasibility Memorandum for the Gude Landfill (the Landfill) was prepared by EA Engineering, Science, and Technology, Inc. (EA) for the Montgomery County (the County) Department of Environmental Protection (DEP). The purpose of this Memorandum is to briefly summarize the potential remediation alternatives that may enable the County to obtain compliance with MDE's pre-established remediation objectives for the Landfill. Other factors that were considered with respect to each remediation alternative include: compliance with remediation objectives; implementability and constructability; protection of human health and the environment; reduction of contaminant concentrations, mobility, and volume; and cost.

The remediation alternatives presented also support the investigations and findings of the Nature and Extent Study of the Landfill (EA 2010) that was conducted in 2009-2010. The Memorandum is not intended to be a comprehensive evaluation of each remediation alternative, nor does it represent defined courses of action selected by the County at this time.

Nature and Extent Study Background

The County DEP was directed by the Maryland Department of the Environment (MDE) to conduct a Nature and Extent Study (the Study) (EA 2010) of environmental impacts in the vicinity of, and potentially resulting from, the Landfill. The Study characterized the nature and extent of potential Landfill impacts on groundwater, surface water, surface soils and subsurface soils. The Study included hydrogeologic investigations, fate and transport assessments, and human health and ecological risk evaluations.

The primary components of the Study included, but were not limited to: a waste delineation investigation to identify the approximate horizontal extent of waste around the Landfill perimeter; an aerial and field survey of current and historical features at the Landfill; a protected resource investigation including wetland and forest stand delineations; a historical landfill data review; installation and sampling of new groundwater monitoring wells (and sampling of existing monitoring wells); and sampling and analysis of surface water, surface soils, and subsurface soils.

The Study was submitted to MDE for review on November 19, 2010. Following review, MDE may direct the County to undertake further environmental investigations or to initiate implementation activities (planning, design, permitting, construction, etc.) for recommended remediation actions.

1.2 Regulatory Applicability

In accordance with the U.S. Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA), national criteria for siting, permitting, design, construction, operations, and closure and post-closure care of municipal solid waste landfills are set forth under Title 40 of the Code of Federal Regulations [CFR], Part 258 (40 CFR 258). Subpart A of 40 CFR 258.1(c) states that these criteria do not apply to municipal solid waste landfills that did not receive waste after 9 October 1991. The Landfill ceased waste filling operations and closed in May 1982; therefore, 40 CFR 258 does not apply to the Landfill.

Under RCRA, U.S. EPA delegates the authority to regulate solid waste management activities to state entities. The Landfill is regulated by the State of Maryland under the Code of Maryland Regulations (COMAR) and as directed by MDE. COMAR Title 26, Subtitle 04, Section 7 (COMAR 26.04.07) provides regulations for solid waste management.

Although the Landfill is not currently an active landfill operating under an active Refuse Disposal Permit in Maryland, MDE has the responsibility and authority to protect the quality of the environment and public health and safety under COMAR 26.04.07.03. COMAR 26.04.07.21 provides the minimum design features or standards for a compliance "closure cap" of a municipal solid waste landfill in Maryland. The County DEP has previously maintained and continues to maintain post-closure monitoring, cover system maintenance, water quality protection, explosive gas control and stormwater management responsibilities at the Landfill, and MDE oversees the implementation and compliance of such activities.

Based on existing conditions and historical environmental data (primarily regarding groundwater, surface water and landfill gas) from the Landfill, MDE established the following remediation objectives for the site (MDE 2009):

- No exceedances of maximum contaminant levels (MCLs), established by the EPA as limits for drinking water, in the groundwater at the Landfill property boundary or between the Landfill and adjacent streams (COMAR 26.08.02).

- No non-stormwater discharges to the waters of the State (COMAR 26.08.04.08).

- No lower explosive limit (LEL) exceedances for methane at the Landfill property boundary (COMAR 26.04.07.03B(9)).

Remedial actions for the Landfill will be selected based on their ability to achieve these remediation objectives while also remaining consistent with suitable future reuse options.

1.3 Background

The Landfill is located in central Montgomery County, Maryland, and it is the oldest formal landfill in the County. The Landfill is located on the northern side of East Gude Drive and extends to the northern side of Southlawn Lane, with the primary entrance point at 600 East Gude Drive in Rockville, Maryland. The Landfill was used for the disposal of municipal solid waste and incinerator residues from 1964 to 1982. The site encompasses approximately one hundred sixty-two (162) acres, of which approximately one hundred (100) acres were used for waste disposal (including approximately 16.5 acres of waste encroachment on M-NCPPC property). The Landfill is currently owned and maintained by the County DEP, Division of Solid Waste Services (DSWS).

Landfill construction and operations predated current Subtitle D design standards per RCRA, as referenced in Section 1.2. Therefore, the Landfill was not originally constructed with the following environmental control infrastructure, which is required under Subtitle D: a bottom liner (clay or synthetic), a capping system (clay or synthetic), a leachate collection system, a landfill gas collection system, and a stormwater management system. Soil was reportedly used as daily cover during waste filling operations.

The Landfill was originally permitted by Refuse Disposal Permit No. 73-15-04-02A (Gude-Southlawn/Central Sanitary Landfill), dated February 22, 1973. In 1979, Refuse Disposal Permit No. 79-15-04-06A was issued to the County to revise the grades and elevations of the Landfill. This Permit provided the County capacity for waste disposal through May 1982 when it was mandated to close by the Maryland Department of Health and Mental Hygiene (DHMH, pre-cursor to MDE). In 1982-1983, the Landfill was closed in compliance with DHMH requirements. The site was covered with two (2) to five (5) feet (ft) of soil, although soil cover on the side slopes in places may be less than two (2) ft. The facility name was modified by reference from Gude-Southlawn/Central Sanitary Landfill to Gude Landfill.

From 1982 to the present, County DEP has constructed and actively monitored: a soil cover system on top of the waste mass; a landfill gas collection system, flare station, gas-to-energy power plant and a network of on-site landfill gas monitoring wells; a network of on-site and off-site groundwater monitoring wells; and a network of stormwater management infrastructure at the Landfill. County DEP currently maintains this infrastructure in accordance with best management practices for pre-regulatory era (pre-RCRA) landfills, existing COMAR requirements and approved monitoring plans and directives from MDE. The site ground cover currently consists of open grassy fields with sporadic patches of trees.

As part of final closure of the Landfill, the County conducted voluntary groundwater and surface water monitoring and laboratory analyses through 2009. In 2009, MDE conducted a review of the site's water quality and landfill gas data. In accordance with COMAR regulatory standards, MDE required the County DEP to formalize their existing water quality and landfill gas monitoring programs; prepare Groundwater and Surface Water Monitoring and Landfill Gas Monitoring Plans; initiate semi-annual groundwater and surface water monitoring and quarterly landfill gas monitoring; and to initiate a Nature and Extent Study to assess potential adverse environmental or health and safety impacts in the vicinity of, and potentially resulting from, the Landfill. The Study is described in Section 1.1.

1.4 Site Location and Characteristics

Figure 1 presents a site location map and **Figure 2** presents an aerial view of the site from 2009. The area surrounding the Landfill is mixed use: industrial operations including Washington

Suburban Sanitary Commission Property (east-southeast); a Transcontinental/Columbia Gas natural gas pipeline and the community of Derwood Station South residential development (west-northwest); and M-NCPPC land (north-northeast). The Landfill is also bordered by surface water bodies: Crabbs Branch Stream (north-northeast) and Southlawn Branch Stream (south-southeast).

The depth of waste varies across the site from approximately fifty-five (55) to ninety (90) ft. Total waste in place is estimated at four and eight-tenths (4.8) million tons.

The site topography is plateau-like and consists of gentle relief (i.e., slope) along the top of the waste-mass and sharp relief along the Landfill boundary. The elevation along the top of the plateau gently slopes to the south, with localized mounds and depressions throughout. The side slope falls sharply from the top of the waste-mass to elevations ranging from approximately forty (40) to one hundred (100) ft below the plateau (per the 2009 field survey).

The Landfill is located within the upland section of the Piedmont Plateau physiographic province (Maryland Geologic Society 1968, Trapp and Horn 1997). Unconsolidated sediments overlying bedrock are present at the surface in the vicinity of the site and extend twenty (20) to sixty (60) ft below ground surface (bgs). Based on available groundwater monitoring well construction logs from ATEC Associates Inc. (1988), the sediments primarily consist of silt and clay.

Groundwater is present in the unconsolidated material as well as the bedrock. Groundwater flow is highly dependent on the composition and grain size of the sediments, and therefore water likely moves more readily in the unconsolidated material than in the underlying bedrock. Groundwater in the bedrock is stored in, and moves through, fractures. The degree of fracturing and orientation of bedrock fractures at the Landfill has not been characterized.

The groundwater table is typically present in the unconsolidated sediments along the perimeter of the Landfill and under the Derwood Station residential development, at depths ranging from approximately three (3) to sixty (60) ft bgs. Groundwater recharge at the Landfill is variable and is primarily determined by precipitation, runoff, topographic relief and the capacity of the unconsolidated surface layer to accept water. Variations in groundwater recharge across the landfill surface may significantly affect the groundwater table elevations. The site topography and the natural cover system (grassy surface soil layer) of the Landfill make surface water infiltration likely. Some of the infiltrating water likely moves vertically through the waste mass and then either flows into the bedrock or flows laterally along the boundary between the unconsolidated layer and the surface of the bedrock and discharges to nearby streams and surface depressions.

The contoured groundwater elevation map, based on groundwater elevation data from July 2010, is shown in **Figure 3** (Inferred Groundwater Flow Map). Groundwater flow is primarily to the east and south, with minor flow components to the north and northeast in the northern portions of the site. The minor flow components reflect radial groundwater flow around the edges of the Landfill, which is consistent with mounding.

Major site features of the Landfill property include: an extensive aboveground landfill gas collection system with over one hundred (100) gas extraction wells, a flare station and a gas-to-energy facility; stormwater conveyance piping and stormwater collection ponds; a five-tenths (0.5)-acre concrete pad used for stormwater debris and leaf management; a model airplane flying area and pavilions; a men's shelter with administrative offices (not built on waste); thirty-six (36) on-site and off-site groundwater monitoring wells; seventeen (17) landfill gas monitoring wells; and access roads to site infrastructure.

2.0 NATURE AND EXTENT OF ENVIRONMENTAL IMPACTS

The findings of the Study that are relevant to the evaluation of remediation alternatives are summarized below.

2.1 Identification of Constituents of Concern

Data (2001-2010) collected from the twenty (20) existing and sixteen (16) newly installed groundwater monitoring wells at the Landfill indicate that volatile organic compounds (VOCs) are the primary constituents of concern (COCs). VOCs consistently reported at concentrations exceeding the MCLs in the groundwater monitoring wells include: 1,2-dichloropropane, benzene, cis-1,2-dichloroethene, methylene chloride, tetrachloroethene (PCE), trichloroethene (TCE) and vinyl chloride. Of the more than sixty-one thousand (61,000) constituents analyzed from all groundwater samples collected historically (April 2001 to September 2010) from the twenty (20) existing groundwater monitoring wells at the Landfill, six hundred forty-eight (648) exceedances of MCLs have been reported. As discussed in the following sections, the COC distribution and concentrations vary across the geographical area of the Landfill.

Data collected from five (5) historical surface water sampling locations (2001-2010) and five (5) new locations added during the Study indicate that TCE, cyanide, bis(2-ethylhexyl)phthalate and methylene chloride are the COCs for surface water around the Landfill. Of the more than thirteen thousand (13,000) constituents analyzed from all surface water samples collected historically (May 2001 to September 2010) in streams near the Landfill, thirteen (13) exceedances of MCLs have been reported. Exceedances in surface water were not consistent, and no spatial or temporal trends were identified for the analytes reported in surface water. Based on these findings and analyses, surface water is not expected to be the target of remedial action.

With respect to surface and subsurface soils collected in the vicinity of and on the Landfill site, no detections of the groundwater or surface water COCs were reported. Some reported concentrations for metals exceeded MDE Residential Cleanup Standards for Soils; however, these concentrations were similar to the Anticipated Typical Concentrations for Maryland (MDE 2008). Therefore, the noted detections for metals appear to represent natural background levels of these metals in soils in Maryland. PCB Aroclors were reported at concentrations exceeding cleanup standards in one surface soil sample (at SS-3) and one subsurface soil sample (at MW04-SO-2 to 4), but these isolated occurrences do not indicate a site-wide PCB concern. Based on these findings and analyses, soils are not expected to be the target of remedial actions.

2.2 Distribution of Constituents of Concern

Based on the best available and recent data, COC concentrations in groundwater are highest along the north-northwestern and south-central boundaries of the Landfill (**Figure 4**, Landfill Perimeter Total VOC Concentration Map). Based on the results of the 2010 groundwater sampling events (conducted by EA in July and the County in September), exceedances of MCLs for all seven groundwater COCs were reported in at least one (1) well in the southern portion of the Landfill site (primarily in wells OB11, OB11A, and OB12). Exceedances for all seven COCs were also reported during 2010 in at least one (1) well in the northern portion of the Landfill site (primarily in wells OB03, OB03A, MW-13A, and MW-13B). Occasional exceedances for COCs were reported along the southwestern and eastern boundaries of the Landfill site. These included MCL exceedances for PCE in MW-9, along the eastern boundary of the Landfill, during the two sampling events conducted in 2010. Vinyl chloride is the only COC that consistently exceeds MCLs in these areas.

Overall, comparison of historical sampling events and 2010 sampling events indicate fairly consistent spatial distribution of COCs exceeding MCLs.

2.3 Concentrations of Constituents of Concern Over Time

In general, the reported COC concentration trends in groundwater vary depending on the constituent and the location of the groundwater monitoring well. Trends of increasing COC concentrations are most prominent in the northwestern (vicinity of OB03, OB03A and OB04A) and south-central (vicinity of OB11, OB11A, and OB12) portions of the Landfill site. COC concentrations have generally decreased since 2001 in the southwestern corner of the site (in the vicinity of OB01, OB02, and OB02A).

2.4 Risk Evaluation

As part of the Study, conceptual site models (CSMs) were used to identify potential receptors (e.g., wildlife and humans) with potential exposure to impacted environmental media in the vicinity of and on the Landfill. Groundwater, surface water, surface soils and subsurface soils were identified as potential exposure media with respect to the Landfill site, although these trends are not well defined and are generally within the same order of magnitude. For exposure pathways that were found to be complete (i.e., likely to lead to exposure to the impacted media), a risk evaluation was performed to assess whether reported concentrations present concerns for human or ecological health. Based on the results of the risk evaluations, there are currently no human health or ecological concerns associated with exposure to groundwater.

3.0 ANALYSIS OF REMEDIATION ALTERNATIVES

In order to achieve the MDE pre-established remediation objectives for the Landfill, several ongoing site compliance issues need to be mitigated. These issues are the drivers for remediation:

- Concentrations of VOCs that exceed MCLs in the groundwater monitoring wells that are located at or beyond the property boundary of the Landfill. Exceedances are consistently reported in samples collected from OB03/OB03A and OB11/OB11A, located in the north-northwestern and south-central portions of the Landfill, respectively. Exceedances are also noted in MW-9 and MW-13A/MW-13B, located off-site west and northwest of Landfill, respectively. In order to meet MDE's objectives for the Landfill, constituent concentrations must be below MCLs at the property boundary and between the Landfill and adjacent streams.

- The presence of leachate seeps on side slopes and stormwater ponding (e.g., standing water) on the interior of the Landfill. Leachate seeps must be addressed to redirect leachate back into the waste mass and to prevent surface runoff of contaminants (e.g., non-stormwater discharges). Stormwater ponding must be minimized to reduce the potential for infiltration and protect water quality.

- Detections of methane above the five (5.00) percent by volume LEL threshold in the landfill gas monitoring wells located at the northwestern and south-central property boundaries of the Landfill. Exceedances are consistently reported in W-02, W-05, W-06, W-07, W-25, W-26 and W-30. Methane concentrations are required to be below the 5.00 percent threshold, preferably to non-detect levels.

Remediation alternatives for addressing these compliance issues were evaluated using selected factors similar to those used in Feasibility Studies and Assessments of Corrective Measures (see also **Table 1**):

- Compliance with Remediation Objectives for Groundwater, Non-stormwater Discharge, and Landfill Gas
- Implementability and Constructability
- Protection of Human Health and the Environment
- Reduction of Contaminant Concentrations, Mobility and Volume
- Cost

As previously noted, this discussion of remediation alternatives is not intended to be a comprehensive evaluation nor does it represent defined courses of action selected by the County. The alternatives considered are targeted at addressing the remediation objectives for the Landfill site for groundwater, but each alternative also may affect strategies for landfill gas, leachate seeps (non-stormwater discharge) and stormwater management. The alternatives may be implemented separately in select portions of the Landfill site or they may be combined as required and feasible to achieve the most effective overall remedial outcome. To address leachate seeps, some regrading of the landfill cover system will likely also be necessary in any areas that are not regraded as part of the implementation of remediation alternatives. This regrading might include significant alterations to the existing stormwater management system, including drainage features and stormwater ponds.

Costs presented for each alternative are generalized estimates, based on professional experience and estimates by EA and County personnel. Some (as cited) are derived from general costing information published by the Federal Remediation Technologies Roundtable (FRTR), which maintains a Screening Matrix and Reference Guide and a Searchable Database of Remediation Technologies. Costs within the ranges presented by the FRTR were selected by considering the size and nature of the Landfill. Total implementation costs for the remediation alternatives are expected to vary widely depending on specific design parameters, permit requirements and construction sequencing of each technology.

3.1 Alternative 1: Monitored Natural Attenuation

Natural attenuation describes a range of natural physical and biological processes that reduce contaminant volumes and concentrations in groundwater. These processes include biodegradation, adsorption, dilution, dispersion, and volatilization. Monitored Natural Attenuation (MNA) is a remediation technology that combines these natural processes with a carefully designed groundwater monitoring program to achieve remediation goals.

MNA is advantageous because it results in a reduction of mass of constituents in groundwater; organic contaminants are transformed to innocuous byproducts rather than being transferred from one medium (e.g., groundwater) to another (e.g., activated carbon or the atmosphere). At many sites, the most significant natural attenuation process for organic compounds is biodegradation. Chlorinated organic compounds, such as those found at the Landfill, are effectively degraded through a process called dechlorination. Under anaerobic conditions (without oxygen present), PCE is degraded to TCE, which is degraded to 1,2-cis-dichloroethene and finally vinyl chloride. This vinyl chloride requires aerobic conditions (with oxygen present) in order to be degraded finally to chloride, carbon dioxide, and ethane/ethane. These final byproducts are nonhazardous. MNA is non-intrusive and generally less costly than other remediation technologies. However, it should be noted that due to the potential for changes to subsurface conditions that might affect natural attenuation, performance monitoring is of utmost importance to ensure that the natural processes are occurring according to expectations.

Compliance with Remediation Objectives for Groundwater, Non-stormwater Discharge, and Landfill Gas

Groundwater monitoring data indicate that some contaminant concentrations exceed MCLs at the property boundary, despite current natural attenuation processes. Thus MNA is unlikely to meet this remedial objective in the short term. However, the presence of all constituents in the common dechlorination series discussed above – PCE, TCE, cis-1,2-dichloroethene, and vinyl chloride – suggests that reductive dechlorination is occurring at the site. This process is likely responsible for producing the vinyl chloride (a product of the degradation chain) reported in groundwater samples at the Landfill, and indicates the potential for significant degradation of contaminants to below MCLs in the long term. Furthermore, MNA could be an effective part of a remedial strategy if combined with other technologies, such as enhanced bioremediation. This would accelerate the MNA processes, and could be designed to promote the final degradation of vinyl chloride to the innocuous final byproducts. Natural waste decomposition by biological processes is the cause of current gas production at the Landfill, and thus implementing MNA would not be expected to cause changes in gas (methane) generation. MNA would also not be expected to impact non-stormwater discharges or stormwater management at the Landfill.

Implementability and Constructability

MNA would be easily implementable as a remediation alternative, as it would likely only require the addition of some analytical parameters to the existing groundwater monitoring plan, to allow evaluation of the current level of natural attenuation and to provide a benchmark for long-term monitoring. Implementation of MNA would not require the installation of any structures or specialized remediation equipment, and would likely not require any additional monitoring wells. MNA has few potential short-term negative impacts, as it does not result in the generation of any significant volume of remedial wastes, and it does not require disturbance of impacted material (e.g., in-place waste) or introduction of additional constituents into the subsurface.

Gaining regulatory approval for MNA could be possible if it can be shown that site conditions are favorable for natural attenuation and that the size of, and COC concentrations within, the plume of impacted groundwater are stable (not increasing over time). Historical data indicates that the plume may be stable or decreasing in size and concentration in some areas around the perimeter of the Landfill, but that plume size and concentrations are increasing in other areas. A stability analysis would be necessary to further assess the characteristics of the plumes on and off the Landfill site. The reported MCL exceedances and trends of increasing COC concentrations in some areas around the Landfill perimeter may prevent regulatory acceptance of MNA as a sole remediation technology. Education and outreach efforts would likely be required in order to gain public acceptance of MNA. In addition, further evaluation of this alternative would be required to assess the compatibility with potential future land reuse options. Additional investigation would be necessary to evaluate which MNA processes are currently occurring. Further site analyses could also reveal whether biologically mediated MNA processes are occurring at full capacity, or whether natural biological processes could be stimulated by injection of additives as part of an enhanced bioremediation program.

Protection of Human Health and the Environment

The human health and ecological risk evaluations conducted as part of the Study (EA 2010) indicated that reported concentrations do not present human or ecological concerns for contact with groundwater, surface water, surface soil or subsurface soil at the Landfill. The County also performs semi-annual groundwater monitoring along and beyond the Landfill property boundary.

Landfill gas, which is a byproduct of biological attenuation processes, is a potential hazard that requires monitoring and mitigation if warranted. The County is performing ongoing improvements to the gas collection system to prevent methane exceedances from occurring at the Landfill property boundary, and also performs weekly and quarterly landfill gas monitoring along the Landfill property boundary.

Reduction of Contaminant Concentrations, Mobility and Volume

Natural attenuation allows biological and chemical processes to reduce contaminant concentrations in groundwater. Through enhanced monitoring techniques, the associated reductions in the volume of constituents that impact groundwater can be quantified.

Cost

Capital costs associated with MNA are expected to be low, approximately $30,000 per year, as the technology requires no equipment or construction activities. O&M costs for MNA, primarily associated with more extensive monitoring requirements, are expected to be moderate. The total estimated cost of implementing 30 years of MNA, including groundwater monitoring, data evaluation, and periodic site reviews as required by the regulatory agency, is estimated to be approximately $500,000-$1,000,000.

3.2 Alternative 2: Bioremediation

Enhanced bioremediation is an *in situ* (in-place) treatment technology that involves underground injection or placement of nutrients (e.g., carbon-based substrate) or electron acceptors (e.g., oxygen) to stimulate microorganisms that are capable of degrading COCs. The absence of a suitable substrate can be a limiting factor, which inhibits the natural biological degradation of COCs. The addition of food-grade substrate such as vegetable oil, sodium lactate or molasses can stimulate biological reactions in the subsurface to degrade COCs. This form of enhanced bioremediation transforms organic constituents into innocuous byproducts.

Bioremediation can be effective for the treatment of organic constituents, including the chlorinated compounds and benzene found at the Landfill. In designing a bioremediation program, it would be necessary to evaluate what kinds of natural biodegradation are already occurring, and how these processes could be enhanced.

Compliance with Remediation Objectives for Groundwater, Non-stormwater Discharge, and Landfill Gas

If appropriate enhancements (e.g., nutrients or organic substrates) are selected and mixed effectively into the groundwater aquifer, biodegradation would be expected to occur, thereby decreasing COC concentrations below MCLs. The volume of treated groundwater would be constrained primarily by the location and depth of the wells used for injection, and could potentially reduce COC concentrations in both shallow and deep groundwater if injection wells are installed in both unconsolidated material and bedrock. Enhanced bioremediation could potentially increase production of landfill gas (methane), by stimulating microbial activity, but would not be expected to have an effect on non-stormwater discharges or stormwater management at the Landfill.

Implementability and Constructability

Bioremediation is expected to be highly implementable at the Landfill. Installation of injection wells would be required for introduction of nutrients and electron acceptors into the groundwater aquifer. An evaluation of current groundwater conditions, and how different bioremediation strategies would affect these conditions, would also be necessary to determine whether anaerobic or aerobic biodegradation, or a combination of the two, would be most effective. It would also be necessary to design an injection program that achieves sufficient mixing of enhancements into the water contained in the limited permeability bedrock. The ability to use different combinations of wells for each injection event would allow this remediation alternative to be modified in response to shifting site conditions and constituent concentrations. Bioremediation would be expected to have few short-term negative impacts at the Landfill, because it would result in minimal disruption of the site and its existing infrastructure, and the generation of minimal remedial wastes.

Bioremediation is an increasingly common and well accepted method for groundwater remediation (FRTR 2010a). Regulatory acceptance would require a careful plan for design and monitoring of the injection system, to ensure that substrate selection, injection methods, and injection well locations are appropriate to enhance biodegradation at the site. Community acceptance would likely require education about the benefits of bioremediation as compared to more invasive technologies. In addition, further evaluation of this alternative would be required to assess the compatibility with potential future land reuse options.

Protection of Human Health and the Environment

The human health and ecological risk evaluations conducted as part of the Study (EA 2010) indicated that detected concentrations do not present human or ecological concerns for contact with groundwater, surface water, surface soil or subsurface soil at the Landfill. The County also performs semi-annual groundwater monitoring along and beyond the Landfill property boundary.

Landfill gas is a potential hazard that requires monitoring and mitigation if warranted. The County is performing ongoing improvements to the gas collection system to prevent methane exceedances from occurring at the Landfill property boundary, and also performs weekly and quarterly landfill gas monitoring along the Landfill property boundary. Bioremediation could marginally increase gas production, as described above. The landfill gas monitoring program would be adjusted accordingly.

Reduction of Contaminant Concentrations, Mobility and Volume

Bioremediation would be expected to achieve significant reductions in COC concentrations and the volume and concentration of COCs that impact groundwater.

Cost

Capital costs for implementing enhanced bioremediation vary widely, depending on the area treated, the types and amounts of enhancements added, and the infrastructure needed. An enhanced bioremediation program at the Landfill is expected to cost approximately $100,000-$200,000 for injection well installation, plus approximately $40,000-$80,000 per year for injection events, monitoring, and O&M (FRTR 2010a). These costs are based on reported total costs from other sites impacted by chlorinated solvents, where enhanced bioremediation systems were successfully implemented. Groundwater monitoring, data evaluation, and periodic site reviews as required by the regulatory agency above and beyond current semi-annual groundwater sampling may be required. The total estimated cost for 30 years would therefore be approximately $1,300,000-$2,600,000.

3.3 Alternative 3: Landfill Capping

Capping of the waste mass is an integral part of the closure and post-closure care system of a municipal solid waste landfill. Landfill capping can occur through, but is not limited to, the installation of an engineered geosynthetic membrane liner system or an engineered soil cover system. Each capping method would require stormwater management infrastructure and, depending on the degree of waste decomposition, each method would impact landfill gas collection and management across the site. Capping system implementation should consider potential mechanisms to: minimize future maintenance activities; account for differential settlement; reduce the infiltration of precipitation into the waste mass; prevent erosion and sediment transport while assuring proper stormwater management; prevent the migration of landfill gas beyond, and promote landfill gas collection within, the landfill property boundary; and reduce the potential for leachate migration into underlying aquifers and surface water bodies.

Regulatory Applicability

Under the COMAR 26.04.07.21.B. Closure Cap – "*The closure cap shall be designed to minimize infiltration into the landfill and shall be developed through an engineering analysis of the site. The closure cap may be constructed of natural materials found either on the site or imported from an off-site location. Elements of the closure cap may also be constructed of a synthetic or manufactured membrane material.*"

COMAR 26.04.07.21.D Alternatives also states – "*The Department shall consider alternative proposals for landfill closure based upon an engineering analysis of the site. Proposals may involve surcharging the final cover to induce settlement, liquid addition, or other techniques intended to better stabilize the site before installation of the landfill cap.*"

COMAR 26.04.07.21.E. defines minimum design features for closure caps of municipal landfills or, as previously noted, approved alternates with equivalent performance can be considered. A typical cross-section of an engineered geosynthetic or soil cover capping system consists of (from top to bottom):

- Vegetative Support (final earthen cover) Layer – minimum thickness of 6 inches of earthen material (top soil) that is capable of sustaining native plant growth and 18 inches of other acceptable clean earthen fill.
    - Final cover slope to be a minimum of 4 percent to promote surface drainage.
- Protective Cover (drainage) Layer – minimum thickness of 6 inches of clean sand or other natural coarse grained or screened material with an in-place permeability greater than 1×10^{-3} centimeters/second (cm/sec) to promote drainage and protect the low-permeability layer from puncture. Filter fabrics or other synthetic drainage blankets may be considered as substitutes for the fine grained material.
- Low-Permeability (capping) Layer – designed or constructed of geosynthetic material with a minimum thickness of 20 mil and a maximum permeability of 1×10^{-10} cm/sec, or a minimum of 12 inches of clay or other natural fine grained material having an in-place permeability of less than or equal to 1×10^{-5} cm/sec.
    - The capping layer to be a minimum of 4 percent slope.

- Intermediate Cover (separation) Layer – typically 12-18 inches of screened earthen material over the waste mass to protect the low-permeability layer from puncture.

Capping System Installation

The installation of a uniform and low-permeability capping system on the ground surface of a landfill is a common and industry-accepted method for decreasing the amount of precipitation and surface water that has the potential to infiltrate into and contact the waste mass of the landfill. While decreasing infiltration and the generation of leachate, a low-permeability capping system also has the potential to increase the collection efficiency for landfill gas by minimizing fugitive emissions, although a previous surface emissions scan at the Landfill yielded no significant fugitive emissions. The amount of stormwater flow on the surface (e.g., runoff) during precipitation events would also dramatically increase under this scenario. Landfill gas and stormwater management would both need to be managed with properly designed and maintained infrastructure if a low-permeability capping system were installed.

Landfill capping systems, if properly installed and maintained, can achieve long-term reductions in leachate volume by reducing the infiltration of precipitation and can prevent the surface expression of leachate (e.g., seeps). However, the effectiveness of capping systems is dependent on the spatial relationships between the waste mass, the water table at bottom grade of the landfill or through mounding/infiltration within the waste mass with no cap present, and the water table following capping.

If groundwater remains in contact with the waste mass following capping system installation, then capping may not achieve the objective of completely isolating the waste mass from water infiltration.

Current Landfill Conditions

The Landfill currently has a soil cover system that varies in thickness from approximately two (2) to five (5) feet across the Landfill, and potentially less on the side slopes. The site is well vegetated with a mix of open grassy fields and sporadic patches of trees. As previously discussed, the Landfill has an extensive landfill gas collection system as well as stormwater management infrastructure. Due to the permeability of the soil cover system, stormwater that does not naturally run off the site or enter the stormwater conveyance piping network likely infiltrates into the waste mass, which generates leachate. It also should be noted that the Landfill does not have a bottom liner system and that waste was likely placed in direct contact groundwater during Landfill construction or that groundwater mounding has occurred within the waste mass across the majority of the site.

The depth of the waste at the Landfill is reported to be fifty five (55) to ninety (90) ft below ground surface elevation. Groundwater has been detected in the landfill gas extraction wells at depths of approximately twenty five (25) feet below the Landfill surface. Depth to waste below the landfill surface is typically five (5) feet across the site; however, some areas the depth has been noted to be as high as ten (10) feet and as low as two (2) feet. Better spatial resolution regarding the depth of waste would be necessary to determine whether capping would likely bring water levels below the bottom of the waste mass.

<u>Compliance with Remediation Objectives for Groundwater, Non-stormwater Discharge, and Landfill Gas</u>

If groundwater does not contact the waste following installation of a capping system, decreased infiltration and subsequent leachate production combined with natural attenuation processes could lead to compliance with MCLs in groundwater. Groundwater quality would be expected to adjust to the capping system gradually, as constituents present in the groundwater degraded or diffused away from the Landfill. Some increase in constituent concentrations in the groundwater could occur in the short-term, due to decreased dilution of existing leachate by infiltration from the surface. Capping and associated regrading would also likely eliminate the leachate seeps and associated potential non-stormwater discharges currently present on the side slopes of the Landfill. Compliance with landfill gas objectives could be improved through enhanced landfill gas collection and a reduction in potential fugitive emissions following installation of the capping system, and through reconstruction of the landfill gas collection system, which would be necessary after installation of the capping system. Stormwater management infrastructure improvements could be implemented to handle the additional runoff following capping system installation.

<u>Implementability and Constructability</u>

The feasibility of installing an engineered synthetic or soil capping system would need to be assessed with respect to the physical attributes of the Landfill, including the steepness of the side slopes. Installation of a synthetic or soil cap at the Landfill would require disassembling and reassembling the existing landfill gas collection system, which would likely also need to be redesigned to accommodate changes to gas migration patterns caused by capping. Significant modifications to the existing stormwater management system, accounting for increased stormwater runoff resulting from capping, would also be required. In the short-term, installation of the capping system would create significant disturbance of the site, due to surficial construction activities. In addition, regrading may result in waste disturbance in order to effectively install the capping system.

Capping is a typical remedy for impacted groundwater at landfills and is likely to be accepted by regulators and community stakeholders. However, further site characterization and evaluation would be required to demonstrate that waste would not remain in contact with groundwater, and thus that capping would significantly decrease the contribution of COCs to groundwater beneath the Landfill.

In addition, further evaluation of this alternative would be required to assess the compatibility with potential future land reuse options.

<u>Protection of Human Health and the Environment</u>

The human health and ecological risk evaluations conducted as part of the Study (EA 2010) indicated that reported concentrations do not present human or ecological concerns for contact with groundwater, surface water, surface soil or subsurface soil at the Landfill. The County also performs semi-annual groundwater monitoring along and beyond the Landfill property boundary.

Landfill gas is a potential hazard that requires monitoring and mitigation if warranted. The County is performing ongoing improvements to the gas collection system to prevent methane exceedences from occurring at the Landfill property boundary, and also performs weekly and quarterly landfill gas monitoring along the Landfill property boundary. Capping activities would be expected to lead to further improvements in the performance of the gas collection and control system, as discussed above, especially along the perimeter of the site, and would thus be protective of human health and the environment.

Reduction of Contaminant Concentrations, Mobility and Volume

If waste does not remain in contact with groundwater following installation of a capping system, then capping may result in a significant long-term decrease in the mobility of dissolved-phase COCs derived from the waste and the volume of impacted groundwater.

If groundwater remains in contact with the waste mass following capping system installation, then capping may not achieve the objective of completely isolating the waste mass from water infiltration.

Cost

The capping system cost estimate represents a total cost range of approximately $25,000,000 to $34,000,000 (2010$), which includes new stormwater, landfill gas and other site access improvements. Annual O&M costs, including maintenance of the capping system in addition to landfill gas and groundwater monitoring, data evaluation, and periodic site reviews as required by the regulatory agency, are estimated at $100,000 per year for a total 30-year post-closure care and maintenance cost of approximately $3,000,000.

3.4 Alternative 4: In-Situ Barrier Technologies

3.4.1 Impermeable Barriers

In situ impermeable barriers restrict the flow of impacted groundwater or subsurface gases. Although impermeable barriers are a common technology for containment of contamination within a defined area, they may also be used to divert water or gases away from a sensitive area. Impermeable barriers commonly consist of an excavated trench filled with concrete.

Slurry walls could be installed in the paths of the primary groundwater plumes at the Landfill, to divert impacted water, and could also be used to limit migration of landfill gas toward sensitive areas along the property boundary. Slurry walls can only be installed in unconsolidated material (which has an average depth of approximately thirty [30] ft), and would therefore not block flow of deeper impacted groundwater within the bedrock.

Compliance with Remediation Objectives for Groundwater, Non-stormwater Discharge, and Landfill Gas

The installation of impermeable barriers alone would not decrease COC concentrations to MCLs in groundwater along other portions of the site boundary where slurry walls are not constructed. However, slurry wall emplacement along select areas of the perimeter of the Landfill, especially the northwestern boundary, could effectively reduce migration of landfill gas and shallow impacted groundwater toward sensitive areas such as the Derwood Station South residential development. Installation of enhanced gas collection infrastructure adjacent to the slurry wall could further improve gas control along the perimeter of the Landfill. Groundwater flow would be diverted either around or under the slurry wall due to the impermeability of the barrier. In order to decrease contaminant concentrations and meet MCLs, groundwater treatment technologies would need to be implemented, in addition to the slurry walls. Impermeable barriers would not be expected to impact non-stormwater discharges or stormwater management at the Landfill.

Implementability and Constructability

Slurry walls would be constructible at the Landfill, and could be combined with selective excavation and relocation of waste material. Possible short-term negative effects of impermeable barriers would be related to the disturbance associated with construction activities, including waste removal.

Regulatory and community acceptance of slurry walls as a sole treatment technology is unlikely, given its inability to decrease groundwater contaminant concentrations and meet MCLs. However, a slurry wall could be accepted as a method of addressing landfill gas migration and/or shallow groundwater flow along the north-northwestern boundary of the Landfill. Further evaluation of this alternative would be required to assess the compatibility with potential end use options.

In addition, further evaluation of this alternative would be required to assess the compatibility with potential future land reuse options.

Protection of Human Health and the Environment

The human health and ecological risk evaluations conducted as part of the Study (EA 2010) indicated that reported concentrations do not present human or ecological concerns for contact with groundwater, surface water, surface soil or subsurface soil at the Landfill. The County also performs semi-annual groundwater monitoring along and beyond the Landfill property boundary.

Landfill gas is a potential hazard that requires monitoring and mitigation if warranted. The County is performing ongoing improvements to the gas collection system to prevent methane exceedances from occurring at the Landfill property boundary, and also performs weekly and quarterly landfill gas monitoring along the Landfill property boundary. Installation of impermeable barriers could be considered protective of human health and the environment through diversion of landfill gas away from sensitive areas.

Reduction of Contaminant Concentrations, Mobility and Volume

Impermeable barriers would not decrease COC concentrations in groundwater or the volume of landfill gas generated, although they would change gas and water mobility by redirecting flow.

Cost

The cost of impermeable barriers such as slurry walls is typically $5-$10/square foot of wall, or $450,000-900,000 for 3,000 ft of wall (split between the northern and southern sides of the Landfill) averaging thirty (30) ft deep (FRTR 2010b). Impermeable barriers require minimal maintenance, although post-construction costs would include groundwater monitoring, data evaluation, and periodic site reviews as required by the regulatory agency. Annual O&M costs are expected to cost approximately $25,000 per year. The estimated total cost for 30 years is therefore $1,200,000-1,650,000.

3.4.2 Permeable Barriers

In situ permeable barriers are typically reactive and contain materials that destroy or retain constituents known to be present in impacted groundwater. These barriers are placed such that they intercept plumes of impacted groundwater, and can be installed in excavated trenches, or injected into the subsurface by a series of wells. As the groundwater flows into the barrier, constituents are treated *in situ*. Reactive barriers provide active groundwater treatment without groundwater extraction and are a common technology for in-place treatment.

When *in situ* reactive barriers are placed to intercept the majority of the plume of impacted groundwater, they can be highly effective for the treatment of a variety of constituents. Because their locations are fixed, reactive barriers are not easily manipulated to respond to changing groundwater conditions and therefore work best with well-defined and consistent plumes.

Compliance with Remediation Objectives for Groundwater, Non-stormwater Discharge, and Landfill Gas

The effectiveness of reactive barriers at the Landfill would likely be significantly decreased by the fact that barrier installation in bedrock is typically not feasible, preventing treatment of the deeper impacted groundwater within the bedrock. Due to these limitations, permeable reactive barriers would not be effective in reducing COC concentrations to below MCLs in groundwater within the bedrock. By treating shallow groundwater, reactive barriers might be effective at decreasing potential impacts to surface water or shallow groundwater that is traversing into deeper groundwater within the bedrock. Reactive barriers would not be expected to have an effect on landfill gas, non-stormwater discharges, or stormwater management at the Landfill.

Implementability and Constructability

Installation of a permeable barrier along the northwestern border of the Landfill could be combined with selective excavation and relocation of waste material in this area, or the barrier could be injected. Regular monitoring and maintenance would be required to ensure that the reactive substances remain active. Injected reactive barriers would have few short-term negative effects, whereas non-injected barriers would present excavation-related impacts associated with waste removal and the potential exposure to mounded groundwater during excavation activities.

Reactive barriers are an accepted and widely used groundwater treatment technology. At the Landfill, however, this technology may not achieve acceptance by regulatory agencies or community stakeholders as a sole treatment technology, due to incomplete treatment of impacted groundwater within the bedrock. Community stakeholders may also raise concerns regarding the disturbance of waste material during the installation of the barrier.

In addition, further evaluation of this alternative would be required to assess the compatibility with potential future land reuse options.

Protection of Human Health and the Environment

The human health and ecological risk evaluations conducted as part of the Study (EA 2010) indicated that reported concentrations do not present human or ecological concerns for contact with groundwater, surface water, surface soil or subsurface soil at the Landfill. The County also performs semi-annual groundwater monitoring along and beyond the Landfill property boundary.

Landfill gas is a potential hazard that requires monitoring and mitigation if warranted. The County is performing ongoing improvements to the gas collection system to prevent methane exceedances from occurring at the Landfill property boundary, and also performs weekly and quarterly landfill gas monitoring along the Landfill property boundary. Installation of permeable barriers is not expected to affect landfill gas concentrations.

Reduction of Contaminant Concentrations, Mobility and Volume

In situ reactive barriers would reduce COC concentrations and mobility of shallow impacted groundwater, located within the unconsolidated sediments.

Cost

Costs for designing and installing *in situ* reactive barriers are dependent on whether the barrier is injected or installed following selective waste excavation, and on the treatment media selected. For excavated walls, the costs are approximately $25-$35 per cubic foot of wall, or $4,500,000-6,300,000 for 3,000 ft of 2-ft-wide wall averaging thirty (30) ft deep (FRTR 2010b). Post-construction costs would include groundwater monitoring, data evaluation, and periodic site reviews as required by the regulatory agency. The costs of maintaining the barriers are another $2-4 per cubic foot per year, or $10,800,000-$21,600,000 for 30 years for the wall parameters described above. This gives a total cost for non-injected barriers of $15,300,000-$27,900,000.

3.5 Alternative 5: Selective or Extensive Waste Excavation

Waste excavation is a process by which in-place municipal solid waste would be removed from portions of the Landfill and transported off-site in leak-proof containers for treatment and disposal. The waste removal process would use mechanized equipment such as backhoes, excavators, loaders, tri-axle trucks, etc. During the excavation process, there would be the option to source separate recycled or non-burnable materials such as scrap metal, white goods, tires, soil, etc. Waste and recycled materials would likely be transported to the County Shady Grove Processing Facility and Transfer Station for consolidation prior to incineration of waste at the County Resource Recovery Facility. Soil would likely be left on-site, if allowed by the regulatory agency, for regrading of the Landfill soil cover system.

Waste excavation is most likely to occur along the perimeter property boundary of the Landfill, but may occur in other areas of the site. This strategic operation would increase the distance or buffer area between the property boundary and the waste disposal footprint of the Landfill. In the case of an engineered synthetic or soil capping system with riprap down chutes, waste would need to be excavated along the perimeter boundary to install the anchor trench and stormwater management infrastructure.

Compliance with Remediation Objectives for Groundwater, Non-stormwater Discharge, and Landfill Gas

Selective or extensive waste excavation could contribute to increased compliance, in the areas of excavation along the property boundary, with MCLs in groundwater and LELs for landfill gas. Clean fill or an *in-situ* barrier could be placed in the void space of the excavated waste, which could further improve compliance with landfill gas and groundwater regulatory threshold limits at the property boundary and within the monitoring wells. Regrading during filling, following excavation, could also be used to improve non-stormwater discharges and stormwater management in the areas targeted for excavation.

Implementability and Constructability

Selective or extensive waste excavation is expected to be implementable at the Landfill. However, it would create land disturbance and associated concerns with erosion and sediment control, leachate and stormwater management, landfill gas collection, odor, dust and noise. Due to slope stability concerns, once an area has reached a pre-determined elevation during waste excavation activities, clean fill/specified fill placement would need to be initiated, thus implementing a remove and replace operation in step sequence. Each of these concerns could be mitigated with properly designed Operations and Contingency Plans.

In addition, further evaluation of this alternative would be required to assess the compatibility with potential future land reuse options.

Protection of Human Health and the Environment

The human health and ecological risk evaluations conducted as part of the Study (EA 2010) indicated that reported concentrations do not present human or ecological concerns for contact with groundwater, surface water, surface soil or subsurface soil at the Landfill. The County also performs semi-annual groundwater monitoring along and beyond the Landfill property boundary.

Landfill gas is a potential hazard that requires monitoring and mitigation if warranted. The County is performing ongoing improvements to the gas collection system to prevent methane exceedances from occurring at the Landfill property boundary, and also performs weekly and quarterly landfill gas monitoring along the Landfill property boundary. Waste excavation is expected to be protective of human health and the environment by reducing landfill gas emissions along the landfill perimeter.

The selective or extensive excavation of waste may also create the potential for contact with the exposed waste and higher levels of landfill gas, especially by construction workers, in the short term. Waste excavation may also create fugitive emissions of dust, odor and noise, which would be managed through compliance measures noted in an MDE approved operations plan. Personal protective equipment or other precautions would be necessary to prevent human health concerns resulting from this contact with waste and landfill gas. Although contact with waste and landfill gas was not included in the risk evaluation, waste excavation is a common industry practice and protection measures would be addressed in a site specific Health and Safety Plan completed prior to excavation activities.

Reduction of Contaminant Concentrations, Mobility and Volume

Selective or extensive waste excavation would directly decrease the volume of waste present in the Landfill and in potential contact with groundwater in specific areas of the site. The magnitude of resulting decreases in COC concentrations and mobility would be dependent on the volume and location of waste removed, hydrological factors, and possible combination of this alternative with other remediation alternatives.

Cost

The cost for waste excavation is estimated to be approximately $35 per ton (2010$). This estimate includes: waste excavation at $20 per ton; waste transport via truck from Landfill to Transfer Station at $2 dollar per ton; waste processing at the Transfer Station at $10 per ton; and waste transport via rail to the Resource Recovery Facility at $3 per ton. The County estimates excavation of approximately 200,000 tons, which equates to a cost range of $5,000,000-7,000,000 (2010$). This cost estimate does not include clean fill/select fill acquisition and placement costs, ash disposal costs following incineration or any potential revenues from recycling efforts and the sale of electricity that will be generated upon waste incineration at the Resource Recovery Facility.

4.0 SUMMARY AND CONCLUSIONS

The evaluated remediation alternatives are summarized and compared in **Table 1**. The alternatives are targeted at addressing the remediation objectives for the Landfill site for groundwater, but each alternative also may affect strategies for landfill gas, non-stormwater discharges (e.g., leachate seeps) and stormwater management. The alternatives may be implemented separately in select portions of the Landfill site or they may be combined as required and feasible to achieve the most effective overall remedial outcome to ensure continued protection of human health and the environment on a short-term and long-term basis.

Remediation alternatives will also need to be further evaluated to assess their compatibility with potential future land reuse opportunities.

Most of these alternatives (all except capping and selective waste excavation) do not directly address the non-stormwater discharges on the Landfill side slopes. Therefore, some regrading of the landfill cover system may also be necessary to limit leachate seeps under the other scenarios, and would also be designed to facilitate positive drainage of stormwater. This regrading might include significant alterations to the existing stormwater management system, including drainage features and stormwater ponds. Such regrading would be compatible with the bioremediation, *in-situ* barrier, and MNA alternatives discussed above. The cost of regrading as a separate process would be dependent on the intent and the extent of the regrading effort (stormwater management, surface water control, and leachate control).

Table 1
Summary Comparison of Remediation Objectives and Alternatives for the Gude Landfill

Alternative		Monitored Natural Attenuation	Bioremediation	Landfill Capping	Impermeable Barriers	Permeable Barriers	Selective or Extensive Waste Excavation
Compliance with Remediation Objectives	Objective: No Exceedances of Groundwater MCLs at Property Boundary	May not comply at all boundaries in short-term, as indicated by current MCL exceedances	Would decrease VOC concentrations in shallow and deep groundwater	May achieve compliance if waste does not remain in contact with groundwater	Would divert shallow groundwater; may meet MCLs along boundaries where installed	Would decrease VOC concentrations in shallow groundwater only	Possible localized decrease in groundwater VOC concentrations
	Objective: No Non-Stormwater Discharges	Minimal impact	Minimal impact	Likely to eliminate leachate seeps	Minimal impact	Minimal impact	Could eliminate seeps if combined with regrading
	Objective: No Exceedances of Gas Landfill LELs	No change; current gas levels result from natural attenuation	Possible increase in landfill gas production, requiring gas management	Reconstruction of gas collection system could decrease gas levels	Could limit landfill gas migration in selected areas	Minimal impact	Localized decrease in gas levels at property boundaries
Implementability and Constructability		Implementable; requires no construction or maintenance, and relies upon sampling and analysis	Implementable; requires careful design of the injection system, installation of injection wells, and periodic injections	Feasibility assessment would be necessary; requires widespread regrading and reconstruction of landfill gas and stormwater management systems	Constructible within unconsolidated sediments; requires small-scale construction and waste relocation	Constructible within unconsolidated sediments; requires small-scale construction, injection and/or waste excavation	Implementable, but requires land disturbances and mitigation of impacts from construction and exposed waste
Protection of Human Health and the Environment		No effect on gas levels[2]	May increase gas levels[2]	Would likely include gas collection system improvements[2]	Could limit gas levels in sensitive areas[2]	No effect on gas levels[2]	Expected to limit gas levels at property boundary[2]
Reduction of Contaminant Concentration, Mobility, and Volume		Gradual natural decrease in VOC concentrations and volume of impacted groundwater	Would reduce VOC concentrations and volume of impacted groundwater	Would reduce volume and mobility; less if waste remains in contact with groundwater following capping	Would reduce mobility but not VOC concentrations or volume of impacted groundwater	Reduced VOC concentrations in smaller volume of impacted shallow groundwater	Would decrease the volume of waste; some decrease in contaminant concentrations and mobility
Cost[3]		\$500,000-\$1,000,000	\$1,300,000-\$2,600,000 (in areas of impacts)	\$25,000,000-\$34,000,000 (whole site)	\$1,200,000-\$1,650,000 (3000-ft wall)	\$15,300,000-\$27,900,000 (3000-ft wall)	\$5,000,000-7,000,000 (200,000 tons)

1. The alternatives may be implemented separately in select portions of the Landfill site or they may be combined as required and feasible to achieve the most effective overall remedial outcome to ensure continued protection of human health and the environment on a short-term and long-term basis.
2. Human health and ecological risk evaluations conducted as part of the Nature and Extent Study indicate no complete exposure pathways of concern related to contact with soil and water at the Landfill. However, landfill gas migration is a potential hazard that requires monitoring and mitigation if warranted.
3. Costs represent rough estimates for comparison, from case studies of similar sites, and are expected to vary widely depending on specific design and other related parameters.

5.0 References

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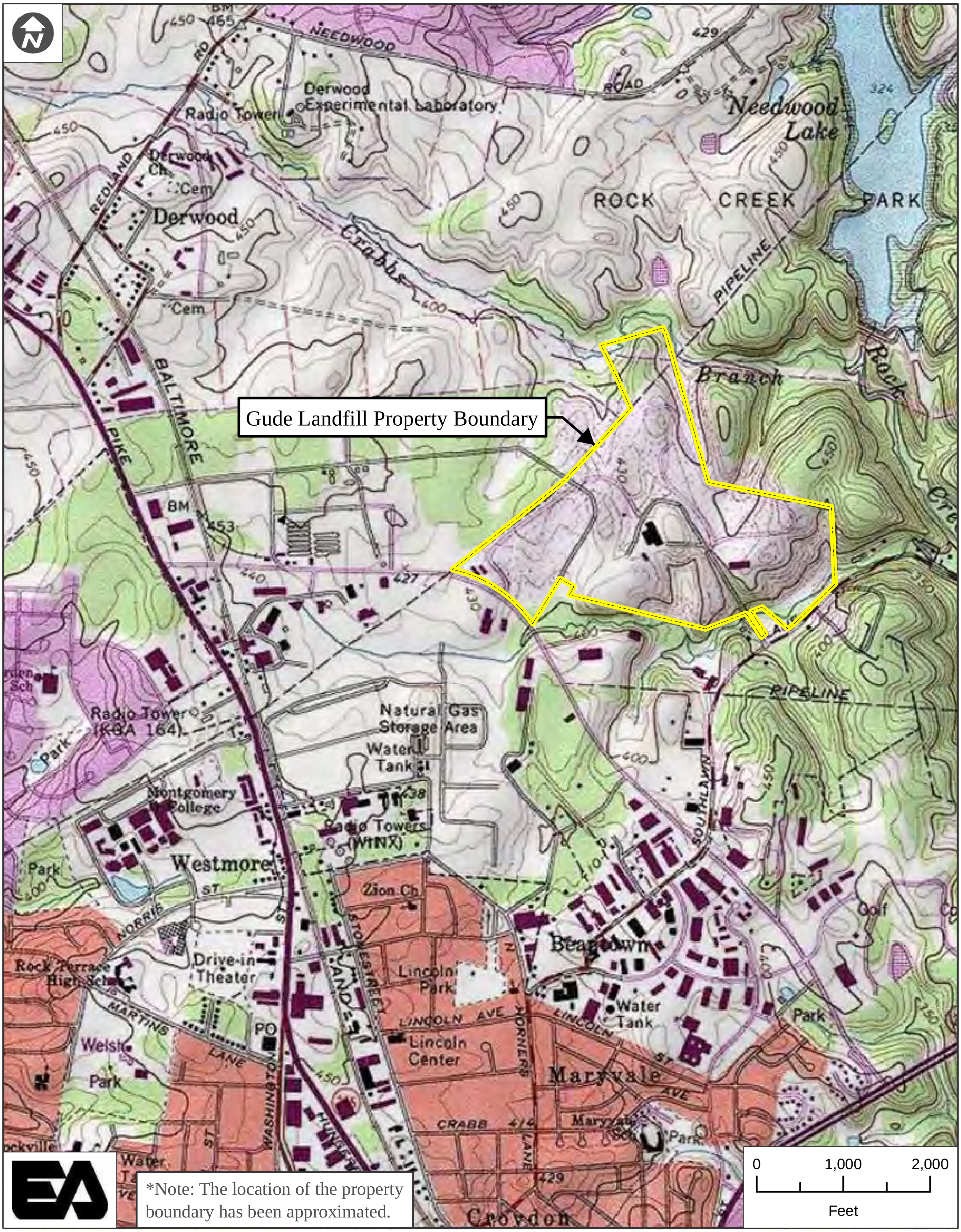
List of Figures

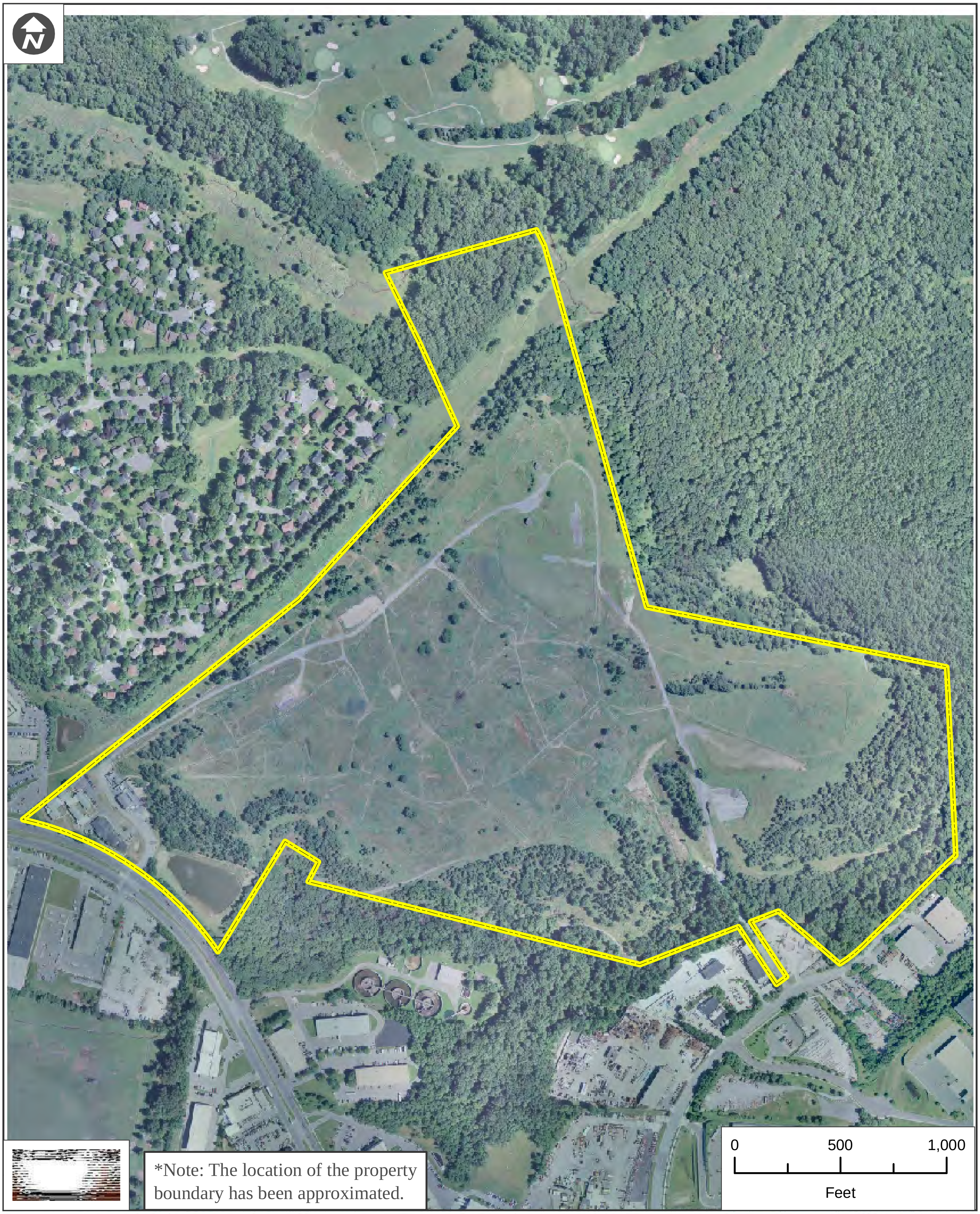


*Note: The location of the property boundary has been approximated.

Gude Landfill
Montgomery County, Maryland

Figure 1. Site Location Map

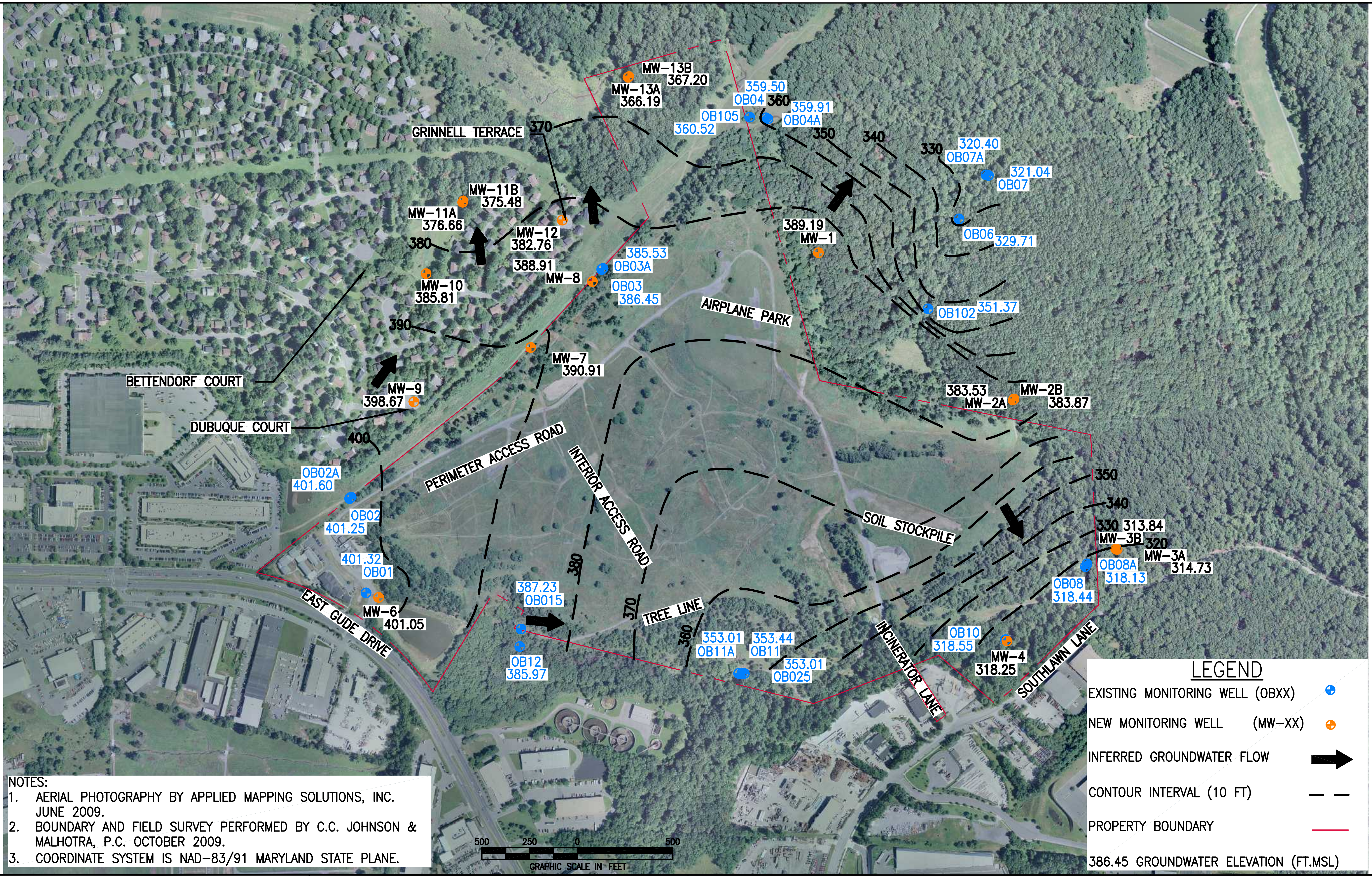
Sources:
- EDR, 2009



Gude Landfill
Montgomery County, Maryland

Figure 2. 2009 Aerial Photo

Source:
Applied Mapping Solutions (AMS) 2009



NOTES:
1. AERIAL PHOTOGRAPHY BY APPLIED MAPPING SOLUTIONS, INC. JUNE 2009.
2. BOUNDARY AND FIELD SURVEY PERFORMED BY C.C. JOHNSON & MALHOTRA, P.C. OCTOBER 2009.
3. COORDINATE SYSTEM IS NAD-83/91 MARYLAND STATE PLANE.

LEGEND
EXISTING MONITORING WELL (OBXX)
NEW MONITORING WELL (MW-XX)
INFERRED GROUNDWATER FLOW
CONTOUR INTERVAL (10 FT)
PROPERTY BOUNDARY
386.45 GROUNDWATER ELEVATION (FT.MSL)

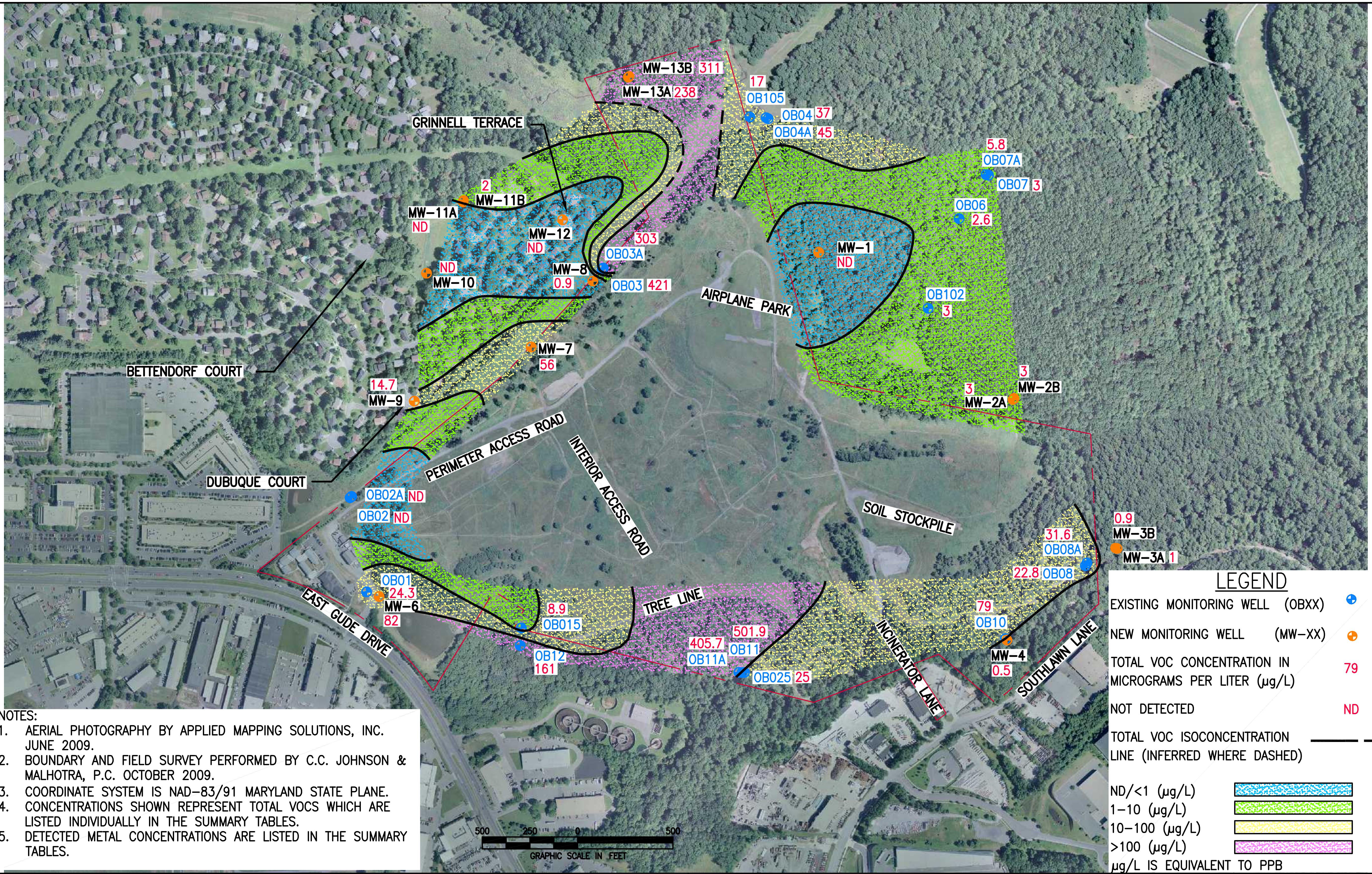
FILE PATH: Q:\PROJECTS\6219608 GUDE PHASE 1\GROUNDWATER\GWFIGURE CONTOURS_.DWG [FIG 4-1] 1/11/11

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

GUDE LANDFILL
MONTGOMERY COUNTY, MARYLAND

FIGURE 3
INFERRED GROUNDWATER FLOW MAP
DATA DATES: JULY 26–AUGUST 2, 2010

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.
PL	JP	OCT. 2010	62196.08
CHECKED BY	PROJECT MGR.	DRAWING NO.	FIGURE
BR	JK		3



NOTES:

1. AERIAL PHOTOGRAPHY BY APPLIED MAPPING SOLUTIONS, INC. JUNE 2009.
2. BOUNDARY AND FIELD SURVEY PERFORMED BY C.C. JOHNSON & MALHOTRA, P.C. OCTOBER 2009.
3. COORDINATE SYSTEM IS NAD-83/91 MARYLAND STATE PLANE.
4. CONCENTRATIONS SHOWN REPRESENT TOTAL VOCS WHICH ARE LISTED INDIVIDUALLY IN THE SUMMARY TABLES.
5. DETECTED METAL CONCENTRATIONS ARE LISTED IN THE SUMMARY TABLES.

LEGEND

EXISTING MONITORING WELL (OBXX)

NEW MONITORING WELL (MW-XX)

TOTAL VOC CONCENTRATION IN MICROGRAMS PER LITER (µg/L) 79

NOT DETECTED ND

TOTAL VOC ISOCONCENTRATION LINE (INFERRED WHERE DASHED)

ND/<1 (µg/L)

1-10 (µg/L)

10-100 (µg/L)

>100 (µg/L)

µg/L IS EQUIVALENT TO PPB

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

GUDE LANDFILL
MONTGOMERY COUNTY, MARYLAND

FIGURE 4
LANDFILL PERIMETER
TOTAL VOLATILE ORGANIC COMPOUND (VOC)
CONCENTRATION MAP, JULY 26–AUGUST 2, 2010

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.
PL	JP	OCT. 2010	62196.08
CHECKED BY	PROJECT MGR.	DRAWING NO.	FIGURE
BR	JK	–	4

FILE PATH: Q:\PROJECTS\6219608 GUDE PHASE 1\GROUNDWATER\ISO MAP 2.DWG [FIG 4-1] 1/11/11