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# FINAL REPORT

# Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module: A Multi-Site Case Study

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## EXECUTIVE SUMMARY

Geosyntec Consultants (Geosyntec) worked with a multi-disciplinary team on a previous project funded by the Environmental Research and Education Foundation (EREF) to develop the Evaluation of Post-Closure Care (EPCC) Methodology. The EPCC Methodology was developed with the aim of providing a technically defensible, performance-based approach for evaluating the site-specific elements of post-closure care (PCC) at municipal solid waste (MSW) landfills regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA). The EPCC Methodology establishes a modular, performance-based approach for evaluating the functional stability of one or more waste management units (WMUs) at a landfill facility. By sequentially addressing the four primary PCC elements (i.e., leachate management, LFG management, groundwater monitoring, and final cover system maintenance) the methodology can be used to demonstrate how and when operation, care, and/or monitoring within each module can be optimized or terminated.

### Goals of the Study

Since its publication in September 2006, Geosyntec is aware of only limited independent attempts to use the EPCC Methodology. Clearly, far more experience is needed to be able to confidently conclude that the methodology is universally useful as a means to define optimization and termination of regulated PCC obligations. To gain this experience, Geosyntec assembled a team (including representatives from EREF industry members and AquAeTer, a consulting firm) to perform a multi-site case study evaluation of the EPCC Methodology to critically examine the methodology and attempt to expose potential weaknesses. The primary goals of this study were to evaluate ten carefully selected case study sites to:

- Determine if the data prerequisites outlined in the EPCC Methodology's Technical Manual are presently available at a "typical" MSW landfill site;
- Critically appraise the methodology's usability in key areas of application in the Leachate, Landfill Gas, and Groundwater Modules, particularly with regard to its sensitivity to certain data requirements, and assess whether the methodology should be improved to address identified limitations;
- Identify data gaps and data collection needs that impede starting or completing an EPCC Methodology evaluation, and assess whether such data gaps constitute "fatal flaws" in the methodology or may be omitted, modified, or replaced by other data; and
- Provide an updated list of specific data that will be needed to complete the Prerequisites Module.

It is recognized that that the ten case study sites probably represent the best-case scenario for data availability. However, the study still serves to "ground-truth" the state of the industry relative to data availability to allow reasonable completion of an evaluation using the EPCC Methodology. As such, this study goes some way toward answering the question "does the EPCC Methodology

work in real situations?" It should be noted that the limited scope of this study cannot be expected to provide a definitive answer as to whether any case study site can actually end regulated PCC within one or more modules. Similarly, this study cannot provide the basis for using the current EPCC Methodology in a predictive capacity. Nonetheless, this study is an important continuation in the development of tools and metrics to evaluate environmental performance and PCC requirements that result from specific landfill operational practices.

**State of the Practice for Performance-Based PCC**

In Section 1 of the final report for the study, the state of the practice related to three alternative approaches (i.e., target values for organic stabilization, risk assessment, and performance-based) to define the duration of PCC was summarized. It is argued that meeting universally applied requirements to demonstrate organic stability under a target value approach would require that the rules for operation and management of all landfill shift towards reducing the organic content and pollution potential of waste prior to landfilling and/or promoting long-term threat reduction through enhanced waste degradation. While such universal stability criteria might appear to simplify proactive decision making regarding implementing measures to accelerate stabilization of the waste within a given timeframe (e.g., bioreactor operation or in-situ aeration), there are several disadvantages to this approach. For example, bioreactor and in-situ aeration operations can be expensive, require large quantities of liquids (so are unsuitable for arid sites), and can be difficult to implement retroactively at closed sites. More importantly, however, site-specific conditions and the actual threat to HHE posed by the undisturbed waste are not considered. Further, as long as some biodegradable waste is buried, it is unlikely that emissions will ever be "zero." Regulators will have to accept that the potential for some residual emission will remain, regardless of how strictly stability criteria are established – a more important consideration is thus whether such residual emissions represent a threat to HHE under site-specific conditions. In the project team's view, therefore, to demonstrate that PCC can be ended, state regulators will need to be convinced with site-specific data that the long-term threat posed by an undisturbed landfill is minimal because the residual emission potential is acceptable.

A performance-based approach such as offered by the EPCC Methodology incorporates components of a target value approach as well as conservative impact and risk assessment approaches, and therefore seem to be a viable and flexible option for making such demonstrations. The methodology is based on the concept that site-specific strategies for managing closed landfills are required to control the duration and cost of PCC while providing long-term protection of HHE. As illustrated on Figure 1-1, such strategies are based upon continual optimization of PCC as a step-down function of the characteristics of leachate and LFG, the performance of the control systems, and the sensitivity of the surrounding environment. Once conditions representing functional stability of the closed landfill can be demonstrated, regulated PCC is completed, although some de minimus level of custodial care would typically still be provided (mainly for the cover). Performance-based approaches to PCC have been increasingly embraced by State regulatory agencies and associations, not least the Interstate Technology and Regulatory Council, which has accepted that some level of custodial care for the

completed landfill property can be provided outside of the regulatory framework (ITRC, 2006c), and the California Department of Resources Recycling and Recovery (CalRecycle), which has incorporated the EPCC Methodology's concept of proactive monitoring in support of step-down demonstration of reducing PCC provisions based on performance (CalRecycle, 2010).

**Critical Review of Data Availability**

Since publication of the methodology, the project team has been made increasingly aware that the prerequisites and data collection requirements might seem daunting to new users of the methodology. This is exemplified by the very limited application of the methodology in the Florida study conducted by Tansel et al. (2008), despite the study authors' statements that their approach was based on the EPCC Methodology. In response, two data checklists were developed to help collect and accounted for the data needed for application of the methodology in a more user-friendly format. These checklists are provided in Appendices 1-1 and 1-2, respectively. The checklists were found to be invaluable for maintaining consistent standards for data collection and assembly during this project, especially by AquAeTer (who were less familiar with the methodology than Geosyntec).

As summarized on Table 3-1, the ten case studies represent a wide range of site conditions, climatic regions, liner and cover systems, and waste ages. The data and site information collected at each site was critically reviewed for completeness and compiled by the visiting project team member based on a standardized 10-15 page summary format, including between three and five standardized figures illustrating the physiographical setting of the site and stylized depictions of the its layout, features, POC, and POE. The ten completed site summaries are provided in Appendix 2. By its nature, the EPCC Methodology utilizes somewhat generic procedures; however, because all sites are unique not all procedures are appropriate in all circumstances. A key finding from this study was that taking the time to characterize a site in this way was invaluable when it came to understanding how and when certain procedures were not applicable or should be modified (as discussed where appropriate in Sections 4 and 5).

The availability of data across the ten case studies was qualitatively assessed through Section 3 (as summarized in Tables 3-2A through 3-5, which reproduce the current data requirements and classification from the Prerequisites Module for use in the Leachate, Gas, GW, and Cap Modules, respectively). Inspection of tables reveals that while data availability at these ten handpicked sites was good, none is currently ready to implement a full EPCC Methodology evaluation; all are lacking data in one or more key area. However, all should be in a position to take advantage of some level of optimization and, potentially, cost reduction. It should therefore be stressed that while the absence of key data may prevent full evaluation of a module, the EPCC Methodology was developed with the intent that every evaluation provide an opportunity to optimize care and/or monitoring. Indeed, the gradual elimination of PCC systems and activities is fundamental to the approach as previously illustrated on Figure 1-1. An intended outcome of this study is that this aspect of the methodology be better illustrated as representing both a positive outcome and the most likely result of any preliminary assessment of the Prerequisites Module.

## Recommendations for Proactive Monitoring

Site operators are encouraged to view application of the EPCC Methodology as a multi-stage process, the first stage of which should always be preliminary assembly and summarization of site information and monitoring data availability. This should be followed by development of proactive monitoring plans with emphasis on collection of leachate data. An important outcome from the study is therefore affirmation of proactive leachate monitoring requirements (provided in Appendix 1-3). These requirements, which have been updated subject to the finding from this study, provide recommendations for the quantity and duration over which leachate monitoring data should be proactively collected and processed. Thereafter, broad characterization of the WMU source, POC, and POE with respect to certain key decision processes is recommended, based on: (i) composite-sump consistency testing and trend analysis for BOD and/or other decision parameters; and (ii) determination of groundwater TOT. Both evaluations have critical implications for the total duration of performance-based PCC. They will also be critical to making proactive decisions regarding implementing enhanced waste degradation operations (e.g., bioreactor), modifying landfill management systems to take advantage of passive control technologies (e.g., constructed wetlands for leachate treatment or bioactive covers for LFG), and/or changing the closure design (e.g., inclusion of a low-maintenance all-soil alternate final cover). Consideration of all of the above is strongly encouraged.

## Updated Assessment of Data Needs for Application of the EPCC Methodology

Section 4 of the report is dedicated to answering the question: "Are the prerequisite conditions and data requirements for the EPCC Methodology reasonable and attainable for a typical MSW landfill?" The major categories of data requirements under the Prerequisite Module are discussed and reassessed based on the observed availability of data at each of the case study sites. The discussion is focused on the impact of persistently missing data for key evaluations in the four PCC modules and the anticipated burden and timeframe associated with addressing data gaps. Where appropriate, this allowed apparent data deficiencies to be accommodated or alternatives suggested without compromising the conservative nature of the EPCC Methodology. The primary deliverable from this review is provided as Appendix 1-4, which represents an updated assessment of data needed for full application of the four PCC Modules under the EPCC Methodology.

## EPCC Methodology Sensitivity to Key Data Requirements and Evaluative Procedures

From the outset of this study, the project team recognized that the outcome, or even initial applicability, of the EPCC Methodology is sensitive to certain data requirements and evaluative processes and that such sensitivity, if significant, could limit the extent to which the methodology is embraced by landfill operators and regulators. These sensitivities were investigated in Section 5, which presents and clarifies the benefits and limitations of current procedures, or provides recommended modifications to an element of the methodology where

this is technically warranted. Section 5 thus seeks to answer to the question: "Can the EPCC Methodology withstand real world application?" Preliminary findings are summarized below.

End-Use Strategy

From review of the case study sites, it was generally concluded that lack of consideration of alternative cover system designs combined with few attempts at far-sighted end use planning may represent a significant limiting factor for full application of the EPCC Methodology. This will probably manifest itself most significantly by reducing the flexibility for passive management options offered in the Cap Module and, by association, in the Leachate and Gas Modules. Overall, an important conclusion from this study should be to deliver the message that while the EPCC Methodology does not specifically advocate for alternative covers and is equally applicable to all cover system designs, it is recognized that a natural analog cover system will invariably be extremely beneficial in terms of providing iterative flexibility for evaluation of the Leachate and Gas Modules (because both modules require development of long-term leachate or LFG management strategies which are largely dependent on the type of cover in place) and opportunities to optimize PCC elements, reduce the total duration of active PCC, and extend the range of options for end use.

Leachate Module

A number of relatively complex statistical and other evaluative procedures are required prior to the Leachate Module user being able to perform analyses of composite-sump consistency and trend behavior for any analyte. Commercial data management software is available to perform these analyses. For this study, however, the project team was able to utilize the detailed descriptions for data processing and statistical manipulation provided in the Technical Manual, coupled with professional judgment, to develop a relatively simple Microsoft Excel® spreadsheet tool. Therefore, while not exactly representing "off the shelf" tools, performing the data analyses required in the Leachate Module should not represent an undue burden for a well-qualified engineer or geologist.

The primary decision parameter (DP) for leachate is BOD for which a statistically significant downward trend in concentration in a representative composite sample is used as an indicator of improving leachate quality. DP analyses require at least eight data points. In addition, to provide confidence that composite leachate data are truly representative of leachate collected across the entire basal area of a WMU, the Leachate Module requires "snap shot" consistency testing to be performed between the selected representative composite sample and at least one sample from each WMU sump. Because of the limited scope of this study, and the importance of BOD in enabling a full Leachate Module evaluation to be performed, investigation of the module's sensitivity to evaluative procedures was mainly limited to BOD data. At the five sites at which BOD data were available, useful progress through the evaluative procedures could be made at each site, from which it was concluded that the preliminary evaluations required in the leachate module are appropriate.

Gas Module

The utility of the Gas Module is greatly dependent on the estimated time that a gas plume would take to migrate from the WMU to a POC probe. In conducting this study, it was concluded that current procedures requiring measurement of internal gas pressure to estimate TOT was it is simply too complicated to be required at all sites for completion of the Gas Module. The project team therefore devised a modified screening approach for bracketed by near-zero and instability-causing gas pressures to define the duration and frequency of gas confirmation monitoring based on upper- and lower-bound TOTs, respectively. Using readily available data from the case studies, all ten sites were found to be in a position to develop reasonable gas CM programs using the new default procedures (which are provided in Appendix 1-5). This should make the Gas Module significantly more user-friendly without compromising its primary purpose of ensuring that modifications to LFG control systems are appropriate and can be demonstrated through CM to be protective of HHE.

Groundwater Module

A groundwater TOT calculation is critical to the outcome of an EPCC Methodology evaluation because the total duration of leachate- and GW-related PCC under a performance-based scenario is defined by the time taken for an unattenuated conservative tracer on the "leading edge" of a hypothetical leachate plume to migrate from the landfill to the GW POC. The project team has not considered modifying these requirements (which will be critical to the regulatory acceptance of a performance-based petition to end GW monitoring). However, to address concerns from within the regulated industry that dependence on such conservative calculations may unduly burden site operators with excessively long PCC periods and result in universal resistance to using the methodology, the project team applied and critically appraised the GW TOT calculation procedures at the ten case study sites. Findings are presented on Table 5-3. In a few cases, calculated GW TOTs were reasonable and within the 30-40 year timeframe assumed for PCC. Where this was not the case, recommendations for optimal assessment of a site based on thorough knowledge of the sites' layout and hydrogeologic models were made throughout Section 5.4. The discussions in Section 5.4 are site-specific and complex, and should be reviewed in their entirety before drawing conclusions. However, key issues for consideration include:

- At sites where the GW TOT is excessive based on there being a long distance from the representative leachate sump or low point on the liner to the GW POC, opportunities to revise the layout of the POC monitoring network or select alternative sumps are often available;
- Where GW TOT is excessive based on slow vertical migration through tight formations comprising the vadose zone (for example, where geology is dominated by tills), it may be possible to argue against GW monitoring on the basis of a USEPA-sanctioned no migration demonstration (NMD); and

- Where GW TOT is excessive based on slow horizontal migration in the saturated zone:
    - Opportunities may exist to assess groundwater flow rate in the monitored unit as stagnant (i.e., below the 5 ft/yr threshold considered representative of an aquifer), in which case GW TOT can be reassessed based on default flow and travel distance assumptions provided in the GW Module; or
    - Opportunities may exist to assess groundwater flow in the monitored unit as *de minimus*, in which case continued monitoring of GW clearly serves no practical purpose in terms of protecting HHE (for example, at one site, groundwater was calculated to flow at a rate of 0.03 ft/year, significantly below the 1 ft/yr threshold considered to represent *de minimus* flow).

Sites at which hydrogeologic conditions are unfavorable but do not yield opportunities for NMD or assessment as stagnant flow or sites at which geometric constraints offer no real opportunities for modifying the GW POC or sump location would be best served by proactive landfill operation and leachate data collection. This reinforces the value of early application of the EPCC Methodology. For example, if the constraints at a site are identified in good time (i.e., before or soon after closure), then the operator has time to consider proactive measures to actively enhance waste degradation and leachate quality. Equally importantly, the operator may be able to collect sufficient leachate data to capture maximum concentrations of all regulated parameters. If subsequent evaluation of the Leachate Module shows that these parameters pass a Source, POC, or POE Evaluation, then having very long GW TOT would be moot as no GW CM would be required.

**Conclusions and Recommendations**

In conclusion, although further experience is needed, this study serves to illustrate that a performance-based approach seems to offer a viable and flexible option for demonstrating that long-term threats posed by a WMU are acceptable based on quantifying the residual emission potential. This study highlights that, while significant data are required to make such demonstrations, taking advantage of proactive data collection plans and good data management strategies can provide immediate cost benefits along the optimization process to functional stability and custodial care, as uniquely offered by the EPCC Methodology.

Several recommendations for updating and improving the EPCC Methodology were made based on the findings from this study, as summarized above and discussed throughout Sections 3 through 5 of the report. For ease of reference, all updated or new materials emanating from this study are provided in Appendix 1. These materials should be inserted where appropriate into the EREF (2006) Technical Manual or used as supplemental resources as suggested.

## ACKNOWLEDGEMENTS

The case study sites evaluated in this study were volunteered by two EREF industry members; Veolia Environmental Services and Waste Management. Many persons within these organizations gave freely of their time and resources to help collect and interpret site records and analytical data and provide first-hand accounts of the precise chronology of construction events. In particular, the assistance provided by the following is gratefully acknowledged:

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Todd Watermolen

# 1. INTRODUCTION

This final report was prepared by Geosyntec Consultants (Geosyntec) of Columbia, Maryland for the Environmental Research and Education Foundation (EREF) of Raleigh, North Carolina to present the results of the study entitled, "*Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module: A Multi-Site Case Study*." EREF is an independent, grant-making, Internal Revenue Service 501(c)(3) charity whose mission is to develop technological innovations that promote the safety of waste service employees and the public and to improve waste service productivity and resource conservation.

## 1.1 Project Background and Terms of Reference

Between 2002 and 2006, Geosyntec worked with a multi-disciplinary team on an EREF-funded project to develop an Evaluation of Post-Closure Care (EPCC) Methodology. The EPCC Methodology was developed with the aim of providing a technically defensible, performance-based approach for evaluating the site-specific elements of post-closure care (PCC) at municipal solid waste (MSW) landfills regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA). The Subtitle D regulations were enacted by the United States Environmental Protection Agency (USEPA) and are codified under Part 258 of Title 40 of the Code of Federal Regulations (i.e., 40CFR 258). Subtitle D was developed to minimize potential environmental impacts from MSW landfills, in part by requiring PCC systems and activities at closed landfills to be installed and conducted in a manner that provides long-term protection of human health and the environment (HHE). Specific requirements for PCC are contained in 40CFR §258.61 (i.e., Subpart F of Subtitle D). 40CFR §258.61(b) specifies that PCC must be provided for a 30-year period, which can be decreased or extended by the director of an approved state solid waste regulatory agency such that the changed period is protective of HHE. However, 40CFR §258.61 neither provides nor references a standardized protocol for evaluating the condition of a landfill to demonstrate that the presumptive 30-year PCC period should be decreased or lengthened. The EPCC Methodology was developed to provide such a protocol.

A project summary report for the EPCC Methodology was prepared by Geosyntec for EREF, dated 6 September 2006. The two-volume report consisted of a main body of text and five appendices. The main report provided an overview of the project and described the development of the EPCC Methodology. The text was designed to describe the philosophy of the approach, familiarize the user with the process elements and structure, present an example of how to apply the approach at a specific landfill site, and summarize the conclusions and recommendations of the project. Appendices A through D provided details of the regulatory and technical basis for developing the EPCC Methodology in the context of evaluating threats to HHE posed by potential landfill releases. The main body and first four appendices comprised Volume I of the report. A detailed Technical Manual including logic-diagram flow charts and step-by-step instructions for completing an EPCC Methodology evaluation was provided in Appendix E,

which comprised Volume II of the report. Electronic copies of both volumes may be requested from EREF.

Electronic copies of this follow-up report may also be requested from EREF. In addition, inquiries into the development, structure, application, and status of the EPCC Methodology, as well as questions and comments regarding this follow up study, are welcomed and should be addressed to:


| | | |
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## 1.2 Key Considerations for Performance-Based Post-Closure Care

### 1.2.1 State of the Practice

Approaches for defining completion of PCC activities can be based on: (i) defining an inert endpoint using universally applicable "target values" to represent organic stabilization; (ii) a risk assessment approach; or (iii) defining the need for PCC in terms of performance in which the potential for the landfill to pose a threat to HHE, and the duration over which a potential unacceptable impact may occur, is quantified using site-specific criteria.

*Target Value (Organic Stabilization) Approach*: A number of national and sub-national (state) agencies have initiated a target value approach to assessing completion of PCC. In the U.S., Wisconsin has implemented a regulatory approach to define PCC completion in terms of stabilization of the undisturbed waste within 40 years after closure (WDNR, 2007). Internationally, Germany has proposed stability criteria (BMU, 2009) based on defining a list of limit values reflecting waste, leachate, and landfill gas (LFG) such that the PCC phase may end only when the emission potential is so low that the disturbed contents would not harm the environment (Stegmann, et al, 2003). Similarly, according to an E.U. waste directive, waste at "final storage quality" requires a situation where active environmental protection measures at the landfill are no longer necessary and the leachate is acceptable in the surrounding environment (Hjelmar & Hansen, 2005).

*Risk Assessment Approach*: The project team is not aware of any state that has promulgated a purely risk assessment approach to demonstrating the end of PCC. Internationally, draft guidance issued in the UK (Environment Agency, 2005) proposed that a demonstration of PCC completion can be based on a site-specific risk assessment in which completion is defined as the point at which a landfill has stabilized to such a degree that the undisturbed contents are unlikely to pose a pollution risk in the environmental setting of the site. Under a Dutch sustainable landfill project (Mathlener, et al, 2006), a landfill is also considered stable when the undisturbed

contents no longer pose an environmental risk. However, many landfill regulators remain largely unfamiliar with risk assessment methodologies and apprehensive about their application. Proponents of the use of risk assessment as the sole means for justifying ending PCC should expect that gaining regulatory consensus and approval might be burdensome.

*Performance-Based (Hybrid) Approach*: In the view of the project team, regulators will need to be convinced with site-specific data that the long-term threat posed by a landfill is minimal (i.e., leachate and LFG quality and quantity represent an acceptable level of emission based on a site-specific definition of the "undisturbed" landfill condition). To demonstrate that PCC can be ended, it is likely that a combination of target values and site-specific criteria will be required, along with acceptance that some level of care for a completed landfill property can be provided outside of the regulatory framework. "Hybrid" approaches such as the EPCC Methodology incorporate components of a target value approach as well as conservative impact and/or risk assessment approaches. By their nature, such hybrid approaches are performance-based and are based on the idea that site-specific strategies for managing closed landfills are required to control the duration and cost of PCC while assuring long-term protection of HHE. These strategies are based upon maintaining the functional stability of the closed landfill (see next Section 1.2.2) by optimizing the level of PCC as a function of the characteristics of leachate and LFG, the performance of the control systems, and the sensitivity of the surrounding environment. In the U.S., performance-based approaches have been increasingly embraced by State regulatory agencies and associations, not least the Interstate Technology and Regulatory Council, which has accepted that some level of custodial care for the completed landfill property can be provided outside of the regulatory framework (ITRC, 2006c), and the California Department of Resources Recycling and Recovery (CalRecycle), which has incorporated the EPCC Methodology's concept of proactive monitoring in support of step-down demonstration of reducing PCC provisions based on performance (CalRecycle, 2010).

### 1.2.2 Functional Stability and Custodial Care

Releases from landfills can impact the environment by migrating into one or more of four primary media: air, groundwater, surface water, and/or the vadose zone (i.e., soil pore spaces). In general, impacts to humans and other receptors occur through these media and, therefore, they represent the link between the contents of a landfill (i.e., waste, leachate, and LFG) and potential impacts to HHE. By understanding the manner in which these media can be impacted by a release from a landfill, potential impacts to HHE can be predicted and avoided, and plans can be developed to monitor for the presence of an impact. The potential threat to HHE posed by the MSW contained in a landfill is directly associated with its degradable organic carbon content and the presence of other constituents like nitrogen (e.g., ammonia), heavy metals (e.g., arsenic, chromium), and inorganic ions (e.g., chloride). Anaerobic biodegradation of MSW produces leachate and LFG and also results in significant settlement of the waste body over time. The quantity and concentration (flux) of landfill emissions and the extent of settlement will decrease over time. The primary function of the engineering controls, careful siting, and management of

landfills is to minimize and mitigate landfill emissions as waste degrades until such time that they are sufficiently low and/or environmentally benign that active operation or maintenance of control systems is no longer required to protect HHE. The time required for a landfill to meet this site-specific condition is primarily controlled by its climatic, hydrogeologic, and environmental setting, manner of operation, overall contaminant load, and the measures taken to control releases.

Building on the above, the term "functional stability" is used to describe a closed landfill that no longer represents a threat to HHE in the absence of PCC (Solid Waste Association of North America, Landfill Division Bioreactor Committee, 2004; Cit. in EREF, 2006). Once a landfill is considered to be functionally stable, PCC under the jurisdiction of the regulatory agency is completed, although some de minimus level of care would typically still be provided (mainly for the cover). This de minimus care is described as "custodial care" (ITRC, 2006c) and includes meeting set-aside or end-use obligations such as satisfying institutional controls and deed restrictions to restore the ecological, recreational, or other value of the land (ITRC, 2004 and 2006b).

For a landfill to achieve the conditions for custodial care the service life of the containment systems (liner and cover) should be significantly in excess of the period during which leachate and LFG production rates progressively decline to acceptable levels. Examples of proactive management changes that reduce long-term reliance on containment include use of enhanced waste degradation techniques such as bioreactor operations (ITRC, 2006a), passive fail-safe design and engineering features such as constructed wetlands for leachate treatment (Goldemund, et al, 2008) and biovents or bioactive covers for fugitive LFG control (Barlaz, et al, 2004; Kjeldsen, et al, 2008). In addition, natural analog, all-soil cover systems that mimic local ecosystems as closely as possible can be used to provide appropriate low maintenance or self-sustaining containment (ITRC, 2003; Dwyer & Bull, 2008). By defining PCC control systems and end-use conditions that emphasize environmental responsibility, engagement of the host community, and minimize the need for land use restrictions and buffers after completion of active PCC, the landfill property can become a community asset that requires minimal long-term active maintenance while remaining protective of HHE.

### 1.2.3 Fundamentals of the EPCC Methodology Approach

The EPCC Methodology establishes a modular, performance-based approach for evaluating the functional stability of one or more waste management units (WMUs) at a landfill facility. By sequentially addressing the four primary PCC elements (i.e., leachate management, LFG management, groundwater monitoring, and final cover system maintenance) the methodology can be used to demonstrate how and when operation, care, and/or monitoring within each module can be optimized or terminated. The methodology's modular approach is described in Section 2.

Concisely, evaluation of a WMU using the EPCC Methodology generally involves examining statistical trends in leachate, LFG generation, and/or groundwater quality, as well as other relevant biological, chemical, and physical data, to estimate future performance based on a demonstration that the flux of potential emissions will only decrease from the current state. The operator may demonstrate either that the landfill meets target values at the source, thereby allowing for a "fast-track" conservative demonstration of completion, or that the landfill passes a rigorous evaluation of threats posed to HHE, first at the point of compliance (POC) or, if necessary, at the landfill's point of exposure (POE). In this way, different aspects of landfill management and PCC may be considered independently at different levels (source, POC, POE) as appropriate. If an evaluation shows that no impacts to HHE due to a modification are expected, then PCC elements can be modified and monitoring performed to confirm that the decision to modify PCC was valid. If, on the other hand, the evaluation shows that impacts would be expected, then the operator continues PCC without modification until the element can be reevaluated. In this way, rather than relying on a determination that PCC is either complete or must be continued at the same level of intensity, the EPCC Methodology follows a step-down approach, evaluating each potential exposure mechanism and allowing for the possibility that certain aspects of care can be discontinued while others are maintained. For example, it may be appropriate to reduce or discontinue leachate management or groundwater monitoring while, at the same time, continuing LFG management and cover inspections. Further, where groundwater monitoring is required, it is generally not needed for the very large number of constituents that could potentially be contained in a landfill release; rather, monitoring may only be needed to detect constituents that are uniquely indicative of a release.

### 1.2.4 Using the EPCC Methodology to Optimize Post-Closure Care

The EPCC Methodology can be used during facility operation to identify measures that should reduce the long-term need for active PCC, and accelerate the potential transition to semi-passive or passive PCC. For example, well in advance of final closure, an owner/operator is strongly encouraged to apply the Prerequisites Module to ascertain current and future data requirements, conceptually evaluate interim and long-term WMU management options based on the current conditions at the facility, and perform broad feasibility and economic analyses of operational or design changes that could be implemented to reduce the need for active PCC in the future. Such changes could include proactive monitoring and collection of additional environmental data (to enhance future evaluation of the WMU), implementing enhanced waste degradation operations (such as a bioreactor), modifying landfill management systems to take advantage of passive control technologies (such as constructed wetlands for leachate treatment), or changing the closure design to include installation of a low-maintenance all-soil alternate final cover. In this way, the longer-term outlook for PCC and potential options for proactively optimizing management of the WMU can continue to be identified before funds are used on unnecessary activities. It may be most useful to evaluate the oldest closed WMUs at an active site first; in this way, the older closed WMUs can serve as an information base for anticipating the behavior

of the active portions of sites at closure (and may allow for reduction of certain activities at part of the landfill).

A conceptual illustration of a landfill's step down progress from active PCC through passive PCC and eventually to custodial care in accordance with the above procedure is presented as Figure 1-1. Examples of modifications to a leachate management system, in increasing order of the level of modification to original operating conditions, might include:

- Optimizing current leachate collection and removal system (LCRS) operation and leachate management (e.g., minimizing leachate generation to resize leachate storage facilities, rescheduling monitoring events or leachate disposal to POTW, realigning leachate transmission systems to take advantage of gravity flow conditions);
- Implementing long-term lower maintenance or passive engineered leachate controls (e.g., replacement of electric pumps with wind- or solar-powered models, gravity drainage of leachate into constructed wetlands, natural biofilters, or infiltration galleries); or
- Ceasing LCRS operations and leachate management altogether such that no leachate control activities remain for which active operation or maintenance is required.

Similarly, LFG generation at very low levels may well continue long after it is economically or technically feasible to collect and/or utilize the gas. Passive treatment systems such as the utilization of waste derived compost or organic-rich soils to actively encourage methane oxidation in biocovers or specially constructed bioventing systems can provide a means of passive low maintenance emission control. Examples of modifications to an existing LFG management system that could be considered include the following:

- Scaling back from operating a fully active gas collection and control system (GCCS) across the entire landfill to an intermittently operated active GCCS, or changing from a LFG-to-energy facility to smaller utilization projects;
- Scaling back from continuous or intermittent GCCS operation over the entire landfill to operation over some portions of the landfill only (e.g., emissions 'hotspots'); or
- Shutting-down an active GCCS and converting to a passive system using passive flares with solar self-ignition systems, biovents, bioactive capping, and/or cut-off trenches.

Used in this way as intended, the EPCC methodology can be a powerful tool for understanding the impacts of past and present operational practices on the duration and cost of PCC.

## 1.3 Study Objectives and Scope

### 1.3.1 Primary Objectives

The previous project to develop the EPCC Methodology focused on optimizing PCC maintenance and monitoring requirements and evaluating scenarios allowing a site to end regulated PCC. However, the methodology was applied to only one example site (a closed pre-Subtitle D landfill unit at an active facility in Delaware) during the study. Since its publication in September 2006, Geosyntec is aware of only one independent attempt to use the methodology – a limited application of some portions of the Leachate and Landfill Gas Modules at two closed landfills in Florida (Tansel et al., 2008). Far more experience is needed to be able to confidently conclude that the methodology is universally useful as a means to define optimization and termination of regulated PCC obligations. To gain this experience, Geosyntec and EREF assembled a team to perform a multi-site case study evaluation of the EPCC Methodology to critically examine the methodology and expose its potential weaknesses.

The primary goals of this study were to evaluate ten selected case study sites to:

- Determine if the data prerequisites outlined in the EPCC Methodology's Technical Manual are presently available at a "typical" MSW landfill site;
- Critically appraise the methodology's usability in key areas of application in the Leachate, Landfill Gas, and Groundwater Modules, particularly with regard to its sensitivity to certain data requirements, and assess whether the methodology should be improved to address identified limitations;
- Identify data gaps and data collection needs that impede starting or completing an EPCC Methodology evaluation, and assess whether such data gaps constitute "fatal flaws" in the methodology or may be omitted, modified, or replaced by other data; and
- Provide an updated list of specific data that will be needed to complete the Prerequisites Module.

It is recognized that certain data collection efforts will likely be needed in the future to satisfy all module evaluation requirements in accordance with the overall approach of the EPCC Methodology. It is also recognized that the ten case study sites selected probably represent the best-case scenario for data availability at a Subtitle D WMU. However, this study still serves to "ground-truth" the state of the industry relative to data availability to allow reasonable completion of an evaluation using the EPCC Methodology.

### 1.3.2 Project Scope

#### 1.3.2.1 Task 1: Screening Criteria and Site Selection

Under Task 1, three levels of screening criteria were developed:

- *Critical Screening Criteria*: Criteria that must all be met in order for a site to be considered as a candidate for inclusion in the study (i.e., to eliminate sites with significant data gaps which, although perhaps more representative of a "typical" site, would not be useful for this study);
- *Site Variability Criteria*: Additional criteria to narrow down the list of candidate sites and provide a representative cross section of sites for the study; and
- *Data Requirements*: Detailed information and data needed for a site to make the final list of ten sites.

The first two screening levels were used to develop a screening criteria "Checklist 1" for site selection, targeting candidate sites for potential inclusion in the study, and communicating site selection criteria and data requirements to site managers. Thereafter, a more detailed "Checklist 2" with standard procedures for data collection and assessment of data gaps at the final screening level was developed based on the comprehensive procedures of the EPCC Methodology Prerequisites Module.

The site screening and case study selection process under Task 1 is described more fully in Sections 3.1 and 3.2.

#### 1.3.2.2 Task 2: Comprehensive Site Data Collection

Under this second task, the team visited the case study sites to assemble available data (i.e., such data as has already been collected and is on file at the site or elsewhere) for a preliminary evaluation. Initial collation activities and screening/quality control of collected data was undertaken, such that data quality can be formally confirmed by the project team to be of sufficient quality for inclusion in the study. All data collection and processing activities under this task were conducted with a view to maximizing the efficiency of any additional data collection in the future. Data requirements were based on: (i) site operational records (e.g., annual weight/volume of refuse accepted, landfill disposal areas, waste types, etc.); (ii) site-specific data (e.g., liner and cover system components, on-site and/or off-site structures, surface water bodies, stormwater management features, etc.); (iii) leachate characterization data; (iv) landfill gas data; (v) groundwater data; (vi) cover system and settlement data; and (vii) meteorological data.

Data collection protocols and activities are described more fully in Section 3.3. The case study sites are described in Section 3.4.

#### 1.3.2.3 Task 3: Cross Evaluation of Data Sets

Under Task 3, the available data sets from the ten sites visited in Task 2 were evaluated for completeness, paying particular attention to situations in which the conservative nature of the PCC modules needs to be reconsidered based upon the relative importance of persistently

missing data. Under current procedures in the Prerequisites Module, such missing data could keep an otherwise promising site from entering the evaluation process. Using Checklist 2 from Task 1 to guide data collection allowed objective cross evaluation between sites and identification of "roadblock" data requirements that were considered essential during development of the EPCC Methodology but most/all sites have trouble obtaining (e.g., internal gas pressure in a landfill for evaluation of the Gas Module, due to practical or regulatory difficulties with shutting down an active gas extraction system for long enough to obtain a valid measurement).

Section 4 of this report is dedicated to answering the question: "Are the prerequisite conditions and data requirements for the EPCC Methodology reasonable and attainable for a typical MSW landfill?" The findings from Task 3 are discussed and recommendations provided for overcoming problems with persistently missing data and data roadblocks, including suggestions for potential modifications to portions of EPCC Methodology modules to make them more responsive to real world data. In this regard, the type and quantity of some data required is reassessed along with the current classification of certain data as "critical" or non-critical" for successful implementation of a module.

#### 1.3.2.4 Task 4: Sensitivity Analysis

The EPCC Methodology recommends data evaluation methods (e.g., generation of a single representative value for maximum and/or current leachate analyte concentration from a series of temporal measurements) that are not easily evaluated using "off the shelf" tools and may limit the methodology's current usability. In addition, the methodology is likely to be sensitive to certain input requirements and evaluative processes (e.g., leachate trend analysis or groundwater time-of-travel). Under Task 4, the team attempted to "break" the methodology through critical evaluation of the sensitivity of the methodology to key inputs/processes using actual site data combined with a number of assumptions (where necessary to fill data gaps).

The findings from Task 4 are discussed in Section 5 in the context of answering the question: "Can the EPCC Methodology withstand real world application?"

#### 1.3.2.5 Task 5: Summary Report

Task 5 required that a final summary report to review and discuss the findings from the study be provided to EREF. This report constitutes completion of Task 5. Conclusions and recommendations from the study are provided in Section 6.

# 2. UPDATED OVERVIEW OF THE EPCC METHODOLOGY

Under Subtitle D, an owner/operator is required to monitor and maintain a closed landfill for the duration of the PCC period. Specific requirements for PCC activities at MSW landfills as contained in 40CFR §258.61 include four elements: (i) leachate management; (ii) monitoring explosive landfill gas (LFG) migration; (iii) groundwater monitoring; and (iv) maintaining the integrity and effectiveness of the final cover. The main purpose of the EPCC Methodology is to demonstrate how/when operation and/or monitoring of these PCC elements can be optimized or terminated. Additional care and site-management activities may be required at a closed MSW landfill (including, for example, LFG collection and control, site access control and security, stormwater management, and general site maintenance). Although these activities are not specifically within the scope of Subtitle D, they nevertheless represent necessary care to be provided during the PCC period and are therefore addressed where appropriate in the EPCC Methodology.

## 2.1 Key Features

### 2.1.1 Recommended Application and Limitations

The EPCC Methodology can be used during facility operation to identify measures that should reduce the long-term need for active PCC, and accelerate the potential transition to semi-passive or passive PCC. Well in advance of final closure, an owner/operator is strongly encouraged to apply the Prerequisites Module to ascertain current and future data requirements, conceptually evaluate interim and long-term WMU management options based on the current conditions at the facility, and perform broad feasibility and economic analyses of operational or design changes that could be implemented to reduce the need for active PCC in the future. Whether or not a pre-closure evaluation is made, a full EPCC Methodology evaluation should be performed no later than ten years after closure. Thereafter, at a minimum 10-year frequency, evaluation of one or more PCC modules should be performed as necessary to update information and reconsider PCC elements that are still necessary. In this way, the long-term outlook for PCC and potential options for proactively optimizing management of the WMU can continue to be identified before funds are used on unnecessary activities. Evaluation frequencies should also be decided on site-specific bases (e.g. during five-year permit renewals, or other intervals based upon site-specific conditions).

Each of the four PCC modules comprising the EPCC Methodology could be used at any Subtitle D MSW landfill facility that is subject to the requirements of 40CFR §258.61. The EPCC Methodology was not developed with the intent that it be applied at sites that have already been released from some or all PCC obligations by the regulatory agency. Because a landfill facility can have several different WMUs (e.g., phases, areas, and/or cells) that may each require different types of PCC, the methodology is intended for application at specific WMUs instead of an entire landfill facility.

The EPCC Methodology was developed specifically for application at WMUs regulated under Subtitle D; therefore, its application at any other type of facility may not be universally appropriate. However, its usefulness in evaluating PCC needs for other kinds of facilities may be considered in discussions with owners/operators of such facilities, taking into account the differing characteristics of such facilities and contained wastes. For example, because it is common for operating Subtitle D MSW landfill facilities to contain one or more closed WMUs that pre-date the regulation, the EPCC Methodology was developed so that it could be applied to both lined and unlined WMUs. Unlined WMUs may not have the means to collect and characterize leachate quality over a sufficient period to characterize historical leachate quality and generation at the WMU, but might choose to assess PCC duration at these units using assumed values that are highly conservative. Suggested considerations and important restrictions regarding the applicability of each PCC module to unlined Subtitle D landfills are provided in the methodology's Technical Manual.

### 2.1.2 Modular Approach

The modular approach to the EPCC Methodology is illustrated on Figure 2-1. Where the methodology is applied in full, the five modules are designed for evaluation in the specific order shown. Therefore, before evaluating the four PCC modules, the two evaluations in the Prerequisite Module are undertaken: (i) an end-use strategy should be identified; and (ii) the module-specific data requirements and prerequisites must be identified and completed. The Leachate and Landfill Gas Modules are largely independent of each other and both their source media have the potential to impact groundwater and/or to be affected by the condition of the cap. Their shared status in this regard is inferred by their being placed side-by-side on Figure 2-1. However, the reason for placing the Leachate Module ahead of the Landfill Gas Module is that modifying the leachate management strategy (which must, by association, be accompanied by defined cap performance requirements) has the potential to affect LFG generation and migration/emission potential at the WMU. An acceptable leachate management strategy should, therefore, be established before any further evaluations can take place, and this strategy must then be carried forward consistently into all subsequent modules. The Groundwater Module is placed after these two modules because both leachate and LFG are potential sources of impacts to groundwater and should be characterized prior to evaluating the adequacy of groundwater monitoring systems. Finally, the cap provides the ultimate level of control for other PCC components and, therefore, the cap's structure as well as maintenance and monitoring activities must be consistent with the outcome of all other modules. For this reason, the Cap Module is placed last.

Prior to evaluation of PCC under any EPCC Methodology module, the user must define the end use for the WMU being evaluated and satisfy module-specific data requirements and prerequisites. Defining an end-use strategy and establishing data requirements and prerequisites are placed in the stand-alone Prerequisites Module to encourage proactive identification of potential limitations ahead of attempting to apply the EPCC Methodology procedures in their

entirety. As previously described in Section 2.1.1, this will help identify that proper data are available, and additional data of sufficient quality are collected, before expending a significant level of effort on evaluating PCC at a WMU. Because it is critical examination of the data requirements for each PCC module that is the focus of this study, specific details and procedures pertaining to the Prerequisites Module are examined in more detail in Section 2.2.

After prerequisites have been satisfied, application of each of the four PCC modules generally involves: (i) an evaluation of whether a change in PCC is appropriate; and (ii) subsequent monitoring to confirm that any change in PCC did not produce an unexpected outcome. Key features of every evaluation using one of the four PCC modules include the following:

- Evaluations cannot be made for any of the four PCC modules until prerequisites are satisfied and the data required for the evaluations have been collected; and
- Trends in indicators of environmental quality are evaluated based on quantitative, statistical evaluations of data that are intended to provide a rational basis for making decisions about the future need for PCC; and

Two new types of monitoring are proposed in the EPCC Methodology, both of which are designed to provide a high level of confidence that any decision to alter PCC was appropriate and protective of HHE:

- *Confirmation Monitoring*, which is performed during the PCC period to confirm that a change in PCC systems and/or activities resulted in the outcome that was predicted; and
- *Surveillance Monitoring*, considered "insurance" monitoring, which is performed on a geometrically reducing schedule after Confirmation Monitoring has demonstrated that PCC for a module is no longer required.

Termination of PCC can only occur for an element (or all elements) after Confirmation Monitoring has demonstrated that no further maintenance is needed and subsequent Surveillance Monitoring has demonstrated that no further monitoring is needed. For the Leachate, Gas, and Groundwater Modules, completion of Surveillance Monitoring represents the completion condition for regulatory PCC within these modules, although this status might be predicated on the long-term performance of the cap. For example, completing PCC in the Leachate Module may mean that no maintenance or monitoring of leachate controls or potentially impacted media is needed as long as the cap continues to provide some minimum level of infiltration control.

#### 2.1.2.1 Leachate Module

Leachate represents one of the two primary sources of threat to HHE posed by a landfill (the other being LFG); therefore, demonstrating that leachate is not a potential threat to HHE is a primary driver for functional stability and elimination of active leachate management. The main purpose of the Leachate Module is to evaluate how LCRS operation and other leachate

management activities may be modified, optimized, or terminated if leachate does not threaten HHE. Where it is necessary to continue managing leachate in the medium or long term, the module facilitates decision-making with regards to how this may be done in a more effective, low maintenance, or self-regulating way such as using wetlands or natural biofilters for onsite treatment with direct discharge rather than transporting untreated leachate to offsite publicly-owned treatment works (POTW) for disposal. Potential threats to HHE posed by a leachate release are evaluated using a step-up approach based on:

- The existence of adequate monitoring data collected over a sufficient period of time to confidently characterize the leachate source in terms of regulated parameters in groundwater and/or surface water;
- A demonstration that the historical concentration trend for a leachate decision parameter is decreasing or steady;
- A proposed strategy for long-term leachate management;
- Demonstration of the acceptability of the proposed leachate management strategy based on evaluation of the potential threat to HHE at the groundwater and/or surface water POC; and
- Successful navigation through a series of post-modification confirmation monitoring processes (including in the Groundwater Module) that provide a check on the accuracy of original evaluations.

In the first step, leachate data are processed to address censored data, outliers, and distributional form. Thereafter, a statistically representative mean is computed for each analyte. The second step requires selection of a decision parameter for which a statistically significantly steady or decreasing trend must be demonstrated. Research (Cit. in EREF, 2006[1]) indicates that about half the organic carbon of MSW may be sequestered and that mobilization of metals in leachate over the long term is unlikely unless landfill conditions are allowed to deteriorate significantly. Furthermore, as the material in a landfill degrades, the bottom-most MSW layers become well decomposed and act as a biofilter with a relatively inexhaustible attenuating capacity for

[1] Since publication of the EPCC Methodology, the project team has actively continued to conduct and/or review research efforts and published studies related to long-term leachate quality, carbon sequestration in landfills, and development of a bottom-most biofilter. A number of studies have provided additional support for the procedural assumptions used during development of this critical step of the Leachate Module, including Barlaz (2006), USEPA (2006; 2007), and Barlaz, et al (2007) in relation to organic carbon sequestration, and Robinson, et al (2004) which describes recommendations by the environmental protection agency in the U.K. for landfill designs to include a stabilized buffer layer above the leachate collection system to neutralize and potentially remove heavy metals from leachate. Finally, two EREF-funded studies (Statom, et al, 2004; Gibbons, et al, 2007) evaluated long-term trends of inorganic ions, metals, and volatile organic compounds (VOCs) in leachate as a function of time using a robust data set with variability in climate, waste composition, the age of waste at the time of capping. Findings from Gibbons, et al (2007), a multi-year longitudinal study used an expanded database of more than 1,400 sample events from 101 closed landfill cells of various MSW ages, are particularly relevant here because many of the case study WMUs used in this report were also included in that study. Results indicated that a majority of constituents show a decreasing trend with time in the post-closure period generally consistent with BOD as the major indicator.

consuming degradable organics and heavy metals in leachate. For this reason, and assuming that it is emission of leachate from the base of the landfill that will remain of primary concern, biochemical oxygen demand (BOD) is typically used as the primary decision parameter in analysis of leachate trend behavior (if the BOD trend is steady or decreasing, a deeper evaluation for regulated parameters is conducted; if the BOD trend is increasing, then it cannot be confidently concluded that concentrations of regulated parameters have peaked). Other useful indicators of long-term leachate management requirements are chemical oxygen demand (COD), ammonia-nitrogen ($NH_4$), an important surface water analyte, degradation of which is limited under anaerobic conditions, and chloride ($Cl^-$), a conservative indicator useful for defining future GW monitoring requirements.

#### 2.1.2.2 Landfill Gas Module

Under Subtitle D, LFG management is required primarily to control subsurface migration of explosive gases. The main purpose of the Gas Module is thus to provide a technically defensible procedure by which to evaluate modifying an existing LFG control and migration monitoring system such that the intensity of monitoring and maintenance activities can be reduced or eliminated because it is demonstrated that there is no threat to HHE through LFG migration. Although the Gas Module focuses on the requirements for monitoring migration of explosive gases, compliance with applicable air quality and greenhouse gas (GHG) control regulations is also required. In addition, there may be other reasons why a LFG control system was installed at a landfill (e.g., methane utilization, odor control, or mitigation of gas-to-groundwater impacts); these should all be considered to define the current need for LFG management.

Once a future LFG management strategy has been proposed, which may or may not incorporate continued operation of an active LFG control system, its suitability needs to be evaluated. This qualitative evaluation is related mainly to the extent of the modification proposed as well as the remaining LFG generation and gas migration potential given the WMU's environmental and geologic setting. The approach involves a step-down evaluation in which a fast-track screening evaluation is initially performed. Thereafter, if a clear decision on modifying LFG controls cannot be made using screening criteria, a site-specific risk assessment for LFG migration is undertaken. Passing a screening or risk evaluation allows implementation of the proposed LFG management strategy, along with an appropriate monitoring program based on the time of travel for gas migration through the unsaturated zone from the toe of study unit to monitoring probes at the POC.

#### 2.1.2.3 Groundwater Module

The primary purpose of the Groundwater (GW) Module is to provide a basis for deciding when GW monitoring may be terminated. In addition, portions of the GW Module provide guidance on modifying or optimizing the monitoring program during intermediate steps of the PCC period. The GW Module typically follows evaluation of the Leachate and Gas Modules to characterize the landfill source (taking into consideration the effect of existing/proposed cover conditions and

any proposed modifications to leachate and/or LFG management) and assess whether source leachate or LFG poses a current or future threat to HHE at the GW POC and/or POE. The systematic approach in the GW Module is based on:

- Estimating the TOT for a potential leachate release to migrate from an appropriate upgradient landfill release location (sump or low point on the base of the liner) to the downgradient GW POC;
- Optimization of GW monitoring activities such that the duration and frequency of monitoring and the list of monitored analytes are suitable based on site-specific conditions;
- Transfer of GW monitoring to a Confirmation Monitoring (CM) program, which is performed for sufficient duration (based on the TOT) to confirm that any potential impacting releases to GW that might have occurred in the past would have already reached the POC and been detected if they had actually occurred; and
- Eventual termination of all GW monitoring through a process of geometrically decreasing Surveillance Monitoring following completion of CM.

The GW Module requires calculation of two TOT terms: (i) maximum TOT (which is used to establish the optimal duration of GW monitoring); and (ii) minimum TOT (which establishes the optimal GW monitoring frequency).

#### 2.1.2.4 Cap Module

Installing a final cover system (closure cap) that minimizes infiltration into the waste is the primary focus of landfill closure requirements under Subtitle D. The purpose of a cap is also to limit exposure to leachate, LFG, or waste via direct contact, groundwater, or surface water at levels that would constitute a threat to HHE. This requires that the cap provide containment until the threat posed by leachate, LFG, and waste is de minimus. Therefore, the central questions to answer with regard to cap performance are:

- Does containment of leachate, LFG, and/or waste need to be continued?
- If the condition of the cap were to change, or if there were no cap, would the quantity and/or quality of leachate, LFG, and/or waste change in a way that would adversely threaten HHE and thus require active maintenance of containment?
- Given some performance requirements for the cap, what needs to be done for the cap to fulfill, and continue to fulfill, its required function?
- At what stage and under what conditions can it safely be assumed that the level of PCC required in the Cap Module will be de minimus?

The Cap Module is the final component in the evaluation process, because the cap system at a WMU is not an entity in itself, but exists primarily to control leachate, LFG, or direct contact with waste. As such, the status of the Leachate and Gas Modules (and hence the Groundwater Module) are generally dependent on a certain level of cap integrity and, by association, maintenance. Evaluation of the Cap Module will likely show that some care of the cap will be needed even after completion of regulated PCC to continue satisfying local land-use requirements, comply with any deed restrictions, contain the waste, and/or maintain the outcomes of the other three PCC modules. As previously introduced in Section 1.2.2, this phase of de minimus care after completion of regulated PCC is termed custodial care. In addition to providing de minimus oversight of cap integrity, a custodial care program would also include property management obligations that are typical of any property owner, such as paying property taxes, assuming responsibility for upkeep of access controls, and complying with local zoning ordinances and property use restrictions identified in the deed. In many ways, the level of custodial care required in these circumstances is entirely similar to the care required at sites exiting post-remediation care under well-established USEPA brownfield programs.

#### 2.1.2.5 Final Outcome

The multiple outcomes provided for under the EPCC Methodology can vary from fully active PCC still being required under all modules, to partially active or passive PCC in one or more modules, and finally to no post-closure requirements and custodial care. Any module(s) still requiring active PCC can be revaluated in the future when conditions at the WMU change. Every effort should be taken to reevaluate the WMU as soon as appropriate. Subsequent reevaluations will likely be simpler than initial evaluations as the requisite data are identified and the intensity of PCC in one or more other modules may have already been reduced. In these cases, the reevaluation can be focused on only those the items which caused the module to remain in active PCC. Where it is identified that a module is likely to remain under active status for a long period unless proactive measures are taken to reduce the long-term PCC requirements at the WMU (e.g., bioreactor operations or in-situ aeration), these should be considered.

## 2.2 Prerequisites Module

A number of module-specific prerequisites and minimal data requirements must be satisfied before evaluations in any PCC module can commence, as the existence of some conditions at a WMU may affect application of a particular module. In some cases, determining whether a prerequisite is satisfied is elementary: for example, if a WMU does not have a LCRS and leachate data has not been collected via some other means, then clearly the Leachate Module cannot be utilized (because there is no leachate management). In other cases, prerequisites may relate more to the condition of the WMU, status of PCC, and extent of monitoring and recordkeeping. If module-specific data requirements and prerequisites cannot be fulfilled for any subsequent module in the EPCC Methodology, then more data or more conservative assumptions may be required prior to the evaluations in that particular module.

The Prerequisites Module essentially comprises two separate steps:

- Define the end use for the WMU being evaluated; and
- Identify that data requirements and prerequisites for each module are satisfied.

Defining an end-use strategy and establishing data requirements and prerequisites are placed in the stand-alone Prerequisites Module to encourage early identification of potential limitations ahead of attempting to apply the EPCC Methodology procedures in their entirety. This will help identify that proper data are available, and additional data of sufficient quality are collected, before expending a significant level of effort on evaluating PCC at a WMU.

The EPCC Methodology was developed for use at any point during, or prior to, the PCC period at a Subtitle D WMU. An owner/operator can thus conduct an initial evaluation before closure to identify the required data that should be collected during PCC. This pre-closure application is strongly recommended and will, at a minimum, require implementation of the Prerequisites Module, although preliminary examination of the other four modules may also be advantageous.

It is recognized that the Prerequisites Module is proactive and encourages considerable collection and management of data some time before they are likely to be utilized. Some of the data may not be required under permit conditions and there may be additional data management efforts (e.g. converting historic data records to electronic format). These efforts are a critical component of the EPCC Methodology and their postponement may simply delay application of the methodology. However, a key component of this study is to examine the significance of persistently missing data and provide recommendations for overcoming problems with data "roadblocks" including, where possible, suggestions for potential modifications to the Prerequisites Module and/or portions of other modules. This is consistent with the vision for the EPCC Methodology during its development; the modular nature of the methodology was always intended to allow it to be flexible, dynamic, and responsive to the reality of data collection.

### 2.2.1 General Conditions and End Use Strategy

The end use obligations and strategy for a WMU will govern the outcome of each module and the final condition of the WMU; as such, these must be considered from the outset of an EPCC Methodology evaluation. Developing and defining an end-use strategy involves defining the long-term condition of the WMU site and its relationship with the surrounding environment (e.g., environmental protection systems, waste containment systems, property uses at the site, etc.) that will form the basis for the evaluations performed under the EPCC Methodology. In many cases, the strategy might formalize institutional controls for longer-term care. Once an end-use strategy has been defined, it must be carried forward consistently into future evaluations in subsequent PCC modules. It is recommended, therefore, that as wide a range of potential end uses is included in the definition and scope of the overall strategy developed. In this way, some alternatives or changes in end use within defined ranges may be considered during subsequent

module evaluations without the need to reevaluate whether the proposed alteration is consistent with the overall strategy. This will enable evaluation of the EPCC Methodology as a whole to be more flexible.

When a component of PCC in any module has been completed with respect to the regulatory framework (i.e., evaluations have demonstrated that regulated PCC can safely be eliminated and all remaining care activities transferred from a regulated PCC program to a post-regulatory custodial care program), predetermined end use obligations for the site must continue to be met. This forms the primary basis for defining the requirements of custodial care. Developing an end-use strategy is by necessity site-specific and is likely to be a somewhat iterative process. The strategy will need to consider:

- Land use designation requirements under Subtitle D and other local, state, or federal brownfield regulations as they relate to the WMU site;
- The availability, provision, maintenance, and enforcement of deed notices, restrictive covenants, zoning/ordinance laws, and/or other forms of institutional control, the circumstances in which they apply, and their associated costs;
- The cost-effectiveness and practicality of proposed end use alternatives; and
- Other non-technical issues and potential liabilities, including legal issues, regulatory limitations, and/or community concerns.

It is extremely important to recognize the significant potential contribution of the end-use strategy towards the timing and eventuality of transferring care activities at the WMU to custodial care. It is strongly recommended that this contribution be optimized and be defined in as flexible a manner as practicable.

### 2.2.2 Module-Specific Prerequisites and Data Requirements

In addition to providing background information on meeting the general prerequisites for an EPCC methodology evaluation, the Prerequisites Module describes in detail the specific prerequisites and data requirements for each of the four PCC modules. The Prerequisites Module comprises Chapter 3 of the EPCC Methodology Technical Manual; it is strongly recommended that this chapter be reviewed prior to or in conjunction with the remainder of this report.

Module-specific prerequisites and data requirements are described in the remainder of this section. For each PCC module, data requirements are listed according to four classifications as follows:

- *Critical (C)*: These data are considered essential for completion of a module and therefore must be available for evaluation. Unavailability of any data with this classification constitutes a prerequisite failure for the module in question and excludes the possibility of fully evaluating the module at the current time. However, where these data are not available and cannot be reasonably obtained, the EPCC methodology allows substitution of values from other credible sources if it is identified in an evaluation that this is acceptable.
- *Non-Critical (NC)*: Successful completion of an evaluation is considered possible without these data, but the outcome of the evaluation may be more limited.
- *Flag (F)*: This data may or may not be required depending on site conditions and the type and/or level of evaluation performed (e.g., groundwater characteristics are not required for any evaluation relating to a direct leachate release to surface water).
- *Supplemental (S)*: These additional data may be required only for a risk evaluation at the POE where previous source and POC evaluations have failed. Although it is not required to have all these data before entering a module, they are listed to facilitate proactive data assembly should the need or desire to perform a risk evaluation arise at a later stage.

The Prerequisites Module also specifies data quantity and collection frequency and provides guidance on data collection methodologies and quality control. A full listing of required data for all four PCC modules in accordance with the C, NC, F, and S classification system is reproduced in Tables 3-2A through 3-5 where presented in relation to data availability findings from this study.

#### 2.2.2.1 Leachate Module

The prerequisites and data requirements for application of the Leachate Module are provided in Section 3.3 of the Technical Manual. In brief, the module's five prerequisites are: (i) existence of a LCRS with the means to sample leachate; (ii) no evidence of current impacts caused by leachate; (iii) adequate data on leachate quality and quantity from established sample points at the WMU with which to establish behavioral trends using an appropriate statistical approach; (iv) adequate site information to characterize the WMU in relation to its surrounding environment and identify and characterize receiving bodies for potential leachate releases; and (v) selection of an appropriate (i.e., conservative, unattenuated) indicator parameter for groundwater Confirmation Monitoring. Chloride is the primary indicator of choice; however, use of this anion is generally predicated on there being clear distinction (e.g., order of magnitude difference in chloride concentrations) between source leachate and background groundwater quality.

The Leachate Module data requirements are listed in Table E-3-1 of the Technical Manual. The major categories of data are: (i) prerequisites (e.g., identification of groundwater and/or surface water standards); (ii) site details (e.g., liner and LCRS layout and basegrades, sump types and

locations, locations of the POC and POE, waste acceptance records, cover system design, and topographic survey data); (iii) characteristics of receiving bodies and hydrogeologic data; (iv) leachate monitoring data for indicator parameters and regulated analytes; and (v) other data (e.g., meteorological data and risk exposure factors).

#### 2.2.2.2 Landfill Gas Module

The prerequisites and data requirements for application of the Gas Module are provided in Section 3.4 of the Technical Manual. In brief, the module's three prerequisites are: (i) existence of a gas management system and/or methane migration monitoring system; (ii) no evidence of current impacts caused by LFG based on screening or secondary criteria for migration and groundwater; and (iii) adequate data with which to characterize LFG generation and composition, WMU internal pressure, and LFG emission and/or migration from the WMU to its receiving environment. Compliance with non-Subtitle D regulation of LFG emissions under the USEPA's New Source Performance Standards (NSPS) and Emissions Guidelines (EG) obligations (USEPA, 1996), or other applicable local, state, or federal rules and regulations related to LFG and GHG emissions control, should also be accounted for.

The Gas Module data requirements are listed in Table E-3-2 of the Technical Manual. The major categories of data are: (i) prerequisites (e.g., LFG migration monitoring records); (ii) site details (e.g., gas control system type and design, WMU layout and locations of the POC and POE, waste acceptance records, operational practices, and cover system design); (iii) characteristics of sensitive receptors for methane migration; (iv) LFG monitoring data and WMU internal gas pressure; and (v) other data (e.g., meteorological data and risk exposure factors).

#### 2.2.2.3 Groundwater Module

The prerequisites and data requirements for application of the Groundwater (GW) Module are provided in Section 3.5 of the Technical Manual. In brief, the module's three prerequisites are: (i) existence of a Detection Monitoring Program (i.e., groundwater monitoring currently in compliance with permit conditions for a Subtitle D landfill); (ii) availability of adequate data and site information for hydrogeologic characterization; and (iii) selection of an appropriate (i.e., conservative, unattenuated) indicator parameter for groundwater Confirmation Monitoring.

The GW Module data requirements are listed in Table E-3-3 of the Technical Manual. The major categories of data are: (i) prerequisites (e.g., identification of groundwater standards); (ii) site details (e.g., layout of WMU, locations of the groundwater POC and POE, waste acceptance records, and cover system design); (iii) characteristics of receiving bodies and hydrogeologic data; and (iv) other data (e.g., meteorological data).

#### 2.2.2.4 Cap Module

The prerequisites and data requirements for application of the Cap Module are provided in Section 3.6.2 of the Technical Manual. Specific prerequisites and data requirements for performing the evaluations in the Cap Module (assuming the EPCC Methodology is applied in it's entirety) are: (i) an end-use strategy that identifies an acceptable range of cap performance criteria based on regulatory considerations and institutional controls should have been developed; (ii) the outcome status of all previous modules that have undergone an evaluation should have been established and be consistent with the end-use strategy; (iii) an interim or final cap must have been installed and the cap and the cap monitoring and maintenance program must currently be in compliance with existing permit conditions and PCC regulations; and (iv) sufficient data and site information should be available with which to characterize the performance of the cap (e.g., with respect to settlement, control of infiltration, and LFG emissions) during the WMU's active and post-closure periods.

Meeting the first two prerequisite conditions is dependent on the outcomes of previous modules and cannot be directly controlled or influenced through any activities performed in the Cap Module. In this regard, the Cap Module is somewhat different to the previous three PCC modules in that an evaluation must be undertaken and a satisfactory outcome obtained if any previous module was evaluated. This is because evaluation of the previous three modules will almost certainly result in an outcome that is dependent on some level of cap performance. In such cases, simply leaving existing cap-related PCC systems and activities in place (the fallback position taken when failing to meet prerequisites in the Leachate, Gas, or GW Module) may not meet the needs of the other modules.

# 3. SITE SELECTION AND DATA COLLECTION

Geosyntec and EREF assembled a team to perform a multi-site case study evaluation of the EPCC Methodology to critically examine the methodology and expose its potential weaknesses. As a first step, the team developed some screening criteria for site selection in order to identify a candidate list of MSW landfill sites from which to select ten sites for inclusion as a case study. During the site selection process, participation from all EREF industry members with closed MSW landfills was actively sought. In addition, because Geosyntec is already intimately familiar with the EPCC Methodology, a second consulting firm, AquAeTer of Centennial, Colorado, was included in the project team to allow the usability of the methodology under real world conditions to be evaluated independently of the original development team. AquAeTer was selected because they have the expertise in the various PCC components to be able to critically assess site data as well as the assumptions, methods, and criteria embedded in the methodology, and help evaluate the current methodology for omissions, limitations, and/or weaknesses.

## 3.1 Screening Criteria

Three levels of screening criteria were developed: (i) critical screening criteria, to eliminate sites with significant data gaps which would not be useful for this study; (ii) site variability criteria, to narrow down the list of candidate sites and provide a representative cross section of sites for the study; and (iii) data requirements, specifying detailed information and data needed from a case study site. The first two screening levels were used to develop a screening criteria "Checklist 1" for site selection, targeting 20-30 candidate sites for potential inclusion in the study, and communicating site selection criteria and data requirements to site managers. Thereafter, a more detailed "Checklist 2" with standard procedures for data collection and assessment of data gaps at the final screening level was developed based on the comprehensive procedures of the Prerequisites Module such that candidate sites could be assessed based on their ability to meet the EPCC Methodology's data requirements.

### 3.1.1 Checklist 1: Screening for Candidate Sites

Checklist 1 comprised a brief explanatory memorandum entitled "*Invitation to Participate in EREF Post-Closure Care Evaluation Project*" with a two-page questionnaire submitted to managers of candidate sites. A copy of Checklist 1 is provided in Appendix 1-1. Because the checklist enables a site operator to quickly summarize the status of a site in the context of the EPCC Methodology's data requirements, it is recommended that this preliminary checklist be used where the methodology is first applied at a site.

Unless a site was included in this study on the specific advice of EREF industry members (e.g., Site B was specifically selected as a good example of a site lacking a LCRS), the preliminary checklist was used to identify candidate WMUs that could meet all of the critical screening

criteria related to the good compliance status of the WMU, favorable attitude of site managers and regulatory environment, existence of a leachate and LFG management system, and good availability of leachate, gas, and groundwater data. Candidate sites were required to be in Detection Monitoring for groundwater, have a certified final closure cap system installed, and have been closed for at least one year.

Candidate sites were preferred be able to exhibit the following qualitative variability (in descending order of importance):

- *Climate*: To attempt to reflect as many net precipitation and temperature ranges as possible, sites were sought to include, at a minimum, at least one "wet" and one "dry" climatic region, as well as one "cold" and one "hot" climatic region;
- *Hydrogeologic Setting*: One site with high groundwater flow velocity and one with low velocity was sought, with as much additional variability as possible reflected in the sites' vadose zone thickness and the contiguous nature of groundwater bearing strata;
- *Site Layout*: As much variation as possible regarding distance to groundwater POC and POE was sought, and at least one site each was sought with very near and very far LFG receptors; and
- *Years since Cell Closure*: One site at least five years into post-closure was sought, along with one at least ten years into post-closure.

Mean average precipitation and temperature distributions across the continental United States from 1990 through 2007 are shown on Figure 3-1.

### 3.1.2 Checklist 2: Shortlist of Final Sites

The more-detailed Checklist 2 entitled "*Standard Procedures for Site Data Collection*" was developed to submit to managers of the sites that responded favorably to having their site(s) included in the study, and completed the two-page questionnaire from Checklist 1. The purpose of the 13-page Checklist 2 was to provide a standard procedure for sites to record and present their data availability to the project team, thus facilitating objective comparison between sites during the site screening process.

Checklist 2 required that selected sites be in possession of all or most of the following data and information, preferably in electronic format:

- *Site Operational Records*: Information requested included: (i) annual weight/volume of refuse accepted, start/end dates for waste filling in different landfill disposal areas, and data on waste types accepted (e.g., MSW, construction and demolition debris, ash, special wastes, etc.) and approximate percentages; (ii) unique operational practices (e.g., leachate

recirculation); (iii) site and permit conditions and documentation; and (iv) results from waste characterization studies and any retroactive waste sampling activities performed.

- *Site-Specific Design Records and Data*: Information requested included: (i) liner and cover system components, properties, specifications, history of construction, reported performance issues (e.g., erosion damage) and repairs, and state of vegetation; (ii) details, layout, and history of use of LCRS and GCCS; (iii) site size, geotechnical issues, and conditions; (iv) details on surrounding environment and communities, onsite and/or offsite structures, surface waters, and stormwater management features; (v) reported or noticed impacts from the landfill to any media; (vi) identification and layout of monitoring systems for methane migration and groundwater; (vii) identification and characterization of potential receiving water systems; (viii) post-closure plan and site end-use strategy; and (ix) other notable non-technical issues and liabilities.

- *Leachate Characterization Data*: Information requested included: (i) history of leachate collection; (ii) identification of sumps and storage facilities; (iii) leachate analytical data for each year available, with as many analytes as possible in the following categories – Subtitle D Appendix I and II groundwater parameters, key indicator parameters (BOD, COD, $NH_4$, and $Cl^-$), and other regulated parameters in leachate, groundwater, and surface water; and (iv) leachate flow data (by sump and whole site, where possible).

- *Landfill Gas Data*: Information requested included: (i) history of LFG collection and GCCS performance (e.g., date installed, operational period, upgrades, issues, etc.), and identification of wellheads; (ii) LFG data for each year available, including flow and concentration of methane ($CH_4$), oxygen ($O_2$), nitrogen ($N_2$), carbon dioxide ($CO_2$), and non-methane organic compounds (NMOC) as available from NSPS Title V reporting, source tests, NSPS Tier II studies, or previous risk assessment work; (iii) identification and characterization of potential LFG receptors; and (iv) results from previous attempts to model LFG generation and emissions.

- *Groundwater Data*: Information requested included: (i) groundwater monitoring data; (ii) groundwater flow regime, including identification and characterization of subsurface geology and hydrogeology, potable water sources, and other potential receiving bodies; and (iii) results from previous attempts to model groundwater flow at the site.

- *Cover System and Settlement Data*: Information requested included: (i) cover monitoring and maintenance records (to check for history of cracking, erosion damage, etc.); (ii) reported instability issues; (iii) land and/or fly-over surveys and other topographic data; and (iv) data from settlement plates or installed other devices (if any).

- *Meteorological Data*: Information requested included: (i) current and historic data from on-site weather station (if any); and (ii) identification of closest meteorological station.

A copy of Checklist 2 is provided in Appendix 1-2. It is recommended that this checklist be used to plan and conduct site visits to assemble background information and data for application of the EPCC Methodology at a site.

## 3.2 Final Site Selection and Data Collection

To ground truth the true availability of data at each site, the data listed in Checklist 2 were stipulated to have already been collected so that no new sampling or measurements were required at this stage. From the outset, it was acknowledged that an intensive effort to compile and inventory data would be necessary to allow full completion of the checklist, and that this would involve a site visit by the project team. However, the project team was able to use feedback received via this checklist from site managers to narrow the initial shortlist of about 20 candidate sites down to ten final sites for inclusion in the study.

The geographic locations of the ten case study sites (herewith, Sites A through J) are shown on Figure 3-2. As shown on Figure 3-1 and summarized on Table 3-1, with the exception of Sites A and B no two sites experience the same mean climatic conditions. Based on staff availability and familiarity with local site conditions and site personnel, budgetary allocations, site managers' preferred timing for site visitations, and proximity of a site to project team members' offices, it was decided that Geosyntec would visit six sites (Sites A, B, C, F, G, and I) while AquAeTer would visit four sites (Sites D, E, H, and J). The six sites visited by Geosyntec are shown in blue on Figure 3-2 and all table headings while the four sites visited by AquAeTer are shown in brown.

### 3.2.1 Data Collection Protocol

In addition to facilitating final site selection, the feedback provided from efforts by site managers to complete Checklist 2 also allowed the project team to confidently proceed with Task 2 of the project using this checklist as a comprehensive guide to data collection. All site visits were conducted between December 2007 and December 2008; the alphabetical order in which sites are identified generally represents the order in which they were visited. Geosyntec first visited Sites A and B (to fully ascertain the level of effort and complexity associated with data collection, and confirm the adequacy of Checklist 2 to capture data in all required categories). Based on events at these sites, it was decided that allocation of one person and two full days should be sufficient to assemble the requisite data at each site, assuming site managers were on hand to provide assistance with locating records and confirming the chronology of various site plans and events. Given AquAeTer's relative unfamiliarity with the EPCC Methodology, it was also decided that Geosyntec would accompany AquAeTer on their first site visit to provide training and advice on the optimal process for data collection. Therefore, after visiting Site C, Geosyntec trained AquAeTer for one day at Site E before departing for Site F, leaving AquAeTer to complete Site E before backtracking to Site D. Each project team member then independently completed data collection at their remaining two sites.

Although a formal data validation process is not required as a part of the EPCC Methodology, the Prerequisites Module cautions that it is important to make sure (to the extent possible) that any analytical data to be used in an evaluation have been collected and submitted under a

regulatory approved program and samples have been analyzed at laboratories that follow accepted industry standards for QA/QC, especially with regards to the use of dilutions and detection/reporting limits. For all sites, a brief review of the methodologies used for collection and analysis of data was conducted. In addition, every effort to confirm the layout and features of PCC control system and site infrastructure was made based on review of as-built record drawings and construction quality assurance (CQA) reports rather than relying on design plans and reports.

### 3.2.2 Site Descriptions and Summary of Data Collected

The data and site information collected at each site was critically reviewed for completeness and compiled by the visiting project team member based on a standardized 10-15 page summary template. In this way, each summary included a one or two paragraph description of site conditions and data availability in relation to the following categories:

- Overview of the study WMU and landfill property,
- Review of the site area, including description of geologic and hydrogeologic setting, uppermost saturated zone (aquifer) and unsaturated (vadose) zone, availability and findings from of geotechnical and other investigational boring logs, reported hydraulic conductivities, groundwater flow characteristics, physiographical setting, potential point(s) of exposure for leachate and LFG migration, and climate conditions;
- Waste placement, compositional data, and site operating conditions;
- Closure and post-closure plan;
- End-use strategy;
- Liner system design documentation, as-built record drawings and documentation, and CQA reports;
- Leachate management system design documentation, as-built record drawings and documentation, CQA reports, description of leachate recirculation or other proactive management practices, leachate sampling protocols and data, and reported compliance issues and community concerns;
- Cover system, design documentation, as-built record drawings and documentation, CQA reports, topographic surveys, cover monitoring and maintenance programs and records, and reported compliance issues and community concerns;
- LFG control system design documentation, as-built record drawings and documentation, CQA reports, descriptions of current and historic active or passive control system(s) and gas utilization schemes, LFG data, and reported compliance issues and community concerns;

- Groundwater monitoring system layout, monitoring program, well construction details and logs, groundwater analytical data and elevation monitoring, and reported compliance issues and community concerns;
- Surface water monitoring system locations, monitoring program, surface water quality data, and reported compliance issues and community concerns; and
- Methane migration monitoring system layout, monitoring plan and data, and reported compliance issues and community concerns.

In addition, each site summary features between three and five standardized figures illustrating the physiographical setting, stylized depictions of the site layout, features, and POC/POE for potential leachate and methane migration, and geologic and hydrogeologic cross sections. The ten completed site summaries with accompanying figures are provided in Appendices 2-1A through 2-1J. Appendix 2-2 provides a key for the stylized site layout figures in these appendices, as well as for Figures 5-2A through 5-2J in this report.

Table 3-1 provides a summary of the variability between main site characteristics at the ten case studies and a qualitative assessment as to the extent of end use planning at the site. Thereafter, Tables 3-2A through 3-5 reproduce the data requirements and classification from the Prerequisites Module (i.e., critical "C", non-critical "NC", or flag/supplemental "F/S" as described in previous Section 2.2.2) and qualitatively assess the availability of site information and data for the four PCC modules (i.e., Leachate, Gas, GW, and Cap Modules), respectively.

It should be noted here that certain subsections of Section 3.3 (i.e., Prerequisites and Data Requirements for Leachate Module) from the Technical Manual were inadvertently omitted during final publication of the EPCC Methodology in 2006. The omitted sections were the second page of Table E-3-1 and all of Sections 3.3.4 and 3.3.5. Given that these sections are critical to the Leachate Module and provide recommendations for the quantity and duration over which leachate monitoring data should be proactively collected and processed, it is important that they be reinstated and are reproduced in their entirety in Appendix 1-3. These reinstated sections will henceforth constitute final recommendations for proactive leachate monitoring; therefore, they have been updated subject to the discussion in Section 4.2.2.

The color-coded, qualitative system used to indicate the extent of planning and availability of data in each category listed in Tables 3-1 through 3-5 is provided in the key overleaf. It should be noted that certain data requirements, such as availability of analytical leachate data summarized in Table 3-2B, require more in-depth presentation than can be afforded using this qualitative assessment. These findings are presented and discussed in more detail in Sections 4 and 5.

## Key to qualitative assessment symbols used in Tables 3-1 through 3-5

| Symbol | End Use Strategy (Table 3-1) | PCC Modules (Tables 3-2A through 3-5) |
|---|---|---|
| √√√ | Comprehensive planning for beneficial end use of the property has been conducted, with engagement of the local community. | Complete site information or data record available. Sufficient information or data are considered to be available in this category to complete analysis of the module. |
| √√ | Significant planning for long-term beneficial reuse of the property has been conducted. | Site information or data record mostly complete. Analysis of module likely to be possible with data record, but some minimal substitution using conservative default data may be necessary. |
| √ | Minimal planning for long-term reuse of the property has been conducted. | Site information is significantly lacking or some data are available, but record is incomplete. Completion of module unlikely to be possible without addition information or data collection. |
| X | Baseline condition – no end use planning beyond compliance with permit requirements for restricted future use of the property under 40CFR §258.61(c)(3). | Site information or data record known not to exist. Completion of module will not be possible without additional information or data collection. |
| ? | N/A | Availability of site information or status of data unknown. |
| ? | N/A | Not investigated as part of this study. |

# 4. REVIEW OF DATA AVAILABILITY AND DATA GAPS

Since publication of the EPCC Methodology in 2006, it has become apparent to the project team that some operators may consider the methodology too restrictive and overly burdensome in its data requirements as compared to what is perceived will be accepted by the state agency when reviewing a petition to end PCC. Notwithstanding the reality of such perceptions, a key objective of this study has always been to attempt to better align the comprehensive "wish list" of data currently listed as critical for successful application of the methodology with the actual availability of site records, permit documentation, and monitoring data found to be typically available at a closed or partially closed Subtitle D site. The availability of data across the ten case studies was reported in Section 3. In Section 4, the major categories of data requirements under the Prerequisite Module are discussed and reassessed based on the observed availability of data at each of the case study sites.

## 4.1 General Observations

### 4.1.1 Proposed Modifications to Prerequisites and Data Requirements

In the remainder of Section 4, discussion is focused on reviewing data gaps and persistently missing data in relation to current recommendations and classifications. Where appropriate, this allows apparent data deficiencies to be accommodated or alternatives suggested without compromising the conservative nature of the EPCC Methodology. The primary deliverable from this review is provided as Appendix 1-4, which represents an updated assessment of data needed for full application of the four PCC Modules under the EPCC Methodology. Appendix 1-4 should thus be used to fully replace the prerequisites and data requirements listed in Table E-3-1 (Leachate Module), Table E-3-2 (Gas Module), Table E-3-3 (GW Module), and Section 3.6.2 (Cap Module) of the Technical Manual. Note the following changes and simplifications made in Appendix 1-4 relative to the previous versions of the tables:

- A reassessment of the definition of "Critical" and "Non-Critical" data is made where appropriate to focus data collection activities on obtaining those data without which completion of a module evaluation will not be possible.
- A new mid-level "Optimal" classification was developed to reflect a new emphasis for data requirements under the EPCC Methodology (essentially, moving away from a best-case "wish list" scenario towards a "minimum requirements" approach). Optimal data requirements are above non-critical and will be beneficial to have in terms of optimizing the duration and intensity of certain PCC activities, but are not considered critical for completion of a module evaluation.
- Tables E-3-1 and E-3-2 currently list prerequisites and data requirements by sub-module for the Leachate and Gas Modules, respectively. This is not considered useful: data

should be considered on the basis of whether or not they will be required for completion of an entire module.

- Previous classifications "Flag" and "Supplemental" have been combined into a single category as "Potentially Critical."

In accordance with the above, and in the considered opinion of the project team, where existing classifications for certain data requirements could be modified based on a qualitative reassessment process, changes to the Prerequisite Module line items were made as follows in Appendix 1-4:

- New or significantly modified line items are listed in **blue**;
- Line items are listed in **green** where existing "Critical" (C) data requirements are downgraded to "Non-Critical" (NC);
- Existing line items changed to the new "Optimal" (O) status are listed in **orange**;
- Existing "Flag" (F) and "Supplemental" (S) line items changed to the new "Potentially Critical" (PC) status are listed in **pink**: and
- Unchanged line items remain listed in **white**.

### 4.1.2 Impact of Persistently Missing Data

Based on the project team's review of data requirements, a "Critical" classification in Appendix 1-4 represents a line item without which it has been verified from this study that completion of a module will not be successful. Similarly, an "Optimal" classification represents a line item that will be beneficial, but not essential, to completing a module. Generally, the unavailability of optimal data will trigger use of conservative assumptions in their absence. Although this will invariably prolong the duration of certain PCC activities it will not ultimately prevent such activities from being modified or ended.

The impact of persistently missing data for key evaluations in the four PCC modules in accordance with the new classifications in Appendix 1-4 and the anticipated burden and timeframe associated with addressing data gaps is discussed (to the extent possible, given the limited scope of this project) throughout the remaining subsections. However, it is important to stress that while the absence of some key data may prevent full evaluation of a module and thus not enable a PCC system to be eliminated, the EPCC Methodology was developed with the intent that every evaluation provide an opportunity to optimize care and/or monitoring activities. Indeed, the gradual elimination of PCC systems and activities is fundamental to the approach as previously illustrated on Figure 1-1.

## 4.2 Leachate Module

### 4.2.1 General Prerequisites and Site Characterization Data

*Key Finding: Inspection of Table 3-2A shows that all four critical prerequisite items (which essentially comprise the "go, no-go" decision for entry to the Leachate Module) are fully available at every case study site (with the minor exception of some historic surface water monitoring records at Site G).*

Proposed Action: Given the relatively fast travel time and readily apparent flow direction for surface water in the hydrogeologic context, the requirement to assemble current and historic groundwater (GW) and surface water (SW) at background and POC monitoring locations is relaxed for SW. Changes to leachate management systems, activities, and/or monitoring programs can be assessed in terms of their likely effect on current and future SW quality and flow without the need to have characterized historic SW conditions. The same is not true for GW conditions where historic variations in flow and chemical constituents between background and POC monitoring locations can have a significant bearing on monitoring the long-term performance of a leachate management system. Thus, Appendix 1-4 now shows this item divided in two: assembly of current and historic GW data remains a critical data requirement under "General Prerequisites" whereas assembly of current and historic SW data is now a new non-critical line-item under the same category.

*Key Finding: Critical information regarding the layout of the WMU, liner basegrades, operational practices, and cover system design is, for the most part, fully available at all sites.*

Proposed Action: Notwithstanding the good availability of these data, information regarding site-wide or cell-specific operating practices such as leachate recirculation is downgraded from critical to non-critical in Appendix 1-4 because such practices positively affect current and future performance and leachate quality. Thus, the absence of detailed knowledge about such practices means an evaluation should remain conservative and will not compromise the outcome of a Leachate Module evaluation. The requirement to obtain detailed knowledge regarding the layout and basegrades of the liner is also downgraded from critical to optimal in Appendix 1-4. While such information is beneficial, conservative assumptions built into the Leachate Module can account for its absence and therefore its classification as critical is not correct. If basegrade elevations are unknown, it can be assumed that the liner elevation is at ground level and that the low point on the liner is in the plan center of the landfill. Indeed, such assumptions were used to characterize the old unlined portion of Site H (see Figure 5-2H as referenced in Section 5).

*Key Finding: Ample geologic and hydrogeologic information and monitoring data generally exists with which to adequately characterize subsurface conditions, GW flow dynamics, and vertical/horizontal TOT to the POC or property boundary (POE). This is probably testament to the fact that Subtitle D is driven in large part by strict requirements to protect GW resources, and so Subtitle D landfills tend to have had a detailed geologic and hydrogeologic study*

*conducted during their permitting process. Further, at pre-Subtitle D WMUs (e.g., Sites B and C), documentation for a post-Subtitle D expansion on the same or adjacent property can generally be used to provide any information lacking from the original landfill design and permitting phase. At Site I, the only fully closed pre-Subtitle D case study, detailed geologic and hydrogeologic information was also available, although the extent to which this is typical of other older closed sites needs to be further investigated.*

Proposed Action: No relaxation of any critical data requirements for the "Characteristics of Receiving Bodies and Hydrogeologic Data" category is allowed in Appendix 1-4.

*Key Finding: Table 3-2A shows that scant information regarding the characteristics of surface water (e.g., mixing zones, peak/average flow rates and/or volume, uses, etc.) is available at the case study sites.*

Proposed Action: This line item is currently listed as a non-critical and its unavailability probably represents the fact that SW controls and monitoring at landfill sites is typically required only for stormwater discharges and is regulated outside of Subtitle D (generally under a state-administered NPDES permit for general discharges from the site). Further, many Subtitle D sites (e.g., Sites C and G) do not routinely discharge any stormwater. However, because most long-term strategies for passive leachate management will invariably have to consider discharge or seepage of benign leachate or treated effluent to SW, it is recommended that this line item be upgraded from non-critical to optimal. Importantly, this does not represent a significant burden because historic SW conditions are not of significant interest; it is current and future conditions that will be of primary concern.

### 4.2.2 Leachate Monitoring Data

As indicated on Table 3-2A, all five categories of required leachate monitoring data are currently listed as critical. Inspection of the table shows that four sites (Sites A, E, F, and I) currently lacks critical data in one or more of these five categories. However, because of the very large quantity of data represented by these five categories, the available of key leachate monitoring data is indicated on expanded Table 3-2B and discussed in the subsections below.

#### 4.2.2.1 Suitability of Leachate Monitoring Program

*Key Finding: No leachate data are available for unlined Site B and the old WMU comprising Site H, both of which lack a LCRS; therefore, the total number of sites for which the availability of data is assessed is 8½ (i.e., 8½ represents 100% of sites with a LCRS). Of these, all sites generally have a significant quantity of leachate monitoring data available. However, this likely does not reflect the reality for most closed sites given that the majority of operators monitor leachate for a limited analyte list only as required for compliance with permit conditions or as an ongoing condition for POTW disposal.*

Proposed Action: Although the Leachate Module is careful not to broadly recommend additional monitoring above that required for permit compliance, and is focused on eliminating leachate management and monitoring activities not adding to them, proactive collection of key decision parameters (DPs) and sufficient data to statistically characterize regulated parameters (RPs) in GW and SW is strongly advocated. These data will be essential to enable a demonstration to be made at some appropriate future time that leachate does not pose a threat to HHE as a result of predetermined GW and/or SW discharge scenarios. A summary outline of proactive monitoring requirements for the Leachate Module is provided as Appendix 1-3.

#### 4.2.2.2 Leachate Decision Parameters

*Key Findings: The primary (i.e., Tier 1) DP for leachate is BOD for which a statistically significant downward trend in concentration at a representative composite leachate sampling point (e.g., storage tank or master sump) is used as a surrogate indicator of improving leachate quality. Where a Tier 1 DP downtrend cannot be demonstrated, a Tier 2 demonstration of non-trending but dilute leachate quality based on absolute BOD concentrations below 100 mg/L and a BOD/COD ratio less than 0.1 can be substituted. In both cases, DP analyses require at least eight data points. Table 3-2B shows that a composite leachate sample is regularly collected for analysis at 7½ case study sites (88% of total case study sites featuring a LCRS). At least eight monitoring events have been conducted, and some post-closure data are available at all closed sites.*

*The following potential limitations are apparent: (i) Site J does not collect a composite sample; however, sump data could serve as surrogate composite data as allowed under Leachate Module procedures, and ample BOD and COD sump data are available; (ii) Site A, with an impressive 280 leachate analytes available, has neither BOD nor COD data because Florida regulations require that leachate be tested at least annually for all Subtitle D Appendix I and II parameters but not for macro-indicators of leachate quality; and (iii) BOD data is further lacking at Sites E and F, again probably because leachate monitoring is focused on characterizing potential leachate leaks to GW. Thus, only 5½ sites (65%) are currently in a position to attempt to make a Tier 1 or Tier 2 demonstration of decreasing DP trend. The utility of the BOD and COD composite data is somewhat hindered by the fact that only four sites (47%) have WMU-specific data; at the other sites, the composite sample represents leachate from the entire site, including still-active WMUs. Use of this composite data source is conservative because such leachate is likely to be of much higher strength than that from the closed/inactive study WMU. However, using this data to demonstrate a deceasing trend may be problematic and yield overly conservative UCLs to represent maximum and current leachate concentrations.*

Proposed Action: No relaxation of the requirements for BOD data as a critical element is possible. Because of the importance of a Tier 1 DP trend analysis as the main "go, no-go" decision for full evaluation of the Leachate Module, unavailability of BOD data is a significant issue. Although collection of COD data as a Tier 2 DP analyte is not strictly critical, it is

strongly advised to enhance flexibility during evaluation of the Leachate Module. Therefore, all landfill operators should be encouraged to proactively include BOD and COD in their leachate sampling programs. Where feasible, it will be advantageous to collect a composite sample that reflects WMU-specific leachate concentrations rather than an average for the whole site. This will avoid being overly conservative by using a site-wide rather than WMU-specific DP composite concentration. Given that only single parameters are involved, this should not be a significant cost issue.

#### 4.2.2.3 Regulated Parameters

*Key Finding: Full application of the Leachate Module as currently stipulated requires at least four and eight date points (for UCL and UPL calculation, respectively) for every RP using representative composite data, and at least one data point for every RP at each sump location (see further discussion in Section 4.2.2.5 below). Given the module's requirement to statistically compare leachate quality to all federal, state, and other site-specific standards for GW and SW quality, this represents a very large number of analytes[2]. A lesser, but nevertheless significant, list of analytes is regulated as a SW standard at most sites, although considerable overlap between GW and SW analyte lists typically exists. For example, the default federal list (per 40CFR Part 445, Subpart B) includes only nine analytes, including one Appendix I analyte.*

Proposed Action: Within the scope of this study, the number of analytes routinely monitored in SW and GW is assumed to represent the "standard" applied to the site; therefore, in accordance with current EPCC Methodology protocol, data for all these analytes should be available for statistical analysis of leachate quality. This is a reasonable assumption in that any petition to reduce or eliminate leachate management and GW/SW monitoring as a result of demonstrable absence of threat to HHE would be expected to include every analyte currently monitored in receiving environmental media at the site. For this reason, and those discussed below, no relaxation of the critical requirement to obtain sufficient data to statistically characterize every RP in composite leachate is considered possible.

With regard to availability of data for GW analytes, of the 8½ case studies having leachate data only Site A currently exceeds the full list of 276 parameters required under Appendix I and II. This is because Florida regulations require that leachate be tested at least annually for all Subtitle D Appendix I and II parameters. However, Site A still does not monitor sufficient parameters in leachate to match all 289 parameters monitored in GW at the site. Of the remaining case studies, the number of analytes available in composite leachate exceeds that monitored in GW at Sites C, D, E, G, and H, is close to that monitored in GW at Site I, and is about half that monitored in GW at Sites F and J (although Site J does not collect a composite sample, sump data could serve as surrogate composite data as allowed under Leachate Module procedures). This represents

[2] For example, the list of GW analytes regulated under Subtitle D alone includes 62 Appendix I and 214 Appendix II analytes, for a total of 276 (although it is recognized that Appendix I is intended to serve as a surrogate for Appendix II, which is only monitored if Appendix I parameters are found to be present). State regulations, local ordinances, and/or site permit conditions often add a few more analytes to the federal list.

about 75 – 41 percent of the federal GW analyte list at sites handpicked for inclusion in the study. The availability of such RPs in leachate at other sites is likely to be much lower, especially in states that do not mandate large analyte lists such as Florida and Illinois. Based on the case study findings, collecting sufficient samples of the errant data will likely represent a significant effort in terms of cost and time. However, subject to satisfactory sump consistency testing as described in Sections 4.2.2.5 and 5.2, operators should be encouraged by the fact that all analytes that can be statistically confirmed as a "non-detect" in leachate should immediately be removed from further evaluation under the Leachate Module and, because they are not present at the WMU source and therefore cannot impact GW or SW, be excluded from all further monitoring programs. Thus, the increased short-term cost and effort of additional leachate monitoring should often be more than offset by long-term savings.

With regard to availability of data for SW analytes, the situation appears to be much better than for GW. The number of analytes available in composite leachate greatly exceeds the number monitored in SW at all of the 8½ case studies having leachate data except Site A (which has 280 versus a necessary 290). Another positive finding is that 7½ of 8½ case studies (88%) have ammonia-N leachate data (Site D is the sole exception). As previously summarized, developing a passive long-term leachate management strategy will likely consider SW discharge of leachate, and ammonia-N is the most highly recommended decision parameter for evaluating discharge of dilute leachate or treated effluent.

Finally, as noted in the previous discussion on DPs, the utility of the RP composite data is somewhat hindered by the fact that only four sites (47%) have WMU-specific rather than whole-site data. Although use of this composite data source is conservative because such leachate is likely to be of much higher strength than that from the closed/inactive study WMU, it will likely yield very high representative maximum and current leachate concentrations.

#### 4.2.2.4 Leachate Flow Data

*Key Finding: The case studies generally fared well in terms of availability of leachate flow data. Recent WMU-specific leachate generation was reportedly measured at four sites (Sites A, D, E, and I), and whole site measurements were available at 3½ of the other sites (Sites E, G, and J) having leachate data. Only at Site C was leachate flow not routinely measured.*

Proposed Action: WMU-specific quantification of leachate flow is often useful in the Leachate Module, not least as a Tier 3 DP demonstration, in which BOD concentrations can be substituted with BOD flux (i.e., concentration multiplied by flow) such that the total quantity of leachate generated at the WMU contributes to demonstrating an overall decreasing trend in BOD load to potential receiving systems. In addition, leachate flow data may be used for fate and transport modeling under a POC and/or POE Evaluation, and/or to calibrate site-specific hydrogeologic models of leachate generation which can then be used to estimate future generation and treatment/discharge rates under modified leachate management scenarios and cover properties. Nevertheless, given that all of the above uses of leachate flow data will be beneficial, but not

essential, to completing a module and that conservative default assumptions such as HELP model output could be used in their absence, this requirement is modified from critical to optimal in Appendix 1-4.

#### 4.2.2.5 Sump-Specific Data

*Key Finding: In order to have confidence that composite leachate data are truly representative of leachate collected across the entire basal area of a WMU, full application of the Leachate Module requires "snap shot" consistency testing to be performed between the selected representative composite sample and a sample from all WMU sumps for all RPs. However, as shown on Table 3-2B, only 3½ case studies (Sites C, G, ½H, and J) have good sump-specific data availability (Site D has data for a very limited suite of analytes). Based on these findings, significant collection of errant data will likely be required at most sites. However, the number of sumps is not excessively large, ranging from 2 to 14 with mean less than 6. Given that current (not maximum) sump concentrations are of most interest in this comparison, a single round of sampling should be enough to demonstrate consistency in most cases.*

Proposed Action: No relaxation of the critical requirement to obtain sump-specific data for all RPs is considered possible. Assuming that the number of sumps found in this study is typical of Subtitle D landfills, it is considered that sump-specific sampling should not be a significant additional data issue in terms of time but will represent a meaningful short-term cost to obtain a full suite of analytes at each sump. Again, as discussed above, operators should be encouraged that all analytes that can be statistically confirmed as a "non-detect" at all leachate sampling locations should immediately be removed from further evaluation under both the Leachate and GW Modules.

## 4.3 Landfill Gas Module

### 4.3.1 General Prerequisites and Site Characterization Data

*Key Finding: Inspection of Table 3-3 shows that mixed results were returned regarding the data availability for the four critical prerequisites which essentially comprise the "go, no-go" decision for entry to the Gas Module. The excellent availability of data at all sites for the remaining critical line item – current and historic GW monitoring and flow – is discussed in relation to the GW Module in Section 4.4. At many sites, however, less-than-optimal data records were returned for migration monitoring data, surface emissions monitoring data, and history of compliance for gas management at the site.*

Proposed Action: In the context of LFG management, Subtitle D is primarily concerned with control subsurface migration of explosive gases. However, it is recognized in the Gas Module that there may be other reasons why a LFG control system was installed at a landfill, including compliance with NSPS regulations, odor control, or mitigation of gas-to-groundwater impacts,

and these should also be considered to define the current need for LFG management before any evaluation to modify LFG controls is embarked upon. Therefore, it remains appropriate for include screening for permit compliance with gas migration monitoring, surface emissions monitoring, and gas-to-groundwater impacts along with other records of compliance and the absence of prolonged odor problems or other gas-related issues. However, it should be clarified that this remains a screening protocol only aimed at identifying any fatal flaws in a strategy to evaluate future performance of a modified LFG control system and does not entail assembling data, because past performance will not be a useful indicator of future LFG migration potential. Thus, the wording of these screening criteria has been modified accordingly and the line items colored blue in Appendix 1-4.

*Key Finding: Interestingly, no data were found at any site for the non-critical GW monitoring well headspace sampling item.*

Proposed Action: This remains a potential source of current or future gas migration data. Therefore, this line item is not removed from Appendix 1-4.

*Key Finding: Critical information regarding the layout of the WMU and network of POC monitoring probes, extent of the buffer zone between the WMU and property boundary, and sensitivity of receiving systems is generally available at all sites along with ample geologic and hydrogeologic information to adequately characterize vadose zone conditions and horizontal TOT to the POC/POE. Again, the latter is probably testament to the fact that Subtitle D is driven in large part by strict requirements to protect GW resources, and so any Subtitle D landfills tend to have a detailed geologic and hydrogeologic study conducted during the permitting process.*

Proposed Action: No relaxation of any critical data requirements under "Site Details" or "Characteristics of Sensitive Receptors" category is allowed in Appendix 1-4.

### 4.3.2 Landfill Gas Monitoring Data

Data required under the LFG monitoring data portion of Table 3-3 were significantly lacking; no site has any data related to internal gas pressure and only Sites D and I come anywhere close to having sufficient data in other categories. A clear finding from this study must therefore be that, with the exception of gas migration monitoring data, gas-related data are not collected and reported with the same level of diligence as GW or leachate data. This probably reflects the non-centric status of LFG management under Subtitle D. However, since publication of the EPCC Methodology in 2006, the project team has had the opportunity to critically review data requirements for, and the method of application of, this aspect of the Gas Module. As emphasized by the almost complete lack of these data at the handpicked case study sites, a key component of this study must be to redefine critical monitoring data requirements for the Gas Module.

*Key Finding: The Gas Module provides a procedure to evaluate modifying an existing LFG control and migration monitoring system such that the intensity of monitoring and maintenance activities can be reduced or eliminated because it is demonstrated that no threat to HHE exists as a result of gas migration. Evaluations conducted within the module are based in large part on estimating when LFG generation will be sufficiently low to allow such modifications. A major practical obstacle to accurately performing this evaluation is having a complete waste tonnage record in order to run a WMU-specific LFG production model such as LandGEM (USEPA, 2005). In this regard, the findings from the case studies are mixed, mostly because most sites only track incoming waste via gate receipts but do not accurately account for waste placement on a WMU-specific basis.*

Proposed Action: Although waste placement data on a WMU-specific basis were found to be lacking, the project team found that site operators usually maintain reasonably accurate temporal airspace utilization records from which a waste mass can be back-calculated using survey volumes. Thus, lack of a complete waste placement record should not represent a fundament limitation to the methodology, although backing-out a waste mass from AutoCAD volume calculations will incur some additional cost and effort. Based on this, proposed changes to Gas Module data requirements in Appendix 1-4 are: (i) change of status for the two line items for waste placement records and aerial surveys under "Site Details" from non-critical to optimal; and (ii) addition of a new optimal line item for airspace utilization records.

*Key Finding: The WMU-specific current and historic LFG generation and collection rates are currently listed as non-critical and critical data requirements, respectively. The former is intended to provide qualitative insight into the input parameters used to model LFG generation at the WMU. The total LFG flow collected from the WMU was intended to be used to calibrate modeled predictions using waste tonnages and demonstrate a decreasing trend in LFG generation from the WMU. However, from review of LFG management practices at the case studies, it is clear that most sites generally monitor total flow to a central flare or landfill gas-to-energy (LFGTE) project, but do not monitor flow on a WMU basis. Thus, LFG collection data are only useful where the whole site is the study WMU (e.g., Sites D, E, and I). In addition, flow rates are often maintained at compliance levels that maximize flare/LFGTE operational efficiency and rarely are an accurate reflection of actual LFG potential.*

Proposed Action: Given the above, modeling LFG generation based on waste placement data is generally preferred to extrapolating WMU-specific collection data to predict current and future LFG generation. As a result, the need for current LFG collection data is revised from critical to optimal in Appendix 1-4. It should be noted from a technical standpoint, however, that WMU-specific flow data may be most useful towards the end of the operational life of LFG system mandated under NSPS or when insufficient delivery of LFG is rendering a LFGTE project financially unattractive. At this time, operators are likely to be attempting to maximize collection rates that are representative of true LFG generation potential.

*Key Finding: As currently written, measurements of internal gas pressure in the WMU are considered essential to calculate a TOT for gas migration following modification to a LFG management system. No case study site has these data (although Site G reportedly has the means to collect some data using pressure probes installed through the final cover). Furthermore, discussions with site operators revealed universally strong reluctance at attempting to collect such data because of the need to temporarily shut down active LFG controls in the process (a potentially serious non-compliance event under NSPS).*

Proposed Action: To improve the utility of the Gas Module, this requirement must be redefined as it is too onerous to be required at all sites for completion of the module. In this regard, the project team has devised a modified screening approach bracketed by near-zero and instability-causing gas pressures to define the duration and frequency of gas confirmation monitoring based on upper- and lower-bound TOTs. The new procedure is described in Section 5.3.1 and Appendix 1-5; however, in Appendix 1-4, the need for current internal pressure data is revised from critical to optimal. In addition, although meteorological data and atmospheric data will be necessary during gas confirmation monitoring (CM), such data collected before the onset of CM will not be useful. Therefore, collecting these data is removed as a Gas Module prerequisite in Appendix 1-4.

## 4.4 Groundwater Module

*Key Findings: Most GW data requirements directly overlap with those of the Leachate Module and are repeated in the GW Module only so they are properly accounted for at unlined sites which skip the Leachate Module. As previously discussed in Section 4.2.1, ample geologic and hydrogeologic information and monitoring data generally exists with which to adequately characterize subsurface conditions, the groundwater flow dynamics, and vertical/horizontal TOT to the POC or property boundary (POE). Thus, as indicated on Table 3-4, no significant GW data are missing at any site.*

*At all sites (except Site B which lacks leachate data) selection of chloride as a GW CM indicator parameter with clearly distinct, order-of-magnitude concentration differences between GW and leachate was possible. However, whether a typical Subtitle D site monitors chloride concentrations in both GW and leachate remains in question. At Site B, inspection of GW quality in relation to leachate quality from the post-Subtitle D landfill expansion on the same property could serve to confirm the suitability of chloride for this role. The primary concern in this regard is mainly related to saline GW conditions.*

Proposed Action: No modification to any classifications for data requirements under the Groundwater Module is proposed in Appendix 1-4.

## 4.5 Cap Module

*Key Findings: Critical prerequisites for evaluation of the Cap Module are that an End-Use Strategy has been defined and the outcomes from the Leachate, Gas, and GW Modules have been established. Inspection of Table 3-5 reveals that adequate end use strategies that take account of cap performance criteria have not been developed at many sites. The implications of this are discussed in term of end-use planning in Section 5.1. Given the preliminary nature of this study, evaluation of the Leachate, Gas, or GW Modules has not been completed at any site and so the status of these prerequisites cannot be established. With regard to cap performance data, three case studies (Sites C, H, and J) have areas that are interim-capped only and thus lack design and construction details for a final cap. Data availability is reasonably good at the other final-capped case studies, probably reflecting that closure capping is the most recent major construction activity to have taken place at the WMU and operators have required high levels of CQA and detailed as-built documentation.*

Proposed Action: Generally, no changes to the current prerequisite requirements for the Cap Module are proposed in Appendix 1-4. However, in order to emphasize its significant importance, the need for settlement data is broken out from other cap performance data requirements into its own line item.

# 5. EVALUATION OF KEY ELEMENTS OF THE METHODOLOGY

It is recognized that the outcome, or even initial applicability, of the EPCC Methodology is likely to be sensitive to certain data requirements and evaluative processes and that such sensitivity, if significant, may limit the extent to which the methodology is embraced by landfill operators and regulators. In particular:

- The Leachate Module recommends demonstration of statistically robust consistency testing between composite and sump-specific samples for all regulated parameters and a decreasing trend in a selected decision parameter;
- The utility of both the Gas and Groundwater Modules is greatly dependent on the estimated time that a gas plume in the vadose zone or a leachate release in groundwater, respectively, would take to migrate from a WMU to a POC probe/well; and
- All modules are dependent on defining clear strategic goals for the final cover condition and property end use.

To assess potential sensitivities in critical areas, the project team subjected the methodology to targeted evaluation of key inputs/processes in using data from the case study sites combined with a number of assumptions, where necessary, to fill data gaps. Based on the above, Section 5 presents and clarifies the benefits and limitations of current procedures, or provides recommended modifications to an element of the methodology where this is technically warranted.

## 5.1 End Use Strategy and Requirements for Long-Term Maintenance

Baseline Cases (Little/No End-Use Planning) – Five Sites: There is no evidence of any proactive end use planning at Sites E, G, H, or I beyond an operational or closure permit commitment to comply with baseline Subtitle D obligations under 40CFR §258.61(c)(3) for restricted use of the property post-landfilling. At best, a statement is made in the permit to the effect that the end use for the property at these sites will be for general recreational use or low impact open green space. At Site C, a strategy to turn the property over the local government for use as a park has been considered. While this represents some consideration of end use of the property above baseline obligations, there is very little tangible evidence that the operator has paid this any real attention to this.

Improved Case (Some End-Use Planning) – One Site: Although there is little evidence of comprehensive end-use planning at Site D, the closure capping strategy has evolved from use of a prescriptive geosynthetic cover system to an all-soil evapotranspirative (ET) cover system across the last portions to be capped.

Best Cases (Significant End-Use Planning) – Four Sites: At Sites A, B, F, and J, significant proactive effort has been made to plan for beneficial reuse of the property.

- Site A: The Wildlife Habitat Council (WHC) has certified a program already underway at the site to gradually turn the site over as wildlife habitat as landfilling operations are completed and site areas closed. To date, large portions of the property are home to a range of native wildlife, including alligators, wood ducks, and coots. Manmade retention ponds have been stocked with catfish and bream. Numerous pristine wetland areas have been preserved and maintained. In addition, as part of a wetland mitigation project, the operator has deeded a parcel of wetlands to the state for use as an educational facility.
- Site B: The permit application proposes that "upon completion of operations, the facility will be maintained as a closed landfill with vacant grassed land, ponds, and wetlands…suitable as wildlife habitat." An approximately 100-acre onsite borrow area will be restored as approximately equal areas for a lake and wetland migration area. The site operator has also applied to participate in the WHC "Wildlife at Work" program.
- Site F: An imaginative comprehensive end-use plan for community reuse of the completed site has been developed as illustrated on Figure F-5 (Appendix 2-1F). The plan shows the site redeveloped as a broad-based series of open spaces featuring nature trails, a learning center, sports fields, playgrounds, and parks.
- Site J: At this site, the end use plan is to return the site to its original use for cattle grazing or to consider "enterprises that can be established without jeopardizing the integrity of the containment systems or endangering public health." Although this in itself represents a simple end use plan, Site J plans to install an ET cover system across the entire landfill that should significantly increase the range of enterprises that fit this description. Leachate management at Site J is also via gravity drainage to an onsite evaporation pond, which will be extremely beneficial in terms of developing a long-term leachate management strategy that is compatible with low-maintenance reuse of the property as intended.

In summary, of the ten case study sites, three (Sites A, B, and J) appear to have taken truly voluntary steps to proactively develop a beneficial end-use plan in which some long-term maintenance activities may be transferred to a property maintenance program (i.e., outside of regulated PCC) and/or reduced without jeopardizing the intended use of the property. The end-use plan at Site F was developed in response to an expansion permitting effort where public engagement was considered essential to a successful outcome, and is thus cannot be considered truly voluntary. The same issues may drive development of such strategies at more sites in the future. It must be emphasized that end use plans at Site A and B sites focus mainly on the local site environment and not on the WMU itself (i.e., modification of the final cover system to accommodate more imaginative or flexible end uses was not considered). This may be more of an issue at geosynthetics-capped Site A than at the clay-capped pre-Subtitle WMU at Site B. Similarly, at Site F, the plan focuses on uses of the facility that will be compatible with a

prescriptive (i.e., geosynthetic) Subtitle D cover system and not on modification of the cover to expand the range of end use options. At Site J, and partially at Site D, a natural analog ET cover system been installed; at Site J use of an ET cover has occurred in conjunction with planned beneficial reuse of the entire site (including the cover) for livestock grazing.

Overall, plans such as those at Sites J, F, A, and B (and belatedly at Site D) should be encouraged at every Subtitle D landfill. However, it must be a general conclusion from this study that lack of consideration of alternative cover system designs combined with few attempts at far-sighted end use planning may represent a significant limiting factor for full application of the EPCC Methodology. This will probably manifest itself most significantly by reducing the flexibility for passive management options offered in the Cap Module and, by association, in the Leachate and Gas Modules.

## 5.2 Leachate Module

The primary (i.e., Tier 1) decision parameter (DP) for leachate is BOD for which a statistically significant downward trend in concentration at a representative composite leachate sampling point (e.g., storage tank or master sump) is used as a surrogate indicator of improving leachate quality. Where a Tier 1 DP downtrend cannot be demonstrated, a Tier 2 demonstration of non-trending but dilute leachate quality based on absolute BOD concentrations below 100 mg/L and a BOD/COD ratio less than 0.1 can be substituted. In either case, the analysis requires at least eight data points. In addition, to provide confidence that composite leachate data are truly representative of leachate collected across the entire basal area of a WMU, the Leachate Module requires "snap shot" consistency testing to be performed between the selected representative composite sample and at least one sample from each WMU sump.

Given the limited scope of this study, and the importance of BOD in enabling a full Leachate Module evaluation to proceed, investigation of the Leachate Module's sensitivity to evaluative procedures is limited to:

- Trend analysis for composite and sump-specific BOD data (i.e., Tier 1 DP testing);
- Absent a demonstrable downtrend for BOD, examination of BOD and BOD/COD quality criteria using composite and sump-specific data (i.e., Tier 2 DP testing); and
- Consistency testing between composite and site-specific BOD data.

It is important to realize that composite-sump consistency would have to be established for all regulated parameters in any real application of the Leachate Module.

### 5.2.1 Tools for Evaluation of Leachate Data

A number of statistical and other data preparation procedures are required prior to the Leachate Module user being able to perform analyses of composite-sump consistency and trend behavior for any analyte; these are relatively complex and will not be significantly elaborated on here. In brief, leachate data are first processed to address censored data (essentially, assigning a statistically representative value for non-detect parameters which is not necessarily zero), test for and remove outliers, and test for distributional form (i.e., normal, log-normal, non-parametric, or no distribution). Thereafter, a representative 95% upper confidence limit (UCL) and upper prediction limit (UPL) of the mean is computed for each analyte[3]. At least four and eight data points are required to compute a UCL and UPL, respectively. The final step requires demonstration of a statistically significantly steady or decreasing trend in a selected decision parameter (in this case, BOD) using Sen's test[4]. Use of these and similar statistical methods to help make environmental impact decisions is common (e.g., USEPA, 1988; Sara, 2003). Commercial data management software such as DUMPStat® (www.discerningsystems.com) is available to perform these analyses. For this study, the project team was able to utilize the detailed descriptions for data processing and statistical manipulation provided in Section 4.2 of the Technical Manual, coupled with professional judgment, to develop a Microsoft Excel® spreadsheet-based tool to perform the analysis described herewith. Therefore, while not exactly representing "off the shelf" tools, performing the data analyses required in the Leachate Module should not represent an undue burden for a well-qualified engineer or geologist.

### 5.2.2 Discussion of Preliminary Case Study Findings

A summary of composite and sump-specific data availability and findings from consistency testing and trend analyses at the case study sites is provided in Table 5-1. As shown, only 3½ case studies (Sites C, D, ½H, and I) of the 8½ sites having a LCRS (i.e., 41% of the total) have sufficient composite BOD data for trend analyses to be performed. Of these, only at Sites D and I where the entire closed landfill represents the study WMU is this data series WMU-specific. At the other sites, the composite sample represents leachate from the entire site, including still-active WMUs. The Leachate Module allows use of this broader composite data source as being conservative (because site-wide leachate is likely to be of much higher strength than that from an older closed/inactive WMU). However, as will be discussed, using this data at still-active sites to demonstrate a deceasing trend may be problematic and/or generate overly conservative UCLs to represent maximum and current leachate concentrations for the WMU.

[3] In brief, a 95% UPL is used to statistically compare consistency between a leachate composite data series and a single sump-specific concentration. A 95% UCL is used to compare a leachate constituent to an absolute standard such as a MCL; if the 95% UCL is below the MCL, there is 95% confidence that the true concentration is below the MCL. It should be noted that if background GW concentrations exceed the standard for a particular analyte, or if there is no standard, then the mean is compared to a 95% UPL for the background mean (e.g., groundwater samples from one or more background wells). Use of these and similar statistical methods to help make environmental impact decisions is common (e.g., USEPA, 1988; Sara, 2003).

[4] Sen's test is a simple nonparametric estimator of trend which is robust to outliers, missing data, and non-detects and provides both an estimate of the rate of change and a test of the null hypothesis of no trend (Sen, 1968).

At five of the case studies (Sites C, D, G, ½H, and J), some sump-specific BOD data are available. Findings from each site are discussed in the subsections below. Additional details on the LCRS, leachate data, and figures showing the layout of each site are provided in Appendix 2.

#### 5.2.2.1 Site C

This 47-ac, pre-Subtitle D clay-lined WMU, which has been inactive since 1997, is contiguous with an active landfill operation. Although the external sideslopes are at final grade, additional waste will be placed over the WMU in the future. There are five sumps, all of which have been sampled at approximately annual frequency along with the composite (whole-site storage pond) since 1996.

BOD Trend Testing: BOD trend was tested at all six sampling locations (i.e., composite sample POND and all five sumps LCS-1 through LCS-5); however, none was found to exhibit a statistically decreasing or steady trend. For the composite sample, this probably reflects the fact that high-strength leachate streams from still active portions of the landfill are comingled at the storage ponds (as reflected by the fact that the 95% UCL using the most-recent four samples is higher than that calculated using the entire data series). However, at sump LCS-5, the current UCL is an order of magnitude lower than the maximum UCL. This is significant in that a UCL is not a simple reflection of absolute mean concentrations, but also a measure of standard deviation (i.e., the more data variability, the higher the calculated 95% UCL). Given that Sen's test requires use of at least eight samples, and sampling is only conducted annually, this suggests that Site C could be well on the way towards a demonstrable decreasing BOD trend in a few more years.

BOD and BOD/COD Quality Criteria: For both composite POND and sump LCS-5 samples, Tier 2 DP testing fails to meet the stringent quality criteria applied absent of a decreasing trend that BOD concentrations and the BOD/COD ratio of the last eight data points are all less than 100 mg/L and 0.1, respectively.

Consistency Testing: Consistency testing using BOD data was conducted between the composite sample and all five sumps, as well as between one sump LCS-5 and the other four sumps. The latter test was conducted because the Leachate Module allows use of a "surrogate" composite sample for a WMU where a true composite is not available. LCS-5 was selected based on the assumption that the sumps were constructed chronologically and thus this would represent leachate from the most-recently placed waste. Table 5-1 shows 100% consistency between both the composite-sump and sump-sump data.

Overall, Site C appears to support the decision processes built into the Leachate Module in that a decade of inactivity under a clay cover has placed this WMU somewhere near being able to demonstrate decreasing leachate concentrations, and thus render it somewhere near the position of beginning a proper evaluation of the Leachate Module. In the meantime, the WMU operator

should take advantage of opportunities to optimize leachate, GW, and/or SW monitoring as described in Section 4.

5.2.2.2 Site D

Site D is a large 177-ac, 8-cell Subtitle D landfill that was closure capped utilizing a range of different cover system types across different portions of the WMU, including clay-only, geosynthetic, and ET systems. Final closure occurred in 2006. There are 14 sumps, all of which have been sampled at approximately annual frequency since 2001, although five sumps have been sampled on less than eight occasions. Regular composite sampling from aboveground leachate storage tanks has been ongoing since 1991.

BOD Trend Testing: BOD trend was tested in the composite sample LCTK and at the nine sumps with eight or more data points; however, with the exception of LCS-13, none was found to exhibit a statistically decreasing or steady trend. The decreasing trend evident at LCR-13 was the reason this sump was selected as the surrogate composite in the subsequent consistency testing exercise. This near-universal lack of BOD trending behavior probably reflects the fact that the WMU was only recently closed. On a positive note, however, both LCTK and LCS-13 appear to be exhibiting much lower, more stable BOD concentrations in recently collected samples (as evidenced by significant differences between the 95% UCL calculated using the four most-recent data points versus the entire data series). This suggests that Site D could already be progressing towards a demonstrable decreasing BOD trend.

BOD and BOD/COD Quality Criteria: For composite LCTK, Tier 2 DP testing fails to meet the stringent quality criteria applied absent of a decreasing trend that BOD concentrations and the BOD/COD ratio of the last eight data points are all less than 100 mg/L and 0.1, respectively.

Consistency Testing: Consistency testing using BOD data was conducted between the composite LCTK and all 14 sumps, as well as between one "surrogate composite" sump LCS-13 and the other 13 sumps. Inspection of Table 5-1 reveals that 12 of 14 sumps, including LCS-13, were consistent with LCTK; further, 12 of 13 sumps were consistent with LCS-13. In both cases, LCS-12 was found to be inconsistent. It is concluded that this sump represents a potential "hot sump" at which the Leachate Module recommends conducting higher frequency, targeted Consistency and Trend Monitoring (CTM) as described in Section 4.2.6 of the Technical Manual. CTM is used for rapid collection of the data needed to transfer the status of surrogate composite to the "hottest" sump, thus enabling evaluation of the Leachate Module to be resumed relatively quickly (albeit with higher assigned representative concentrations for one or more RPs).

Overall, Site D again appears to support the decision processes built into the Leachate Module in which full evaluation is predicated on demonstrating decreasing concentration of BOD in a composite leachate data series. Despite having been closed for one year only (relative to the age of data collected), the site appears to be progressing towards being able to begin proper

evaluation of the Leachate Module. Site D clearly illustrates the value of proactive leachate monitoring and preliminary evaluation of data consistency and trend. Having identified LCS-12 (and perhaps LCS-6) as hot sumps, the operator is in a position to focus monitoring efforts at these sumps. In the meantime, the WMU operator should take full advantage of opportunities to optimize leachate, GW, and/or SW monitoring as described in Section 4.

#### 5.2.2.3 Site G

This 26-ac, 2-cell Subtitle D lined and capped WMU is contiguous with an active landfill operation, although site geometry means that no additional waste can be placed over the WMU in the future. The WMU was operated over a relatively short period from 2003 through 2005 with final closure capping occurring in 2006. This means that all sumps represent waste of approximately the same age. There are three sumps, all of which have been sampled at regular intervals along with the composite (whole-site storage tanks) since 2003.

Relatively few data for the composite sample L-310 were able to be collected from the facility during site visit by the project team; therefore, insufficient data are available for any evaluation as indicated in Table 5-1. However, given that this location represents leachate from the entire active facility rather than just the closed WMU, use of one of the three sumps as a surrogate composite provides findings that are more useful. The middle sump L-306 was selected as a reasonable average location.

BOD Trend Testing: A decreasing BOD trend was evident at sumps L-305 and L-306 but not at L-307. However, all 95% UCLs calculated for the data are still extremely high at these sumps, probably reflective of the fact that the WMU was only recently closed.

BOD and BOD/COD Quality Criteria: Not tested.

Consistency Testing: Both L-305 and L-307 were consistent with the surrogate composite sump L-306.

Based on these findings, Site G appears ready to begin proper evaluation of the Leachate Module. However, despite exhibiting a downward BOD trend and good sump-sump consistency, leachate concentrations at Site G remain high. This means that evaluating threats to HHE at the POC and/or POE, and developing a passive or semi-passive leachate management strategy (e.g., utilizing constructed wetlands) may be challenging. Opportunities to optimize leachate, GW, and/or SW monitoring based on non-detect parameters in leachate may also be limited, but should be explored to the fullest extent possible. Overall, however, it can be concluded that Site G again supports the decision processes built into the Leachate Module.

#### 5.2.2.4 Site H

Site H comprises two separate study WMUs – an old historic unlined area that was closed in 1993 and partially overfilled by the Subtitle D-compliant geosynthetic liner system to the three new units comprising the remainder of the case study site. No leachate data are available from the old area; for this reason, Site H has been considered as two "half sites" in discussions of leachate data availability). The three new units each comprise three cells, have a total combined footprint of 27-ac, are currently inactive with intermediate soil cover, and are contiguous with active landfill operations. In addition, the middle unit (Cells 5, 6, and 7) has been used since 2004 to recirculate leachate from the entire site. Although each cell has its own sump, leachate data are reported per three-cell unit as shown on Table 5-1. Leachate data are reported since 2000 from the whole-site leachate storage tank and each of the three-cell units (herewith "sumps" for simplicity of discussion).

BOD Trend Testing: BOD trend was tested at all four sampling locations, although only the composite TANK was found to exhibit a statistically decreasing or steady trend. This is somewhat surprising given TANK includes whole-site leachate from an active site while sump CELLS 5, 6, 7 represents a leachate recirculation cell.

BOD and BOD/COD Quality Criteria: As would be expected given the extremely high 95% UCL value of 14,700 mg/L calculated for BOD using the most-recent four data points, Tier 2 testing does not offset the non-trending situation observed for CELLS 5, 6, 7.

Consistency Testing: Consistency testing using BOD data was conducted between the composite sample TANK and the three sumps, as well as between sump CELLS 5, 6, 7 and the other two sumps. The latter sump was selected because this represents leachate from a recirculation unit and thus would be expected to show rapid onset of a BOD downtrend (potentially setting up "hot sump" issues with the other units that should be identified at the earliest opportunity). Encouragingly, Table 5-1 shows 100% consistency between both the composite-sump and sump-sump data.

In conclusion, findings from Site H sound a strong note of caution against immediate embarkation on a full Leachate Module evaluation despite having demonstrated sump consistency and a downward BOD trend in the whole site composite TANK. Most importantly, at both the TANK and CELLS 5, 6, 7 sampling locations, the most-recent 95% UCL for BOD is significantly higher than that calculated using the entire data series. While this finding may seem counter to having already demonstrated a decreasing trend in composite TANK data, it should be remembered that a UCL is not a simple reflection of absolute mean concentrations, but also a measure of standard deviation; therefore, significantly higher variability between the last four data points than amongst the entire data series is the likely cause of this apparent abnormality. This finding for BOD suggests that leachate concentrations for many RPs will also remain relatively high, which means that sump consistency analysis for RPs and subsequent Source/POC/POE Evaluations may find that few reductions in leachate management and

monitoring are possible. Nevertheless, proactive monitoring of composite and sump-specific leachate in accordance with suggested EPCC Methodology protocols (see Sections 4.2 and Appendix 1-3) should be ongoing such that opportunities to optimize leachate, GW, and/or SW monitoring based on non-detect parameters in leachate can be explored to the fullest extent possible. Findings from Site H clearly illustrate the value of proactive leachate monitoring and the Leachate Module's multi-faceted preliminary evaluation of data consistency, trend, and derivation of statistically representative parameter concentrations to build a comprehensive picture of landfill behavior relative to leachate emissions. Thus, Site H again supports the main decision processes built into the Leachate Module.

#### 5.2.2.5 Site I

Site I is a pre-Subtitle D landfill that ceased active operation in 1989 and was closed in 1991. The WMU was constructed in 10 cells according to a design originating in the 1970's; however, only in the newest one third of the landfill area has a "true" LCRS been installed. To mitigate this, a subsurface cutoff wall was installed around the toes of the older portions to intercept leachate and direct towards the newer LCRS portion. Closure capping at the site comprises both clay and geosynthetic systems, the latter having been installed over the newer portion. Although 11 sumps exist in this portion, all but three gravity drain to one central sump location MH-9 and thus are not "true" sumps in terms of representing low points on the liner at which leachate could accumulate. Two of the remaining three sumps pump leachate to one location MH-TE-7 which in turn pumps to MH-9. Leachate from MH-9 is pumped to composite location TANK.

BOD Trend Testing: BOD data from the composite sample TANK is available for the period 1992 through 1999. Evaluation of composite data reveals a deceasing BOD trend with very low 95% UCL values well below 100 mg/L.

BOD and BOD/COD Quality Criteria: Not tested.

Consistency Testing: No sump-specific data have been collected.

Based on the above, once at least one round of sampling at the four sump locations has been conducted to allow for consistency testing of all RPs, a de minimus task, Site I will be fully prepared to begin proper evaluation of the Leachate Module. Given the characteristics of composite data, it seems likely that evaluating threats to HHE at the POC and/or POE, and developing a passive or semi-passive leachate management strategy (e.g., utilizing constructed wetlands to provide final polishing prior to direct discharge of treated effluent) will be fruitful. Further, opportunities to optimize leachate, GW, and/or SW monitoring based on non-detect parameters in composite and sump-specific leachate samples should be available.

#### 5.2.2.6 Site J

Site J is a large 244-ac, 11-module WMU contiguous with active landfill operations. Approximately 32 acres of sideslope cover to three cells have been closure capped using an all-soil ET cover system; the remainder of the WMU is interim-capped only. Leachate collection is via two gravity drains; L-01 drains leachate from Modules 1 – 5, while L-02 drains Modules 6 – 11. Leachate data at Site J are very limited; only five and four BOD data points are available for L-01 and L-02, respectively. The site is located in a relatively dry climatic region and does not generate significant quantities of leachate. An open leachate evaporation pond serving the entire facility provides a composite sampling location POND, although no data from this location was seen by the project team.

The only evaluation currently possible at Site J is calculation of a 95% UCL for BOD at the two sumps using the four most-recent data; in this regard, the findings were positive in that the value for L-01 (representing leachate from the older modules) was an order of magnitude lower than that for L-02 (representing newer modules). More positive is the fact that leachate management at Site J is via gravity drainage to an onsite evaporation pond. This will be extremely beneficial in terms of sustaining a long-term passive leachate management strategy after full closure of the facility. Therefore, despite the current lack of leachate data at Site J, it is anticipated that collecting sufficient data to allow a rewarding evaluation of the Leachate Module in the not-too-distant future will be relatively straightforward.

## 5.3 Landfill Gas Module

In the Gas Module, once a future LFG management strategy has been proposed (which may or may not incorporate continued operation of an active LFG control system), its suitability is evaluated qualitatively based mainly to the extent of LFG control modification proposed as well as the landfill's remaining LFG generation potential and environmental and geologic setting. The approach involves a step-down evaluation: initially, a qualitative screening evaluation is performed to estimate when future LFG generation will fall below de minimus levels in a site-specific context followed, if necessary, by a more detailed engineering or risk evaluation[5]. Passing a screening or risk evaluation allows implementation of the proposed new level of LFG management, subject to a technically appropriate Confirmation Monitoring (CM) program with duration and frequency based on a conservatively estimated time of travel (TOT) for gas migration from the landfill through the unsaturated buffer zone to monitoring probes at the POC and thence to the property boundary POE.

[5] If a clear decision on modifying LFG controls cannot be made solely based on the screening approach, a site-specific risk assessment should be undertaken using the procedures outlined in the Gas Module or a reasonable alternative. This is not discussed in this report, mainly because there is currently no widely accepted methodology for the completion of such engineering or environmental risk analyses. Development of such an approach, particularly one that considers latent surface emissions such that air quality and GHG control criteria can be demonstrably met in the absence of active LFG controls, represents an important opportunity for future expansion of the EPCC Methodology's capabilities, but is beyond the scope of this study.

### 5.3.1 Calculating Time of Travel (TOT) for Gas Migration

The current procedure for establishing a CM program based on calculating TOT for gas migration in the Gas Module is described in Section 5.3 of the Technical Manual. In brief, maximum and minimum TOTs for gas migration are calculated based on one-dimensional application of Darcy's law for advective flow in the uppermost porous media under an assumed minimum and maximum pressure gradient, respectively, from the WMU toe to a POC monitoring probe in the direction of the shortest distance to the property boundary. For simplicity of application, Table E-5-4 of the Technical Manual provides a range of TOTs (per 100-ft horizontal travel distance) based on a reported maximum hydraulic conductivity in the vadose zone and measured maximum internal gage pressure in the WMU. If the gas POC is further than 100 feet from the WMU, the relevant TOT value is simply multiplied accordingly to derive the necessary TOT; this procedure is extremely conservative given that the influence of the advective pressure gradient will decease inversely with distance from the landfill.

As currently written, measurements of internal gas pressure in the WMU are essential for calculating a gas migration TOT. However, as previously discussed in Section 4.3, no case study site has collected these data and, furthermore, the project team's discussions with site operators revealed universally strong reluctance at attempting to collect such data. In conducting this study, it was therefore concluded by the project team that this monitoring requirement be redefined as it is simply too complicated to be required at all sites for completion of the Gas Module. In this regard, the project team devised a modified screening approach for Table E-5-4 bracketed by near-zero and instability-causing gas pressures to define the duration and frequency of gas CM based on upper- and lower-bound TOTs, respectively. The revised table, along with a discussion of its technical basis, is provided as Appendix 1-5.

### 5.3.2 Case Study Application of Proposed Modified TOT Procedure

The case study sites were used to "ground truth" the reasonableness of the modified TOT procedure in Appendix 1-5. The layout of a generic WMU in relation to the gas POC and POE is provided on Figure 5-1, where "Stratum 1" represents the uppermost porous media and "$TOE_{GAS}$" represents the WMU toe closest to the property boundary of concern (considered adjacent to the nearest offsite property to the WMU). Thereafter, Figures 5-2A through 5-2J depict the site-specific gas related features "GAS POC," "GAS POE," "Distance X," and "Distance Y" shown on generic Figure 5-1.

Table 5-2 summarizes findings from each of the case study sites in relation to the site layout shown on each of the figures. Inspection of the table reveals that at 5 of 10 sites, Distance X is of the order of 100 ft while at 3 sites, Distance X is substantially less than 100 ft. Only at Site J is there a significant distance from $TOE_{GAS}$ to the GAS POC monitoring probe. If these case study sites represent typical gas POC layouts at Subtitle D landfills, an excessive duration of gas CM based on long travel distances is unlikely to be common.

#### 5.3.2.1 Sites A and H (Fast-Moving Conditions for Gas TOT)

At Site A (i.e., sandy vadose zone with $k = 5.4 \times 10^{-2}$ cm/s and Distance X = 100 ft), the total duration of gas CM based on maximum TOT would be limited to six months. However, the price paid for such high permeability and fast potential gas migration is that the frequency of CM based on minimum TOT would be 2 days. Inspection of Figure 5-2A reveals that there is no practicable scope for relocating GAS POC at Site A such that the CM frequency could be reduced, because the POC and the POE are co-located.

At Site H (i.e., sand/gravel vadose zone with $k = 4 \times 10^{-2}$ cm/s and Distance X = 20 ft), the total duration of gas CM based on maximum TOT would be relatively short at two years (i.e., 20/100 × 5 years). However, again the frequency of CM based on minimum TOT would be intense at 3 days, and again inspection of Figure 5-2H reveals that there is no practicable scope for relocating GAS POC at Site H because the POE is within 20 ft of the POC.

In summary, at both Sites A and H, site-specific WMU pressure measurements are the only reasonable recourse for a site operator seeking to reduce the intensity of monitoring (although it should be remembered that, all going well, gas migration monitoring could be permanently eliminated in only six or 24 months following successful completion of gas CM in the absence of remaining active LFG controls).

#### 5.3.2.2 Sites F and I (Slow-Moving Conditions for Gas TOT)

At the opposite end of the spectrum, two sites (Sites F and I) are not assigned either a maximum or minimum TOT value on Table 5-2 (and thus will not require any gas CM). This is based on these sites being located in low permeability till or silt deposits that exceeds the minimal condition for vadose zone permeability ($k \leq 5 \times 10^{-5}$ cm/s) from Appendix 1-5.

#### 5.3.2.3 Sites C, E, and G (Geometric Constraints on Modifying Gas TOT)

At Sites C and G, with lower-range vadose zone $k$ values and Distance X < 100 ft, CM programs would be developed based on maximum TOTs (duration of CM) in the range of 4 – 8 years and minimum TOTs (frequency of CM) in the range of bimonthly to quarterly. Relocation of GAS POC is not really practicable or desirable at these two sites. It is unlikely that a site operator would consider a gas CM program developed around these figures to be overly burdensome.

At Site E, with vadose zone $k = 4 \times 10^{-4}$ cm/s and Distance X = 80 ft, the situation is even better: gas CM for a total duration of eight years would require monitoring only three times in years 0, 4, and 8.

#### 5.3.2.4 Sites B, D, and J (Opportunities to Modify Gas TOT)

Opportunities for modifying the location of GAS POC at the remaining three sites are presented together in this final subsection. Note that, to clearly identify the presence of a migrating gas plume rather than just a temporary, localized condition, the Gas Module does not recommend installing new CM probes closer than 50 feet from the WMU toe.

At Site B, with relatively high vadose zone $k = 7.53 \times 10^{-3}$ cm/s and Distance X = 100 feet, the duration and frequency of gas CM would be 5 years and 15 days, respectively. However, Distance Y from GAS POC to GAS POE is 700 feet, meaning that a potential gas plume could migrate a considerable distance from the WMU while still remaining on the property with ample time for corrective action to be taken to prevent it reaching the POE to any significant extent. Thus, in an effort to avoid bimonthly monitoring over a five-year period, an additional monitoring location (GAS POC NEW) could be added 600 ft from $TOE_{GAS}$ as shown on Table 5-2 and Figure 5-2B. In this way, the existing GAS POC would serve to detect a slower-moving gas plume (and so conservatively define the duration of CM) while GAS POC NEW would serve detect a faster-moving gas plume prior it to having migrated too close to the POE.

At Site D, with vadose zone $k = 4.6 \times 10^{-4}$ cm/s and Distance X = 110 feet, the duration and frequency of gas CM would be 11 and 5½ years, respectively. At this site, the operator could significantly reduce gas CM requirements by installing a substitute probe GAS POC NEW a distance of 50 feet from $TOE_{GAS}$ as shown on Figure 5-2D. This would reduce the duration and frequency of CM to 5 and 2½ years, respectively, meaning that only three monitoring events in five years would be required.

Finally, and worst of all on initial evaluation, is Site J, with vadose zone $k = 6 \times 10^{-5}$ cm/s (which just misses the cut-off for no CM on revised Table E-5-4 in Appendix 1-5) and has very long Distance X = 275 feet. Here, the duration and frequency of gas CM would be 28 and 14 years, respectively, (although gas CM would thus require monitoring to be performed on only three occasions in years 0, 14, and 28). However, the operator could significantly reduce gas CM requirements by installing a substitute probe GAS POC NEW a distance of 50 feet from $TOE_{GAS}$ as shown on Figure 5-2J. As at Site D, this would reduce the duration and frequency of CM to 5 and 2½ years, respectively, meaning that only three monitoring events in five years would be required.

## 5.4 Groundwater Module

The GW Module provides guidance on modifying or optimizing the GW monitoring program during intermediate steps of the PCC period, and ultimately ending GW monitoring, based on characterization of the leachate source and hydrogeologic model. The systematic approach to evaluating the module centers on determination of the time of travel (TOT) for a potential leachate release to migrate from a sump or low point on the base of the WMU to the downgradient POC. The GW TOT calculation is critical to the outcome of an EPCC

Methodology evaluation because the total duration of leachate- and GW-related PCC under a performance-based scenario is defined by the time taken for an unattenuated conservative tracer on the "leading edge" of a hypothetical leachate plume to migrate from the landfill to the GW POC. Generally, it is assumed that chloride will serve as the tracer of choice as previously discussed in Section 4.4.

### 5.4.1 Calculating Time of Travel in Groundwater

The GW Module requires calculation of two TOT terms:

- Maximum TOT, which is used to establish the optimal duration of monitoring and is calculated using a simplified two-dimensional Darcian flow path based on the time taken for leachate to release to migrate vertically through the vadose zone from the base of the WMU to the GW surface in the uppermost monitored hydrostratigraphic unit and then horizontally in the saturated zone to the GW POC; and
- Minimum TOT, which establishes the optimal monitoring frequency and is calculated assuming horizontal migration of leachate from the downgradient toe to the GW POC (vertical migration is assumed instantaneous and is ignored).

With some caveats related to special circumstances involving a No Migration Demonstration (NMD) for vertical flow in the vadose zone[6] or stagnant groundwater flow conditions for horizontal flow in the saturated zone[7], the conservative nature of the GW Module requires that: (i) the migration distance start at the most upgradient sump or low point on the WMU liner from which a leachate leak could reasonably be assumed to originate; and (ii) "time zero" for the TOT calculation is not at closure, but at the most-recent time at which an unacceptable leachate release could have occurred.

While the project team is not considering modifying any requirements related to the procedures and assumptions for calculation of TOT (which will likely be critical to the regulatory acceptance of a performance-based petition to end GW monitoring), concerns have been voiced from within the regulated industry that dependence on such conservative calculations may unduly burden site operators with excessively long PCC periods and result in universal resistance to using the methodology. In critical appraisal of the methodology's utility and sensitivity to these input requirements and evaluative processes, the team applied the GW TOT calculation procedures at the ten case study sites.

[6] Performing a NMD is a USEPA-sanctioned procedure in accordance with guidance document EPA530-R-99-008 (USEPA, 1999). See discussion in Section 6.2.2 of the Technical Manual.

[7] In brief, if the average GW velocity is less than 1 ft/yr and the GW POC is a minimum of 100 ft downgradient of the WMU, then GW monitoring serves no practical purpose and should be eliminated. If the average GW velocity is below 5 ft/yr, groundwater may be considered stagnant. However, to remain conservative, a default GW velocity of 5 ft/yr should be assumed. Technical justification for determining lower-bound conditions to represent stagnant GW flow is provided in Section 6.2.3 of the Technical Manual.

### 5.4.2 Case Study Application of the Groundwater TOT Procedure

The procedures for calculating maximum and minimum TOT from a WMU to the GW POC are described in Appendix E-3 of the Technical Manual. To illustrate the geometric and hydrogeologic characteristics of a site in relation to the calculations performed, the layout of a generic WMU in relation to the GW POC and POE is provided on Figure 5-1, where:

- "Stratum 1" and "Stratum 2" (if present) represent unsaturated units below the WMU;
- Regardless of whether one or two upper strata are present, "Stratum 3" always represents the uppermost monitored saturated unit (aquifer)[8];
- "SUMP" represents the most upgradient low-point on the liner from which leachate could migrate vertical through "Distance A" to the top of the groundwater table (or top of Stratum 3 if the aquifer is confined) and the maximum horizontal migration "Distance B" to the POC monitoring well "GW PC;"
- "Distance D" represents the additional horizontal distance from GW POC to the property boundary "GW POE" (generally considered adjacent to the nearest offsite property downgradient of the WMU);
- "$TOE_{GW}$" represents the downgradient WMU toe closest to GW POE, separated from GW POC by minimum horizontal migration "Distance C;" and
- Upgradient and downgradient wells "GW UP" and "GW DN," respectively, separated by "Distance I," are used to calculate a representative hydraulic gradient across the WMU.

Table 5-3 summarizes findings from each of the case study sites in relation to the site layout features shown on Figure 5-1. The table also refers to the series of Figures 5-2A through 5-2J which depict the layout of GW-related features shown on Figure 5-1 at each of the case studies.

#### 5.4.2.1 Sites B and H (Straightforward Hydrology, Short TOT)

The hydrogeologic model at Sites B and H is straightforward in that the uppermost unit is also the aquifer. At both sites, this unit comprises sands and gravels with high hydraulic conductivity, *k*, on the order of $10^{-2}$ to $10^{-3}$ cm/s and shallow groundwater, yielding near-instantaneous vadose zone TOTs down through Distance A and maximum saturated zone TOTs through Distance B of between 7 and 15 years. Given the reasonableness of these timeframes,

[8] Note, therefore, that the unit comprising "Stratum 1" with reference to the GW Module often differs from that comprising this unit for the Gas Module; as a result, the data in the yellow-colored cells representing Stratum 1 on Tables 5-2 and 5-3 is different at six of the ten case studies. In most cases (e.g., Sites A, B, C, D, and H) this is because groundwater occurs in the uppermost unit, meaning that Stratum 1 and 2 do not exist in the context of the GW Module (i.e., GW Stratum 3 = Gas Stratum 1). At Site F, this is because the base of the WMU is below a distinct stratigraphic unit. Thus, the Gas Module must be concerned with gas migration in the upper till (Gas Stratum 1) whereas the GW Module is concerned with vertical migration down through the middle and lower tills (GW Stratum 1 and 2) to the aquifer (GW Stratum 3).

no modification to GW monitoring features is proposed at these sites. Despite the simplicity of these calculations, each site has certain interesting features related to calculation of GW TOT that are worthy of further discussion.

At pre-Subtitle D Site B, which lacks a LCRS and therefore has no sumps, the base grading of the liner is nevertheless known from site record drawings. Groundwater flow is reasonable but not overly fast at 8 ft/year. Fortunately for the purposes of the GW module, the low-point on the base of the "liner" is along the downgradient toe of the WMU (see Figure 5-2B) and a GW POC well GWC-104 is located close to the WMU; therefore, Distances B and C are identical (120 ft) and the maximum and minimum TOT are also equal (because vadose zone TOT does not make a meaningful contribution to the maximum).

Site H comprises two study WMUs. Groundwater flow is extremely fast but varies directionally around the site (see Figure H-2 in Appendix 2-1H), meaning that any one of three monitoring wells could potentially serve as the GW POC; however, site geometry and predominant hydrogeologic conditions mean that monitoring well MW-3A serves as the most conservative GW POC for both WMUs. It should be noted that this is somewhat coincidental and may not necessarily be the case at every site comprising multiple WMUs for evaluation. Similar to Site B, the old unlined WMU at Site H lacks a LCRS with sumps. At this WMU, however, the base grading on the "liner" is unknown; therefore, according to the procedure in the GW Module, a midpoint on the plan area of the WMU is selected as the assumed point from which leakage of leachate could occur for calculation of maximum TOT (as shown on Figure 5-2H). The lined WMU at Site H comprises three subunits, each of which in turn comprises three cells each with an individual sump closely located along the northern toe of the units. Constructed grades for each of the nine sumps are known. To calculate TOT from this WMU, the sump (LCR-3) with the lowest base elevation at the most upgradient of the three subunits was selected as the starting point for the maximum TOT calculation.

Because the two WMUs at Site H are both considered to represent the case study, the greater of the two calculated values (i.e., 11 years for migration from LCR-3 to MW-3A) is the representative maximum TOT for Site H as a whole. The single closest point to GW POC on the downgradient toe of either WMU is $TOE_{GW}$; therefore, migration from the unlined WMU represents the minimum TOT (i.e., 21 months).

#### 5.4.2.2 Sites A and D (Straightforward Hydrology, Long TOT, Opportunities to Modify TOT)

The hydrogeologic model at Sites A and D is similarly straightforward to that of Sites B and H in that the uppermost unit is also the aquifer in which groundwater flows reasonably fast at 10 – 20 ft/year. At Site A, this unit comprises sand with very high hydraulic conductivity ($k = 1 \times 10^{-2}$ cm/s). Thus, despite considerable seasonal fluctuations in GW elevations around the site, a near-instantaneous vadose zone TOT down through Distance A is always evident. However, the maximum saturated zone TOT is 149 years, mainly because Distance B from LCS-01 to MW-11 is long at 1,700 ft and the hydraulic gradient, *i*, at the site fluctuates considerably (sometimes

even reversing) to yield a very low average value of 0.00033. At Site D, the uppermost unit comprises loess ($k = 4.6 \times 10^{-4}$ cm/s) and groundwater is shallow with good hydraulic gradient. However, again the maximum saturated zone TOT is long at 183 years, mainly because uncertainty as to the predominant direction of groundwater flow, coupled with the geometry of the WMU and location of sumps, conservatively penalizes Site D to a very long Distance B measurement of 3,700 ft from LCS14 to MW-201S.

At both sites, this TOT would potentially subject site operators to the worst of all possible situations – a GW monitoring period that is not unreasonable, but that clearly represents a very onerous financial and administrative commitment. One option to address this would be to petition for the frequency of monitoring to be substantially reduced to a multi-year cycle, based on the 13 and 16 year minimum TOTs calculated. For example, at Site A, even under a 15-year monitoring frequency leachate could not travel more than 170 ft past MW-11, considerably within the 350-ft distance to the property boundary (i.e., Distance D). Similarly, under an 8-year monitoring frequency, leachate could not travel more than 162 ft past MW-201S at Site D, again considerably within the 275-ft distance to the property boundary.

A better solution could be to revise the layout of the GW monitoring regime such that the maximum TOT is reduced. In practical terms, this means reducing Distance B. At Site A, a new monitoring well GW POC NEW could be installed downgradient of LCS-01 for the purposes of CM such that Distance B is reduced to 450 ft and the maximum TOT becomes a more manageable 40 years (see Table 5-2). Unfortunately, there may be cause to argue that the most upgradient sump under this new monitoring regime would cease to be LCS-01 but would rather be LCS-02 (see Figure 5-2A) for which there is no practicable scope for reducing Distance B, which is 1,250 ft for this sump. Thus, the maximum TOT would be reduced by only 25% to 111 years. However, inspection of site records (see summary in Appendix 2-1A) reveals that LCS-01 collects leachate from the oldest of the four cells comprising the WMU and that this cell was constructed having a clay liner only and was not subject to the level of CQA provided during construction of the more modern geosynthetic-lined cells. Based on this, it is argued that as the lowest point on the oldest portion of the lowest quality liner at the WMU, LCS-01 represents the point at which monitoring for a potential leachate release should be targeted.

At Site D, the situation is potentially much better; again, inspection of site records (see summary in Appendix 2-1D) reveals that basegrades and sump elevations across the entire WMU are known. Thus, it is reasonable to argue that, all things being equal, the lowest sump at the most downgradient slope of the liner is most likely to accumulate leachate and leak over time. The geometry of the WMU is favorable to such reassessment; the sump with the lowest base elevation (LCS01) is near the location of lowest liner basegrade, which is also near at the downgradient toe (see Figure 5-2D) such that Distances B and C are essentially equal at 330 ft and the maximum TOT thus equals the minimum TOT at 16 years.

The above discussion clearly illustrates the advantage provided by taking the time to comprehensively summarize the availability of data and site records and describe important

features of a WMU as exemplified by the ten site summaries provided in Appendix 2. Only because of what is known about Sites A and D does the possibility exist to petition to establish a CM monitoring regime that is somewhat counter-intuitive to the general procedures in the GW Module.

#### 5.4.2.3 Sites E and G (Complex Hydrogeology, Geologic Constraints, Medium-Long TOT)

The hydrogeologic models at Sites E and G are more complex than those for the previously discussed case studies in that one or more unsaturated units exist above the uppermost saturated unit. At both sites, the lithology is dominated by glacial tills.

At Site E, the vadose zone unit comprises silty clay till with very low hydraulic conductivity ($k = 1 \times 10^{-7}$ cm/s) while the aquifer unit comprises basal till with significantly higher hydraulic conductivity ($k = 1 \times 10^{-4}$ cm/s) in which groundwater is calculated to flow at 6.6 ft/year. Thus, both vadose zone TOT down through Distance A (40 ft) and saturated zone TOT across Distance B (400 ft) contribute approximately equal TOTs of 77 years and 61 years, respectively, for a combined maximum TOT of 138 years. However, it is considered likely that the very long vadose zone TOT of 77 years probably meets the conditions for a successful NMD petition, in which GW monitoring is not required if it can be demonstrated that the calculated vadose zone TOT exceeds the operating life of the WMU plus 30 years[9].

Assuming a NMD petition were not conducted or not successful, then because Distance A cannot be changed, the maximum TOT at Site E cannot be less than 77 years plus some additional TOT component for horizontal migration to a practical monitoring location. In this regard, the WMU layout and groundwater flow regime is fortuitous in that the most upgradient sump LCR-6 is located close to the downgradient WMU toe, and considerable scope for reducing Distance B exists through installation of a new CM well closer to this sump (see GW POC NEW on Figure 5-2E). By reducing Distance B to 50 ft, the saturated zone TOT is greatly reduced from 61 to 8 years; however, the maximum TOT is still 85 years because of the contribution of the vadose zone TOT.

If the maximum TOT could not be reduced beyond 85 years at Site E, the normal recourse open to a site operator would be to petition to significantly decrease the monitoring frequency to reflect a similarly slow migration potential based on minimum TOT. However, Site E is not fortunate in this regard; the $10^{-7}$ cm/s silty clay till comprising the uppermost zone for horizontal leachate migration through Distance C (80 ft) is reported to contain lenses and seams of sands and silts with $k = 4 \times 10^{-4}$ cm/s. Coupled with a high hydraulic gradient and low porosity, this means that the minimum TOT is calculated at 3 years. No scope to increase this value by relocating a CM well further from the WMU exists, because Distance D is only 20 ft. It is

[9] It is important to note that a formal NMD is a complex procedure and was not conducted within this study. Therefore, assertion that the WMU may meet the conditions for a NMD to be successful is speculative and is provided only to illustrate the options that may be available to an operator to reduce the burden of GW monitoring over the long term.

difficult to envision how Site E could argue for a better case than 85 years of CM with, at best, 3-year monitoring frequency.

Similarly, but to a lesser extent in terms of its effect on maximum TOT, at Site G the vadose zone beneath the WMU comprises a 23-ft thick till unit with very low hydraulic conductivity ($k$ = 1.83 × $10^{-7}$ cm/s) above ten feet of a high permeability sand. The aquifer comprises a fast-flowing sand/gravel unit in which groundwater is calculated to flow at over 160 ft/year. Thus, the vadose zone TOT (40 years) down through Distance A (33 ft) contributes significantly more towards a combined maximum TOT of 47 years than the saturated zone TOT (7 years) across Distance B (1,130 ft). Although relatively long, the vadose zone TOT of 40 years is not likely to mean that a NMD would be successful at this site. Because Distance A cannot be changed, the maximum TOT at Site G cannot be less than 40 years plus some additional TOT component for horizontal migration to a practical monitoring location. Given that the saturated zone TOT contributes only 15% of the maximum TOT, relocating GW POC is probably not worthwhile.

As previously discussed, the normal recourse open to the site operator in this type of case would be to petition to significantly decrease the monitoring frequency to reflect a similarly slow migration potential based on minimum TOT. However, similar to Site E, the $10^{-7}$ cm/s till comprising the uppermost zone for horizontal leachate migration through Distance C (100 ft) is reported to contain a sand/gravel outwash layer with $k$ = 2.67 × $10^{-2}$ cm/s. This yields a very short minimum TOT of 225 days (7½ months) at Site G. This means that, under the current monitoring regime, CM would be required for 47 years at about biannual frequency. Minimal scope to significantly change these CM requirements exists because Distance D is only 100 ft, and sufficient time must be always be allowed to detect migration of a leachate plume beyond the GW POC before it reaches the property boundary. However, by relocating the CM well further from the WMU, Site G could perhaps end up being allowed annual monitoring without extending the CM period.

#### 5.4.2.4 Site F (Complex Hydrogeology Dominated by Tills, Stagnant Groundwater)

Similar to Sites E and G, the hydrogeologic model at Site F is complex with vadose zone lithology dominated by two till units with extremely low hydraulic conductivities (on the order of $10^{-8}$ to $10^{-9}$ cm/s). The two units have approximately equal thickness below the WMU liner of 21 ft and 20 ft, respectively. The aquifer unit comprises dolomite ($k$ = 1.5 × $10^{-4}$ cm/s) in which groundwater is calculated to flow at a stagnant rate of 1.4 ft/year, which is replaced with the default rate of 5.0 ft/yr in accordance with GW Module procedure. Using these inputs, the vadose zone TOT down through Distance A (41 ft) is calculated at 1,252 years and the saturated zone TOT across Distance B (400 ft) is 80 years. The minimum TOT, which is calculated for a Distance C of 100 ft through a silty sand lens above the middle till with reported $k$ = 1.5 × $10^{-5}$ cm/s and $i$ = 0.0009, is even higher at 2,135 years.

The very long vadose zone TOT in excess of 1,250 years is very likely to mean that the conditions for a successful NMD petition can be met at Site F, in which case GW monitoring is

not required (again, a formal NMD was not conducted within this study). Regardless, GW monitoring at this site appears to serve no practicable purpose in terms of protecting HHE. It is concluded that the threat posed to HHE as a result of a subsurface leachate release from Site F is minimal to non-existent. Long-term leachate management at the site would be better focused on issues related to potential build up of leachate head or above grade seeps/breakouts.

#### 5.4.2.5 Site C (Geometric Constraints, Stagnant Groundwater Flow)

This case study represents a WMU at which site geometry and the hydrogeologic model result in potentially troublesome requirements for GW monitoring. The groundwater flow velocity is low and the layout of the WMU in relation to the downgradient property boundary offers little in terms of modifying the POC location.

The hydrogeologic model at Site C is straightforward in that the uppermost unit is also the aquifer. This unit comprises sand with $k = 2.2 \times 10^{-3}$ cm/s and shallow groundwater, yielding near-instantaneous vadose zone TOTs down through Distance A (10 ft). However, a low hydraulic gradient and very long Distance B from sump LCS-2 to monitoring well MW-25R of 2,200 ft conspire to deliver a maximum TOT of 652 years. Even resetting the groundwater velocity to a default minimum 5 ft/year is relatively inconsequential, delivering a TOT of 440 years. Further, inspection of Figure 5-2C reveals no scope to relocate the GW POC and review of the site information summarized in Appendix 2-1C does not identify another sump as being more appropriate to reassign as the starting point for migration (as was successfully recommended at Site D). Based on the very long TOT and slow groundwater flow velocity, it could be argued that GW monitoring at this site serves little practicable purpose in terms of protecting HHE. However, intuitively, this does not seem appropriate given that the uppermost unit is water bearing with relatively high permeability.

Given the unfavorable hydrogeologic conditions and geometric constraints on modifying the TOT for CM prior to ending PCC, this site best illustrates the significant value of proactive landfill operation and leachate data collection. If the WMU had been operated as a bioreactor, and/or sufficient leachate data had been captured early in the operating life of the WMU such that maximum concentrations of all regulated parameters could be calculated and these parameters could be shown to pass a Source, POC, or POE Evaluation in the Leachate Module, then the very long TOT would be moot as no GW CM would be required.

#### 5.4.2.6 Sites I and J (*De Minimus* Potential for Leachate Migration to Groundwater POC)

At Site I, the vadose zone beneath the WMU comprises two units; Stratum 1 is a 4-ft deep silt layer; underlying Stratum 2 comprises 30 feet of extremely low permeability ($k = 1.8 \times 10^{-7}$ cm/s) clay and silt. The vadose zone TOT down through Distance A (34 ft) is calculated at 64 years. It is therefore possible that the site meets the conditions for a successful NMD petition, in which GW monitoring is not required if it can be demonstrated that the calculated vadose zone TOT exceeds the operating life of the WMU plus 30 years.

The aquifer comprises a sand/clay unit ($k = 2 \times 10^{-5}$ cm/s, $i = 0.00041$) in which groundwater is calculated to flow at a rate of 0.03 ft/year, significantly below the 1 ft/yr threshold considered to represent *de minimus* flow for which monitoring of GW serves no practical purpose in terms of protecting HHE. The calculated saturated zone TOT across Distance B (180 ft) from sump MH-TE-5-6 to deep monitoring well MW12 is 6,000 years. Clearly, on this basis, GW monitoring at this site serves no practicable purpose in terms of protecting HHE and should be entirely discontinued (to put this in perspective, groundwater passing beneath the WMU location at the time the pyramids were being constructed would still be nearly a thousand years short of reaching the GW POC well).

The minimum TOT is calculated for a Distance C of 50 ft from sump MH-TE-5-6 to shallow (i.e., perched zone) monitoring well MW03 using a reported pre-development hydraulic conductivity in Stratum 1 of 0.02. This value cannot be verified under current field conditions, because an inward gradient exists in perched groundwater in this uppermost stratum due to leachate pumping. However, because the intent of a GW Module evaluation is ultimately to demonstrate protection of HHE after elimination of active leachate management, it must be assumed that this gradient will eventually return. The minimum TOT so calculated is a more meaningful 36 years. Therefore, while the threat posed to HHE as a result of a deep subsurface leachate release from Site I is minimal due to the fact that the groundwater velocity is de minimus, it could be argued that infrequent monitoring of perched groundwater should be continued during active leachate pumping and continue for a 36-year period post-pumping to demonstrate that near-surface lateral migration of leachate does not occur.

At Site J, the low hydraulic permeability in both the vadose and saturated zones would combine to yield a maximum TOT value of 300 years. The most significant contribution (244 years) to this total is made by the vadose zone TOT. However, as with Sites E and F, it is considered likely that the very long vadose zone TOT would meet the conditions for a successful NMD petition, in which GW monitoring is not required if it can be demonstrated that the calculated vadose zone TOT exceeds the operating life of the WMU plus 30 years. In terms of migration in saturated media, although the GW Module allows the calculated GW velocity in the saturated zone (3.3 ft/year) to be replaced with a default 5 ft/year velocity to reduce the saturated zone TOT to 37 years from 56 years, this does not make a consequential difference to the maximum TOT term. The minimum TOT is 37 years over a Distance C of 185 ft (because the reported horizontal $k$ is two orders of magnitude higher than the vertical $k$ in the tuffs/sandstone material comprising Stratum 1). However, given the significant depth to groundwater (Distance A is 127 ft), the generic minimum TOT calculation procedure is not valid and should be discarded (i.e., assigning a minimum TOT at this site in this way is not considered to be appropriate). Overall, a NMD and the fact that the site is in a dry climatic region with a low leachate generation rate mean it should be relatively easy to argue that GW monitoring at this site serves no practicable purpose in terms of protecting HHE and should be discontinued.

# 6. SUMMARY AND CONCLUSIONS FROM THE STUDY

In Section 1, it is argued that to demonstrate that PCC can be ended, state regulators will need to be convinced with site-specific data that the long-term threat posed by an undisturbed landfill is minimal because the residual emission potential is acceptable. A performance-based approach such as offered by the EPCC Methodology incorporates components of a target value approach as well as conservative impact and risk assessment approaches, and therefore seem to be a viable and flexible option for making such demonstrations. The methodology is based on the concept that site-specific strategies for managing closed landfills are required to control the duration and cost of PCC while providing long-term protection of HHE. As illustrated on Figure 1-1, such strategies are based upon continual optimization of PCC as a step-down function of the characteristics of leachate and LFG, the performance of the control systems, and the sensitivity of the surrounding environment. Once conditions representing functional stability of the closed landfill can be demonstrated, regulated PCC is completed, although some de minimus level of custodial care would typically still be provided (mainly for the cover).

A summary of the EPCC Methodology, with a focus on prerequisites and data requirements, is provided in Section 2. Since publication of the methodology, the project team has been made increasingly aware that the prerequisites and data collection requirements might seem daunting to new users of the methodology. This is exemplified by the very limited application of the methodology in the Florida study conducted by Tansel et al. (2008), despite the study authors' statements that their approach was based on the EPCC Methodology. In response, two data checklists were developed to help collect and account for the relevant data needed for application of the methodology in a more user-friendly format. Development of the checklists (which are provided as Appendices 1-1 and 1-2) is discussed in Section 3. The checklists were found to be invaluable for maintaining consistent standards for data collection and assembly during this project, especially by AquAeTer (who were not previously familiar with the methodology).

As summarized on Table 3-1, the ten case studies represent a wide range of site conditions, climatic regions, liner and cover systems, and waste ages. The data and site information collected at each site was critically reviewed for completeness and compiled by the visiting project team member based on a standardized 10-15 page summary format, including between three and five standardized figures illustrating the physiographical setting of the site and stylized depictions of the its layout, features, POC, and POE. The ten completed site summaries are provided in Appendix 2. By its nature, the EPCC Methodology utilizes somewhat generic procedures; however, because all sites are unique not all procedures are appropriate in all circumstances. A key finding from this study was that taking the time to characterize a site in this way was invaluable when it came to understanding how and when certain procedures were not applicable or should be modified (as discussed where appropriate in Sections 4 and 5).

The project team is aware that some site operators may consider the methodology too restrictive and overly burdensome in its data requirements as compared to what is perceived will be accepted by a State agency reviewing a petition to end PCC. The reality of such perceptions

cannot be addressed by this study; however, a key objective of the study was to attempt to better align the comprehensive "wish list" of data currently listed as critical to successful application of the methodology with the actual availability of site records, permit documentation, and monitoring data found to be available at the case study sites. The availability of data across the ten case studies was qualitatively assessed through Section 3 (as summarized in Tables 3-2A through 3-5, which reproduce the current data requirements and classification from the Prerequisites Module for use in the Leachate, Gas, GW, and Cap Modules, respectively). Inspection of tables reveals that while data availability at these ten handpicked sites was good, none is currently ready to implement a full EPCC Methodology evaluation; all are lacking data in one or more key area. However, all should be in a position to take advantage of some level of optimization and, potentially, cost reduction. It should therefore be stressed that while the absence of key data may prevent full evaluation of a module, the EPCC Methodology was developed with the intent that every evaluation provide an opportunity to optimize care and/or monitoring. Indeed, the gradual elimination of PCC systems and activities is fundamental to the approach as previously illustrated on Figure 1-1. An intended outcome of this study is that this aspect of the methodology be better illustrated as representing both a positive outcome and the most likely result of any preliminary assessment of the Prerequisites Module.

The EPCC Methodology can be proactively used during facility operation or immediately after closure to identify measures that can reduce the long-term need for active PCC and accelerate the transition to semi-passive or passive management. Therefore, a site operator is strongly encouraged to apply the Prerequisites Module as soon as practicable to ascertain current and future data requirements, conceptually evaluate interim and long-term WMU management options based on the current conditions at the facility, and perform broad feasibility and economic analyses of operational or design changes that could be implemented to reduce the need for active PCC in the future. Such early assessments should always include identification of proactive data collection needs to enhance future evaluation. It is recognized that the Prerequisites Module encourages considerable collection and management of data some time before they are likely to be utilized, and that some of the data may not be required under permit conditions. While this will potentially prevent funds being used on unnecessary monitoring and PCC activities (thus realizing immediate cost benefits), an in-depth discussion of the relative costs associated with proactive data collection is beyond the scope of this report. Such discussion is complex given that the potential benefits of a future evaluation are antagonist to the costs associated with conducting a more in-depth evaluation as well as the potential ramifications of not collecting enough data to do so. Results from life-cycle cost/benefit analyses of these antagonistic efforts will likely vary significantly between sites and states, depending on operational, siting, economic, and regulatory factors. This issue needs to be more clearly outlined and discussed to facilitate the decision-making process, perhaps in follow-up work to this study. Suffice to say herein, these data collection efforts are critical to the EPCC Methodology and their postponement may simply delay full application of the methodology in the future. In the opinion of the project team, the value of using an early assessment as a means to provide a site operator with a "heads up" forecast of likely future outcomes given different

operational and PCC system scenarios would more than offset a short-term increase in effort and costs.

Building on the above discussion, site operators are encouraged to view application of the methodology as a multi-stage process, the first stage of which should always be preliminary assembly and summarization of site information and monitoring data availability. This should be followed by development of proactive monitoring plans with emphasis on collection of leachate data. An important outcome from Section 4 (backed up by preliminary evaluation of leachate data in Section 5) is therefore affirmation of proactive leachate monitoring requirements, which are reproduced in Appendix 1-3. These requirements, which have been updated subject to the discussions in this report, provide recommendations for the quantity and duration over which leachate monitoring data should be proactively collected and processed. Thereafter, broad characterization of the WMU source, POC, and POE with respect to certain key decision processes is recommended, based on: (i) composite-sump consistency testing and trend analysis for BOD and/or other decision parameters; and (ii) determination of groundwater TOT. As was discussed in detail in Section 5, both evaluations have critical implications for the total duration of performance-based PCC. They will also be critical to making proactive decisions regarding implementing enhanced waste degradation operations (e.g., bioreactor), modifying landfill management systems to take advantage of passive control technologies (e.g., constructed wetlands for leachate treatment or bioactive covers for LFG), and/or changing the closure design (e.g., inclusion of a low-maintenance all-soil alternate final cover). Consideration of all of the above is strongly encouraged by the project team because, using the methodology's step-down approach to functional stability, they will invariably enhance the longer-term outlook for transition through passive PCC to custodial care.

In Section 4, the major categories of data requirements under the Prerequisite Module were discussed and reassessed based on the observed availability of data at each of the case study sites. The discussion was focused on the impact of persistently missing data for key evaluations in the four PCC modules and the anticipated burden and timeframe associated with addressing data gaps. Where appropriate, this allowed apparent data deficiencies to be accommodated or alternatives suggested without compromising the conservative nature of the EPCC Methodology. The primary deliverable from this review is provided as Appendix 1-4, which represents an updated assessment of data needed for full application of the four PCC Modules under the EPCC Methodology. In some cases, a reassessment of the definition of "Critical" and "Non-Critical" data is made. Other items were added, significantly modified, or deleted. A new mid-level "Optimal" classification was also developed to reflect a new emphasis for data requirements under the EPCC Methodology (essentially, moving away from a best-case "wish list" scenario towards a minimum requirements approach). Generally, the unavailability of optimal data will trigger use of conservative assumptions in their absence. Again, although this will invariably prolong the duration of certain PCC activities, it should be emphasized that it will not ultimately prevent such activities from being modified or ended. Finally, the existing "Flag" and "Supplemental" categories were deemed cumbersome and changed to a single "Potentially Critical" category.

From the outset of this study, the project team recognized that the outcome, or even initial applicability, of the EPCC Methodology is sensitive to certain data requirements and evaluative processes and that such sensitivity, if significant, could limit the extent to which the methodology is embraced by landfill operators and regulators. These sensitivities were investigated in Section 5, which presents and clarifies the benefits and limitations of current procedures, or provides recommended modifications to an element of the methodology where this is technically warranted. The preliminary findings are summarized below.

End-Use Strategy: From review of the case study sites, it was generally concluded that lack of consideration of alternative cover system designs combined with few attempts at far-sighted end use-planning may represent a significant limiting factor for full application of the EPCC Methodology. This will probably manifest itself most significantly by reducing the flexibility for passive management options offered in the Cap Module and, by association, in the Leachate and Gas Modules. Overall, an important outcome from this study should be to deliver the message that while the EPCC Methodology does not specifically advocate for alternative covers and is equally applicable to all cover system designs, it is recognized that a natural analog cover system will invariably be extremely beneficial in terms of providing: (i) iterative flexibility for evaluation of the Leachate and Gas Modules (because both modules require development of long-term leachate or LFG management strategies which are largely dependent on the type of cover in place); and (ii) opportunities to optimize PCC elements, reduce the total duration of active PCC, and extend the range of reuse options. It should also be concluded that the lack of natural analog cover systems at many Subtitle D sites represents wasted opportunity, not least in light of the objectives for custodial care, during which only a *de minimus* level of care would typically still be provided (mainly for the cover), but also because they offer broader scope for restoring the ecological, recreational, or other value of the landfill property (ITRC, 2006b).

Leachate Module: A number of relatively complex statistical and other evaluative procedures are required prior to the Leachate Module user being able to perform analyses of composite-sump consistency and trend behavior for any analyte. Commercial data management software is available to perform these analyses. For this study, however, the project team was able to utilize the detailed descriptions for data processing and statistical manipulation provided in Section 4.2 of the Technical Manual, coupled with professional judgment, to develop a relatively simple Microsoft Excel® spreadsheet tool. Therefore, while not exactly representing "off the shelf" tools, performing the data analyses required in the Leachate Module should not represent an undue burden for a well-qualified engineer or geologist.

The primary decision parameter (DP) for leachate is BOD for which a statistically significant downward trend in concentration in a representative composite sample is used as an indicator of improving leachate quality. DP analyses require at least eight data points. In addition, to provide confidence that composite leachate data are truly representative of leachate collected across the entire basal area of a WMU, the Leachate Module requires "snap shot" consistency testing to be performed between the selected representative composite sample and at least one sample from each WMU sump. Because of the limited scope of this study, and the importance

of BOD in enabling a full Leachate Module evaluation to be performed, investigation of the module's sensitivity to evaluative procedures was mainly limited to BOD data. At the five sites at which BOD data were available, useful progress through the evaluative procedures could be made at each site, from which it was concluded that the preliminary evaluations required in the leachate module are appropriate.

Gas Module: The utility of the Gas Module is greatly dependent on the estimated time that a gas plume would take to migrate from the WMU to a POC probe. In conducting this study, it was concluded that current procedures requiring measurement of internal gas pressure to estimate TOT was it is simply too complicated to be required at all sites for completion of the Gas Module. The project team therefore devised a modified screening approach for bracketed by near-zero and instability-causing gas pressures to define the duration and frequency of gas confirmation monitoring based on upper- and lower-bound TOTs, respectively. Using readily available data from the case studies, all ten sites were found to be in a position to develop reasonable gas CM programs using the new default procedures (which are provided in Appendix 1-5). This should make the Gas Module significantly more user-friendly without compromising its primary purpose of ensuring that modifications to LFG control systems are appropriate and can be demonstrated through CM to be protective of HHE.

Groundwater Module: A groundwater TOT calculation is critical to the outcome of an EPCC Methodology evaluation because the total duration of leachate- and GW-related PCC under a performance-based scenario is defined by the time taken for an unattenuated conservative tracer on the "leading edge" of a hypothetical leachate plume to migrate from the landfill to the GW POC. The project team has not considered modifying these requirements (which will be critical to the regulatory acceptance of a performance-based petition to end GW monitoring). However, to address concerns from within the regulated industry that dependence on such conservative calculations may unduly burden site operators with excessively long PCC periods and result in universal resistance to using the methodology, the project team applied and critically appraised the GW TOT calculation procedures at the ten case study sites. Findings are presented on Table 5-3. In a few cases, calculated GW TOTs were reasonable and within the 30-40 year timeframe assumed for PCC. Where this was not the case, recommendations for optimal assessment of a site based on thorough knowledge of the sites' layout and hydrogeologic models were made throughout Section 5.4. The discussions in Section 5.4 are site-specific and complex, and should be reviewed in their entirety before drawing conclusions.

In conclusion, this study serves to illustrate that performance-based approaches such as the EPCC Methodology offer a viable and flexible option for making a demonstration that long-term threats posed by a WMU are minimal because the residual emission potential is acceptable. This study also highlights that, while significant data are required to make such demonstrations, taking advantage of proactive data collection plans and good data management strategies can provide immediate cost benefits along the optimization process to functional stability and custodial care, as uniquely offered by the EPCC Methodology. Site operators need to be encouraged to view application of the methodology as a multi-stage process, the first stage

always serving as a "head's up" view of future options for optimization. Operators may nevertheless consider the methodology too restrictive and overly burdensome as compared to what is currently perceived will be accepted by the regulator when reviewing a petition to end PCC. The situation is made somewhat more complex by the current uncertainty as to how different states will allow PCC to end. However, in the absence of regulations requiring that a demonstration of PCC completion be based solely on target values for organic stability (an unlikely scenario), most of the data requirements for the EPCC Methodology will also be required for other impact- or risk-based evaluation methods used to establish the end of PCC. Thus, these "restrictive" data requirements are unlikely to be uniquely associated with the EPCC Methodology.

# 7. RECOMMENDATIONS FROM THE STUDY

Several recommendations for updating and improving the EPCC Methodology were made based on the findings from this study. The technical basis for these recommendations is discussed throughout Sections 3 through 5 of the report and summarized in Section 6. For ease of reference, all updated or new materials emanating from this study are provided in Appendix 1. These materials should be inserted where appropriate into the Technical Manual or used as supplemental resources as suggested.

Appendices 1-1 and 1-2 – Data Checklists 1 and 2: These two new data checklists were developed to help collect and account for the relevant data needed for application of the methodology in a more user-friendly format. The checklists are recommended for future users of the EPCC Methodology. However, it is also recommended that the entire Prerequisites Module (Section 3 of the Technical Manual) also be reviewed in conjunction with an initial attempt to use the checklists.

Appendix 1-3 – Proactive Leachate Monitoring: An important outcome from the study is affirmation of proactive leachate monitoring requirements. These requirements, which have been updated subject to the discussions in this report, provide recommendations for the quantity and duration over which leachate monitoring data should be proactively collected and processed. Because these proactive monitoring requirements are integral to the Prerequisites Module, they were redeveloped to be inserted as Sections 3.3.4 and 3.3.5 of the Technical Manual. For this reason, it is strongly recommended that the other leachate prerequisites (see Section 3.3 of the Technical Manual) and the preliminary sections of the Leachate Module (Sections 4.1 through 4.3 of the Technical Manual) be reviewed to provide context before any attempt to implement these proactive monitoring activities.

Appendix 1-4 – Modifications to Data Requirements in Prerequisites Module: This table represents a fully updated assessment of data needed for full application of the four PCC Modules under the EPCC Methodology and should thus be used to fully replace the prerequisites and data requirements listed in Table E-3-1 (Leachate Module), Table E-3-2 (Gas Module), Table E-3-3 (GW Module), and Section 3.6.2 (Cap Module) of the Technical Manual. Note the following changes and simplifications were made relative to the previous versions:

- A reassessment of the definition of “Critical” and “Non-Critical” data is made where appropriate to focus data collection activities on obtaining those data without which completion of a module evaluation will not be possible.
- A new mid-level “Optimal” classification was developed to reflect a new emphasis for data requirements under the EPCC Methodology (essentially, moving away from a best-case “wish list” scenario towards a “minimum requirements” approach). Optimal data requirements are above non-critical and will be beneficial to have in terms of optimizing

the duration and intensity of certain PCC activities, but are not considered critical for completion of a module evaluation.

- Tables E-3-1 and E-3-2 currently list prerequisites and data requirements by sub-module for the Leachate and Gas Modules, respectively. This is not considered useful: data should be considered on the basis of whether or not they will be required for completion of an entire module.
- Previous classifications "Flag" and "Supplemental" have been combined into a single category as "Potentially Critical."

Appendix 1-5 – Revised Lookup Table for Gas Migration TOT: As currently written, measurements of internal gas pressure in the WMU are essential for calculating a gas migration TOT. However, in conducting this study, it was concluded that this monitoring requirement should be redefined as it is simply too complicated to be required at all sites. The project team devised a modified screening approach bracketed by near-zero and instability-causing gas pressures to define the duration and frequency of gas CM based on upper- and lower-bound TOTs, respectively. The revised table, and the technical notes describing development and application of the table, should replace Table E-5-4 and Note (A), respectively, in Section 5.3.3 of the Technical Manual.

Finally, the data and site information collected at each site was critically reviewed for completeness and compiled by the visiting project team member based on a standardized 10-15 page summary format, including between three and five stylized figures depicting the site layout and features, physiographical setting, and POC and POE. The ten completed site summaries are provided in Appendix 2. By its nature, the EPCC Methodology utilizes somewhat generic procedures; however, because all sites are unique not all procedures are appropriate in all circumstances. A key finding from this study was that taking the time to characterize a site in this way was invaluable when it came to understanding how and when certain procedures were not applicable or should be modified. Future users of the methodology are thus encouraged to prepare similar site summaries.

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# TABLES

**TABLE 3-1**
**SUMMARY OF MAIN CHARACTERISTICS OF CASE STUDY SITES**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Site ID | SITE A | SITE B | SITE C | SITE D | SITE E | SITE F | SITE G | SITE H | SITE I | SITE J |
|---|---|---|---|---|---|---|---|---|---|---|
| State | FL | GA | OK | NE | MI | OH | IL | MN | NJ | OR |
| Project Team Member | Geosyntec | Geosyntec | Geosyntec | AquAeTer | AquAeTer | Geosyntec | Geosyntec | AquAeTer | Geosyntec | AquAeTer |
| Site Visit Date | Dec-07 | Dec-07 | Feb-08 | Aug-08 | Apr-08 | Apr-08 | Jun-08 | Oct-08 | Dec-08 | Dec-08 |
| Site Status | Active | Active | Active | Active | Closed | Active | Active | Active | Closed | Active |
| Study WMU Description | Stand alone, 4 cells | Stand alone, single unit | Contiguous, 4 cells | Whole Site, 8 cells | Whole Site, 12 cells | Contiguous, 8 cells | Contiguous, 2 cells | Overfilled unit + Contiguous, 3 cells | Whole Site, 10 cells | Contiguous, 11 cells |
| WMU Footprint (ac) | 39 | 26 | 47 | 170 | 77 | 39 | 26 | 42 + 27 | 73 | 244 |
| WMU Status | Closed | Closed | Inactive | Closed | Closed | Closed | Closed | Closed + Inactive | Closed | Inactive + Closed |
| Mean Annual Temp. (°F)[a] | 60-70 | 60-70 | 60-70 | 50-60 | 40-50 | 50-60 | 40-50 | 40-50 | 50-60 | 50-60 |
| Mean An. Precipitaiton (in)[a] | 45-63 | 45-63 | 36-45 | 27-36 | 27-36 | 36-45 | 36-45 | 27-36 | 45-63 | 13-18 |
| Waste Placement | 1983-1999 | 1983-1995 | 1986-1997 | 1989-2000 | 1983-1994 | 1973-2005 | 2003-2005 | 1969-1993 + 1993-present | 1973-1989 | 1990-2008 |
| Capping Date | 2001 | 1996 | Interim | 2006 | 1999 | 2005 | 2006 | 1993 + N/A | 1991 | Interim + 2006 |
| Cap Type[2] | Synth. | Clay | Soil | Clay/Synth./ET | Synth. | Clay | Synth. | Synth + Soil | Clay / Synth. | Soil + ET |
| Leachate Recirculation | Yes | N/A | No | Yes | No | No | Yes | No + Yes | No | Yes |
| Liner Type[b] | Clay / Synth. | None | Clay | Clay / Synth. | In-situ Clay | In-situ Clay | Synth. | None + Synth. | Clay / Synth. | Clay / Synth. |
| Leachate Sumps | 4 | 0 | 5 | 14 | 6 | 3 | 3 | 0 + 9 | 4 | 2 |
| Groundwater POE | Private well near property line | Private onsite well | Private well, 3,500 ft distal | House, 2,600 ft downgradient of property line | House, 2,750 ft downgradient | Private well, 1,200 ft distal | House, 700 ft downgradient of property line | River at downgradient prop. Line | Shop/office at property line | Nearest house 5-mi. upgrad. (NW) |
| Surface Water POE | Wooded marsh on property | Wooded marsh on property | No SW discharge, but river adjacent | Onsite intermittent stream | SW discharge to ditches then to river | Creek on property | No SW discharge. Creek 1-mi. E. | River at downgradient prop. Line | SW discharge to ditches then to lake | Intermittent stream |
| Gas Control System | Active | Active | Active | Active | Active | Active | Active | Active | Active | Active |
| No. Vertical Wells (V) and/or Horizontal Trenches (H) | 47V | 17V | 39V | 56V | 44V | 24V | 17V | 38V + 7H | 50V + 2H | wells + trenches |
| Gas Utilization | LFGTE | None | LFG-biodiesel (demo. project) | LFGTE | Direct use at adjacent facilty | None | None, but LFGTE planned | LFGTE | None | LFGTE planned for 2009 |
| Gas POE | House at property line | House, 1,500 ft distal | Shop/office on adjacent property | House on adjacent property | Lg. commercial building, adj. property | Lg. commercial building, adj. property | House 1,400 ft distal | House at property line | House at property line | Nearest house 5-mi. upgrad. (NW) |
| WMU End-Use Strategy[c] | √√ | √√ | √ | √ | X | √√√ | X | X | X | √√√ |

Notes: a). See Figure 3-1 for color coding for climatic zones. b). Primary barrier material indicated; where more than one, underlined material is predominant over area of study WMU. c). See Section 3.2 of report for qualitiative key to symbols used.

**TABLE 3-2A**
**AVAILABILITY OF SITE INFORMATION AND DATA FOR THE LEACHATE MODULE**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Source: EPCC Methodology Prerequisites Module (Technical Manual §3.3, Table E-3-1) | | | | Information / Data Availability[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | Item | Classification | | SITE A | SITE B[b] | SITE C | SITE D | SITE E | SITE F | SITE G | SITE H | SITE I | SITE J |
| | | | | FL | GA | OK | NE | MI | OH | IL | MN | NJ | OR |
| General Prerequisites | Current/historic SW and GW monitoring data and flow direction (background and POC) | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√ | √√√ | √√√ | √√√ |
| | Previous/existing impacts attributable to leachate, history and current status of corrective action measures | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Identification of applicable SW standards | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Identification of applicable GW standards | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| Site Details | Layout of WMU; site topography and features; layout and location of SW and GW POC, POE, and property boundary | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | LCRS design (layout, type, components); construction and as-built drawings and details; operation and maintenance history | NC | Non-Critical | √√ | N/A | √√ | √√√ | √√ | √√ | √√√ | √√ | √√ | √√√ |
| | Base grades and liner system layout | C | Critical | √√√ | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√ | √√ | √√√ |
| | WMU cell geometry, size; waste thickness | NC | Non-Critical | √√√ | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√ | √√ | √√√ |
| | Years accepting waste; waste composition; total mass/volume of waste in place | NC | Non-Critical | √√ | √√ | √√ | √√√ | √ | √√ | √ | √√ | √√ | √√√ |
| | Site-wide or cell-specific operational practices (e.g. leachate recirculation) | C | Critical | √√√ | N/A | √√√ | √√√ | √√ | √√ | √√√ | √√ | √√ | √√√ |
| | Cover system design/as built record, physical condition (e.g. health of vegetation), repairs and reoccurring issues (e.g., continued erosion, poorly vegetated areas) | C | Critical | √√√ | √√√ | √ | √√√ | √√√ | √√ | √√√ | √√√ | √√ | √√ |
| | Stormwater management features and performance; any reoccurring seeps/breakouts | NC | Non-Critical | √√ | √√ | √√ | √√ | √√√ | √√ | √√ | √√ | √√√ | √√√ |
| | Topographic surveys and/or settlement data; settlement analysis | NC | Non-Critical | √√√ | √√√ | √ | X | √ | √√√ | √√√ | √√√ | √ | √√√ |
| | Geotechnical stability data; documented slope failures | NC | Non-Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| Characteristics of Receiving Bodies and Hydrogeologic Data | Receiving environment at POE; extent of buffer zone | F | Pot. Critical | √√ | √√ | √√√ | √√√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Location of potable GW point sources within regulatory defined limits | F | Pot. Critical | √√ | √√ | √√√ | √√√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | GW well, LFG migration monitoring well, and other construction and boring logs | NC | Non-Critical | √√ | √√ | √√√ | √√√ | √√ | √√ | √√√ | √√√ | √√ | √√√ |
| | Characteristics of uppermost aquifer (lithology, thickness, hydraulic conductivity) | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Characteristics of vadose zone (lithology, depth to GW, hydraulic conductivity) | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Characteristics of surface water (mixing zones); peak/average flow rates and/or volume; uses | NC | Non-Critical | √ | N/A | √ | √ | √ | √ | √ | √ | √ | √ |
| Leachate Monitoring Data (see also expanded evaluation in Table 3-2B) | Current and historic leachate analytical results for Decision Parameters | C | Critical | X | N/A | √√√ | √√√ | X | X | √√√ | √√√ | √√√ | √√√ |
| | Current and historic leachate analytical results for Regulated Parameters | C | Critical | √√√ | N/A | √√√ | √√√ | √√√ | √√ | √√√ | √√√ | √√√ | √√√ |
| | Current and historic leachate generation rates | C | Critical | √√ | N/A | √ | √√√ | √√√ | √ | √√√ | √√ | √√ | √√√ |
| | Type (sump, pump station, gravity drain, etc) and number of leachate sampling locations | C | Critical | √√√ | N/A | √√√ | √√√ | √√√ | √√√ | √√√ | √√ | √√ | √√√ |
| | Sump-specific data | C | Critical | X | N/A | √√√ | √√√ | X | X | √√√ | √√ | X | √√√ |
| Other Data | Meteorological Data (precipitation, potential evapotranspiration, other climatic data) | C | Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | Risk exposure factors; toxicity information | S | Pot. Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |

Note: a). See Section 3.2 of report for qualitiative key to symbols used. b). Unlined site without LCRS.

**TABLE 3-2B**
**AVAILABILITY OF KEY LEACHATE MONITORING DATA**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Site ID | SITE A | SITE B | SITE C | SITE D | SITE E | SITE F | SITE G | SITE H | | SITE I | SITE J |
|---|---|---|---|---|---|---|---|---|---|---|---|
| State | FL | GA | OK | NE | MI | OH | IL | MN | | NJ | OR |
| Site Status | Active | Active | Active | Active | Closed | Active | Active | Active | | Closed | Active |
| Study WMU Description | Stand alone, 4 cells | Stand alone, single unit | Contiguous, 4 cells | Whole Site, 8 cells | Whole Site, 12 cells | Contiguous, 8 cells | Contiguous, 2 cells | Old Unit | Contiguous, 3 cells | Whole Site, 10 cells | Contiguous, 11 cells |
| Leachate Recirculation | Yes | N/A | No | Previously | No | No | Yes | No | Yes | No | Yes |
| WMU Status | Closure capped 2001 | Closure capped 1996 | Inactive since 1997 | Closure capped 2006 | Closure capped 1999 | Closure capped 2005 | Closure capped 2006 | Overfill lined, 1993 | Currently inactive | Closure capped 1991 | Inactive, 3 cells closed 2006 |
| Description of Leachate Composite Location(s) | Aboveground tanks | None | Pond | Aboveground tanks | Metering station | Master Sump | Aboveground tanks | None | Tank | Aboveground tank | Evaporation Pond |
| Composite Monitoring Locations | 1 | -- | 1 | 1 | 1 | 1 | 1 | -- | 1 | 1 | 1 |
| Composite Data Availability | WMU-specific | -- | Whole site | WMU-specific | WMU-specific | Whole site | Whole site | -- | Whole site | WMU-specific | No |
| No. Analytes Available | 280 | -- | 175 | 123 | 207 | 114 | 202 | -- | 201 | 168 | -- |
| No. Monitoring Events | 32 | -- | 9 | 21 | 92 | 12 | 28 | -- | 50 | 89 | -- |
| Post-Closure Data (years) | 6 | -- | N/A | 1 | 8 | 2 | 1 | -- | N/A | 16 | -- |
| BOD Data Available? | No | -- | Yes | Yes | No | No | Yes | -- | Yes | Yes | -- |
| COD Data Available? | No | -- | Yes | Yes | Yes | Yes | Yes | -- | Yes | Yes | -- |
| Ammonia Data Available? | Yes | -- | Yes | Yes | Yes | Yes | Yes | -- | Yes | Yes | -- |
| Chloride Data Available? | Yes | -- | Yes | Yes | Yes | Yes | Yes | -- | Yes | Yes | -- |
| Description of Leachate Collection Point(s) | Sumps | None | Sumps | Sumps[a] | Sumps | Sumps | Sumps | None | Sumps | Sumps | Gravity drains |
| No. Leachate Sumps | 4 | -- | 5 | 14 | 6 | 3 | 3 | -- | 9 | 4 | 2 |
| Sumps with Leachate Data | 0 | -- | 5 | 14 (+ 1) | 0 | 0 | 3 | -- | 9[d] | 0 | 2 |
| No. Analytes Available | -- | -- | 99 | 3 (+ 62) | -- | -- | 202 | -- | 132 | -- | 115 |
| No. Monitoring Events | -- | -- | 14 | 7 (+2) | -- | -- | 28 | -- | 27 | -- | 39 |
| Post-Closure Data (years) | -- | -- | N/A | 1 (+0) | -- | -- | 1 | -- | N/A | -- | N/A |
| BOD Data Available? | -- | -- | Yes | Yes | -- | -- | Yes | -- | Yes | -- | Yes |
| COD Data Available? | -- | -- | Yes | No | -- | -- | Yes | -- | Yes | -- | Yes |
| Ammonia Data Available? | -- | -- | Yes | No | -- | -- | Yes | -- | Yes | -- | Yes |
| Chloride Data Available? | -- | -- | Yes | No | -- | -- | Yes | -- | Yes | -- | Yes |
| No. Groundwater Analytes[b] | 289 | 123 | 98 | 101 | 191 | 235 | >140 | 103 | | 180 | 217 |
| No. Surface Water Analytes[c] | 290 | 57 | 0 | 7 | 88 | 0 | 0 | 27 | | 0 | 6 |
| Leachate Generation (gpd, average) | 1,250 | Unknown | Not routinely measured | Data available, not summarized | Data available, not summarized | Unknown | Data available, not summarized | Unknown | Data available, not summarized | 1,900 | Data available, not summarized |
| Year for Generation Data | 2006 | | | | | | | | | 2007 | |
| Current leachate disposal method | Truck to POTW | None | Truck to POTW | Truck to POTW | Sewer to POTW | Sewer to POTW | Truck to POTW | None | Truck to POTW | Truck to POTW | Recirculation only |

Notes: a). One sump, LCS-02, was monitored twice for Appendix I parameters (additional data at this sump shown in parenthesis below). b). Number of parameters routinely analyzed in groundwater at site. c). No of parameters routinely analyzed in surface water or stormwater discharges at the site. Where zero is indicated, WMU is subject to State-administered NPDES permit conditions but surface water is not routinely monitoring. d). Phases I through III each have three sumps which are sampled as composite.

**TABLE 3-3**
**AVAILABILITY OF SITE INFORMATION AND DATA FOR THE GAS MODULE**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Source: EPCC Methodology Prerequisites Module (Technical Manual §3.4, Table E-3-2) | | | | Information / Data Availability[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | Item | Classification | | SITE A | SITE B | SITE C | SITE D | SITE E | SITE F | SITE G | SITE H | SITE I | SITE J |
| | | | | FL | GA | OK | NE | MI | OH | IL | MN | NJ | OR |
| General Prerequisites | LFG migration monitoring data | C | Critical | √√ | √√ | ? | √√√ | √√ | √√ | √√ | √√√ | √√√ | √√√ |
| | Surface emissions monitoring data | C | Critical | √√ | √√ | √ | √ | √√ | ? | √√ | √√√ | √√√ | X |
| | Current and historic GW monitoring data and flow characteristics | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Record of compliance; previous/existing impacts attributable to LFG; odor issues; NSPS/EG requirements | C | Critical | √√ | √√ | √√√ | √√√ | √√ | ? | √√ | √√√ | √√√ | √√√ |
| | GW monitoring well headspace data | NC | Non-Critical | X | X | X | X | X | X | X | X | X | X |
| Site Details | LFG collection/control system design (layout, type, radius of influence, and other design calculations) | NC | Non-Critical | √√ | √√ | √√√ | √√ | √√ | √√ | √√ | √√ | √√ | √√ |
| | Reason LFG system was originally installed; history of operation, modification, maintenance, balancing | NC | Non-Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Layout of WMU, site, LFG migration and GW POC, distance to sensitive receptors, and property boundary; extent of buffer zone | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Years accepting waste; annual tonnages; waste placement schedule; total mass of waste in place | NC | Non-Critical | √√ | √√ | √√ | √√√ | √ | √√ | √ | √√ | √ | √√√ |
| | Waste composition and characterization (incl. sampling from boring logs for LFG extraction well installation) | NC | Non-Critical | √√ | √ | √√ | √ | √ | √√ | √ | √ | √ | √√ |
| | Information regarding on-site or planned end use structures (type, occupancy, previous/existing issues) | C | Critical | √√ | √√ | √√√ | √√ | √√ | √√√ | √√√ | √√ | √√ | √√ |
| | Site operational practices | NC | Non-Critical | √√√ | √√√ | √√ | √√√ | √ | √√ | √√ | √√ | √ | √√ |
| | Cover system type, design, details, condition, construction history, repairs, and issues | NC | Non-Critical | √√√ | √√√ | √ | √√√ | √√√ | √√ | √√√ | √√ | √√ | √√ |
| | WMU cell geometry, size; waste thickness | NC | Non-Critical | √√√ | √√ | √√ | √√√ | √√√ | √√ | √√√ | √√ | √ | √√√ |
| | Base grades and liner system details | NC | Non-Critical | √√√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√ | √ | √√√ |
| | Aerial surveys and/or other settlement data | NC | Non-Critical | √√√ | √√√ | √ | X | √ | √√√ | √√ | √√√ | √ | √√√ |
| Characteristics of Sensitive Receptors | Nature and sensitivity of Receptors (anthropogenic or natural) | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Information about and distance to nearest off-site structures (type, occupancy, previous/existing issues) | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Potential on- or off-site ignition sources and other hazards | C | Critical | √√√ | √√√ | √√√ | √√√ | √√ | √√ | √√√ | √√√ | √√ | √√√ |
| | GW and LFG migration monitoring well logs | NC | Non-Critical | √ | √ | √√√ | √√√ | √√ | √√ | √ | √√√ | √√ | √√√ |
| | Sub-surface geologic conditions (vadose zone lithology, grain size, depth to GW, and GW flow velocity) | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Vadose zone hydraulic conductivity | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Depth to uppermost aquifer, aquifer thickness, grain size characterization, hydraulic conductivity | F | Pot. Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Distance to potable water point sources | F | Pot. Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Proximity of potential odor receptors | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| LFG Monitoring Data | Current and historic LFG generation rate; site-specific modeling input parameters; model output | NC | Non-Critical | √√ | √√ | √√ | √√ | √√ | √√ | √√ | √√ | √√ | √√ |
| | Current LFG collection rate | C | Critical | X | X | X | √√ | X | X | X | X | √√√ | X |
| | LFG composition (bulk gases, trace components, NMOC); sampling methods and locations | NC | Non-Critical | √√ | √√ | √√ | √√ | √√ | ? | ? | ? | √√√ | √√√ |
| | Internal gas pressure in WMU (from wellheads, permanent/temporary probes) | C | Critical | X | X | X | X | X | X | ? | X | X | X |
| Other Data | Meteorological data, atmospheric pressure | C | Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | Institutional controls on site end use; end-use plans; non-technical issues relating to site redevelopment | C | Critical | √ | √ | √ | √ | √√ | √√√ | √ | √√ | √√ | √√ |
| | State policies and standards regulating GW quality and use | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Risk exposure factors; toxicity information | S | Pot. Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |

Note: a). See Section 3.2 of report for qualitiative key to symbols used.

**TABLE 3-4**
**AVAILABILITY OF SITE INFORMATION AND DATA FOR THE GROUNDWATER MODULE**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Source: EPCC Methodology Prerequisites Module (Technical Manual §3.5, Table E-3-3) | | | | Information / Data Availability[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | Item | Classification | | SITE A FL | SITE B GA | SITE C OK | SITE D NE | SITE E MI | SITE F OH | SITE G IL | SITE H MN | SITE I NJ | SITE J OR |
| General Prerequisites | Current/historic GW monitoring data (background and POC) | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Record of compliance; documented releases; previous/existing impacts attributable to WMU, history and current status of corrective action measures (if any) | C | Critical | √√√ | √√√ | √√√ | √√√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Selection of groundwater monitoring indicator parameter(s) | C | Critical | √√√ | ? | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Identification of applicable GW standards | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | State policies and standards regulating GW quality and use | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| Site Details | Layout of WMU; site topography and features; layout and location of GW POC, POE, and property boundary | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√ | √√√ | √√√ |
| | Base grades and liner system details (type, design, components) and integrity | NC | Non-Critical | √√√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√ | √ | √√√ |
| | WMU cell geometry, size; waste thickness | NC | Non-Critical | √√√ | √√ | √√ | √√√ | √√√ | √√ | √√√ | √√ | √ | √√√ |
| | Years accepting waste; waste placement schedule; total mass of waste in place | NC | Non-Critical | √√ | √√ | √√ | √√ | √√ | √√ | √ | √√ | √ | √√√ |
| | Waste composition and characterization (incl. sampling from boring logs) | NC | Non-Critical | √√ | √ | √√ | √√ | √√ | √√ | √ | √√ | √ | √√ |
| | Site operational practices | NC | Non-Critical | √√√ | √√ | √√ | √√√ | √ | √√ | √√ | √√ | √√ | √√ |
| | Cover system design, details, condition, construction history, repairs, and issues | NC | Non-Critical | √√√ | √√√ | √ | √√√ | √√√ | √√ | √√√ | √√√ | √√ | √√ |
| | Stormwater management features and performance; history of occurrence of seeps/breakouts | NC | Non-Critical | √√ | √√ | √√ | √√ | √√ | √√ | √√ | √√ | √√√ | √√ |
| | Aerial surveys and other settlement data; settlement analysis; severity of erosion damage | NC | Non-Critical | √√√ | √√√ | √ | X | √ | √√√ | √√ | √√√ | √ | √√√ |
| | Design information related to geotechnical stability; history of slope failures | NC | Non-Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| Characteristics of Receiving Bodies and Hydrogeologic Data | Nature and sensitivity of receiving environment at POE; extent of buffer zone | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Location of potable GW point sources | NC | Non-Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | GW well, LFG migration monitoring well, and other boring logs | NC | Non-Critical | √√ | √√ | √√√ | √√√ | √√ | √√ | √√ | √√ | √√ | √√√ |
| | Characteristics of uppermost aquifer (lithology, grain size, thickness, hydraulic conductivity) | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | GW flow characteristics (predominant direction, velocity, vertical/horizontal components) | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Preferential groundwater flow pathways, recharge and discharge relationships | NC | Non-Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Characteristics of vadose zone (lithology, grain size, depth to GW, hydraulic conductivity) | C | Critical | √√ | √√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| | Other sub-surface geologic conditions | NC | Non-Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| Other Data | Meteorological Data (precipitation, potential evapotranspiration, other climatic data) | NC | Non-Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | Risk exposure factors; toxicity information | S | Pot. Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |

Note: a). See Section 3.2 of report for qualitiative key to symbols used.

**TABLE 3-5**
**AVAILABILITY OF SITE INFORMATION AND DATA FOR THE CAP MODULE**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Source: EPCC Methodology Prerequisites Module (Technical Manual §3.6) | | | | Information / Data Availability[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | Item | Classification | | SITE A FL | SITE B GA | SITE C OK | SITE D NE | SITE E MI | SITE F OH | SITE G IL | SITE H MN | SITE I NJ | SITE J OR |
| General Prerequisites | End use strategy identified with cap performance criteria | C | Critical | √√ | √√ | √ | √ | X | √√√ | X | X | X | √√√ |
| | Outcome of Leachate Module established | C | Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | Outcome of Gas Module established | C | Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | Outcome of Groundwater Module established | C | Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | Interim or final cap installed | C | Critical | √√√ | √√√ | √ | √√√ | √√√ | √√ | √√√ | √ | √√√ | √√ |
| | Cap monitoring and maintenance program in compliance | C | Critical | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ | √√√ |
| Data Requirements | Cap performance data and site information (settlement, infiltration control, emissions control for active and PCC conditions) | C | Critical | √√ | √√ | ? | √√ | √√ | ? | √√ | ? | √√ | ? |
| | Original design basis and construction details for cap | S, F | Pot. Critical | √√√ | √√√ | ? | √√√ | √√√ | √√ | √√√ | ? | √√√ | ? |
| | Site conditions upon which original design is based | S, F | Pot. Critical | √√√ | √√ | ? | √√√ | √√√ | √√√ | √√√ | ? | √√√ | ? |
| | Meteorological data | S, F | Pot. Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | Structure and specifications of cap | S, F | Pot. Critical | √√√ | √√√ | √ | √√√ | √√√ | √√ | √√√ | √ | √√ | √√ |
| | Water balance, gas control modeling | S, F | Pot. Critical | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |

Note: a). See Section 3.2 of report for qualitiative key to symbols used.

**TABLE 5-1**
**SUMMARY OF FINDINGS RELATED TO TREND ANALYSIS OF LEACHATE DATA**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Site ID (State), Status | Composite ID | Sump ID | BOD Data | | | | | | | Tier 1 Test | Tier 2 Test | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. of Samples[b] | Sampling period | 95% UCL (mg/L)[c] | 95% UCL (mg/L)[d] | 95% UPL (mg/L)[e] | Sump-Comp Consistency | Sump-Sump Consistency | BOD Downtrend | BOD Conc. < 100 mg/L | BOD/COD < 0.1 |
| SITE C (OK), Inactive since 1997 | | LCS-1 | 13 | 3/92 - 9/04 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-2 | 14 | 3/92 - 8/06 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-3 | 15 | 3/92 - 8/06 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-4 | 14 | 3/92 - 8/06 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-5 | 14 | 2/92 - 8/06 | 51 | 391 | 819 | Yes | Tester | No | No | No |
| | POND[a] | | 10 | 7/96 - 8/06 | 533 | 364 | 540 | Tester | N/A | No | No | No |
| SITE D (NE), Closed 2006 | | LCS-01 | 7 | 8/01 - 12/07 | -- | -- | -- | Yes | Yes | Insuff. Data | Insuff. Data | Insuff. Data |
| | | LCS-02 | 8 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-03 | 8 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-04 | 8 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-05 | 8 | 8/00- 12/07 | -- | -- | -- | No | Yes | No | -- | -- |
| | | LCS-06 | 8 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-07 | 4 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | Insuff. Data | -- | -- |
| | | LCS-08 | 6 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | Insuff. Data | -- | -- |
| | | LCS-09 | 8 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-10 | 7 | 8/00- 12/06 | -- | -- | -- | Yes | Yes | Insuff. Data | -- | -- |
| | | LCS-11 | 8 | 8/00- 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | LCS-12 | 8 | 8/00- 12/07 | -- | -- | -- | No | No | No | -- | -- |
| | | LCS-13 | 8 | 8/00- 12/07 | 122 | 2,970 | 6,898 | Yes | Tester | Yes | N/A | N/A |
| | | LCS-14 | 5 | 8/01- 12/07 | -- | -- | -- | Yes | Yes | Insuff. Data | -- | -- |
| | LCTK | | 23 | 6/91 - 12/07 | 888 | 2,261 | 1,990 | Tester | N/A | No | No | No |
| SITE G (IL), Closed 2006 | | L-305 | 21 | 2/03 - 11/07 | 3,630 | 7,050 | 4,249 | Insuff. Data | Yes | Yes | N/A | N/A |
| | | L-306 | 20 | 2/03 - 11/07 | 6,867 | 7,050 | 7,337 | Insuff. Data | Tester | Yes | N/A | N/A |
| | | L-307 | 11 | 2/05 - 11/07 | -- | -- | -- | Insuff. Data | Yes | No | -- | -- |
| | L-310[a] | | 6 | 11/03 - 11/05 | N/A | Insuff. Data | Insuff. Data | Tester | N/A | Insuff. Data | Insuff. Data | Insuff. Data |
| SITE H (MN), Inactive | | CELLS 2,3,4 | 26 | 10/00 - 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | | CELLS 5,6,7[f] | 15 | 9/04 - 12/07 | 14,780 | 1,143 | 2,206 | Yes | Tester | No | No | No |
| | | CELLS 8,9,10 | 15 | 9/04 - 12/07 | -- | -- | -- | Yes | Yes | No | -- | -- |
| | TANK[a] | | 29 | 10/00 - 12/07 | 2,874 | 1,970 | 3,952 | Tester | N/A | Yes | N/A | N/A |
| Site I (NJ), Closed 1991 | | MH-TE-3-4 | 0 | -- | -- | -- | -- | Insuff. Data | -- | Insuff. Data | Insuff. Data | Insuff. Data |
| | | MH-TE-5-6 | 0 | -- | -- | -- | -- | Insuff. Data | -- | Insuff. Data | Insuff. Data | Insuff. Data |
| | | MH-TE-7 | 0 | -- | -- | -- | -- | Insuff. Data | -- | Insuff. Data | Insuff. Data | Insuff. Data |
| | | MH-9 | 0 | -- | -- | -- | -- | Insuff. Data | -- | Insuff. Data | Insuff. Data | Insuff. Data |
| | TANK | | 45 | 7/92 - 7/99 | 74 | 68 | 88 | Tester | N/A | Yes | N/A | N/A |
| SITE J (OR), Inactive | | L-01 | 5 | 3/04 - 4/07 | 775 | Insuff. Data | -- | Insuff. Data | -- | Insuff. Data | Insuff. Data | Insuff. Data |
| | | L-02 | 4 | 6/05 - 4/07 | 6,865 | Insuff. Data | Insuff. Data | Insuff. Data | -- | Insuff. Data | Insuff. Data | Insuff. Data |
| | POND[a] | | 0 | -- | Insuff. Data | Insuff. Data | Insuff. Data | Tester | N/A | Insuff. Data | Insuff. Data | Insuff. Data |

Notes: a). Whole-site data, not WMU-specific. b). Orange cells indicate insufficient data available for one or more analysis. c). Calculated using four most-recent data points only. d). Calculated using entire available data series. e).Calculated using eight most-recent data points only. f). Data only included since leachate recirculation commenced in Phase II.

**This table should not be referenced out of context with the discussion in Section 5.2 of the report.**

**TABLE 5-2**
**SUMMARY OF FINDINGS RELATED TO GAS MIGRATION TIME OF TRAVEL**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Site ID | SITE A | SITE B | SITE C | SITE D | SITE E | SITE F | SITE G | SITE H | SITE I | SITE J |
|---|---|---|---|---|---|---|---|---|---|---|
| State | FL | GA | OK | NE | MI | OH | IL | MN | NJ | OR |
| Relating Figure[a] | Fig. 5-2A | Fig 5-2B | Fig 5-2C | Fig 5-2D | Fig 5-2E | Fig 5-2F | Fig 5-2G | Fig 5-2H | Fig 5-2I | Fig 5-2J |
| Stratum 1 (vadose zone) | Sand | Silty sand | Sand | Loess | Silty clay till[d] | Upper till[d] | Till[e] | Sand/Gravel | Silt | Tuffs/Sandst. |
| hydraulic cond., k (cm/s) | $5.4 \times 10^{-2}$ | $7.53 \times 10^{-3}$ | $4.66 \times 10^{-3}$ | $4.6 \times 10^{-4}$ | $4 \times 10^{-4}$ | $1.5 \times 10^{-5}$ | $2.67 \times 10^{-2}$ | $4 \times 10^{-2}$ | $2 \times 10^{-5}$ | $6 \times 10^{-5}$ |
| Distance X (ft) | 100 | 100 | 50 | 110 | 80 | 50 | 80 | 20 | 50 | 275 |
| GAS POC | MWP-4 | GP-2 | GP-4 | GP-3 | BH-11 | GP-6 | GMP24 | GP-5 | P-1 | GP-3 |
| Max. Gas TOT[b] | 6 months | 5 years | 5 years | 11 years | 8 years | None | 4 years | 2 years | None | 28 years |
| Min. Gas TOT[b] | 2 days | 15 days | 3 months | 5½ years | 4 years | None | 12 days | 3 days | None | 14 years |
| Distance Y (ft) | 0 | 700 | 25 | 170 | 20 | 50 | 130 | 20 | 0 | 525 |
| Distance $TOE_{GAS}$ - GAS POC NEW (ft)[c] | -- | 600 | -- | 50 | -- | N/A | -- | -- | N/A | 50 |
| Potential Max. Gas TOT with optimized GAS POC NEW | Not practicable to move POC | -- | Not practicable to move POC | 5 years | Not practicable to move POC | N/A | Not practicable to move POC | Not practicable to move POC | N/A | 5 years |
| Potential Min. Gas TOT with optimized GAS POC NEW | | 90 days | | 2½ years | | N/A | | | N/A | 2½ years |

Notes: a). The generic terms listed in the column below are illustrated on Figure 5-1. Hydraulic conductivity (*k*) values are maximum reliable reported values for uppermost unsaturated stratum. b). Gas TOT calculated based on maximum and minimum default values per 100 ft in new Table E-5-4 (Appendix 1-5). c). This probe does not currently exist, but could be installed to reduce the total Gas TOT and/or total duration of monitoring. d). Assumed for silty sand lens in till. e). Assumed for sand/gravel outwash layer between tills.

**This table should not be referenced out of context with the discussion in Section 5.3 of the report.**

**TABLE 5-3**
**SUMMARY OF FINDINGS RELATED TO GROUNDWATER TIME OF TRAVEL**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

| Site ID | SITE A | SITE B | SITE C | SITE D | SITE E | SITE F | SITE G | SITE H | | SITE I | SITE J |
|---|---|---|---|---|---|---|---|---|---|---|---|
| State | FL | GA | OK | NE | MI | OH | IL | MN | | NJ | OR |
| Relating Figure[a] | Fig. 5-2A | Fig 5-2B | Fig 5-2C | Fig 5-2D | Fig 5-2E | Fig 5-2F | Fig 5-2G | Fig 5-2H | | Fig 5-2I | Fig 5-2J |
| SUMP | LCS-01 | $TOE_{GW}$ | LCS-2 | LCS14 | LCR-6 | LMH #1 | L-305 | LCR-3 | MIDPOINT | MH-TE-5-6 | $TOE_{GW}$ |
| Stratum 1 | -- | -- | -- | -- | Silty clay till | Middle Till | Till | -- | | Silt | Tuffs/Sandst. |
| hydraulic cond., k (cm/s) | | | | | $1 \times 10^{-7}$ | $1.6 \times 10^{-8}$ | $1.83 \times 10^{-7}$ | | | $2 \times 10^{-5}$ | $6 \times 10^{-7}$ (vert) |
| porosity, n | | | | | 0.2 | *0.3* | 0.33 | | | *0.3* | 0.2 |
| Stratum 2 | -- | -- | -- | -- | -- | Lower Till | Sand | -- | | Clay/Silt | -- |
| hydraulic cond., k (cm/s) | | | | | | $6.6 \times 10^{-9}$ | $3.17 \times 10^{-3}$ | | | $1.8 \times 10^{-7}$ | |
| porosity, n | | | | | | *0.3* | 0.39 | | | *0.4* | |
| Stratum 3 (uppermost hydrostratigraphic unit) | Sand | Silty sand | Sand | Loess | Basal till | Dolomite | Sand/Gravel | Sand/Gravel | | Sand/Clay | Tuffs/Clay/Silt |
| hydraulic cond., k (cm/s) | $1 \times 10^{-2}$ | $1.53 \times 10^{-3}$ | $2.16 \times 10^{-3}$ | $4.6 \times 10^{-4}$ | $1 \times 10^{-4}$ | $1.5 \times 10^{-4}$ | $2.67 \times 10^{-2}$ | $4 \times 10^{-2}$ | | *$2 \times 10^{-5}$* | $6 \times 10^{-5}$ |
| porosity, n | *0.3* | *0.3* | 0.35 | 0.34 | 0.2 | 0.2 | 0.29 | *0.3* | | *0.3* | 0.3 |
| GW UP | MW-14 | GWA-102 | MW-22R | MW-106S | MW-101 | MW13 | G01D | MW-1A | | MW11R | MWS-02 |
| GW DN | MW-12R | GWC-105 | MW-28 | MW-201S | MW-103 | MW20 | G23D | MW-3A | | MW12 | MWS-05 |
| Distance I (ft) | 1,820 | 810 | 1,900 | 4,150 | 1,000 | 1,950 | 3,080 | 2,200 | | 2,175 | 1,900 |
| Hydraulic gradient, i | 0.00033 | 0.0015 | 0.00053 | 0.014 | 0.013 | 0.0018 | 0.0017 | 0.001 | | 0.00041 | 0.016 |
| Calculated Ave. GW velocity (ft/yr) | 11.3 | 8.0 | 3.4 | 20.2 | 6.6 | 1.4 | 162.3 | 140.9 | | 0.03 | 3.3 |
| Default GW velocity (ft/yr) | -- | -- | stagnant<br>5.0 | -- | -- | stagnant<br>5.0 | -- | -- | | no flow<br>zero | stagnant<br>5.0 |
| GW POC | MW-11 | GWC-104 | MW-25R | MW-201S | MW-104 | MW14 | G52D | MW-3A | MW-3A | MW12/MW03[f] | MWS-05 |
| Distance A (ft) | 5-30 | < 5 | 10 | 7 | 40 | 21 + 20 | 23 + 10 | 2 | 0 | 4 + 30 | 127 |
| Calculated Max. TOT (Vadose Zone) | < 1 day | < 1 day | < 1 day | 2 days | 77 years | 1,252 years | 40 years | < 1 day | 0 | 64 years | 244 years |
| Distance B (ft) | 1,700 | 120 | 2,200 | 3,700 | 400 | 400 | 1,130 | 1,545 | 965 | 180 | 185 |
| Calculated Max. TOT (Saturated Zone) | 150 years | 15 years | 440 years[j] | 183 years | 61 years | 80 years[j] | 7 years | 11 years | 7 years | 6,000 years | 37 years[j] |
| Distance C (ft) | 150 | 120 | 50 | 330 | 80 | 100 | 100 | 240 | | 50 | 185 |
| Calculated Minimum TOT | 13 years | 15 years | 15 years | 16 years | 3 years[c] | 2,135 years[d] | 7½ months[e] | 21 months | | 36 years[g] | 37 years[h] |
| Distance D (ft) | 350 | 610 | 0 | 275 | 20 | 0 | 380 | 20 | | 0 | 1,000 |
| Distance SUMP - GW POC NEW (ft)[b] | 450 | Not required | Not practicable to move POC | 330[i] | 50 | Not practicable to move POC | Not practicable to move POC | Not required | | Not practicable to move POC | Not practicable to move POC |
| Recalculated Max. TOT (Sat + Vadose) with optimized GW POC NEW | 40 years | | | 16 years | 85 years | | | | | | |
| Duration (upper cell) and Frequency (lower cell) of GW Confirmation Monitoring based on Optimized Conditions | 40 years<br>13 years | 15 years<br>15 years | 440 years<br>15 years | 16 years<br>16 years | Not required, NMD[k] | Not required, NMD[k] | 47 years<br>7½ months | 11 years<br>21 months | | Not required, NMD[k] and no GW flow[l] | Not required, NMD[k] |

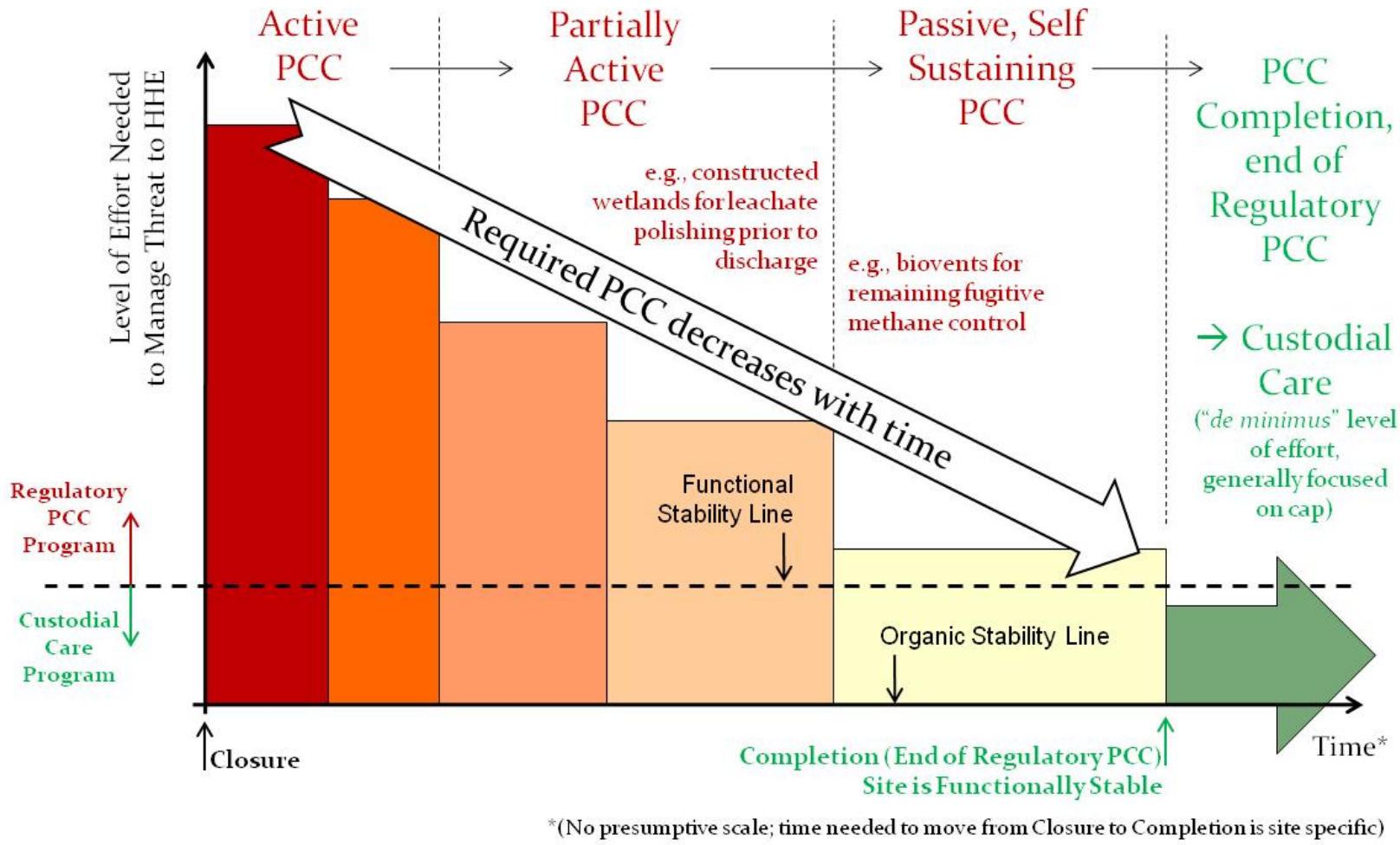
Notes: a). The generic terms listed in the column below are illustrated on Figure 5-1. Hydraulic conductivity (k) values are geometric mean of all reliable reported values for stratum. Where site-specific data are lacking, estimated values for k and n are provided in italics. Hydraulic gradients are averages based on historic GW elevation monitoring in GW UP and GW DN wells. Where available, intermediate wells are included to improve accuracy. b). This well does not currently exist, but could be installed to reduce the total GW TOT and duration of monitoring. c). Lenses and seams of sand and silt are present within the silty clay till range with reported $k = 4 \times 10^{-4}$ cm/s and $i$ and $n$ values assumed equal to Stratum 3. d). Distance C for Site F is for a horizontal silty sand lens with reported $i = 0.0009$ and $k = 1.5 \times 10^{-5}$ cm/s which exists between the upper and middle tills, above level of LHM#1. This lens is monitored as a significant saturated zone. e). Assumed for upper sand/gravel outwash layer between tills, $k = 2.67 \times 10^{-2}$ cm/s. f). MW12 is GW POC for Stratum 3 (Max TOT), MW03 is GW POC for Stratum 1 (Min TOT). g). Historic (pre-development) reported $i = 0.02$ for Stratum 1. h). Horizontal flow in Stratum 1 with $k = 6 \times 10^{-5}$ cm/s. i). At Site D, the GW POC well location is not moved; instead, downgradient sump LCR01 is used as the starting point for migration. j). Calculated using default GW flow velocy of 5 ft/yr. k). Vadose zone TOT exceeds WMU operating life plus 30 years - therefore, it is likely that a NMD petition could be sucessful in which case GW monitoring based on TOT is not required. However, a formal NMD was not conducted. l). GW flow in the saturated zone likely meets the conditions for *de minimus* flow - therefore, continued monitoring of GW serves no practical basis. However, monitoring perched GW for the minimum TOT duration of 36 years may be required.

**This table should not be referenced out of context with the discussion in Section 5.4 of the report.**

# FIGURES

**FIGURE 1-1**
**PERFORMANCE-BASED PCC AND FUNCTIONAL STABILITY**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**




*(No presumptive scale; time needed to move from Closure to Completion is site specific)

**FIGURE 2-1**
**EPCC METHODOLOGY MASTER DIAGRAM**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology**
**Prerequisites Module**
**Environmental Research and Education Foundation**

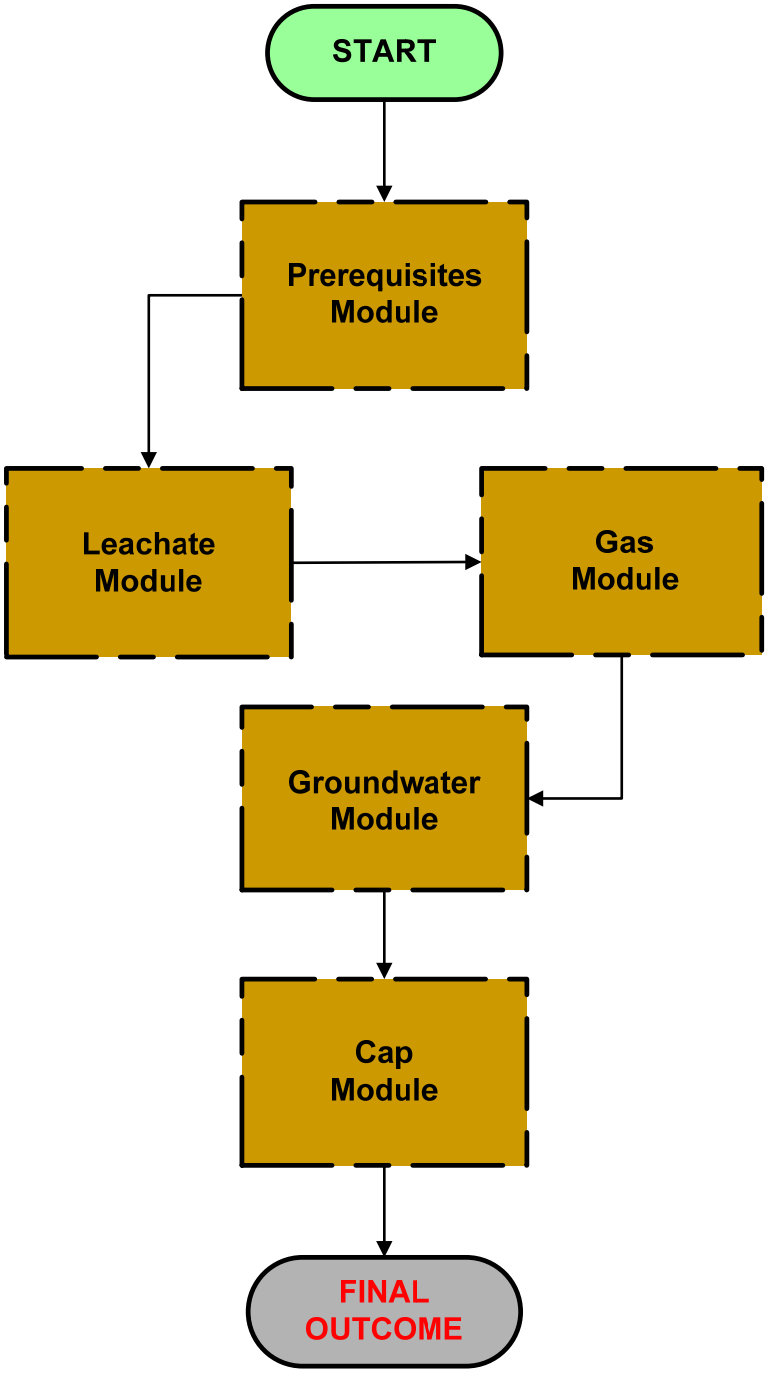
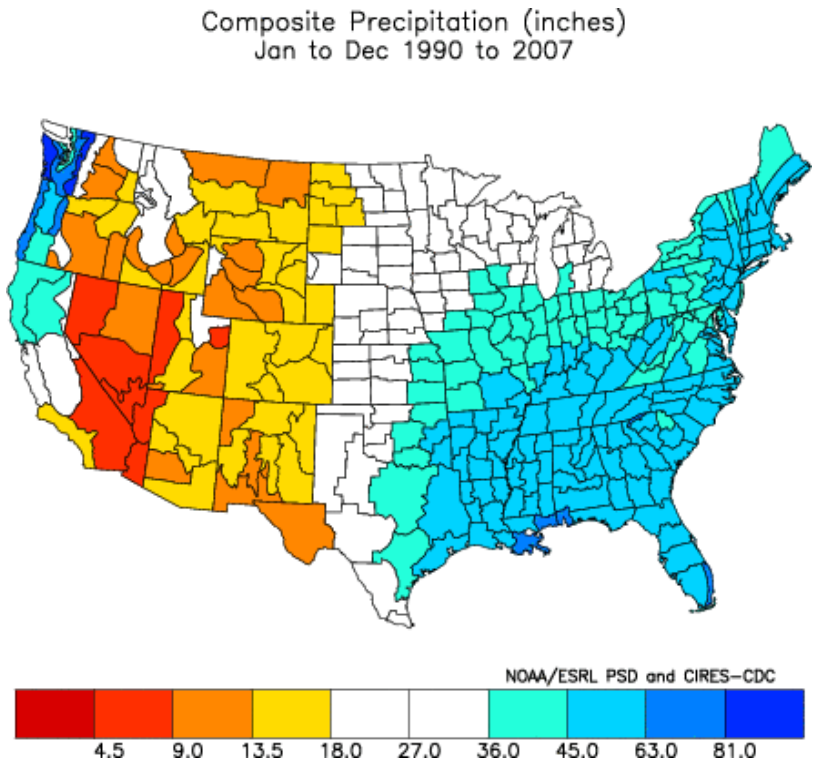
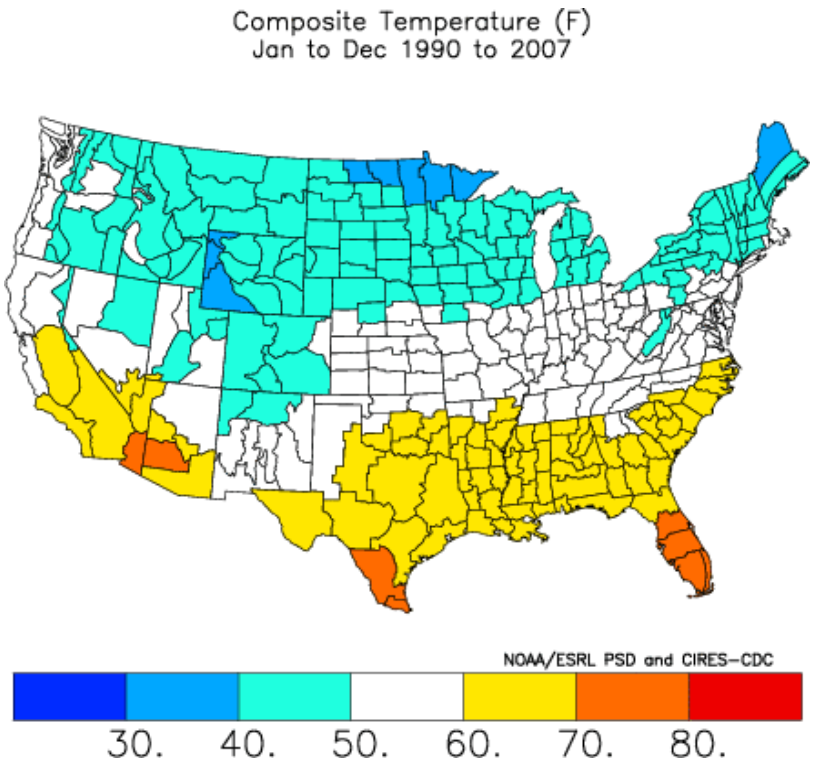


**FIGURE 3-1**
**MEAN ANNUAL PRECIPITATION AND TEMPERATURE**
**IN THE CONTINENTAL UNITED STATES**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

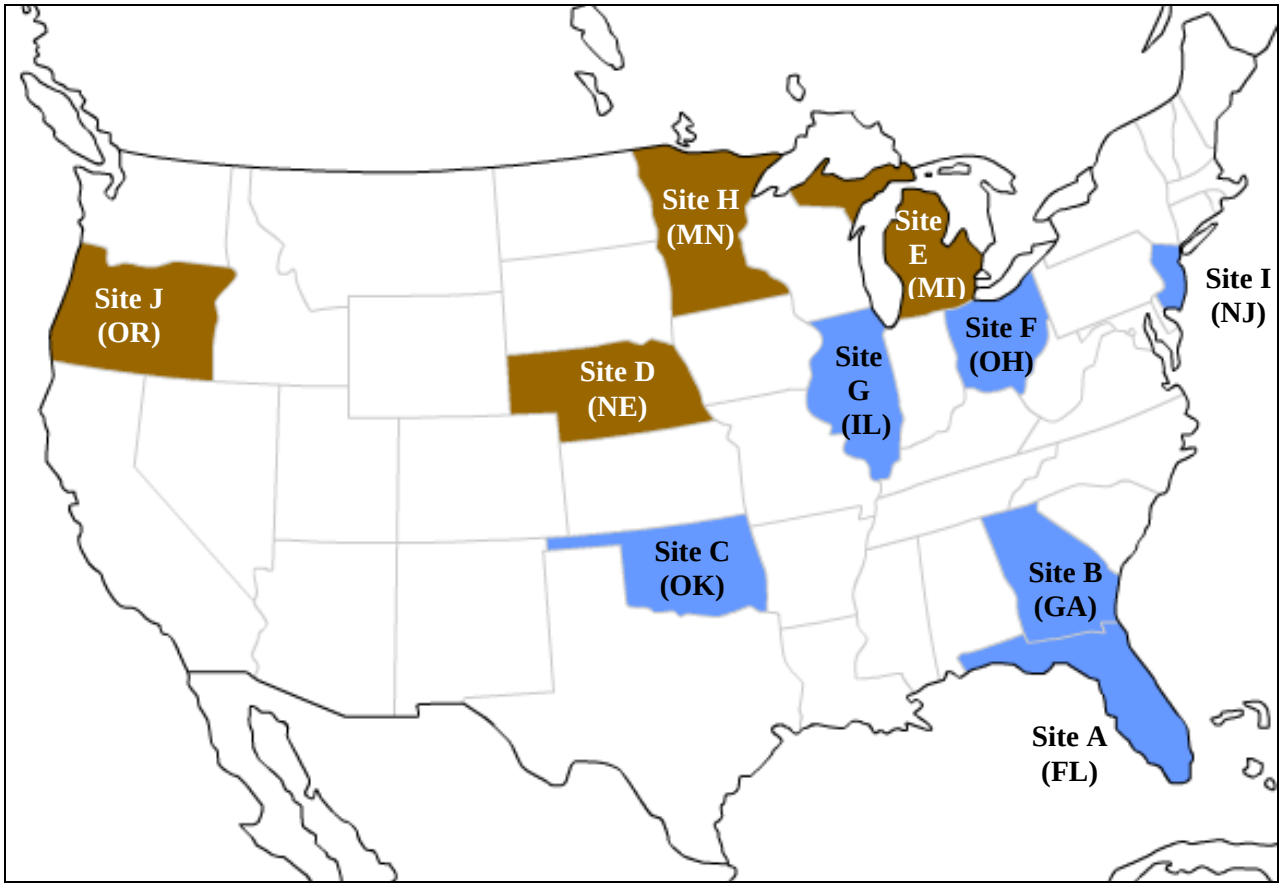



(Source: http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html)

**FIGURE 3-2**
**GEOGRAPHIC LOCATIONS OF CASE STUDY SITES**

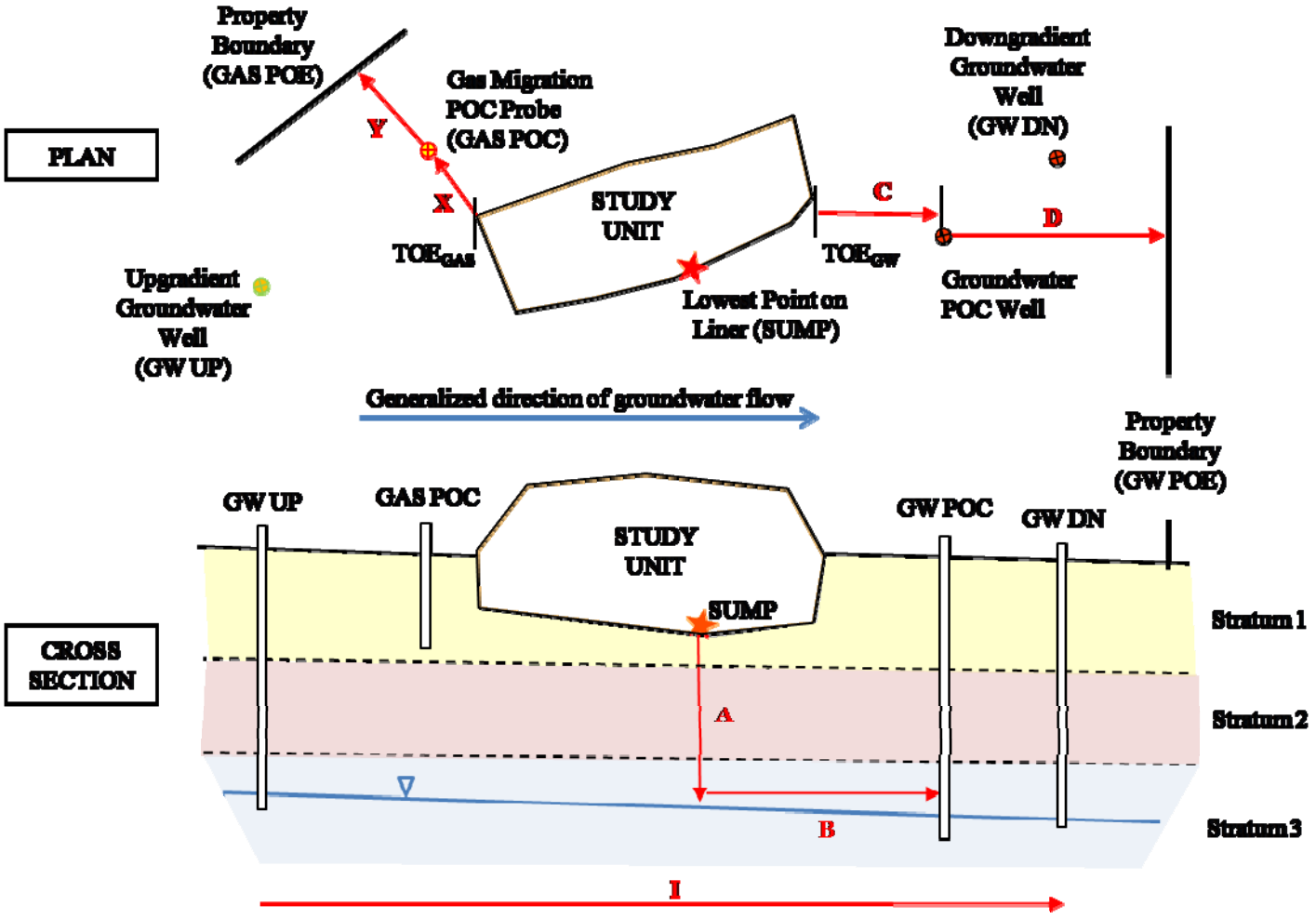
**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**




Note: Site visit, data collection, and primary interpretation of data conducted by Geosyntec (blue shading) or AquAeTer (brown shading)

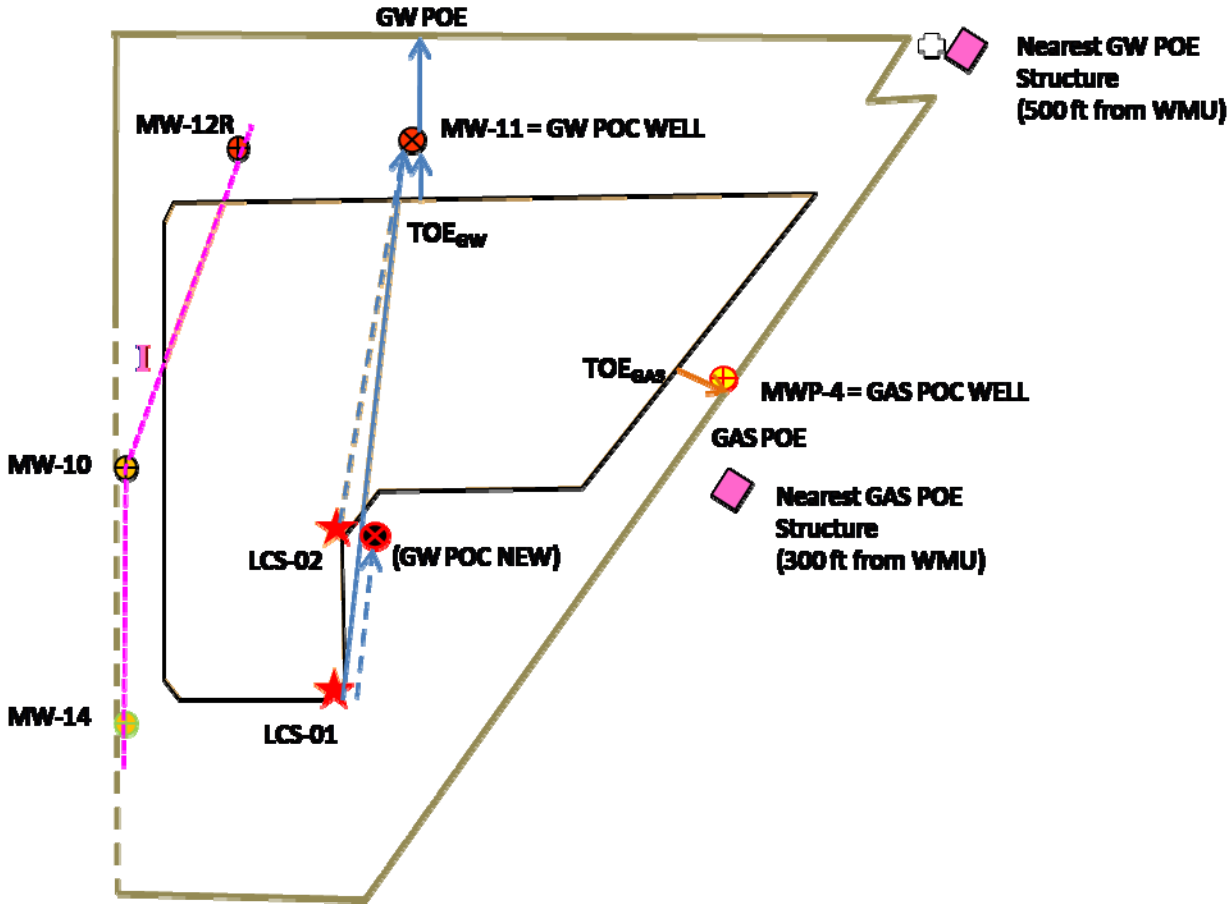
**FIGURE 5-1**
**GENERALIZED HYDROGEOLOGY AND LAYOUT OF CASE STUDY SITES**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**



# FIGURE 5-2A
# SITE A – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

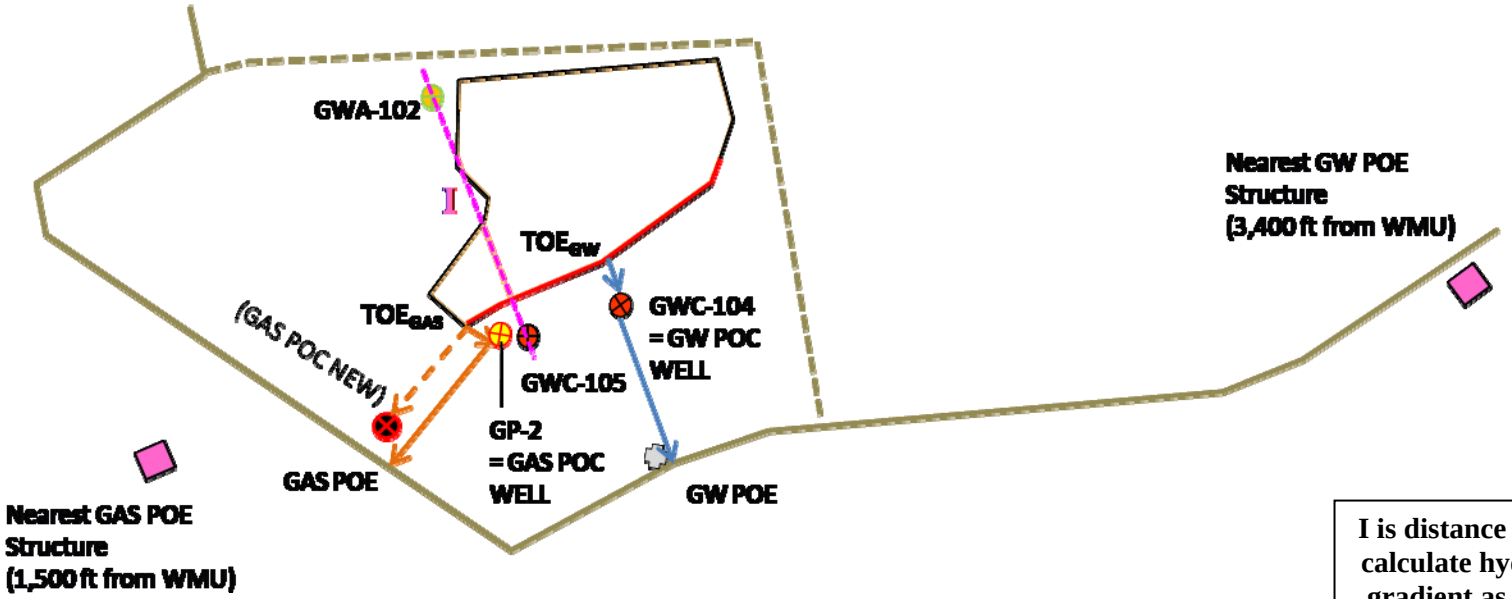



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

**FIGURE 5-2B**
**SITE B – LAYOUT AND MAIN FEATURES**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

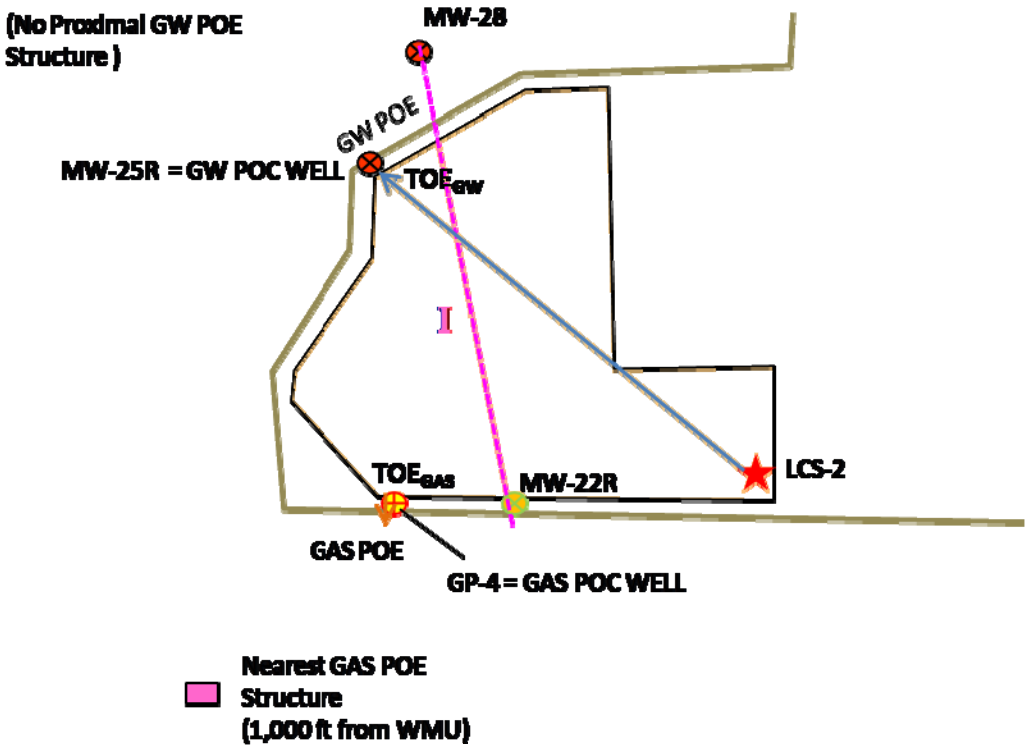



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# FIGURE 5-2C
# SITE C – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

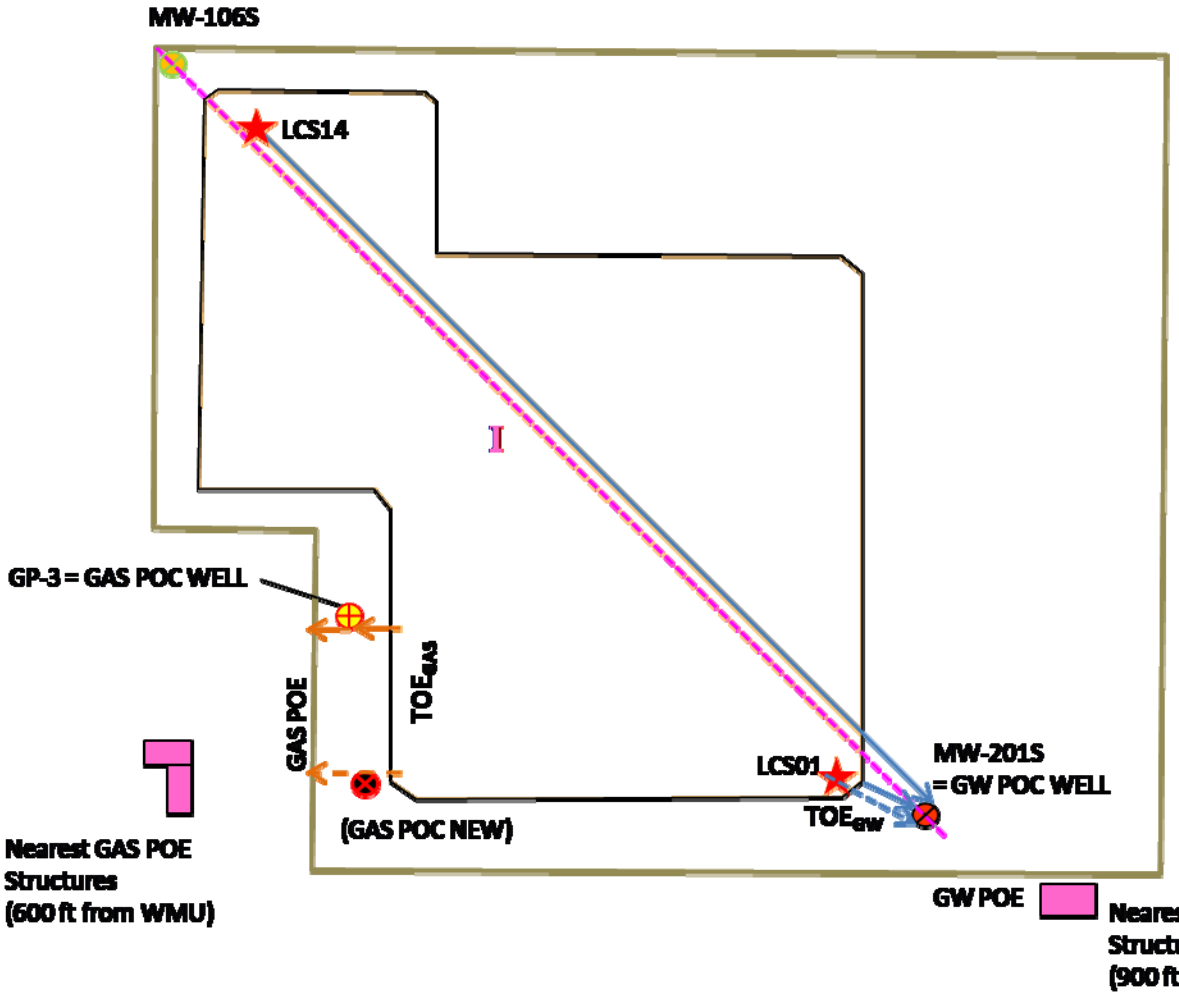



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# FIGURE 5-2D
# SITE D – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

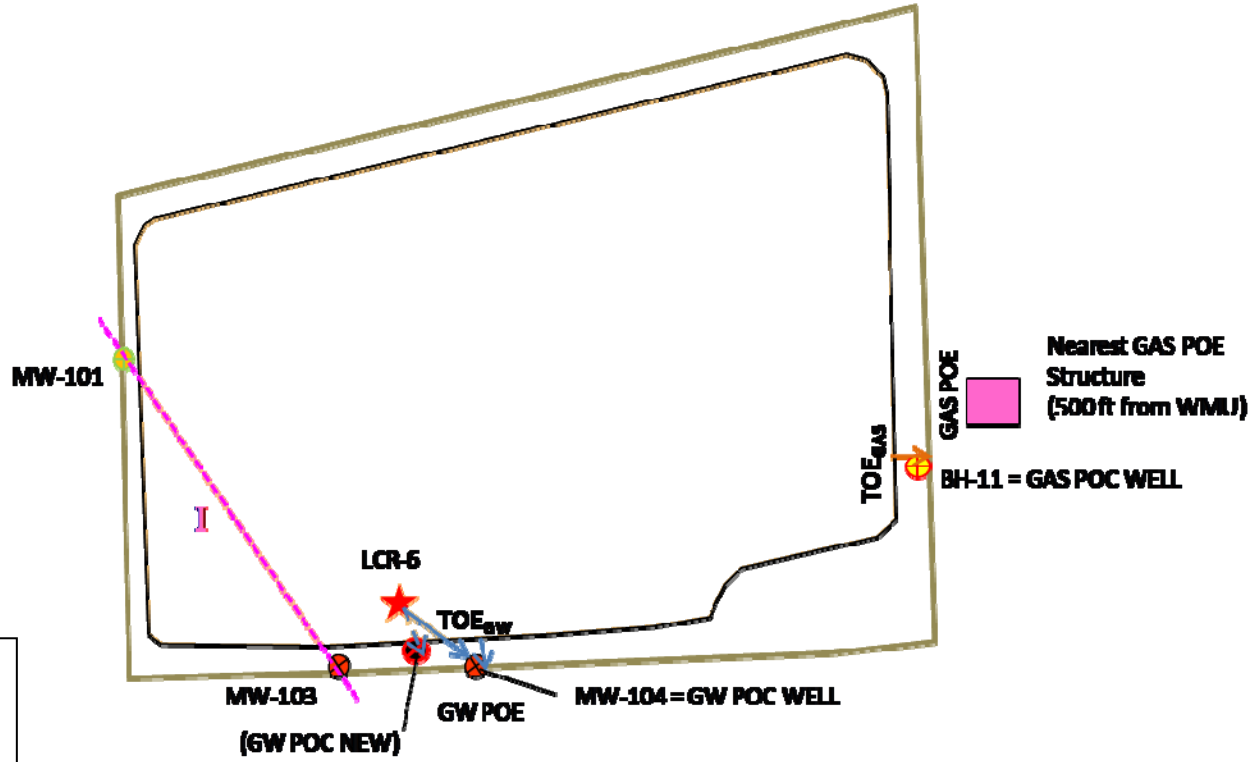



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# FIGURE 5-2E
# SITE E – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**



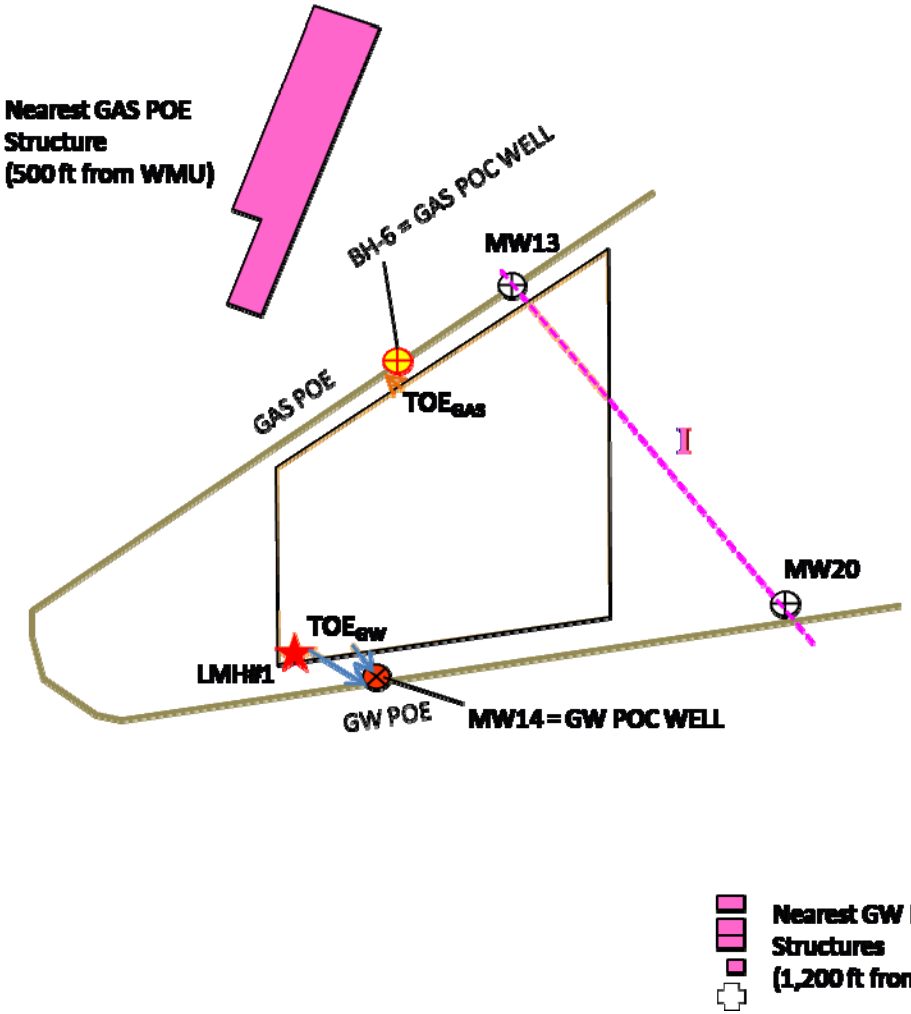

**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

**Nearest GW POE**
**Structure**
**(2,750 ft from WMU)**

# FIGURE 5-2F
# SITE F – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

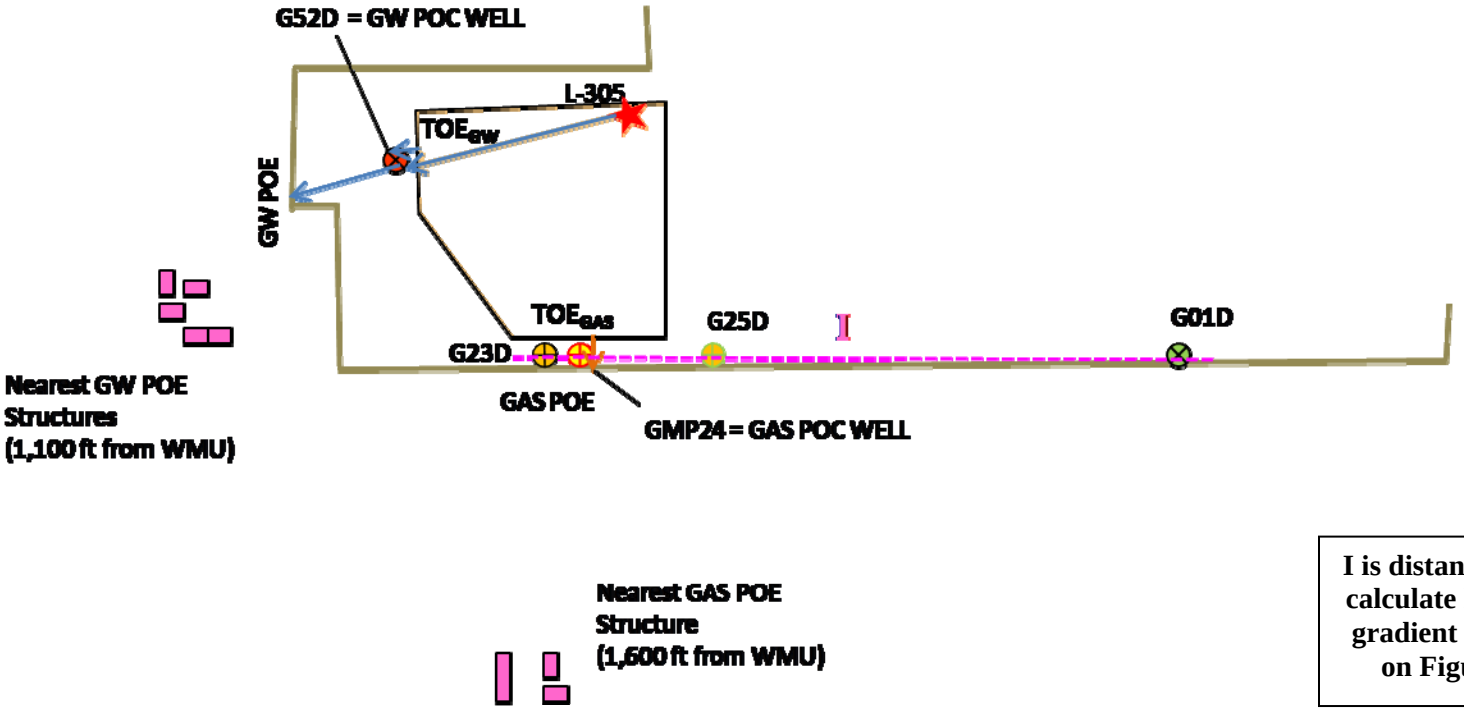



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# FIGURE 5-2G
# SITE G – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

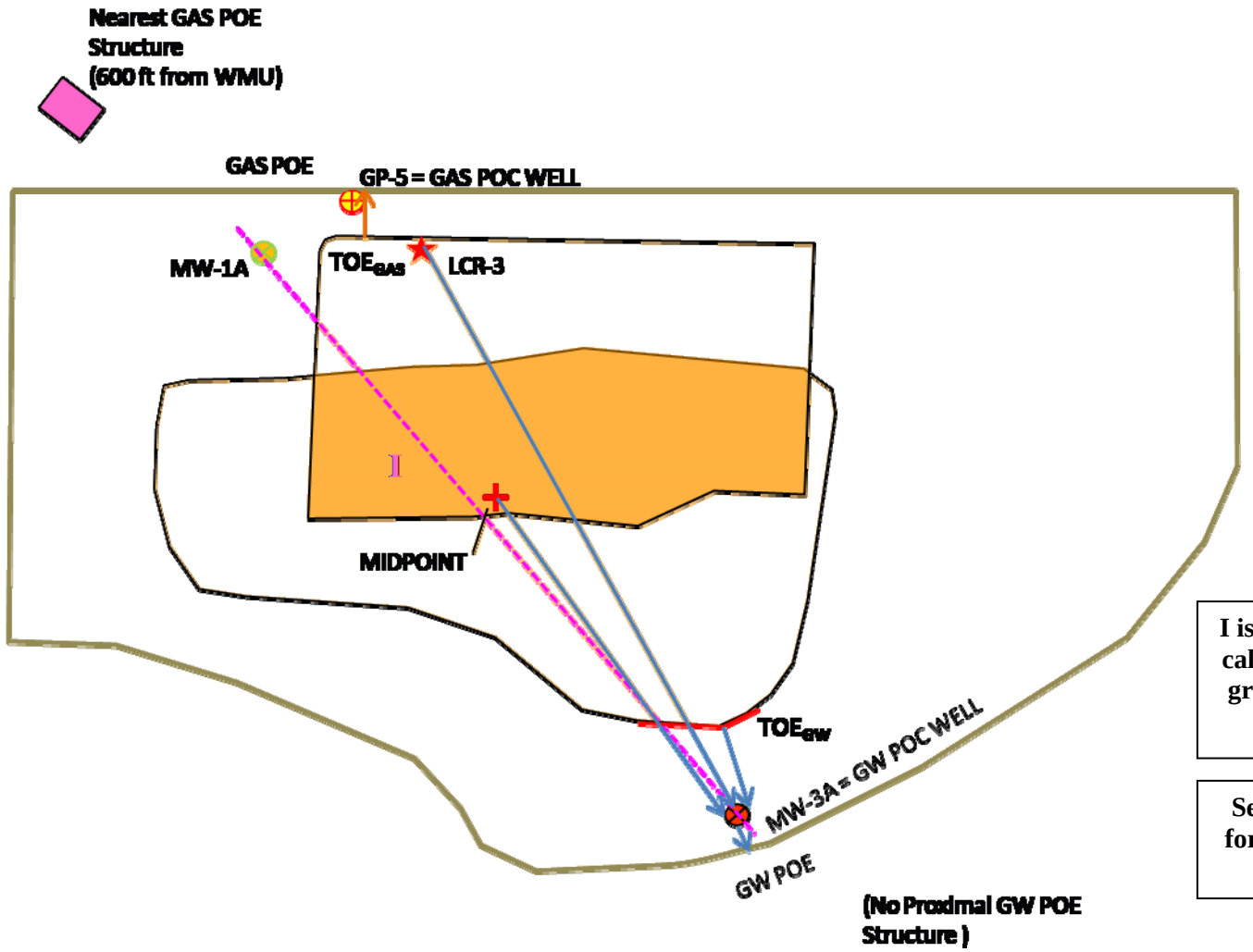



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# FIGURE 5-2H
# SITE H – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

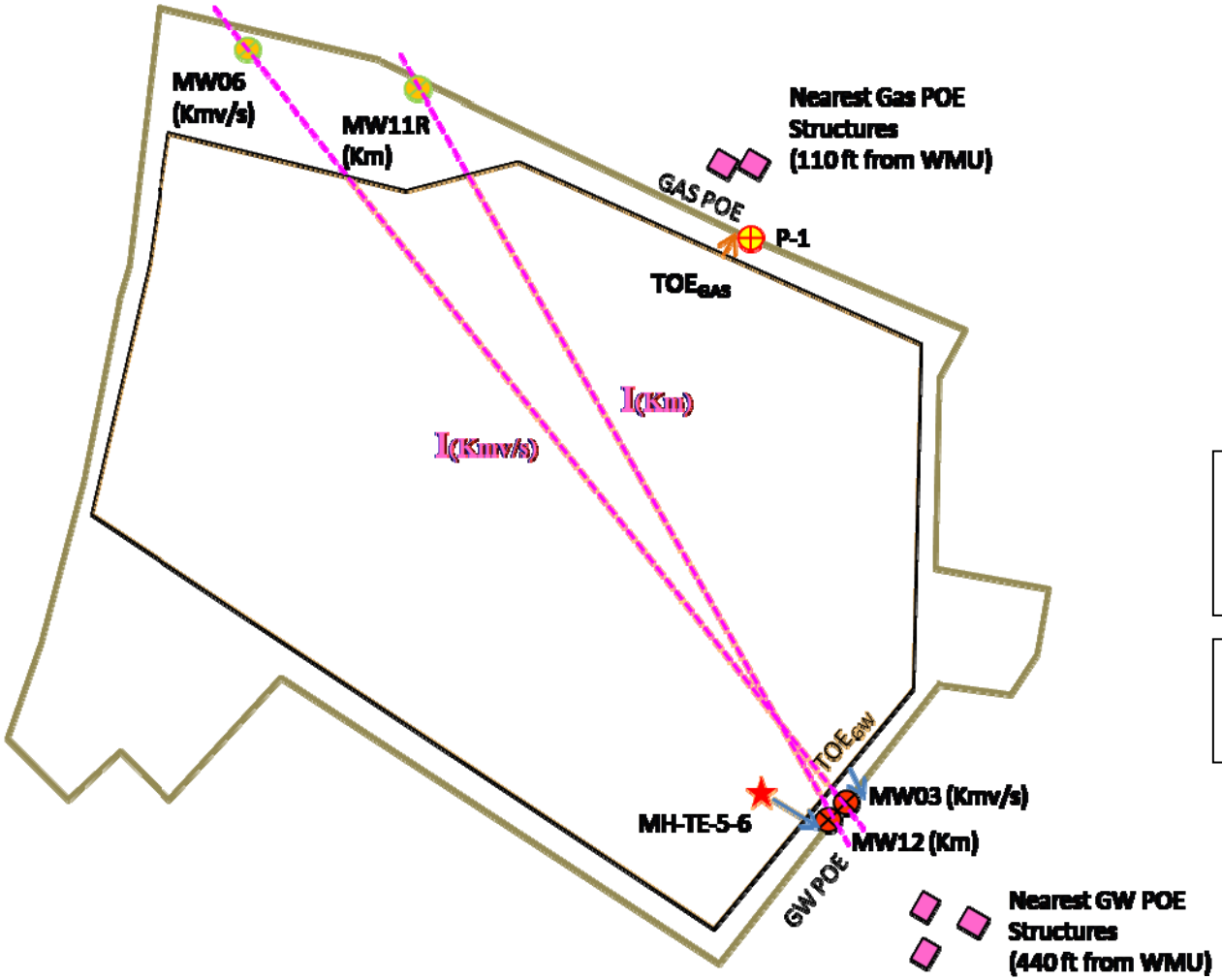



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# FIGURE 5-2I
# SITE I – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**

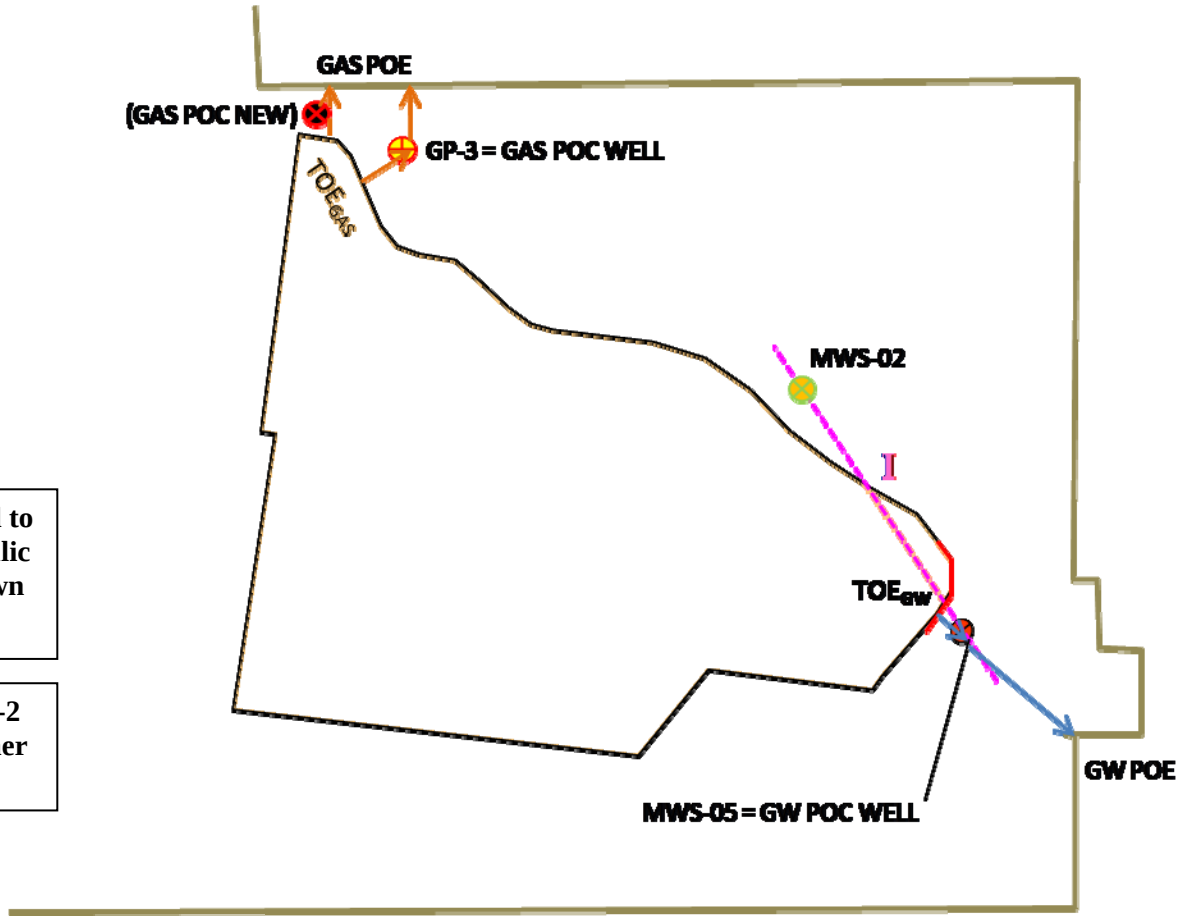



**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# FIGURE 5-2J
# SITE J – LAYOUT AND MAIN FEATURES

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**
**Environmental Research and Education Foundation**




**I is distance used to calculate hydraulic gradient as shown on Figure 5-1**

**See Appendix 2-2 for key to all other symbols**

# APPENDIX 1

# RECOMMENDED UPDATES TO EPCC METHODOLOGY

# APPENDIX 1-1

Geosyntec consultants

10015 Old Columbia Road, Suite A-200
Columbia, Maryland 21046
PH 410.381.4333
FAX 410.381.4499
www.geosyntec.com

## Memorandum

Date: 30 October 2007

To:

Copies to:

From: Jeremy Morris and Mike Houlihan, Geosyntec Consultants

Subject: Invitation to Participate in EREF Post-Closure Care Evaluation Project "*Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module – A Multi-Site Case Study*"

### Introduction

Between 2002 and 2006, Geosyntec Consultants (Geosyntec) worked with a multi-disciplinary team on a project funded by the Environmental Research and Education Foundation (EREF) to develop an "Evaluation of Post Closure Care (EPCC) Methodology." The EPCC Methodology was developed to establish a technically-based evaluation approach of each of the four PCC elements identified in 40 CFR §258.61(a) (i.e., the leachate collection system, LFG monitoring system, groundwater monitoring system, and the landfill cover system) to determine when operation and/or monitoring of these PCC elements can be optimized or terminated. Separate procedures (i.e., modules) were developed for evaluation of each component of PCC but the implementation of these modules cannot be adequately started until the required precursor "Prerequisite Module" is completed. The "Prerequisite Module" was developed to facilitate the evaluation of the four PCC elements through identifying module-specific data requirements. Before the four PCC elements can be evaluated, a preliminary evaluation is conducted through the Prerequisites Module to determine whether available site data are sufficient to perform an in-depth evaluation of the four PCC elements, including whether basic technical data are available for performing the necessary evaluations can be met.

The previous project to develop the EPCC Methodology focused on optimizing PCC maintenance and monitoring requirements and evaluating the scenario of when a site can end regulated PCC. However, the methodology was applied to only one example site during the study. Far more experience is therefore needed to be able to confidently conclude the predictability of the methodology in terms of optimizing/ending PCC obligations. To gain this experience, Geosyntec and EREF have again assembled a team to perform a one-year multi-site evaluation of the EPCC Methodology to critically examine the methodology and expose its potential weaknesses under real world conditions and, ultimately, develop an approach to predict the duration of future PCC activities. Although it is envisioned that Waste Management, Inc. (WM) will provide many of the sites studied, participation from other EREF industry members is actively sought.

As a first step, the team has already developed some screening criteria for site selection in order to identify a candidate list of MSW landfill sites. These screening criteria will be reviewed for each potential candidate site to establish a subset of sites that are likely to have most of the required data (or can effectively obtain the necessary data) for an evaluation of the Prerequisite Module. The goal of this study is to evaluate 10 sites in a variety of locations across the country to establish the specific data that will be needed to complete the Prerequisites Module. The study will also critically appraise the methodology's usability and sensitivity to certain data requirements. It is recognized that certain data collection efforts will likely be needed in the future to satisfy all module evaluation requirements in accordance with the overall approach of the EPCC Methodology. However, the primary goal of this study is to ground-truth the state of the industry relative to data availability to reasonably complete the EREF Methodology.

**Site Selection Criteria**

The remainder of this memo summarizes: (i) criteria that must be met in order for a site to be considered as a candidate for inclusion in the study (i.e., Critical Screening Criteria); (ii) additional criteria to narrow down the list of candidate sites (i.e., Site Variability Criteria); and (iii) detailed information and data needed for a site to make the final list of 10 selected sites (i.e., Data Requirements). Data available in electronic format is preferred.

1. *Critical Screening Criteria*: Candidates sites should be able to meet ALL of the following:
    a. To avoid potential complications with older sites at which MSW and hazardous wastes were co-disposed, sites should be regulated under Subtitle D, unless their inclusion is on the advice of the project team;
    b. The State regulatory environment must be favorable (i.e., voluntary collection of data must not be required to be submitted);
    c. Site management should be cooperative, enthusiastic, and voluntary participants in the study, and the site should not have any ongoing or upcoming plans or issues (e.g., expansion permitting, litigation, significant odor complaints, etc.);
    d. Collection of leachate samples for analyte data and flow measurements must be possible (i.e., the site must have a liner and leachate collection system), except for one site which will be specifically selected with no liner and no leachate source data (in order to evaluate use of the leachate evaluation process for unlined sites);
    e. Measurement of internal gas pressure must be possible using existing site GCCS components, collection of gas data must be possible during routine shutdown of the GCCS without triggering non-compliance with NSPS, and there must be sufficient landfill gas data available to generate a gas curve;
    f. No current evidence of leachate or methane migration issues or impacts;
    g. The site must be monitoring groundwater under a Detection Monitoring program;
    h. A certified final closure cap system must have been installed, and CQA documentation must be available; and
    i. The landfill cell used for the study must have been closed for at least one year.

2. *Site Variability Criteria*: Preferred sites should be able to exhibit the following variability (in descending order of importance):
   a. Climate: The study should try to reflect as many net precipitation ranges as possible; at a minimum, at least one "wet" and one "extremely dry" climate should be included, and preferably one "cold" and one "very hot" climate;
   b. Hydrogeologic Setting: One site with high groundwater flow velocity and one with low velocity should be included, with as much additional variability as possible reflected in the sites' vadose zone thickness and the contiguous nature of groundwater bearing strata;
   c. Site Layout: As much variation as possible regarding distance to groundwater POC and POE, and at least one site each with near/far LFG receptors; and
   d. Years since Cell Closure: One site should be at least five years into PCC, and another at least ten years into PCC.

3. *Data Requirements*: Selected sites should be in possession of all or most of the following data and information. These are broadly categorized as follows, based on the Prerequisites Module in the EPCC Methodology. As many as possible of these data should be available now or be able to be collected within 1-2 years.
   a. Site Operational Records: Annual weight/volume of refuse accepted and into what landfill areas waste was disposed and start/end dates for waste filling; waste types (e.g., MSW, C&D, ash, special wastes) and rough percentages ($^{+}$/- 10%); unique operational practices (e.g., leachate recirculation); site and permit conditions; results from waste characterization studies and waste sampling activities performed (if any).
   b. Site-Specific Data: Liner and cover system(s) components, properties, specifications, history of construction, reported performance issues (e.g., erosion damage) and repairs, and state of vegetation; details, layout, and history of use of LCRS and GCCS; institutional controls (e.g., site security); site size, geotechnical issues, and conditions; details on surrounding environment and communities, on-site and/or off-site structures, surface waters, stormwater management features; reported or noticed impacts from the landfill to any media; identification and layout of monitoring systems for methane migration, groundwater monitoring wells; post-closure plan (total, annual, and future liability and costs) and site end-use strategy; other non-technical issues and liabilities; identification/characterization of potential surface water receiving bodies.
   c. Leachate Characterization Data: History of leachate collection; identification of sumps, storage tanks; leachate quality data for each year available, with as many analytes as possible in the following categories – Appendix I parameters, key biochemical indicators (BOD, COD, ammonia), Appendix II parameters, other regulated parameters; leachate flow quantity data over time.
   d. Landfill Gas Data: History of LFG collection and GCCS (when first installed, how long operated, upgrades, issues), and identification of wellheads; LFG data from system for each year available, including flow and composition (e.g., methane, oxygen, nitrogen, and carbon

dioxide); NMOC data (e.g., from source tests, NSPS Tier 2 studies, risk assessment work, etc.); identification/characterization of potential LFG receptors; previous attempts to model gas generation and emissions (if any).

e. Groundwater Data: Groundwater monitoring data; groundwater flow regime, identification/characterization of subsurface geology and hydrogeology, potable water sources, and other potential receiving bodies; previous attempts to model groundwater flow at the site.
f. Cover System and Settlement Data: Cover monitoring and maintenance records (to check for history of cracking, etc.); instability issues; land/fly-over surveys and other topographic data; data from settlement plates or installed other devices (if any).
g. Meteorological Data: Current and historic data from on-site weather station (if any); identification of closest meteorological station.

**Closing**

Thank you in advance for your participation by reading this far. If you believe that one or more of the sites within your firm may meet all or most of the criteria under (1) and (2) above, and are enthusiastic and supportive of this important effort, please contact Jeremy Morris at (410) 381-4333 or jmorris@geosyntec.com to discuss potential mechanisms and the schedule for participation. At this stage, the specific data requirements under (3) are provided only to facilitate your decision as to whether a site should be considered - we will work closely with you to identify and characterize the site data availability and needs prior to final selection of 10 sites for the study. Because of the year-end deadline for identifying and screening sites, **we would appreciate an initial response indicating your level of interest and a tentative list of candidate sites before 9 NOVEMBER 2007**.

* * * * *

**P R E L I M I N A R Y**
**C H E C K L I S T**

Site Name: _____

Location: _____ State: _____

Contacts: (1) _____

(2) _____

**Main Criteria (please check as appropriate):**

□ MSW Landfill: □ Subtitle D

□ Single separate cell □ Single conjoined cell □ Multiple cells □ Whole site

□ Good Regulatory Environment

□ Cooperative Manager

□ Liner + Leachate Collection System (LCRS) □ Liner, No LCRS □ Unlined

□ Gas Collection and Control System (GCCS): □ Active GCCS □ Passive venting only

NSPS Applies: □ Yes □ No

□ Gas or leachate migration issues or impacts: □ Both □ Gas only □ Leachate only

□ None □ Current □ Past, still an issue □ Past, issues addressed

□ Other high profile issues: □ Past □ Current □ Pending

□ Currently in Groundwater Detection Monitoring under Subtitle D

Years since closure/cessation of waste filling: _____, approx. size of closed cell: _____ ac.

**General Information (check one from each line):**

General Climate:

Rainfall: □ Wet □ Average □ Semi-arid □ Dry

Temperature: □ Hot □ Temperate □ Cold

Hydrogeology:

Subsurface: □ Clays □ Sands □ Silts □ Limestone □ Fractured rock □ Mixture

Groundwater velocities: □ Fast □ Slow □ Moderate

Layout: □ Lots of distance to potential receptors □ Close-by receptors

Capping: □ Final – prescriptive □ Final – alternative □ Interim □ Combination

Please add clarification notes, comments, and/or exceptions as necessary:

# APPENDIX 1-2

Geosyntec consultants

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Columbia, Maryland 21046
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www.geosyntec.com

## Memorandum

Date:

To:

Copies to:

From: Jeremy Morris and Mike Houlihan, Geosyntec Consultants

Subject: Standard Procedures for Site Data Collection (CHECKLIST 2)
EREF Post-Closure Care Evaluation Project: "*Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module – A Multi-Site Case Study*"

CHECKLIST 2 is intended to be used by managers of the sites that responded favorably to having their site(s) included in the study, and completed the one page checklist attached to the "*Invitation to Participate in EREF Post-Closure Care Evaluation Project*" memo from GeoSyntec dated 30 October 2007. The purpose of CHECKLIST 2 is to provide a standard procedure for sites to record and present their data availability to the project team, thus facilitating objective comparison between sites during the site screening process. The intention is that the project team will use CHECKLIST 2 to narrow an initial shortlist of 15-20 candidate sites down to ten (10) final sites for inclusion in the study. It is expected that a data-focused screening effort will be necessary during completion of CHECKLIST 2, which will likely involve a site visit by Geosyntec and/or another consultant.

* * * * *

Attachment: CHECKLIST 2

# MULTI-SITE EVALUATION OF POST-CLOSURE CARE PROJECT

## CHECKLIST 2

Please complete all eight sections as fully as possible. The following symbols are used to facilitate completion of the checklist:

_____ ☑ These items are yes/no question types. Please check (✓) in the affirmative or cross (X) in the negative. If not applicable, write "N/A". In this way, if any item is left unmarked, the project team will assume it is unknown and requires further investigation.

_____ ⚐ These items invite insertion of a comment if appropriate. Please insert a chronological number to signify that an addition has been made. Comments, notes, specifications, etc. should be added in order in Section IX at the end of the checklist. Attach longer specifications (e.g., leachate monitoring parameter list) after the comments section.

**Quick Reference Summary**

Landfill: _____ WMU[1]: _____

Checklist completed by: _____ date: _____

Is final cover in place? _____ ☑ yes, _____ ☑ no

Is there WMU-specific leachate data? _____ ☑ yes, _____ ☑ no

→ Flow? _____ ☑ yes, _____ ☑ no

→ Composition? _____ ☑ yes, _____ ☑ no

→ if yes, how long? _____ years, what frequency? _____ /year

Is there WMU-specific landfill gas data? _____ ☑ yes, _____ ☑ no

→ Flow? _____ ☑ yes, _____ ☑ no

→ Composition? _____ ☑ yes, _____ ☑ no

→ if yes, how long? _____ years, what frequency? _____ /year

Is the WMU currently experiencing a compliance issue of any type? _____ ☑ yes, _____ ☑ no

→ Leachate-related? _____ ☑ yes, _____ ☑ no

[1] WMU = waste management unit (i.e., cell, area, etc.). It is anticipated that individual closed WMUs located at larger multi-unit MSW landfill sites will be used for the study.

→ Landfill gas related? _____ ☑ yes, _____ ☑ no

## I. Site Details

Landfill Name: _____

Address: _____

_____

_____

WMU ID: _____(e.g., cell number, area, name)

Size of WMU proposed for study: _____ ac

_____ tons in place

_____ cubic yards

WMU is contiguous _____ ☑ or separate _____ ☑ to other WMU.

Total number of WMUs at the site = _____.

Site Contact 1:

Name: _____

Title: _____

Phone (office): _____

Phone (other): _____

Email: _____

Site Contact 2:

Name: _____

Title: _____

Phone (office): _____

Phone (other): _____

Email: _____

## II. Drawings

If not collected/copied during site visit, list whether the requested information is known to exist. Please comment on completeness of set and where drawings are stored if not at site office.

1. Design Drawings: _____ ⚑ Paper _____ ☑
   Electronic _____ ☑
2. Construction Drawings: _____ ⚑ Paper _____ ☑
   Electronic _____ ☑
3. As-Built/Record Drawings: _____ ⚑ Paper _____ ☑
   Electronic _____ ☑
4. Other (please specify): _____ ⚑ Paper _____ ☑
   Electronic _____ ☑

5. Do site construction and monitoring details exist to show the following? Please indicate which drawing set has best information.

   a. Layout of site and WMU: _____ ☑ _____ ⚑
   b. Site topography and features: _____ ☑ _____ ⚑
   c. Base grades, liner system layout, and leachate sump locations: _____ ☑ _____ ⚑
   d. Cover system design: _____ ☑ _____ ⚑
   e. Leachate, groundwater, and surface water sampling locations: _____ ☑ _____ ⚑
   f. Property boundary: _____ ☑ _____ ⚑
   g. Layout of the gas collection system (wellfield): _____ ☑ _____ ⚑
   h. Identification of gas system sampling points: _____ ☑ _____ ⚑
   i. Gas migration monitoring well layout: _____ ☑ _____ ⚑
   j. Groundwater point of compliance (POC): _____ ☑ _____ ⚑
   k. Surrounding environment/communities (points of exposure): _____ ☑ _____ ⚑
   l. Information regarding on-site structures (type, occupancy): _____ ☑ _____ ⚑
   m. Information regarding nearest off-site structures (type, occupancy): _____ ☑ _____ ⚑
   n. Potential on- or off-site ignition sources and other hazards: _____ ☑ _____ ⚑
   o. Other pertinent features (please specify): _____ ☑ _____ ⚑

## III. Reports and Plans

If not collected/copied during site visit, list whether the requested information is known to exist. Please comment on completeness and where documents are stored if not at site office. Please note any modifications to original plans (e.g., updated monitoring requirements or applicable standards).

1. Engineering design report: _____ ⚐ Paper _____ ☑
   Electronic _____ ☑
2. Construction and/or CQA report: _____ ⚐ Paper _____ ☑
   Electronic _____ ☑
3. Site operating permit or plan: _____ ⚐ Paper _____ ☑
   Electronic _____ ☑
4. Environmental monitoring plan: _____ ⚐ Paper _____ ☑
   Electronic _____ ☑
5. Other (please specify): _____ ⚐ Paper _____ ☑
   Electronic _____ ☑

6. Does information exist to describe the following? Please indicate which document set has best information.

   a. Conceptual model/calculations (HELP, MULTIMED): _____ ⚐ Paper _____ ☑
   Electronic _____ ☑

   b. Geologic/hydrogeologic studies: _____ ⚐ Paper _____ ☑
   Electronic _____ ☑

      b1. Groundwater flow characteristics: _____ ☑ _____ ⚐

      b2. Thickness and characteristics of uppermost aquifer: _____ ☑ _____ ⚐

      b3. Locations of downgradient potable GW point sources: _____ ☑ _____ ⚐

   c. Boring logs: Paper _____ ☑
   Electronic _____ ☑

   d. Construction specifications (materials, procedures, etc.): _____ ⚐ Paper _____ ☑
   Electronic _____ ☑

e. Gas generation modeling (LandGEM), system design: _____ ⚑ Paper _____ ☑
Electronic _____ ☑

f. Closure/post-closure plan: _____ ⚑ Paper _____ ☑
Electronic _____ ☑

g. End use strategy: _____ ⚑ Paper _____ ☑
Electronic _____ ☑

h. Other (please specify): _____ ⚑ Paper _____ ☑
Electronic _____ ☑

## IV. General Records

If not collected/copied during site visit, list whether the requested information is known to exist. Please comment on completeness and where records are stored if not at site office.

1. Environmental monitoring reports and records:

a. Surface Water: _____ ⚑ Paper _____ ☑
Electronic _____ ☑

→ Monitoring Duration: _____ years, starting _____ (year).
→ Monitoring Frequency: _____ (events/year).

b. Other (please specify): _____ ⚑ Paper _____ ☑
Electronic _____ ☑

2. Operation and maintenance records (note duration/dates): _____ ⚑

a. Waste receipts, waste placement records: _____ ⚑ Paper _____ ☑
Electronic _____ ☑

b. Onsite stream separation, recycling: _____ ⚑ Paper _____ ☑
Electronic _____ ☑

c. Daily/intermediate cover: _____ ⚑ Paper _____ ☑
Electronic _____ ☑

d. Maintenance issues (seeps, breakouts, slope failures): _____ ⚐ Paper _____ ☑
Electronic _____ ☑

e. Other (please specify): _____ ⚐ Paper _____ ☑
Electronic _____ ☑

3. Leachate collection system records: Paper _____ ☑
Electronic _____ ☑

a. History of operation, modification, maintenance: _____ ☑ _____ ⚐

b. Was leachate recirculation practiced: ____ ☑

If yes, for how long: _____ years, do records exist: ____ ☑

4. Landfill gas collection system records: Paper _____ ☑
Electronic _____ ☑

a. Record of gas system compliance: _____ ☑ _____ ⚐

b. History of operation, modification, maintenance, wellfield balancing: _____ ☑ _____ ⚐

c. Surface gas fugitive emissions monitoring (through cover system): _____ ☑ _____ ⚐

d. Other (please specify): _____ ☑ _____ ⚐

5. The WMU currently has a cap monitoring and maintenance program which is in compliance with existing permit conditions and PCC regulations: _____ ☑ _____ ⚐.

6. Other monitoring and survey data (note duration/dates):

a. Onsite meteorological data collection: _____ ⚐ Paper _____ ☑
Electronic _____ ☑

b. Topographic surveys: _____ ⚐ Paper _____ ☑
Electronic _____ ☑

c. Other (please specify): _____ ⚐ Paper _____ ☑
Electronic _____ ☑

## V. Leachate Data

1. Leachate chemical composition (quality) data has been collected:
   a. Regularly, for past _____ years at _____ frequency.
   b. Intermittently (please clarify), for past _____ years _____ ⚐
   c. Never, but LCRS could be sampled: _____ ☑ _____ ⚐

2. Please list site-specific leachate analyte list (see below): _____ ☑ _____ ⚐
   → in particular, analyte list includes:
   a. Federal Appendix I parameters: _____ ☑
   b. Federal Appendix II parameters: _____ ☑
   c. Biochemical indicators (pH, BOD, COD) _____ ☑
   d. Ammonia: _____ ☑
   e. Chloride: _____ ☑
   f. Anions/cations: _____ ☑

3. Data collection/analysis is under an accepted QA/QC protocol: _____ ☑ _____ ⚐

4. Leachate generation (flow) data has been collected:
   a. Regularly, for past _____ years at _____ frequency.
   b. Intermittently (please clarify), for past _____ years _____ ⚐
   c. Never, but flow could be measured: _____ ☑ _____ ⚐

5. Total number of leachate sampling locations for:
   a. Collecting composite samples (e.g., master sump, storage tanks) = _____.
   b. Collecting sump-specific samples = _____.
   c. Measuring leachate flow = _____.

6. There is no evidence of current impacts caused by leachate:
   a. At the WMU's groundwater point of compliance (POC) _____ ☑

b. At surface water sampling locations _____ ☑

7. With regards to #6:

a. The WMU has always been free of impacts of concern _____ ☑

b. Previous such impacts have been satisfactorily addressed (i.e., the leachate source is now properly controlled, the impacts remedied, and/or the site has returned to a normal monitoring program) _____ ☑ _____ ⚑

c. With regards to #7b, the history and current status of corrective measures is known and documented: _____ ☑ _____ ⚑

## VI. Landfill Gas Data

1. Gas migration monitoring system exists: _____ ⚑

a. WMU-specific system: _____ ☑

b. Part of whole site system: _____ ☑

c. Landfill gas migration monitoring data exists: _____ ⚑ Paper _____ ☑

Electronic _____ ☑

→ Monitoring Duration: _____ years, starting _____ (year).

→ Monitoring Frequency: _____ (events/year).

2. Landfill gas collection and control system (GCCS) exists at WMU: _____ ⚑

a. Active GCCS, NSPS applies: _____ ☑

b. Active GCCS, NSPS does not apply: _____ ☑

c. Passive controls only (e.g., vents, etc.): _____ ☑ _____ ⚑

d. No controls at all (e.g., gas diffuses through cover): _____ ☑ _____ ⚑

3. With regards to #2a/b, active GCCS comprises _____ extraction wells.

a. GCCS connected to blower/flare _____ ☑, landfill gas-to-energy (LFGTE) system _____ ☑, other gas utilization system _____ ☑, other (please specify) _____ ☑.

b. If not NSPS, why was the active GCCS installed? _____ ☑ _____ ⚑

b1. Permit requirement: _____ ☑ _____ ⚑

b2. Odor control: _____ ☑ _____ ⚑

b3. Migration control: _____ ☑ _____ ⚑

b4. Energy generation or methane utilization: _____ ☑ _____ ⚑

b5. Other (please specify): _____ ☑ _____ ⚑

4. There is no evidence that gas migration currently causes impacts[2] at the:

a. WMU (onsite), based on Primary _____ ☑ or Secondary _____ ☑ Criteria _____ ⚑

b. Gas migration POC, based on Primary _____ ☑ or Secondary _____ ☑ Criteria _____ ⚑

c. Groundwater POC, based on Primary _____ ☑ or Secondary _____ ☑ Criteria _____ ⚑

5. With regards to #4:

a. The WMU has always been free of gas impacts _____ ☑

b. Previous such impacts have been satisfactorily addressed (i.e., the gas source is now properly controlled and the impacts remedied) _____ ☑ _____ ⚑

c. With regards to #5b, the history and current status of corrective action measures is known and documented: _____ ☑ _____ ⚑

6. Field measurement of gas flow and composition has been performed:

a. Regularly at individual wellheads, for past _____ years at _____ frequency.

b. Regularly at central location (flare station), for past _____ years at _____ frequency.

c. Intermittently, for past _____ years _____ ⚑

d. Never: _____ ☑ _____ ⚑

---

[2] Based on the following Primary Screening Criteria:

(i) *Migration*: No detections of methane greater than 0.5% or 10% of the lower explosive limit (LEL) in gas probes at the migration monitoring POC or in on-site structures for a period of at least one year; and

(ii) *Groundwater*: No groundwater impacts (i.e., verified concentrations of gas-related VOC parameters at the groundwater POC above regulatory action levels) that could be attributable to landfill gas with current the GCCS in operation are evident.

Or Secondary Screening Criteria:

(i) *Migration*: If methane has been detected in the past four quarters of gas migration monitoring, the detected methane concentrations must be less than 5% at the lateral POC and less than 1.25% within on-site structures; or

(ii) *Groundwater*: It must be demonstrated that there is a steady or decreasing concentration trend of gas-related VOC parameters at the groundwater POC for a minimum of three years of consecutive monitoring.

7. With regards to #6, can the amount of gas flow from the study WMU be separated from whole-site flow (if applicable)? _____ ☑ _____ ⚑

8. With regards to #6, gas composition data exists for:

   a. Bulk gases (methane, carbon dioxide, nitrogen, hydrogen, oxygen): _____ ☑ _____ ⚑

   b. Trace components: _____ ☑ _____ ⚑

   c. NMOC: _____ ☑ _____ ⚑

   d. Other (please specify): _____ ☑ _____ ⚑

   d. Sampling methods are known: _____ ☑ _____ ⚑

   e. Data collection/analysis is under an accepted QA/QC protocol: _____ ☑ _____ ⚑

## VII. Groundwater Data

1. A Detection Monitoring Program (DMP) exists for monitoring groundwater media at the WMU's POC in compliance with 40 CFR §258.54: _____ ☑

2. If the answer the item #1 was NO:

   a. The DMP has been suspended and elimination of all groundwater monitoring requirements has already been approved by the State agency (e.g., as the result of a successful No Migration Demonstration): _____ ☑

   b. The WMU being monitored in accordance with Assessment Monitoring (AM), consistent with 40 CFR §258.55: _____ ☑

   c. The WMU is in Assessment of Corrective Measures under 40 CFR §258.56: _____ ☑

3. If the answer the item #1 was YES:

   a. The WMU has always been free of impacts of concern _____ ☑

   b. Previous impacts have been satisfactorily addressed (i.e., the leachate source is now properly controlled, the impacts remedied, and/or the site has returned to Detection Monitoring under Subtitle D or equivalent) _____ ☑ _____ ⚑

4. With regards to #2 or #3, the record of compliance or history of monitoring under AM and/or corrective measures required per ACM is documented and available: _____ ☑ _____ ⚑

5. Groundwater monitoring data (elevation, chemistry) is collected at:
   a. _____ upgradient, _____ cross gradient, and _____ downgradient POC wells;
   b. At _____ frequency, and started in _____ (month, year); and
   c. Includes the following analytes:
      c1. Federal Appendix I parameters: _____ ☑
      c2. Federal Appendix II parameters: _____ ☑
      c3. Site-specific analyte list (please specify): _____ ☑ _____ ⚑
      c4. Chloride: _____ ☑ _____ ⚑
      c5. Other conservative GW tracer _____ ☑

## VIII. Cap Data

1. The WMU has an interim _____ ☑ or final _____ ☑ cap system.
   a. If interim, please comment on future capping plans _____ ⚑.
   b. If final:
      b1. The original design basis and construction details are available: _____ ☑ _____ ⚑
      b2. The original design has been modified: _____ ☑ _____ ⚑

2. Cap performance:
   a. Cap has a history of requiring repair and stability/erosion issues: _____ ☑ _____ ⚑
   b. Cap has a history of geotechnical instability, slope failures: _____ ☑ _____ ⚑
   c. Settlement analysis has been performed: _____ ☑ _____ ⚑

## IX. Additional Information

Please supplement as necessary:

# APPENDIX 1-3

## RECOMMENDED PROACTIVE LEACHATE MONITORING

As discussed in Sections 4.1 and 4.2.2 of the report, the following sections describing proactive leachate monitoring requirements should be inserted into the Prerequisites Module as Sections 3.3.4 and 3.3.5 of the Technical Manual. Current Table E-3-1 should be replaced with the updated table in Appendix 1-4.

### 3.3.4 Recommended Leachate Monitoring Data

1. *Leachate Decision Parameters*: If possible, data necessary to apply all three tiers of DP trend analysis (i.e., BOD, total flow, and COD)[1] should be collected. For each data series, the following requirements should be observed:

A. Collect at least eight composite leachate samples no more frequently than quarterly.

B. It is strongly recommended that[2]:

   a. The total period over which DP data are collected exceeds 10 years; and

   b. DP data collection commence at least five years before the anticipated date of WMU closure or include the last 20 percent of the active life of the WMU, whichever is greater.

C. If collection of composite data reflecting leachate collected across the entire WMU is not possible or these data are not available, sump-specific data may be pooled and used to generate a surrogate composite value. In this case, the sampled sumps should represent at least 75% of total leachate generation from the WMU (if total flow is known) or include all sumps (if total flow is unknown). Sampling should be performed according to the schedule for composite sampling in Conditions (A) and (B) above.

2. *Regulated Parameters*: The leachate SW and GW RPs required were previously identified in Section 3.3.3. Current concentrations of all RPs in leachate will be calculated from these data using methods specified in the Leachate Module (which have certain minimum data

[1] Note that if BOD or COD data are also required as an RP, then the most stringent conditions for data collection and largest quantity of data specified should be observed such that the frequency of sampling and number of samples is consistent with the requirements for both sets of parameters.

[2] Data collection earlier and over a longer period will generally be advantageous to the WMU owner/operator, as capture of pre-closure data will likely include peak concentrations. The 10 year period for data collection is intended to improve the overall representativeness of the data series.

requirements). It is recommended that maximum values also be calculated (although conservative default values are provided where this is not desired or possible). For all RPs, the following requirements should be observed:

A. Start data collection at least five years before attempting an initial Leachate Module evaluation.

B. Collect composite leachate samples at least biannually. If collection of composite data reflecting leachate collected across the entire WMU is not possible or these data are not available, sump-specific data may be pooled and used to generate a surrogate composite value. In this case, the sampled sumps should represent at least 75% of total leachate generation from the WMU (if total flow is known) or include all sumps (if total flow is unknown). Sampling should be performed according to the schedule for composite sampling in Condition (A) above.

C. To calculate a statistically representative maximum value for a RP from an entire composite or sump-specific data series, at least eight data points will be required, there must be a five to ten year separation between the first and last sample included in the calculation, and no more than two post-closure data points may be included in the data series. Samples should be collected semi-annually. Note the following:

   a. The relatively long period specified is intended to improve the overall representativeness of the data series, while focusing on collection of pre-closure data is intended to provide for capturing peak concentrations;

   b. Calculation of maximum values is not obligatory for successful completion of the Leachate Module, but will be used for determining whether GW Confirmation Monitoring is required (i.e., when GW monitoring may be ended) or for optimizing ongoing groundwater monitoring requirements; and

   c. If fewer data are available but a competent demonstration of having captured peak concentrations can be made, then maximum values may be calculated using this reduced data set.

D. To demonstrate consistency between current composite and sump-specific concentrations, eight composite samples and one sample from each sump will be required for each parameter (see Condition (E) below for more information related to sump-specific sampling). Thereafter, the number of samples required to calculate a statistically representative current value for a RP depends on whether comparison of leachate quality will be to background or a regulatory standard. Where comparisons will be to background (i.e., the background concentration of a RP exceeds the standard), eight current samples will be required. In addition, it will be necessary to collect 4 - 8 background groundwater samples on an annual sampling frequency, starting as early as possible, in order to generate a representative

background value. If comparison will be to a regulatory standard, a minimum of four independent samples should be obtained[3].

C. If sufficient composite data are available, only collection of a single 'snapshot' sump-specific sample is required to evaluate overall representativeness of composite samples[4]. To provide for appropriate data representativeness, sump-specific snapshot sampling should occur no more than 2 years prior to the date of Leachate Module evaluation. Where the total number of sumps at a WMU is large, sumps may be targeted on the basis of leachate generation during snapshot sampling. Target sampling should satisfy the following two conditions:

   a. Any sump that individually represents 10% or more of total leachate generation should be sampled; and

   b. The cumulatively leachate flow at the sampled sumps should represent at least 75% of total leachate generation.

3. *Data Preparation*: Specific statistical data preparatory procedures are required prior to the hypothesis testing analyses in the Leachate Module. These methods include:

   a. Treatment of censored data (i.e., non-quantifiable measurements);

   b. Determination of outliers; and

   c. Testing of distributional form and assumptions.

   These three steps are integral to any statistically rigorous analysis of environmental data. In each case, an overview of the general statistical approach is provided in non-technical terms along with a recommended approach in Sections 2.2.1 through 2.2.3 of the Statistical Procedures document in Appendix E-1. Thereafter, a more complete statistical discussion of each topic is provided, including a wide variety of possible methods and discussion of their respective strengths and weaknesses, is provided in Attachments A through C.

[3] This is another reason why collection of more than the minimum snapshot of sump-specific samples is strongly recommended, as the existence of a least 4 sump-specific samples will allow sump-specific data to be compared to a regulatory standard if appropriate (i.e., if sump-specific data are consistent with composite data, but represent a more complete or otherwise better data series).

[4] It is important to note, however, that it may be beneficial to have more data than the term snapshot sampling implies, because additional sump-specific data could be required if it cannot be demonstrated that the snapshot data are consistent with composite data (if additional sump-specific samples are necessary, up to 4 samples may need collecting on a semi-annual basis, and this could delay evaluation of the Leachate Module). Where the total number of sumps at a WMU is large such that this sump-specific sampling effort will be time-consuming or expensive, sampling of 25% of sumps on a rotational basis is suggested.

### 3.3.5 Are All Prerequisites Satisfied?

Once the prerequisites from Sections 3.3.2 and critical (Classification "*C*") data requirements from Table 3-1 and Sections 3.3.3 and 3.3.4, have been met, the Leachate Module may be evaluated. To be able to perform a risk evaluation in Sub-Module L-E, however, supplemental (Classification "*S*") data will be required as shown in Table 3-1, although this is not a general prerequisite for entry to the Leachate Module. The lack of any flag (Classification "*F*") data will limit the type of evaluations that may be performed. If any prerequisite conditions or data requirements cannot be met, the Leachate Module may not be evaluated until such future time that these conditions or requirements are satisfied.

**APPENDIX 1-4**

**PROPOSED MODIFICATIONS TO DATA REQUIREMENTS IN PREREQUISITES MODULE**

**Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module**

**Environmental Research and Education Foundation**

| Module and Category (Table/Section of Technical Manual) | | Item | Current Classification | | Proposed Reclassification | |
|---|---|---|---|---|---|---|
| PREREQUISITES MODULE (SECTION 3.2) | | End Use Strategy | C | Critical | | |
| LEACHATE MODULE (TABLE E-3-1) | General Prerequisites | Current/historic GW monitoring data and flow direction (background and POC) | C | Critical | | |
| | | Current/historic SW monitoring data | C | Critical | NC | Non-Critical |
| | | Previous/existing impacts attributable to leachate, history and current status of corrective action measures | C | Critical | | |
| | | Identification of applicable SW standards | C | Critical | | |
| | | Identification of applicable GW standards | C | Critical | | |
| | Site Details | Layout of WMU; site topography and features; layout and location of SW and GW POC, POE, and property boundary | C | Critical | | |
| | | LCRS design (layout, type, components); construction and as-built drawings and details; operation and maintenance history | NC | Non-Critical | | |
| | | Base grades and liner system layout | C | Critical | O | Optimal |
| | | WMU cell geometry, size; waste thickness | NC | Non-Critical | | |
| | | Years accepting waste; waste composition; total mass/volume of waste in place | NC | Non-Critical | | |
| | | Site-wide or cell-specific operational practices (e.g. leachate recirculation) | C | Critical | NC | Non-Critical |
| | | Cover system design/as built record, physical condition, repairs and reoccurring issues | C | Critical | | |
| | | Stormwater management features and performance; any reoccurring seeps/breakouts | NC | Non-Critical | | |
| | | Topographic surveys and/or settlement data; settlement analysis | NC | Non-Critical | | |
| | | Geotechnical stability data; documented slope failures | NC | Non-Critical | | |
| | Characteristics of Receiving Bodies and Hydrogeologic Data | Receiving environment at POE; extent of buffer zone | F | Flag | PC | Pot. Critical |
| | | Location of potable GW point sources within regulatory defined limits | F | Flag | PC | Pot. Critical |
| | | GW well, LFG migration monitoring well, and other construction and boring logs | NC | Non-Critical | | |
| | | Characteristics of uppermost aquifer (lithology, thickness, hydraulic conductivity) | C | Critical | | |
| | | Characteristics of vadose zone (lithology, depth to GW, hydraulic conductivity) | C | Critical | | |
| | | Characteristics of surface water (mixing zones); peak/average flow rates and/or volume; uses | F | Flag | O | Optimal |
| | Leachate Monitoring Data | Current and historic leachate analytical results for Decision Parameters | C | Critical | | |
| | | Current and historic leachate analytical results for Regulated Parameters | C | Critical | | |
| | | Current and historic leachate generation rates | C | Critical | O | Optimal |
| | | Type (sump, pump station, gravity drain, etc) and number of leachate sampling locations | C | Critical | | |
| | | Sump-specific data | C | Critical | | |
| | Other Data | Meteorological Data (precipitation, potential evapotranspiration, other climatic data) | C | Critical | | |
| | | Risk exposure factors; toxicity information | S | Supplemental | PC | Pot. Critical |
| GAS MODULE (TABLE E-3-2) | General Prerequisites | Screening for compliance with LFG migration monitoring criteria | C | Critical | | |
| | | Sreening for compliance with surface emissions monitoring criteria | C | Critical | | |
| | | Screening for gas-to-groundwater impacts | C | Critical | | |
| | | Record of compliance; previous/existing impacts attributable to LFG; odor issues; NSPS/EG requirements | C | Critical | | |
| | | GW monitoring well headspace data | NC | Non-Critical | | |
| | Site Details | LFG collection/control system design (layout, type, radius of influence, and other design calculations) | NC | Non-Critical | | |
| | | Reason LFG system was originally installed; history of operation, modification, maintenance, balancing | NC | Non-Critical | | |
| | | Layout of WMU, site, LFG migration and GW POC, distance to sensitive receptors, and property boundary; extent of buffer zone | C | Critical | | |
| | | Years accepting waste; annual tonnages; waste placement schedule; total mass of waste in place | NC | Non-Critical | O | Optimal |
| | | Airspace utilization records | | | O | Optimal |
| | | Waste composition and characterization (incl. sampling from boring logs for LFG extraction well installation) | NC | Non-Critical | | |
| | | Information regarding on-site or planned end use structures (type, occupancy, previous/existing issues) | C | Critical | | |
| | | Site operational practices | NC | Non-Critical | | |
| | | Cover system type, design, details, condition, construction history, repairs, and issues | NC | Non-Critical | | |
| | | WMU cell geometry, size; waste thickness | NC | Non-Critical | | |
| | | Base grades and liner system details | NC | Non-Critical | | |
| | | Aerial surveys and/or other settlement data | NC | Non-Critical | O | Optimal |
| | Characteristics of Sensitive Receptors | Nature and sensitivity of Receptors (anthropogenic or natural) | C | Critical | | |
| | | Information about and distance to nearest off-site structures (type, occupancy, previous/existing issues) | C | Critical | | |
| | | Potential on- or off-site ignition sources and other hazards | C | Critical | | |
| | | GW and LFG migration monitoring well logs | NC | Non-Critical | | |
| | | Sub-surface geologic conditions (vadose zone lithology, grain size, depth to GW, and GW flow velocity) | C | Critical | | |
| | | Vadose zone hydraulic conductivity | C | Critical | | |
| | | Depth to uppermost aquifer, aquifer thickness, grain size characterization, hydraulic conductivity | F | Flag | PC | Pot. Critical |
| | | Distance to potable water point sources | F | Flag | PC | Pot. Critical |
| | | Proximity of potential odor receptors | C | Critical | | |
| | LFG Monitoring Data | Current and historic LFG generation rate; site-specific modeling input parameters; model output | NC | Non-Critical | | |
| | | Current LFG collection rate | C | Critical | O | Optimal |
| | | LFG composition (bulk gases, trace components, NMOC); sampling methods and locations | NC | Non-Critical | | |
| | | Internal gas pressure in WMU (from wellheads, permanent/temporary probes) | C | Critical | O | Optimal |
| | Other Data | ~~Meteorological data, atmospheric pressure~~ | ~~C~~ | ~~Critical~~ | Not Required | |
| | | Institutional controls on site end use; end-use plans; non-technical issues relating to site redevelopment | C | Critical | | |
| | | State policies and standards regulating GW quality and use | C | Critical | | |
| | | Risk exposure factors; toxicity information | S | Supplemental | PC | Pot. Critical |
| GROUNDWATER MODULE (TABLE E-3-3) | General Prerequisites | Current/historic GW monitoring data (background and POC) | C | Critical | | |
| | | Record of compliance; documented releases; previous/existing impacts attributable to WMU, history and current status of corrective action measures (if | C | Critical | | |
| | | Selection of groundwater monitoring indicator parameter(s) | C | Critical | | |
| | | Identification of applicable GW standards | C | Critical | | |
| | | State policies and standards regulating GW quality and use | C | Critical | | |
| | Site Details | Layout of WMU; site topography and features; layout and location of GW POC, POE, and property boundary | C | Critical | | |
| | | Base grades and liner system details (type, design, components) and integrity | NC | Non-Critical | | |
| | | WMU cell geometry, size; waste thickness | NC | Non-Critical | | |
| | | Years accepting waste; waste placement schedule; total mass of waste in place | NC | Non-Critical | | |
| | | Waste composition and characterization (incl. sampling from boring logs) | NC | Non-Critical | | |
| | | Site operational practices | NC | Non-Critical | | |
| | | Cover system design, details, condition, construction history, repairs, and issues | NC | Non-Critical | | |
| | | Stormwater management features and performance; history of occurrence of seeps/breakouts | NC | Non-Critical | | |
| | | Aerial surveys and other settlement data; settlement analysis; severity of erosion damage | NC | Non-Critical | | |
| | | Design information related to geotechnical stability; history of slope failures | NC | Non-Critical | | |
| | Characteristics of Receiving Bodies and Hydrogeologic Data | Nature and sensitivity of receiving environment at POE; extent of buffer zone | C | Critical | | |
| | | Location of potable GW point sources | NC | Non-Critical | | |
| | | GW well, LFG migration monitoring well, and other boring logs | NC | Non-Critical | | |
| | | Characteristics of uppermost aquifer (lithology, grain size, thickness, hydraulic conductivity) | C | Critical | | |
| | | GW flow characteristics (predominant direction, velocity, vertical/horizontal components) | C | Critical | | |
| | | Preferential groundwater flow pathways, recharge and discharge relationships | NC | Non-Critical | | |
| | | Characteristics of vadose zone (lithology, grain size, depth to GW, hydraulic conductivity) | C | Critical | | |
| | | Other sub-surface geologic conditions | NC | Non-Critical | | |
| | Other Data | Meteorological Data (precipitation, potential evapotranspiration, other climatic data) | NC | Non-Critical | | |
| | | Risk exposure factors; toxicity information | S | Supplemental | PC | Pot. Critical |
| CAP MODULE (SECTION 3.6) | General Prerequisites | End use strategy identified with cap performance criteria | C | Critical | | |
| | | Outcome of Leachate Module established | C | Critical | | |
| | | Outcome of Gas Module established | C | Critical | | |
| | | Outcome of Groundwater Module established | C | Critical | | |
| | | Interim or final cap installed | C | Critical | | |
| | | Cap monitoring and maintenance program in compliance | C | Critical | | |
| | Data Requirements | Cap performance data and site information (e.g., ~~settlement,~~ infiltration control, emissions control for active and PCC conditions) | C | Critical | | |
| | | Cap settlement data (e.g., time-series topographic aerial/land surveys, settlement plates or other point-source data) | C | Critical | | |
| | | Original design basis and construction details for cap | S, F | Suppl./Flag | PC | Pot. Critical |
| | | Site conditions upon which original design is based | S, F | Suppl./Flag | PC | Pot. Critical |
| | | Meteorological data | S, F | Suppl./Flag | PC | Pot. Critical |
| | | Structure and specifications of cap | S, F | Suppl./Flag | PC | Pot. Critical |
| | | Water balance, gas control modeling | S, F | Suppl./Flag | PC | Pot. Critical |

| Key | |
|---|---|
| BLUE | New or substantially modified line item |
| GREEN | Status of line item downgraded from critical to non-critical |
| ORANGE | Status of line item changed to optimal |
| PINK | Status of line item changed to potentially critical |

**This appendix should be used to fully replace the Tables and Sections of the Prerequisites Module listed in the righthand column. See discussion in Section 4.1 of the main report for more details.**

# APPENDIX 1-5

## PROPOSED REVISION TO GAS MODULE TIME OF TRAVEL LOOKUP TABLE

As discussed in Section 5.3.1 of the report, current Table E-5-4 in Section 5.3.3 of the Technical Manual should be replaced with the revised lookup table below.

**Table E-5-4 (Revised): Estimated TOT for LFG Plume Given Internal WMU Gas Pressure and Maximum Intrinsic Vadose Zone Hydraulic Conductivity**

| Max. Vadose Zone Hydraulic Conductivity, k (cm/s)[5] | Time of Travel per 100 ft Horizontal Distance[4] | | | | | |
|---|---|---|---|---|---|---|
| | Default Max.[1] | Maximum WMU Internal Gage Pressure (in.-w.c.) | | | | Default Min.[1] |
| | | 5 | 10 | 20 | 60 | |
| $> 5 \times 10^{-2}$ | 6 months | 30 days | 15 days | 7 days | 3 days | 2 days |
| $5 \times 10^{-2}$ - $5 \times 10^{-3}$ | 5 years | 12 months | 6 months | 90 days | 30 days | 15 days |
| $5 \times 10^{-3}$ - $5 \times 10^{-4}$ | 10 years | 10 years | 5 years | 2½ years | 9 months | 6 months |
| $5 \times 10^{-4}$ - $5 \times 10^{-5}$ | 10 years | 10 years | 10 years | 10 years | 8 years | 5 years |
| $< 5 \times 10^{-5}$ | GAS CONFIRMATION MONITORING NOT REQUIRED[2,3] | | | | | |

Notes:

1. Default values to be used where site-specific measurement is not undertaken. Default maximum TOT is based on internal gage pressure of 1 in.-w.c., default minimum TOT is based internal gage pressure of 100 in.-w.c.
2. Confirmation monitoring for gas migration is not required because the low hydraulic conductivity of the vadose zone will tend to manifest more readily as cover surface emission exceedences, instability, or visible vegetative stress, all of which will be noticed during cover inspections. See Note (A)(a).
3. If this condition applies, go to Step (1)(i) upon exiting the table.
4. When actual values fall in between the values shown on the table, the user should move to the more conservative value. For example, if internal gage pressure = 15 in.-w.c. and vadose zone k = $5 \times 10^{-3}$ cm/s, TOT = 5 years.
5. The hydraulic conductivity values provided are for water (i.e., typically reported values for saturated hydraulic conductivity). The TOT values have been corrected to allow for the fact that the hydraulic conductivity for LFG for the soil medium will be different. The correction is based on the intrinsic permeability of the soil and assumptions of LFG composition and properties. The user should also apply the worst-case (i.e., highest) hydraulic conductivity zone expected at the landfill, including any known or suspected preferential paths for LFG migration.

The technical basis for the revised table is provided below, and should be used to replace current Note (A) in its entirety in Section 5.3.3 of the Technical Manual.

A. The project team devised the modified screening approach for revising Table E-5-4 by bracketing near-zero and instability-causing gas pressures to define the duration and frequency of gas CM based on upper- and lower-bound TOTs, respectively. The values in the table are conservative and dependent upon the internal LFG pressure within the refuse mass and the horizontal conductivity of the vadose zone soils adjacent to the landfill. The analysis that was conducted to determine these values was based on Darcy's law, which models the advective (i.e., pressure gradient) movement of a gas in a porous media[1]. Diffusive gas movement was assumed to be insignificant. The technical basis for assigning representative conditions for calculation of TOT is as follows:

   a. *Default Maximum TOT*: The minimum recordable internal gage pressure is set at one inch of water column (1 in-w.c.). It is reasonable to assume that driving pressures lower than this value will not result in significantly different rates of gas migration. Therefore, in the absence of actual gage pressures, the Gas Module user should assume a default maximum TOT per 100-ft travel distance from revised Table E-5-4 relative to the maximum vadose zone hydraulic conductivity reported at the site. The maximum TOT is then used to establish the duration of CM, based on the assumption that a gas plume would not move slower than under these conditions (i.e., CM would detect a gas plume if it were to migrate). The maximum TOT is cut off at 10 years for 100 ft; it is assumed that subsurface gas migration at a rate slower than this <u>from the time that a screening evaluation suggests that modification to LFG controls is appropriate</u> will not be cause for concern because the low hydraulic conductivity of the vadose zone will tend to drive LFG issues at the site to manifest themselves as surface emission exceedences or visible vegetative stress. Indeed, where $k \leq 1 \times 10^{-5}$ cm/s, no CM is required (regardless of distance to the POC) because the expected rate of gas migration would be expected to be de minimus such that LFG issues would not manifest as offsite migration.

   b. *Default Minimum TOT*: The maximum reasonable internal gage pressure is set at 100 in-w.c. In practical terms, this is an extremely high value; for example, calculations of geosynthetic cover system stability under conditions of elevated pore gas pressures typically exceed a factor of safety of 1.0 at about 8 – 12 in-w.c. (i.e., 10% of the maximum value proposed in the table). Therefore, before such pressures were ever actually encountered at a geosynthetic-capped landfill, significant cover system instability and potential failure conditions should be noticed (at a soil-capped landfill,

[1] Darcy's law was applied in one dimension (horizontal). It relates the velocity in the horizontal direction in terms of pressure and permeability. Viscosity and gas density, which also enter into Darcy's equation, were assumed to be constants based on characteristics of a gas comprised of 55% methane and 45% carbon dioxide, which typically represents as-generated LFG. The horizontal velocity for LFG was then calculated by inserting the specific values for pressure and conductivity from the table and the constants for viscosity and density. The TOT was calculated from the velocity and the designated horizontal distance of 100 feet.

such elevated pressures could not arise due to venting through the cover). Indeed, the screening process in the Gas Module is sufficiently conservative that the project team is confident such sites could not actually pass and be considered suitable for elimination of active LFG controls. In the absence of actual gage pressures, the Gas Module user should assume a default minimum TOT per 100-ft travel distance from revised Table E-5-4 relative to the maximum vadose zone hydraulic conductivity reported. The minimum TOT is then used to establish the frequency of CM, based on the assumption that a gas plume would not move faster than under these conditions (i.e., CM would not fail to detect a gas plume before it had travelled much beyond the POC, at which point rapid corrective action such as re-ignition of an active LFG system could be implemented to prevent significant migration to the property boundary).

c. *TOT based on Actual Gage Pressure*: Measurement of internal gage pressure remains an optimal (but not critical) requirement under the revised Gas Module prerequisites and, where feasible, the user is encouraged to measure internal pressure in the WMU. Therefore, revised Table E-5-4 continues to provide look-up TOT values based on a range of actual gage pressures between the minimum and maximum assumed default values.

d. In summary, site operators continue to be encouraged to collect actual gage pressure measurements at the time that LFG modifications are proposed because, depending on site-specific geometry and vadose zone characteristics, this could significantly reduce the required frequency and duration of CM relative to the new default TOT values proposed on Table E-5-4. However, because the TOT for gas migration in the vadose zone is typically fast – often weeks or months – resorting to default values from the table should not represent an undue additional monitoring burden at the POC gas probes during CM, especially considering that it will occur for a fixed duration only while an effort to reduce or eliminate active LFG management is being evaluated.

# APPENDIX 2

# SUMMARY OF CASE STUDY SITES

## APPENDIX 2-1A

## SUMMARY – SITE A (FLORIDA)

### Overview

Study WMU: Site A is a four-phase, lined WMU with LCS covering approx. 39 acre footprint, with estimated capacity of 2.4MM tons and constructed with about 100 ft max depth of waste. Phase 1 of the WMU opened as the county landfill in 1983 and stopped receiving waste on 26 July 1999. The county landfill was designed to accept about 215 cy of MSW per day. By 1993, the site was taking 1,500 tpd. Phases 2-4 were constructed in 1993 and filled by 2001. The entire WMU is a Subtitle D landfill (Class I Landfill according to Florida SWM regulations). WMI acquired the site in 11/1987. The original WMU permit expired 12/1989, renewed in 1993 and again in 1998.

Property: According to the site permit renewal application (PRA) dated 6/1993, the total property size is 424 acres. Site A is located on an 89-acre parcel originally approved for landfill disposal in 10/1982. According to the original 2/1982 design report, the property was not in use prior to siting the landfill. Site A is one of two permitted separate WMUs on the property, the other one is much larger (139 acres, 13 phases) and still active, having commenced operation in 1999.

The physiographical setting of the property and study unit is shown on Figure A-1. A stylized depiction of the site layout is provided as Figure A-2.

### Site Information

Geologic and Hydrogeologic Setting: The site is located in karst terrain in which a relatively thick, continuous clay layer overlies the Floridian aquifer throughout most of the site. No springs, caves, or sinkholes are known to exist in the site vicinity (the closest sinkhole is about 15 miles SE). Several filled solution features exist where depth to limestone is in excess of 70-95 ft bgs; these features are now filled with well compacted sands and clays and have been stable for many years. Generally, the surface soils are Pliocene-Pleistocene age Pamlico fluvial deposits extending to a depth of 30-40 ft. Depth is regulated by the underlying irregular ancient limestone surface.

The geologic units are subdivided into three hydrogeologic units: the surficial aquifer system (undifferentiated terrace and alluvial deposits of the Holocene and Pleistocene and the Citronelle formation of the Pliocene) which provides a small amount of water for domestic supply locally,

the Floridian aquifer system (comprised mostly of Ocala Group limestones in the landfill vicinity) which is the main drinking water source in the region, and the sub-Floridian confining units (undifferentiated Lisbon and Tallahatta formations).

Locally, there are two perched water-bearing zones in silty sands and the plugged, filled, ancient solution features (clays) above the Floridian aquifer, the only true aquifer. The water elevation in the perched water table is highly dependent on the frequency and intensity of rainfall. The upper perched water table moves towards the N surface water body after heavy rainfall and does not exist except near this water body during dry periods. Water levels in the lower perched zone appear to drop little during dry weather but rise significantly after a period of prolonged rain. The surficial deposits are not considered to be hydraulically connected to the limestone aquifer, except possibly in karst depressions

Saturated Zone: Water in the Upper Floridian aquifer originates almost entirely as precipitation, recharge occurs by direct infiltration where the aquifer is covered by thin sandy soil, by vertical leakage form perched aquifers, by streams, and by solution features such as sinkholes (when they are not filled with clayey sediments). About 40% of the local area is considered to have moderate to high recharge potential. The permeability of the aquifer is largely attributable to secondary porosity resulting from dissolution of carbonate rock. The aquifer is considered to be under confined or semi-confined conditions due to the presence of a continuous clay or clayey sand which lies directly on top of the limestone. The aquifer is fully saturated with artesian water levels remaining above the tope fo the limestone at all times.

Boring Logs: 2/1982 report provides 4 pre-development "test hole" boring logs (TH1 – TH4 on Figure A-3) down to water table, approx. 25 ft bgl (142-152 ft-msl). All boring logs show GW potentiometric surface encountered in clay (CL, approx. permeability $3x10^{-8}$ cm/sec). Boring logs for MW-01 to MW-16 show depth to bedrock (limestone) of 40 – 100 ft bgl. The limestone is typically found at 110-130 ft-msl.

Hydraulic Conductivity: Slug tests were performed in MW-01, MW-02, MW-03, MW-05, MW-10, MW-11, and MW-12 in 1990, giving k values of $5.46x10^{-2}$ cm/sec to $2.5x10^{-5}$ cm/sec (average $1x10^{-2}$ cm/sec). According to a 1988 design report, the silty clays and clays beneath the site exhibit k values of $10^{-7}$ – $10^{-9}$ cm/sec, silty sands have k values of $10^{-5}$ cm/sec, and weathered limestone has k values of $10^{-5}$ cm/sec.

Groundwater: Groundwater flow direction and gradient change significantly during the year (during a one-year monitoring period in 1992, groundwater was observed to fluctuate from 147 – 162 ft-msl); for this reason, the State required additional cross- and downgradient wells to be installed in 1993. However, the aggregate groundwater flow direction is considered to be NNE and ENE. The horizontal flow gradient is very low. The hydraulic conductivity of the Floridian is reported as 9-119 ft/day, with groundwater velocity of 0.1-1 ft/day. Groundwater elevations are regularly recorded during groundwater monitoring events. Useful upgradient and

downgradient elevation data are available from 3 and 4 wells, respectively, for the period 5/1988 through 8/2007. Monthly GW potentiometric plots are available from 6/1991 to 12/1992, annual plots exist for 2003 to 2005. GW elevations in relation to the liner basegrades are summarized on Figure A-3. Elevations range from about 156-125 ft-msl in all proximal monitoring wells. This means that the min liner elevation (155 ft-msl at downgradient toe in Phases 2, 3, and 4) is generally above the high GW elevation.

Unsaturated (Vadose) Zone: The surficial sediments are unconsolidated sands and clayey sands interspersed with lenses of clay and occasional lenses of gravel. All surficial sediments are uniform in composition. The sands consist mainly of fine to medium grained quartz mixed with varying amounts of clay. The clays are low permeability, high plasticity, CH type clays to silty clays. The 2/1982 boring logs all show GW in clay (CL), overlain by layers of MH (approx. permeability $10^{-7}$ cm/sec), SC (approx. permeability $2x10^{-4}$ cm/sec), and SP (approx. permeability $5x10^{-2}$ cm/sec), although SP is generally removed prior to site development.

Physiographical Setting: According to the 2/1982 report, the average ground elevation of the 89-acre Site A parcel is 165 ft-msl, and the high water level in the surface water body N of the WMU is approx. 160 ft-msl. General features are very gently sloping areas with slow surface runoff under natural conditions. Soils are predominated by one type, the Fuquay series, consisting of well drained, loamy textured soils; typically, surface soils are 20-in. thick, sand textured and subsurface soils are > 40-in. think, sandy clay loam textured. "These strongly acid soils are low in fertility and low in available water capacity." According to the FEMA flood map, only the N surface water body is located within the 100-year flood zone, and all areas above 160 ft-msl will not be impacted by a 100-year flood.

Potential Point(s) of Exposure: The properties surrounding the site are not zoned, the predominant and use is agricultural grazing lands or woods, wetlands, and marshes. A number of private houses are located within a few hundred feet of the E and S property line. According to a 1990 water well survey, 15 wells permitted for domestic or agricultural use were located within a mile of the landfill; no public water supply wells or pipelines for water supply existed at that time. Locations of on-site structures are known from site topo surveys; locations of off-site houses and other structures are estimated based on review of a recent aerial photo, dated 3/2006.

Climate: The 2/1982 report gives average rainfall from 55-60 in/year, with 40% occurring between Jun and Sep. The 1/1992 permit conditions include monthly on-site rainfall measurement. On-site daily rainfall data are available electronically for 1/1996 through 11/2007. Max and min annual occurred in 2005 (92.4-in) and 2006 (39.3-in). Composite monthly data from 1990 to 2007 compiled by NOAA indicate regional climatic conditions of 45-63 in mean annual precipitation and 60-70 °F mean annual temperature.

## Waste Placement and Operations

General: The 6/1993 PRA states that the existing WMU consist of six phases (four basal and two overlay) which are subdivided. Phase 1 was existing when site was taken over from the county by WMI. Phase 1 comprises 3 units, Phase 2 comprises 4 units, Phase 3 comprises 6 units, and Phase 4 comprises 2 units. Phase 5 comprises 3 lifts and Phase 6 one lift. According to 6/1993 PRA, the general progression of waste filling was towards N and E. Yard waste is unloaded in designated areas and periodically shredded or ground in a tub grinder. A 12-in. layer of mixed ground yard waste and soil can be used as alternative intermediate cover.

Waste Placement Data: Annual waste placement data are available for 1986 through 1999. Monthly data are available for 1993-1997 and 1999. The site operated between 1983 and 26 July 1999. Waste placement between 1983 and 1986 has been estimated at a constant rate based on landfill volume. Total estimated waste in place is 2,413,314 tons. Reported waste acceptance and compaction rates in 2001 were 1,300 tpd and 1,500 pcy, respectively.

Waste Composition: Monthly "commodity summary calculations" are available for 1997-1999, indicating tons of household (residential, municipal, and citizen's use), industrial, commercial, C&D, and yard waste handled, as well as boiler fly ash residue, sewage sludge, industrial sludge, "other", and recyclables. Household waste generally comprised the largest component of the incoming waste stream and was fairly stable at approx. 14,500-20,000 tons/month in 1997 and 18,500-26,700 tons/month in 1999. Quantities of industrial waste handled varied considerably, for example ranging from 1,500-28,500 tons/month in 1998.

## Closure and Post-Closure (C/PC) Plan

The WMU was certified closed on 6/19/2002 by the State and entered a 30-year Post Closure Long-Term Care program in accordance with Chapter 67-701, FAC. "Permittee is to monitor and maintain the integrity and effectiveness of the final cover as well as other appurtenances of the facility in accordance with the approved closure plan for 30 years from the date of closing. Before expiration…the Department may extend the time period if the closure design or closure operation plan is found to be ineffective." The long term care permit for the WMU is renewed every 10 years, most recently in 10/2007. The most recent permit renewal application was submitted in 8/2007. Recirculation is allowed except in Phase 1. Permittee must manage stormwater, comply with air quality and odor control criteria, manage and monitor LFG, and monitor surface water, GW, and leachate quality.

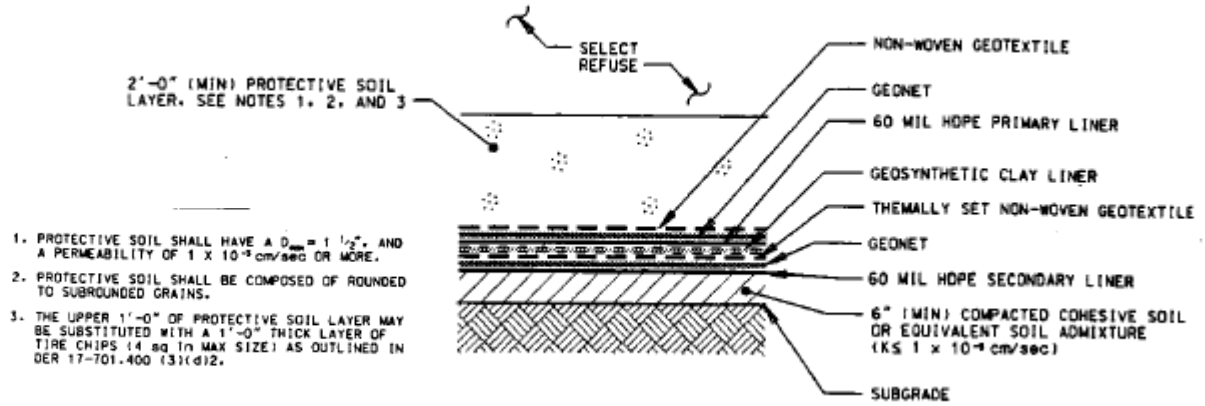
## End Use Strategy

The Wildlife Habitat Council (WHC) has certified the facility's wildlife habitat program. The facility is home to a range of native wildlife, including alligators, wood ducks, coots, other birds

and mammals. Man-man retention ponds (W of Site A) have been stocked with catfish and bream. Numerous pristine wetland areas have been preserved and maintained, notably to the N and W of Site A. In addition, as part of a wetland mitigation project, WMI has deeded approx. 2.2 acres of wetlands to the State.

## Liner System

Design: Design plans from 5/1989 and permit drawing "Landfill Sequencing Plan" (6/1993) show design base grades for the entire 39-acre site. Phase 1 comprises 3 units (total 7.7 acres), Phase 2 = 4 units (total 11.6 ac), Phase 3 = 6 units, Phase 4 = 2 units (combined total 20 acres). All of Phase 1 was existing when site was taken over from the county by WMI in 1989. According to site manager, Phase 1 Unit 1, covering approx. 5 acres, has a compacted clay liner only comprising 3-ft of $10^{-7}$ cm/sec with 1-ft $10^{-3}$ cm/sec drainage layer above, as shown on design plans for the county dated 4/1987. Phase I Units 2 and 3 reportedly have geomembrane liners, but this is unconfirmed, and 5/1989 design drawings show Phase 2 geomembrane liner tie into clay liner for Phase 1 Unit 3. The 6/1993 PMA states that "Phase 1 consists of 7.74 acres…50% of this area has no underlying leachate collection system, while the remaining 50% has a clay liner and collection system." Phase 2 through 4 have a double liner with GCL, design shown below based on 6/1993 permit.




All of Phase 1 and LCS-01 and LCS-02 were existing when the WMU was taken over from the county by WMI in 1989. The sump base dimensions and elevations are not known; however, the basegrades on Phase 1 are shown on the 5/1989 design plans as 164 ft-msl. The design basegrades in Phase 2 vary from 160-165 ft-msl (upslope toe) to 155-160 ft-msl (downslope toe). Phases 3 and 4 share the same design basegrade highpoints, varying from 160-165 ft-msl. The design basegrade low points in Phase 3 are the same as for Phase 2. The design basegrade low points in Phase 4 are 155-159 ft-msl. The liner basegrades are not below the seasonal high groundwater table.

The base of both LCS-03 and LCS-04 is a 15-ft square at elevation 151 ft-msl, filled with drainage sand.

CQA and Construction Records: None seen.

As-Built Drawings: None seen.

### Leachate Management System

Design: In the 5/1989 design plans, all leachate from the WMU was drained to an open storage/evaporation pond fitted with aerators (formerly located S of the current aboveground storage tank location, E of Phase 1 and 2). The bottom elevation of the pond was 170 ft-msl. According to the 6/1993 design plans for the site (see below), it was intended that aboveground tanks would replace the pond once constructed. At various times, leachate has also been disposed of via recirculation or transportation to POTW.

Permit drawing "LCS Piping Plan" (6/1993) shows four leachate sumps LCS-01 to LCS-04. A 6-in. gravity toe drain around the W and S perimeter of Phase 1 drains to LCS-01. A gravity toe drain around N and E of Phase 1 drains to LCS-02. A conventional LCS exists in Phase 2 through 4. The primary LCRS consists of a geonet/geotextile drainage layer, sloped at 2%. Leachate collection pipes (8-in slotted SDR-11 HDPE) are installed above the drainage layer, draining at 1% to sumps equipped with submersible pumps. LCS pipes are overlain by river rock aggregate, protected by geotextile layer. The LCS drainage layer is also overlain by geotextile, in turn overlain by 24-in. protective soil layer. Phases 2 and 3 drain to LCS-03. Phase 4 drains to LCS-04. Vertical wetwells are installed above all sumps. 5/1989 design shows a valve box with check valve for LCS-03 and LCS-04. Leachate is pumped via forcemain via leachate sampling vault LSV-1 to storage tanks. A leachate out-loading area is shown E of the tanks.

CQA and Construction Records: None seen.

As-Built Drawings: None seen.

Leachate Recirculation: There are three leachate recirculation trenches beneath the surface of the WMU cover as shown on 8/2007 topo. Each trench is connected to three stick-up pipes located equidistant along its length. The LR system is described in the 6/2002 permit application for the facility. Leachate from Site A and the other WMU onsite is allowed to be recirculated over the lined limits only (i.e., not in Phase 1).

Leachate recirculation quantities are recorded on a bulk monthly basis. Electronic data are available for 1992-1995 and 2002-2006. Incomplete paper records are available for 1995-1998.

Leachate Sampling and Data: The 1/1992 permit required quarterly monitoring at L-1, at the former Leachate Pond #1. The 6/1993 permit drawing "LCS Piping Plan" shows a dedicated leachate sampling vault, LSV-1, at the current storage tank location. The 10/2007 permit also refers to L-1, a composite sampling location at the two 48,000 gal. aboveground storage tanks. The monitoring frequency in the 10/2007 permit is annual, to be performed in conjunction with GW, and must include conductivity, pH, DO, color (field) and total ammonia-N, bicarbonate, chloride, mercury, iron, nitrate, sodium, TDS, and all Appendix I (lab).

Composite leachate flow quantities are recorded on a bulk monthly basis at the storage tanks. Electronic data are available for 1992-1995 and 2002-2006. Incomplete paper records are available for 1995-1998.

Sump specific monthly leachate flow data are available for 4-12/1997 and 1-2/1998.

*Leachate Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | COD | BOD |
|---|---|---|---|---|---|---|
| Tanks (composite), L-1 | 32 | 4/1992 2/2007 | 280 | 1,000 mg/l | -- | -- |

Compliance Issues and Community Concerns: None reported.

## Cover System

Design: The maximum crest elevation across Phases 2 to 4 shown on the 5/1989 design drawings is 248 ft-msl. The maximum crest elevation at Phase 1 shown is 231 ft-msl. Final cover design (bottom-top) comprised 6-in initial cover, 12-in intermediate cover, 12-in compacted clay ($5 \times 10^{-6}$ cm/sec) and 18-in vegetated soil cover. This design was superseded by the 6/1993 PRA cover design which requires (bottom-top) 12-in compacted cohesive soil, 40-mil "Coverseal" 2-sided textured geomembrane, geocomposite, 18-in misc. cover soil, 6-in vegetative support soil.

CQA and Other Construction Records: The 1/1998 CQA report for stage 1, which cites the 6/1993 PRA, states that the compacted cohesive soil layer was red and white clay from on site borrow, tested under ASTM D-698 Proctor to be $2.1 \times 10^{-8}$ cm/sec at 90% compaction. The cover was constructed in Jun/Jul 1996, with vegetation completed in 3/1997. Minor repairs were made to upper soil layers in 7/1997. CQA was performed on all cover components. The 2/2001 CQA report for stage 2, which cites a 3/1998 PRA (with same cover design except 40-mil HDPE textured geomembrane), uses the same cohesive soil source, compacted/smoothed with a drum roller, not tested. The cover was constructed from Apr-Jun 2000, and vegetated in 11/2000. CQA consisted of thickness checks and visual inspection. The final 9/2001 CQA report for stage

3 states that construction and CQA was essentially the same as for stage 2. The cover was constructed from Apr-Jul 2001, and vegetated in 8/2001. Three leachate recirculation trenches were installed immediately below the final cover in stage 3.

As-Built Drawings: The 6/1993 PRA states that Phases 1 and 2 had already achieved intermediate or final grades, and that portions of the southern slopes of Phase I had already received final cover. The remaining final cover was constructed in three stages. The as-built drawings (ABDs) for stage 1 (10.2 acres) from 1/1998 shows cover applied to Phase 1 and some lower sideslopes of Phases 2 and 3. The maximum crest elevation shown in Phase 1 is 242 ft-msl. The ABDs for stage 2 (20 acres) from 2/2001 shows remaining sideslope cover applied to Phases 2 to 4. The ABDs for stage 3 (8 acres) from 9/2001 shows final cover applied to the crest of Phases 2 to 4. The maximum crest elevation shown is 262 ft-msl over Phase 4.

Topographic Surveys: Several electronic aerial topo surveys flown between 2001 and 2007 are available. The max crest elevation shown on the 2/2007 topo is approx. 258 ft-msl, suggesting only 4 ft of settlement in six years through a maximum depth of waste of about 107 ft (i.e., 262 ft – 155 ft), or about 4% of max waste depth.

Cover Monitoring and Maintenance: The cover is regularly mowed and all gas collection and control system (GCCS) components except wellheads are buried. Monthly Title V wellhead monitoring program includes and visual inspection of cover vegetation and erosion. Quarterly surface scans for fugitive methane emissions have been conducted since 8/1999. With the exception of a persistent erosion issue downslope of the cover access road about half way up the W side of the WMU, only occasional settlement around well shafts, minor downslope erosion gullies, and occurrence of small bare areas has been reported. According to site manager, all cover issues are promptly repaired.

Compliance Issues and Community Concerns: None reported.

## Landfill Gas Control System

Active Gas Control System: The GCCS for Site A currently comprises 47 wells, although W-33 was decommissioned in 4Q 2004. The Title V permit from 7/1998 authorizes the operation of a GCCS at the "active 39-acre parcel…" currently consisting of "21 gas extraction wells, a condensate collection system, blowers, utility flare, and all associated piping. This constitutes Phase I of the GCCS, startup date reported as 9/1996. Gas generation modeling in Title V was estimated at 730 scfm in 1999 based on AP-42 default values ($k$=0.04/yr, $L_0$=100 $m^3$/Mg). Phase II expanded the GCCS to 41 wells; the startup date given for Phase II is 12/1998. The 1999 GCCS design shows a LFG flare located E of Phase 1/2 to which all LFG from Site A is delivered.

Gas Utilization: A 4.8MW LFGTE facility has been installed at the site, drawing LFG from both WMUs, and the flare location for Site A has been dismantled. However, it appears that the Site A flare was operated intermittently as recently as 5/2006.

Passive Gas Vents: None.

Construction Details and As-Built Drawings: A GCCS record drawing from 11/1999 shows layout of 47 vertical wells of which only 6 were not already installed at that time. A perimeter header carries LFG to a single condensate knockout. All leachate cleanout risers and manholes are connected to the GCCS.

Landfill Gas Data: Monthly Title V wellhead monitoring is performed at all 47 wells. Total flow to the Site A flare was recorded intermittently 2-5 times per month between 1997 and 2004 and ranged from 410-970 scfm between 1999 and 2004. Site manager estimates current gas generation is 300-400 scfm, based on flow to maintain vacuum when larger WMU at site is offline.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Flare Log | Total flow, total blower hours | $O_2$ and $CH_4$ | Intermittent monthly records 1999-2006 (P&E) |
| Wellheads, W-01 to W-47 | -- | $O_2$ and $CH_4$ | Intermittent monthly records 1998-2006 (P&E) |
| Surface Scans | -- | Methane content only | Quarterly, since 3Q 1998 |

Compliance Issues and Community Concerns: None reported.

## Groundwater Monitoring System

Layout: Ten GWM wells are described in the original 1/1992 and most recently renewed 10/2007 permit conditions, including 9 compliance wells, all proximal to the WMU and monitoring the Floridian Aquifer. MW-01, MW-11, MW-12, and MW-15 are downgradient, MW-10 and MW-13 are side gradient, and MW-02, MW-02, and MW-14 are upgradient. The 1/1992 permit conditions describe removing MW-5 (location unknown) from the monitoring network. One upgradient well (MW-16) was to be installed off-site and designated as background "for the period prior to landfill expansion activity. At that time, it shall be re-evaluated to determine its adequacy." This was subsequently replaced with MW-21, a combined upgradient well for both WMUs on the property (per 10/2007 permit). MW-12 was also replaced with MW-12R. According to the 6/1993 PMA, all wells are screened in the limestone unit except MW-03 (clay near top of limestone) and MW-06 (sand).

Monitoring Program: The allowable horizontal zone of discharge (ZOD) is the S, E, and W property boundaries and the high water mark in the N wetland/woodland system. The vertical ZOD extends from the ground surface to the top of the Floridian Aquifer. The monitoring frequency in the 10/2007 permit is semi-annual and must include level, conductivity, pH, DO, turbidity, temperature, color (field) and total ammonia-N, chloride, mercury, iron, nitrate, sodium, TDS, and all Appendix I (lab).

Construction Details: Boring logs and well development details are available.

Groundwater Data: Potentiometric maps from 8/2003 and 8/2004 show GW elevations range from 151-150 ft-msl at the upgradient S toe and 140-150 ft-msl at the downgradient N toe. This means that the min base of liner (155 ft-msl) is consistently above the high GW elevation, but base elevations in sumps LCS-03 and LCS-04 (151 ft-msl) are potentially below groundwater.

A summary of analytical data is provided in the table below.

*Groundwater Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | $Cl^-$ | Na | K |
|---|---|---|---|---|---|---|
| Upgradient, distal MW-16 | ND | -- | -- | -- | -- | -- |
| Upgradient, distal MW-21 | 25 | 1/1995 8/2007 | 270 | Y | Y | Y |
| Upgradient, proximal MW-02, MW-03, MW-14 | 54 | 5/1988 8/2007 | 179 | Y | Y | Y |
| Crossgrad., proximal MW-10, MW-13 | 45 | 7/1990 8/2007 | 179 | Y | Y | Y |
| Downgrad., proximal MW-01 | 54 | 5/1988 8/2007 | 289 | Y | Y | Y |
| Downgrad., proximal MW-11, MW-12, MW-12R, MW-15 | 44 | 7/1990 8/2007 | 178 | Y | Y | Y |

Compliance Issues and Community Concerns: An investigation into elevated iron concentrations in GW was required by the State, conducted between 2005 and 2007. The report on findings concluded that wells with elevated iron concentrations should be cleaned and redeveloped, and that inert nitrogen rather than air should be used to operate bladder pumps.

## Surface Water Monitoring System

Locations: All stormwater is retained in W and N perimeter pond-channels, then discharged via the natural wetland/woodland located along the N property boundary. The allowable horizontal

zone of discharge is the S, E, and W property boundaries and the high water mark in the N wetland/woodland system. Specific permit conditions from 1/1992 and 10/2007 cite two monitoring locations SW-1 and SW-2 for compliance monitoring, both in the N boundary wetland/woodland near the locations at which stormwater discharges from the pond-channels.

Monitoring Program: The monitoring frequency in the 10/2007 permit is semi-annual, to be performed in conjunction with GW, and must include conductivity, pH, DO, turbidity, temperature, color (field) and unionized ammonia, hardness, copper, mercury, iron, nitrate, zinc, TDS, TOC, TSS, COD, total phosphates, fecal coliform, chlorophyll A, total nitrogen, and all Appendix I (lab).

Surface Water Data: Available data from the electronic GW database is summarized in the table below.

*Surface Water Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | NH4+ | BOD |
|---|---|---|---|---|---|---|
| Downgrad., proximal SW-1* | 34 + 7 | 4/1990 2/2007 | 290 | Y | | Y |
| Downgrad., proximal SW-2** | 7 | 3/2003 2/2007 | 290 | -- | | Y |

*Reported as SW-02 prior to 1Q 2003 and as SW-01R since 1Q 2003.
** Reported as SW-02R.

Compliance Issues and Community Concerns: None reported.

## Methane Migration Monitoring System

Layout: 8/2007 PRA shows 15 methane migration monitoring (MMM) wells (MWP-1, MWP-3 through MWP-13, MW-14A, MWP-15 through MWP-17) are located around the WMU toe or at the property boundary. The 2/2001 gas monitoring plan shows 12 existing MMM permanent probes (GP-1 through GP-5 and GP-10 through GP-14) around the WMU (well/probe numbers match between MWP and GP designation). No additional MMM wells were planned. According to 2/2001 plan, no MMM was conducted prior to 11/1987. The first methane survey at WMU toe was conducted in 1/1998 at 22 locations spaced 150-200 ft apart using 36-in deep barhole probes. Gas was detected at 3 locations on the S perimeter and 5 on the W perimeter.

Monitoring Plan and Data: Quarterly monitoring of all permanent probes/wells and on site structures is specified in the 2/2001 plan and 10/2007 permit. Quarterly monitoring records from 17 locations designated PBH-1 to PBH-17 and 7 buildings are available. It is assumed that PBH and MWP numbers correspond. Occasional methane detections at <5% are noted; PBH-13 has a number of methane hits at 15-20%.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| 17 Perm. Probes, "PBH" | -- | Quarterly, 1Q 1996 – 2Q 2007 (E) | Some quarters missing from record |

Compliance Issues and Community Concerns: Some minor gas migration issues reported by site manager, fixed by improving wellfield operation. Not of concern for some time.

**FIGURE A-1**
**Site A Physiographical Setting**

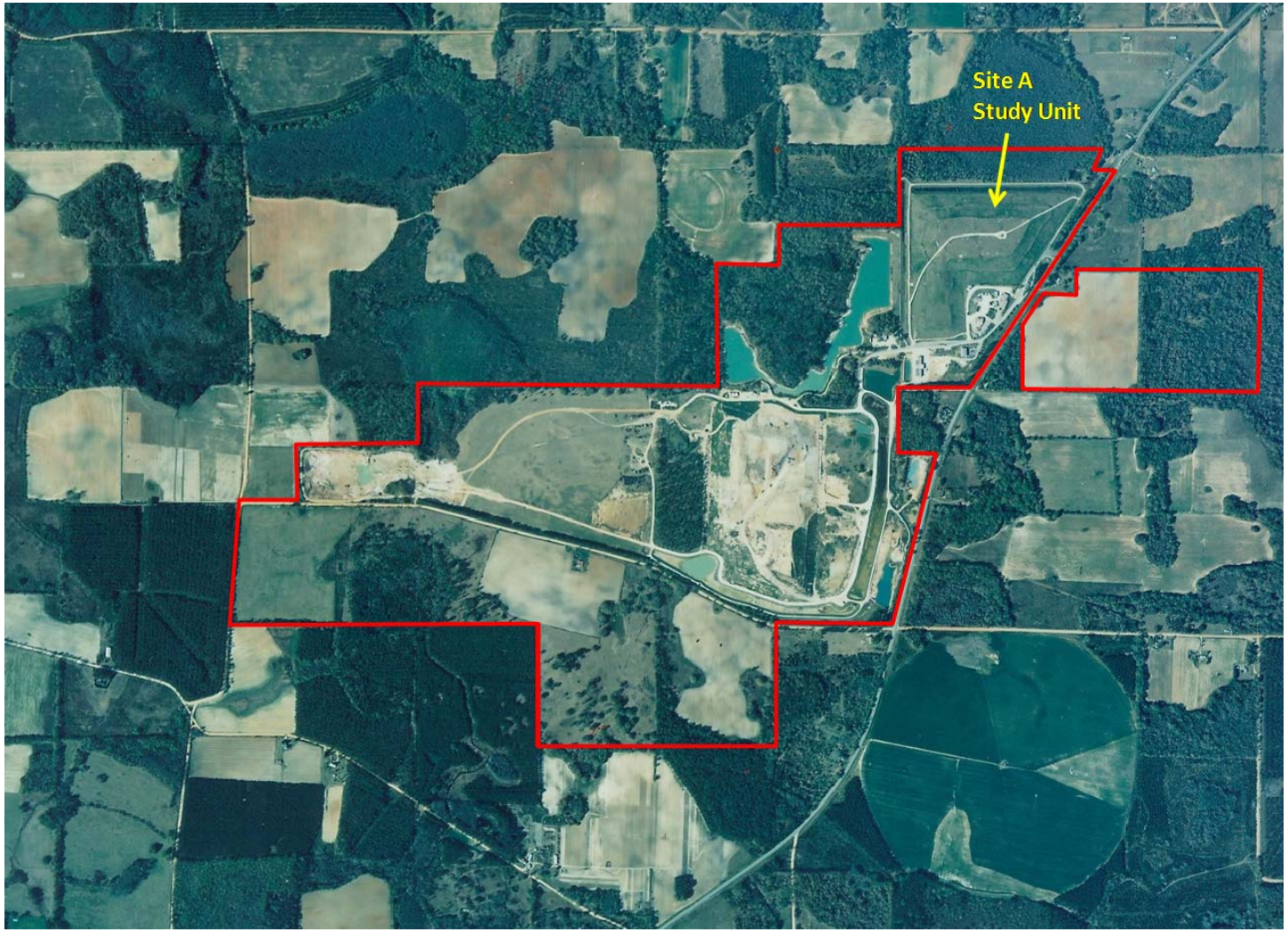


**FIGURE A-2**
**Site A Layout and Features**

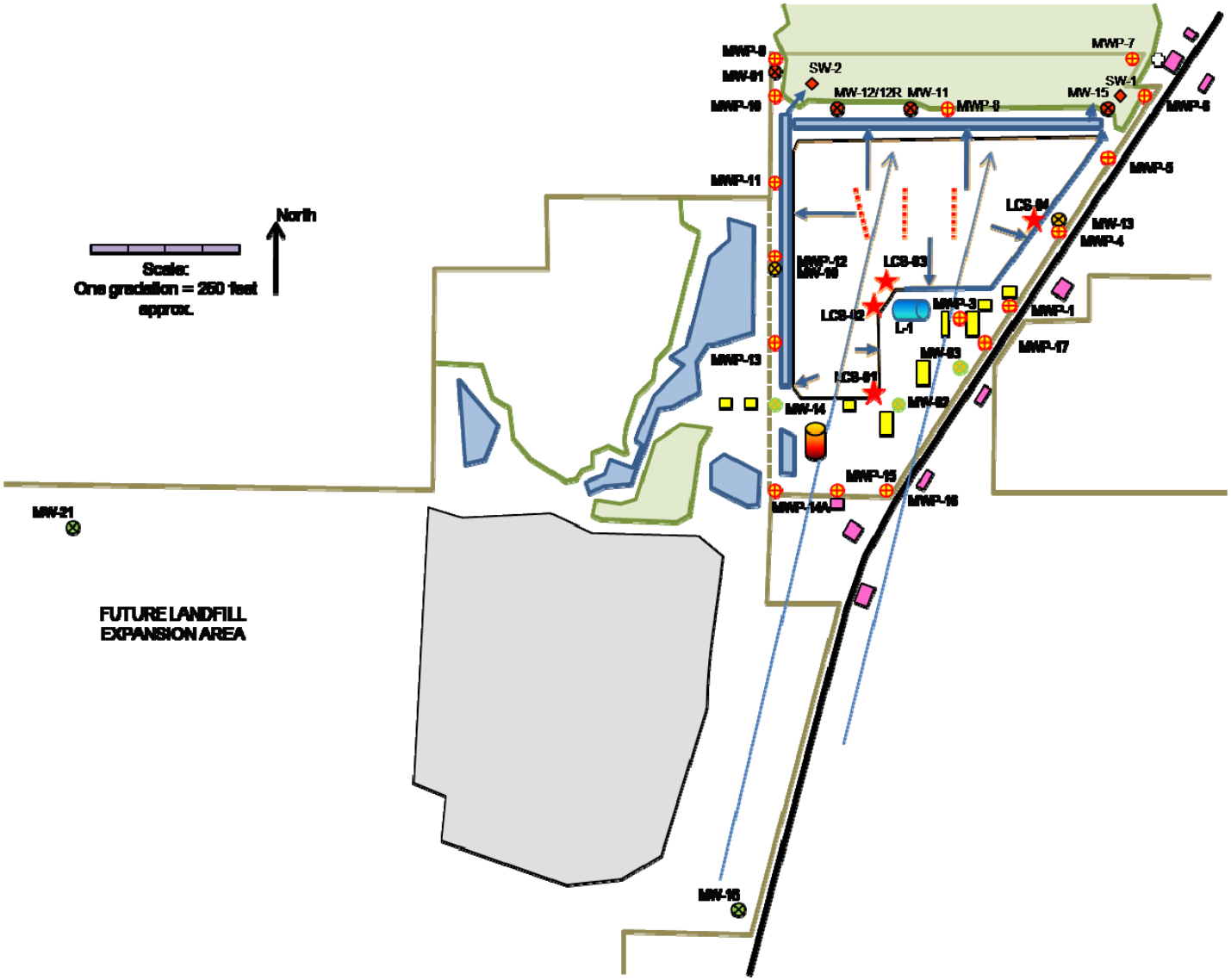
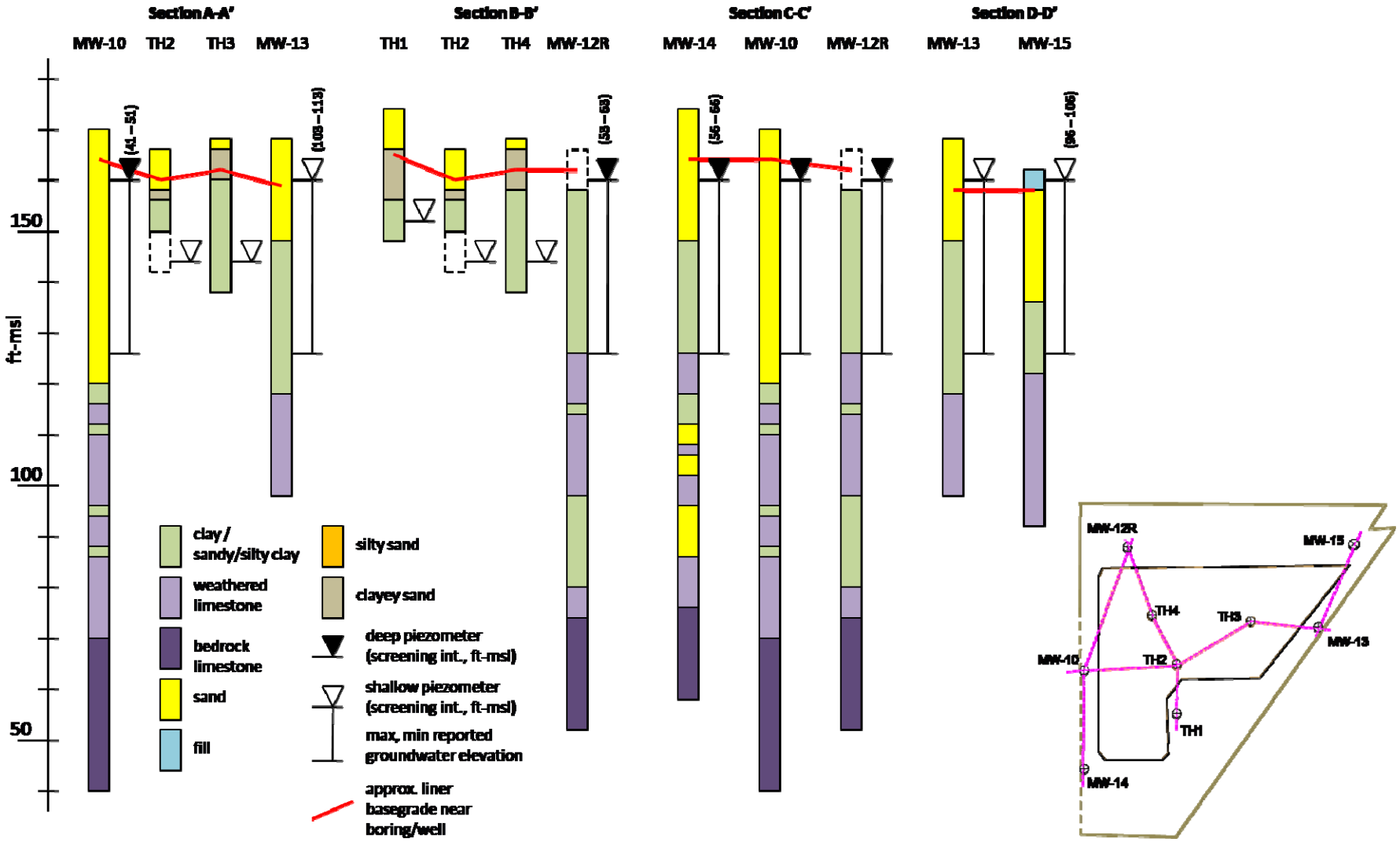


**FIGURE A-3**
**Site A Geologic & Hydrogeologic Cross Sections**



# APPENDIX 2-1B

# SUMMARY – SITE B (GEORGIA)

## Overview

Study WMU: Site B is a single unlined WMU with approx. 26 acre footprint (although some earlier records report it as 20.2 or 20.8 acres) and constructed with about 90 ft max depth of waste. The Title V Operating Permit Application dated 3/1997 states that the WMU has an estimated capacity of 1MM CY. The WMU opened in 1983 and stopped receiving waste on 25 June 1995. WMI acquired the site in 1991.

Property: Site B is one of two permitted separate WMUs on the property, the other one is much larger (100 acres) and still active, having commenced operation in 3/1994 with a maximum permitted capacity of nearly 8MM CY. The total property size is 742 acres, with 410 acres delineated in 1991 as jurisdictional wetlands. The property is subdivided into two parcels: Parcel 1 containing Site B is approx. 126 acres, while Parcel 2 comprises the remaining 616 acres, with 100 acres developed for the non-study WMU, and the remaining 516 acres available for buffers, wetlands mitigation, soil borrow, and potential future landfill expansion areas.

The physiographical setting of the property and study unit is shown on Figure B-1. A stylized depiction of the site layout is provided as Figure B-2.

## Site Information

Geologic and Hydrogeologic Setting: A comprehensive Hydrogeologic/Geotechnical Investigation (H/GI) was prepared in 4/1992 for development of the new WMU on the property. This provides a review of regional geology and hydrogeology. Generally, sands and clays (Satilla Formation) exist in the 0-10 ft above the water table, underlain by a 50-ft thick layer of quartz sand containing pebbles and gravel which forms the surficial aquifer (Cypresshead Formation). Below that, three layers of clays, sandy clays, and sands (>200 ft thick) comprise the confining unit (Hawthorne Group) for the main productive aquifer, the Upper Floridian, comprising porous limestone. This aquifer is the most productive in the area and supplies almost 50% of the groundwater used in the state.

Saturated Zone: The H/GI describes a site-specific hydrogeologic study based on 41 soil borings and 13 test pits advanced in 1990-91. 17 borings penetrated to 30 ft bgl, five to 40 ft, and one to 50 ft. The uppermost sediments generally consist of sands containing variable amounts of clay and silt. These sands are typically dark yellowish orange, reddish brown, and white in color.

The most distinctive unit within the surficial sediments is a layer of grey, soft, fat clay which ranges in elevations from 12.5 – -17 ft-msl and has a thickness of 0 – 28 ft. The 4/1992 H/GI suggests the thickness of this clay unit varies from about 10-15 ft beneath Site B. The clay layer is a locally effective confining unit where present. However, the Groundwater Monitoring Program from 2/1993 indicates that Wells GWA-103, GWC-102, and GWC-104 were to be constructed in well pairs, with partner wells given a "D" suffix. The well pairs were to be screened above and below a "fat, grey clay unit" in the permeable zone, but documentation of well constructed dated 4/1993 indicates that well pairing was not necessary because the clay unit was not encountered. Where the clay layer is absent, and above and below this bed where present, fine to medium grained, poorly graded sand predominates. The lithology of the unit so described is consistent with the Cypresshead Formation. At elevations ranging from -7 – -38 ft-msl, a grey to grayish olive green, dense, silty sand was encountered. Borings penetrated to -73 ft-msl without encountering the bottom of this unit, consistent with the lithology of the Coosawhatchie Formation of the Hawthorne Group.

Boring Logs: Boring logs from groundwater monitoring well installation are available for all 14 GWMP wells. Selected borings were used to develop three stylized cross sections in Figure B-3, supplemented with data from three borings from the H/GI in the vicinity of Site B (i.e., B-7L, B-7S, and P-4).

Hydraulic Conductivity: In 7/1990, in-situ slug tests were performed at 5 locations for the landfill expansion, with reported values ranging from $1.65 \times 10^{-3}$ to $1.82 \times 10^{-5}$ cm/s. Vertical hydraulic conductivity measured in laboratory tests on 18 undisturbed samples ranged from $1.5 \times 10^{-3}$ to $4.7 \times 10^{-8}$ cm/s, with the lower values recorded in sands which contained some clay. In-situ horizontal conductivity tests were conducted on 13 piezometers in 1992, with reported values ranging from $7.53 \times 10^{-3}$ to $3.51 \times 10^{-5}$ cm/s. Vertical hydraulic conductivities for the dense micaceous sand ($3.1 \times 10^{-8}$ cm/s to $9.8 \times 10^{-8}$ cm/s) and clay unit ($1.1 \times 10^{-7}$ cm/s to $1.9 \times 10^{-8}$ cm/s) were calculated from consolidation data.

Groundwater: Groundwater elevations are regularly recorded during groundwater monitoring events and flow around the property is well characterized. The surficial aquifer is locally recharged onsite in topographically higher areas, resulting in radial flow to the onsite wooded wetlands from a higher natural crest between the WMUs. Flow under Site B is generally parallel to the W and S toes, varying in direction accordingly between these two boundaries. Useful downgradient elevation data are available from 9 wells for the period 10/1991 through 3/2007. Useful upgradient elevation data are available from 4 wells for the period 4/1993 through 3/2007. Available GW potentiometric plots from 7/1995 through 12/2005 show little variation in the potentiometric surface or flow directions below Site B. GW elevations in relation to the liner basegrades are summarized on Figure B-3. Elevations range from 11-15 ft-msl in two proximal upgradient wells (GWBs) and 3-9 ft-msl in the four most proximal downgradient wells (GWCs).

This means that the min base of waste (10 ft-msl at downgradient toe) is consistently above the high GW elevation.

Unsaturated (Vadose) Zone: Summary details regarding the unsaturated zone are shown on Figure B-3, using information from the boring logs listed above. Some additional details regarding soil properties, descriptions of soil cuttings, recovery rates, etc. are available but not summarized. Vadose zone data were verified using information from a line of six passive gas vents (PV-1 through PV-6) installed between the WMUs in 1Q 1997 following detection of two VOCs in a GW monitoring well (GWC-13, a well for the active lined WMU but located in the valley between the two WMUs on the property), and subsequent fingerprint studies indicating these were due to gas migration. The vents were advanced to depths of 12.5-14 ft, 6 in. below the GW surface encountered during drilling.

Physiographical Setting: The H/GI also describes the site in terms of physiographical setting (topography, surface water features, wetlands, soils, vegetation, climate, land use, and water use). The natural drainage area for the site is a low lying swamp N of both WMUs. The swamp is naturally wooded. The nearest river to the site lies approximately 1300 ft E. The 100-year flood plain for the river is defined as the 12 ft-msl elevation, encompassing the majority of the swathe of wetlands occupying the central portion of the property, N of the two WMUs. The basegrades at the N and E toe of Site B are below the 100-year flood elevation. However, surface topography separates the 100 year flood line from the toe of the landfill in this location.

Potential Point(s) of Exposure: Locations of on-site structures are known from site topo surveys, locations of off-site houses and other structures are estimated based on review of recent Google EARTH© map. A local ordinance requires that all drinking water wells be screened in artesian aquifers; water from the surficial aquifer may only be used for irrigation and other agricultural uses. In 1991, 10 domestic water wells were located within one mile of the proposed landfill expansion. The locations of onsite (2), private (11), and public (2) wells near the site are provided on a map dated 1990 in the Groundwater Monitoring Program, dated 2/1993. The H/GI gives wind direction data for 1986-1990 sourced from the Nat. Climatic Center, 1992. There is no clear prevailing wind direction; 2/8 wind direction percentages are <10% (N, SW), 5/8 are <15%, and the max is 17.0% (S).

Climate: The H/GI gives mean monthly precipitation from 1931-60 as 2-4 in. (ONDJFMAM) and 5-7 in. (JJAS). Mean monthly pan evaporation using 1986-90 data ranged from 2 in. (DJ) to over 9 in. (MJJ), meaning that evaporation routinely exceeds precipitation. Composite monthly data from 1990 to 2007 compiled by NOAA indicate regional climatic conditions of 45-63-in. mean annual precipitation and 60-70 °F mean annual temperature.

## Waste Placement and Operations

General: The earliest available (11/1986) set of design plans (for vertical expansion of Site B) show waste is to be placed in six 10-ft lifts, with 1-ft of int. soil cover between lifts. A NS cross section shows existing filling had mostly occurred at N end of WMU, already up to Lift 6. The plan was then for filling to start at the S end, to meet at the center. The total design capacity of the WMU at this stage was 922,400 CY, comprising 614,900 CY MSW + 307,500 CY cover soil. Life expectancy = 15 years. 6-in. of daily cover is to be placed.

A revised (3/1994) set of design plans (also for vertical expansion of Site B) provides some operations details which assume waste intake of 350 TPD. The total remaining capacity given at this stage is 231,940 CY (MSW + cover soil), or 199,670 CY (MSW only), providing additional life expectancy of 1 year. Again, 6-in. of daily cover is to be placed with 12-in. of int. cover required where any area is inactive for one month.

Waste Placement Data: Available from the Title V Operating Permit Application dated 3/1997. The site operated between 1983 and 1995. Annual waste placement from 1991 through 1993 is known, waste placement from 1983 through 1990 is estimated at 28,600 tpy. Waste placement in 1994 and 1995 is estimated from final capacity, assuming airspace utilization of 0.6 TPCY. Total estimated capacity is 1,058,600 CY.

Waste Composition: Mostly unknown. All 17 gas well (and 3 attempted leachate sampling) boring logs from 7/1999 wellfield installation indicate mostly dry, occasionally damp "HHT", with occasional hits of soil, wood, tires, metal (all dry or damp).

## Closure and Post-Closure (C/PC) Plan

The 11/1986 design plans provide a C/PC Plan, mostly concerning sequencing of closure and PC events, nothing of real value is shown or discussed. The PC use of the landfill is intended as a "passive recreational area." Three downgradient groundwater monitoring wells (GWM) wells were to be installed (no date is specified). The layout of the GWM well networks was to be analyzed and possibly revised every 5 years. Methane monitoring was required in all on-site structures and at marked locations at min. 200-ft spacing along the WMU toe using barhole probes. Cover is to be inspected monthly through the end of the 5$^{th}$ year of PC, then quarterly through the end of the 10$^{th}$ year. Site access control was to be provided. The revised 3/1994 C/PC Plan includes maintaining integrity of cover and quarterly monitoring of 9 GWM wells and 9 methane migration monitoring (MMM) probes. Total cost is estimated at $2.2MM, with $1.7MM for GWM and $72k for MMM.

The Final Closure Report for Site B was submitted to the State in 2/1996, certifying that final cover test results meet Subtitle D requirements as per the 3/1994 design. The site closure certificate was issued by the State in 7/1996. PCC is required for "…at least 30 years after the

Director has issued the closure certificate. The period may be extended by the Director where necessary to adequately protect human health and the environment."

### End Use Strategy

The development plans for the expansion WMU on the property (6/1992, rev 12/1992) propose that "…upon completion of operations, the facility will be maintained as a closed landfill with vacant grassed land, ponds, and wetlands. The facility will be maintained as a suitable wildlife habitat." An approximately 100-acre onsite borrow area will be restored as approximately equal areas for a lake and wetland migration area (as shown on Figure B-2).

WMI has applied to participate in the Wildlife Habitat Council (WHC) "Wildlife at Work" program at the property. The application form states that over 400 acres on the property are available for wildlife management, with approximately 115 acres of constructed and natural wetlands. A high diversity of wildlife and wetland bird species are frequently observed, especially on the large area of reclaimed wetlands on the SW area of property. In 2007 and 2008, winter and spring surveys of wildlife classes (vascular plants, birds, mammals, reptiles, amphibians, fish, insects and arachnids, and crustaceans) in different habitats (wetlands, open water, hardwood forests, fields/meadows, and bare soil with pioneer vegetation) were scheduled to be conducted.

### Liner System

Design: There is no engineered liner, and no details are provided as to what, if any, preparation of subgrades was conducted prior to waste placement. The 11/1986 design plans refer to the base elevation simply as "existing ground surface." The design plans show a basegrade low point running along the entire length of the NE and E toe of the WMU at approx. 10 ft-msl. The toe was constructed by excavating a toe berm, 2-ft deep and piled 2-ft high, such that top of berm is at 12 ft-msl. The opposite (upslope) elevation along the W toe is approx. 22-25 ft-msl with no toe berm, just a perimeter ditch outside the limit of waste. A slight NS slope runs across the base from approx. 25 ft-msl at N toe to 15 ft-msl at S tow; again, no toe berms were constructed at the N or S toes. Based on review of groundwater elevations (see Figure B-3), the WMU basegrades are consistently above high groundwater level.

CQA and Construction Records: N/A

As-Built Drawings: N/A

### Leachate Management System

Layout and Design: There is no leachate collection, transmission, treatment, or disposal system.

CQA and Construction Records: N/A

As-Built Drawings: N/A

Leachate Generation Rate: N/A

Leachate Recirculation and/or Disposal: N/A

Leachate Sampling and Data: An attempt was made to drill for leachate samples in 7/1999 at same time as the wellfield was being installed. Three borings (EW-L1 through EW-L3) were advanced through the waste, all to a depth of 50-ft. It is understood that no free leachate was recovered as the waste was too dry. However, the electronic GW data set for Site B includes unidentified sample location L-1, with 3 sampling events between 2/2002 and 9/2006 for 151 analytes, incl. BOD and COD but not chloride. This may represent leachate sampling, but is not a reliable source of data.

*Leachate Data (Electronic) – UNCONFIRMED*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | COD | BOD |
|---|---|---|---|---|---|---|
| Vertical Well, L-1 | 3 | 2/2002, 9/2006 | 151 | | Y | Y |

Compliance Issues and Community Concerns: None reported.

## Cover System

Design: The 11/1986 design drawings show 3-ft cover soil on side slopes and 2-ft cover soil on the WMU crest. Cover was to be "uniform compacted clean earth." The max design elevation shown was 65-70 ft-msl, sloping E to W with SW-orientated stormwater interceptor berms. The revised 3/1994 plans show higher final grades (max crest elevation is 108 ft-msl), an access road, and stormwater management features (benches, culverts, downdrains, channels). The final cover design cross section is min 18-in. recompacted soil ($10^{-5}$ cm/s) overlain with min 6-in. vegetative support soil. The slope is shown as "varies," suggesting a common cross section across all side slopes and the crest.

CQA and Other Construction Records: The Final Closure Report (FCR) for Site B was submitted to the State in 2/1996, certifying that final cover test results meet Subtitle D requirements as per the 3/1994 design. The sequencing of cap certification took place over 4 years. Cover soil testing was conducted using Shelby tubes (for laboratory testing of hydraulic conductivity) and hand auger borings (to verify soil depth). Between 1992 and 1994, the cap thickness was measured at 20 locations and exceeded 30-in. at all locations. In 1993, cover soil samples were collected at another 8 locations across 8 acres on the lower final cover slopes. All recovered soil samples were classified as "grey, clayey fine sand (SC)." Laboratory results indicated permeabilities of 5.9 – 1.1 x$10^{-8}$ cm/s. The thickness of the clay layer was reported as greater

than 2.5 ft at all locations. The FCR also gives cover soil hydraulic conductivity results from a further 12 sample locations across final sections of the upper cover area, with results ranging from $3.3x10^{-6}$ to $2.6x10^{-8}$ cm/s (based on falling head permeability tests). The thickness of the cap was measured at 48 locations and exceeded 30-in. at all locations. Closure certification was issued by the State in 7/1996.

All 17 gas well (and 3 attempted leachate sampling) boring logs from 7/1999 wellfield installation indicate cover consists of 2-ft of damp to dry "black dirt" underlain by 3-ft of dry "clay."

As-Built Drawings: An as-built final contour map dated 2/1996 is provided in the FCR, based on a 12/1994 aerial survey supplemented with a 1/1996 ground survey of higher elevations on landfill. The max crest elevation shown is 104 ft-msl.

Topographic Surveys: A number of electronic aerial topo surveys flown between 2003 and 2007 are available. The max crest elevation shown on a recent (3/2007) topo is approx. 95 ft-msl, suggesting 9 ft of settlement in 11 years through a maximum depth of waste of about 90 ft (i.e., 104 ft – 15 ft), or about 10% of max waste depth.

Cover Monitoring and Maintenance: The cover is regularly mowed and all gas collection and control system (GCCS) components except wellheads are buried. Monthly Title V wellhead monitoring program includes visual inspection of cover vegetation and erosion. Occasional settlement around well shafts, minor downslope erosion gullies, and occurrence of small bare areas has been reported, but nothing significant. According to site manager, all minor cover issues are promptly repaired. Quarterly surface methane monitoring scans since 2001 have revealed a slight excess around one well on one occasion (2Q 2003). Surface scan data availability are listed in the section discussing the GCCS.

Compliance Issues and Community Concerns: None reported.

## Landfill Gas Control System

Active Gas Control System: Installation of a network of 17 wells, EW-1 through EW-17, was completed in 7/1999. There are no plans to extend the GCCS in the future. The landfill GCCS was installed as part of NSPS requirements for the expanded facility.

Gas Utilization: None. LFG from both WMUs is flared at a single location.

Passive Gas Vents: Six out-of-waste vents installed to mitigate gas to GW impacts, 1Q 1997.

Construction Details and As-Built Drawings: As-built information for the active GCCS is provided on a single sheet dated 9/1999. The well schedule is provided, with well bore depth varying from 27-68 ft.

Landfill Gas Data: Monthly Title V wellhead monitoring is performed at all 17 wells and 6 vents. Total flow to the flare is recorded daily and ranged from 450-550 scfm between 1/2001 and 1/2003 and 400-250 scfm between 1/2004 and 4/2004.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Wellheads, EW-1 – EW-17 | Total to flare, intermittent monthly records 2001-04 (P) | Monthly, incomplete 1/2000 – 7/2004 (P) 8-10/2007 (E) | |
| Gas Vents, PV-1 – PV-6 | N/A | Monthly, incomplete 1/2000 – 7/2004 (P) | |
| Surface Scans | N/A | Quarterly, incomplete 1Q 2001 – 2Q 2003 (P) | Methane content only |

Compliance Issues and Community Concerns: Gas impacts to GW have occurred, see discussion in GW section.

## Groundwater Monitoring System

Layout: Three WMU-specific upgradient wells exist: GWA-101 (distal), GWA-102 and GWA-103 (both proximal, and more accurately described as side gradient wells), plus two wells designated GWB-112 and GWB-112 (both proximal) between the two WMUs, upgradient or side gradient of Site B but potentially downgradient of the E toe of the other WMU. GWB-112 and GWB-113 were installed in 11/2002 in response to a State request to monitor potential gas impacts to GW in that vicinity. Six downgradient wells exist: GWC-101 through GWC-106, all proximal.

Monitoring Program: The Groundwater Monitoring Program (GWMP) from 2/1993 indicates that Wells GWA-103, GWC-102, and GWC-104 will be constructed in "well pairs," with partner wells given a "D" suffix. The well pairs were to be screened above and below a "fat, grey clay unit" in the permeable zone. However, documentation of well constructed dated 4/1993 indicates that well pairing was not necessary because the clay unit was not encountered. Upgradient monitoring of GWA-101 ceased in 3/2003 and was replaced from 10/2003 with GWA-2, an upgradient well for the new WMU. The monitoring frequency is semi-annual.

The 11/1986 design plans show three downgradient GW wells (detail provided), but in different locations to any currently existing wells. These historic wells (MW-1 to MW-3) are referred to in the 4/1992 H/GI Report which states they are screened in the surficial aquifer and to be replaced in 1992. These wells were to be slotted to 20 ft below the GW table and to be monitored on semi-annual basis for COD, pH, chlorides, conductance, temp, iron, color true APHA, turbidity, $BOD_5$, TSS, TDS, nitrates, and fecal coliform.

Construction Details: Boring logs and well development details are available for all wells except MW-1 to MW-3. The GWMP from the revised 3/1994 design plans shows the location of all wells designated "A" or "C" and states that all GW wells in the surficial aquifer are "screened above clay zone."

Groundwater Data: A summary of analytical data is provided in the table below. Data are available for all parameters for which monitoring is required by the State.

*Groundwater Data (Electronic)*

| ITEM | No. Wells, Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | | |
|---|---|---|---|---|---|---|
| Upgradient, distal GWA-101 | 1, 23 | 4/1993, 3/2003 | 98 | Y | | |
| Upgradient, distal GWA-2 | 1, 6 | 10/2003, 9/2007 | 98 | Y | | |
| Upgradient, proximal GWB-112 – GWB-113 | 2, 4 | 3/2006, 9/2007 | 84 | Y | | |
| Crossgrad., proximal GWA-102 – GWA-103 | 2, 25 | 4/1993, 3/2003 | 98 | Y | | |
| Downgrad., proximal MW-1 – MW-3 | 3, 4 | 10/1991, 3/1993 | 5 | Y | | |
| Downgrad., proximal GWC-101 – GWC-106 | 6, 34 | 4/1993, 9/2007 | 123 | Y | | |

Compliance Issues and Community Concerns: Following detection of two VOCs in a GW monitoring well (GWC-13, a well for the active lined WMU but located in the valley between the two WMUs on the property), and subsequent fingerprint studies indicating these were due to gas migration, a line of six passive gas vents (PV-1 through PV-6) was installed between the landfills in 1Q 1997. The vents were advanced to depths of 12.5-14 ft, 6 in. below the GW surface encountered during drilling. An installation report for the passive vents was provided in 2/1997.

In 3/2000, low levels of vinyl chloride were detected and subsequently verified in GWC-12 (a well for the new WMU). Because of the proximity of this well to GWC-13 and to Site B, it was believed that landfill gas was also affecting this well. In 4/2001, a report was submitted to the State with a request to abandon and remove the two wells, GWC-12 and GWC-13. In a 4/2002 letter, the State approved abandonment, but required replacement wells GWB-112 and GWB-113 be installed between the WMUs and monitored under the GWMP for Site B.

A VOC detection in GWB-112 occurred in 3/2007, verified in 9/2007. This is again likely due to gas migration, but has triggered development of an Assessment Monitoring plan (in preparation). The VOC concentration in question is three orders of magnitude below the MCL.

## Surface Water Monitoring System

Locations: There are two reported monitoring locations, SW-1 and SW-2, both distal. SW-1 is immediately outside the E property boundary at outflow of a culvert under a public road draining from the natural wetland/woodland system downgradient of Site B. SW-2 is the outflow from the large on-site stormwater management (SWM) pond, upgradient of both Site B and the natural wetland/woodland system draining to SW-1. SW-2 is shown on the 3/1994 design plans, but SW-1 is not. However, recent monitoring maps show SW-1 but not SW-2, suggesting that SW-2 is no longer actively monitored.

Monitoring Program: Monitoring frequency is annual, in conjunction with GW.

Surface Water Data: Available data from the electronic GW database is summarized in the table below. No data for SW-1 is included in the database.

*Surface Water Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | COD | BOD |
|---|---|---|---|---|---|---|
| Downgrad., distal SW-2 | 16 | 4/1993, 7/1997 | 57 | X | | |

Compliance Issues and Community Concerns: None reported.

## Methane Migration Monitoring System

Layout: The original MMM Plan (dated 10/1992) states that monitoring began in 3Q 1991 at 27 barhole probe locations. A map shows barhole locations spaced approximately equal around the perimeter of the landfill. Nine permanent monitoring probe locations, GP-1 through GP-9, all proximal and installed at approximately equal spacings around the perimeter of Site B, are shown on the 3/1994 design plans. The total depth and screened depth of the probes are not known.

Monitoring Plan and Data: MMM is required quarterly. The first recorded monitoring event found for on-site structures and the barhole probes was 3Q 1991. The barhole probes were used through 3Q 1993. Some methane hits were recorded during each monitoring event, with values occasionally reaching 60-70% methane. Gas migration monitoring data from GP-1 through GP-9 and in on-site structures has been conducted on a quarterly basis since 4Q 1993. Occasional

hits of methane, generally at less than 4% by volume, have occurred at some wells, none in structures.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Start, End | Frequency | Notes |
|---|---|---|---|
| Perm. Probes, GP-1 – GP-9 | 4Q 1993, 3Q 2006 | Quarterly | P, incomplete |
| Barhole Probes, BP-1 – BP-27 | 3Q 1991, 3Q 1993 | Quarterly | P, incomplete |

Compliance Issues and Community Concerns: Gas impacts to GW have occurred, see section on GW.

**FIGURE B-1**
**Site B Physiographical Setting**

**FIGURE B-2**
**Site B Layout and Features**

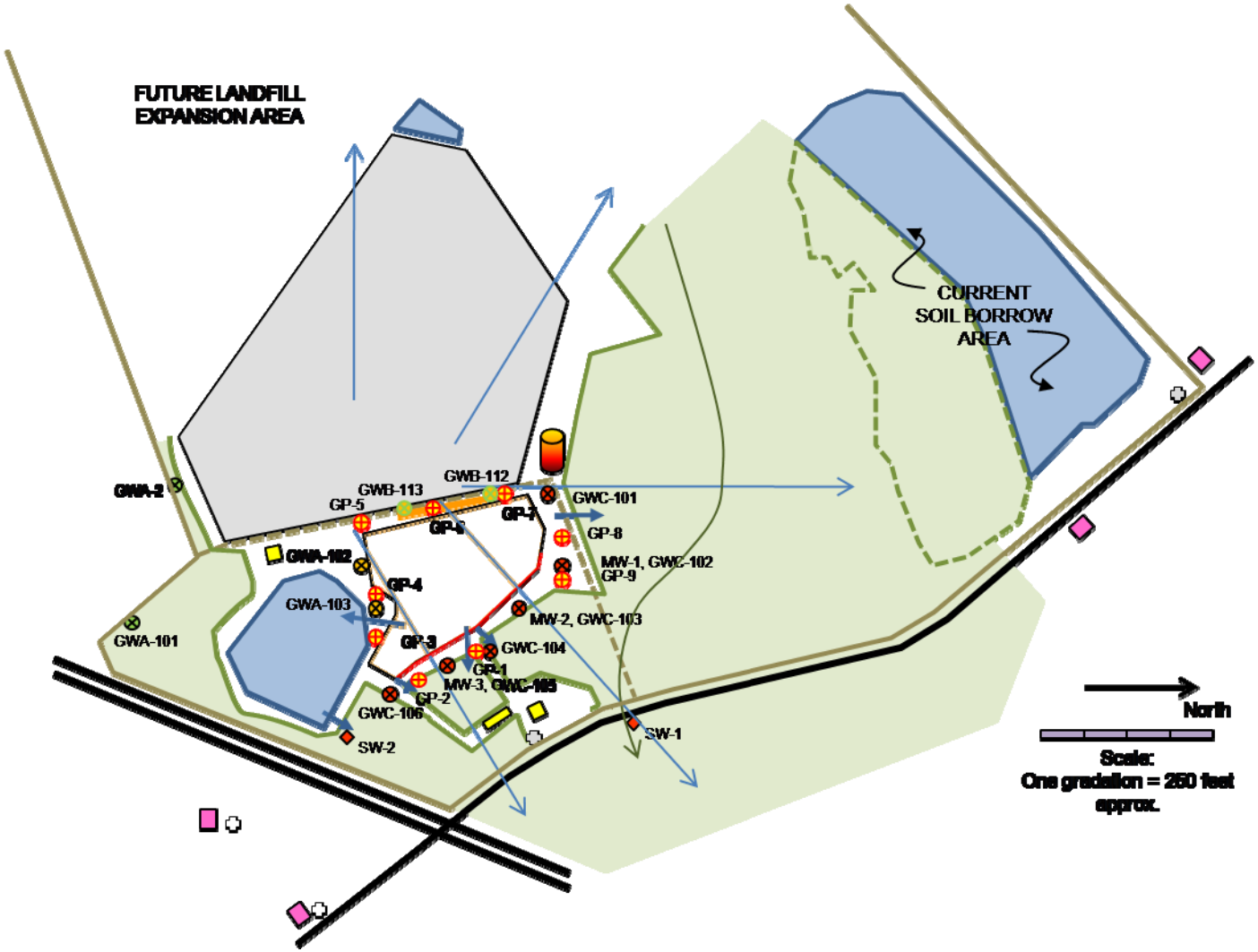
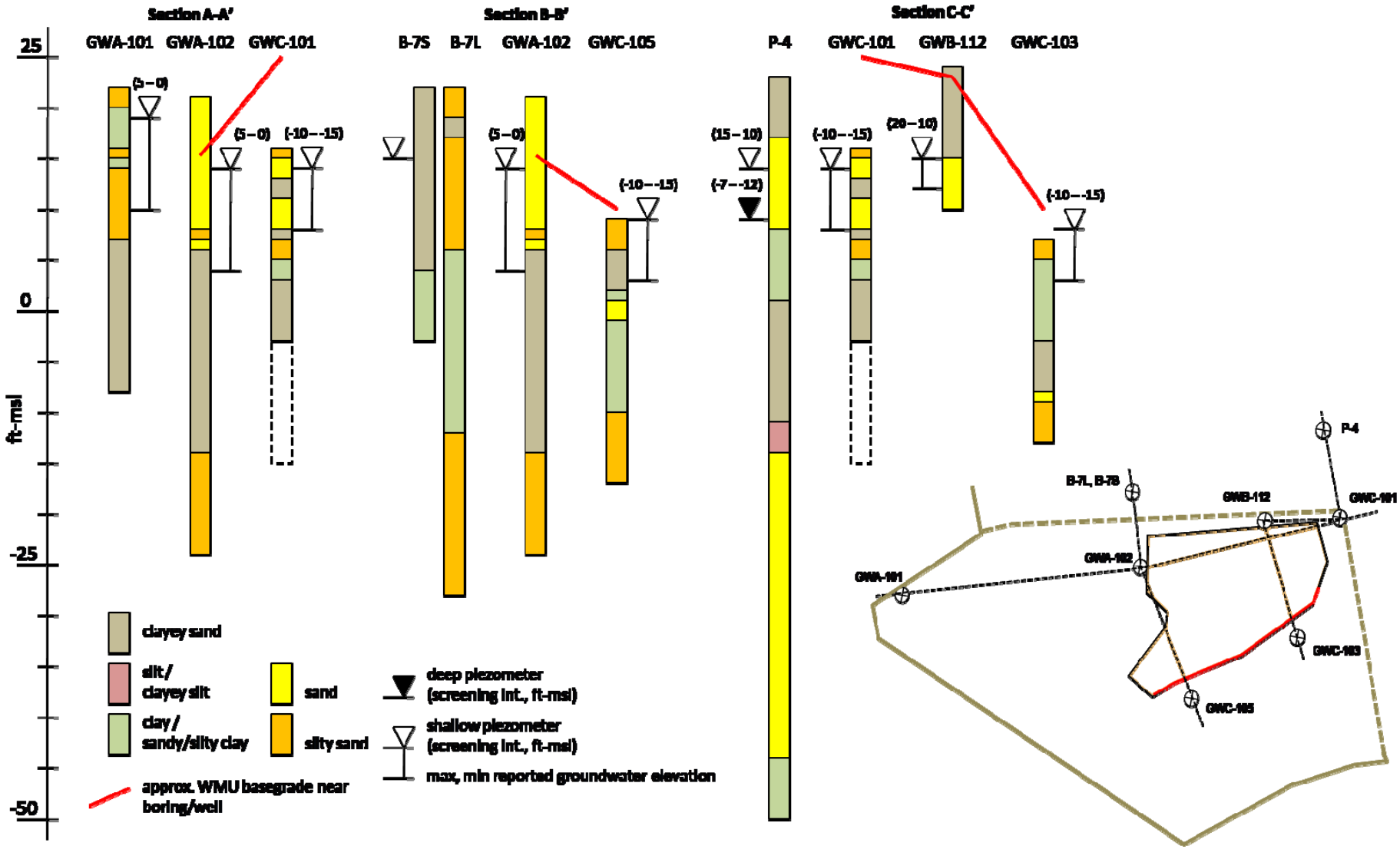


**FIGURE B-3**
**Site B Geologic & Hydrogeologic Cross Sections**



# APPENDIX 2-1C

# SUMMARY – SITE C (OKLAHOMA)

## Overview

Property: The original MSW landfill operating permit is dated 11/1986; the 62-ac., six-phase landfill began accepting waste in 11/1987. The 3/1999 Title V permit application lists the design capacity of the landfill as 6.5Mcy, excluding final cover. A pre-existing 70-ac RCRA facility dating from 1975-1987 is also present on the property, E of the MSW landfill. The original MSW landfill capacity has been significantly increased twice: (i) in 2002, when a permit application to fill the valley between the MSW landfill and RCRA landfill was prepared; and (ii) in 2007, when a lateral expansion for MSW landfill operations to a 45-ac area N of the RCRA cell was prepared, expanding the waste disposal area from 87-ac to 132-ac and the landfill permit boundary from 102-ac to 160-ac (although the 3/1999 Title V permit application lists the total property size as 270-ac). The new total design capacity of the landfill is 18.46Mcy.

Study WMU: The study WMU comprises four pre-Subtitle D units (Phase I – IV) with footprint area of approximately 47-ac. The current maximum elevation of the study WMU is about 1,290 ft-msl, the toe is at about 1,150 ft-msl.

The physiographical setting of the property and study unit is shown on Figure C-1. A stylized depiction of the site layout is provided as Figure C-2.

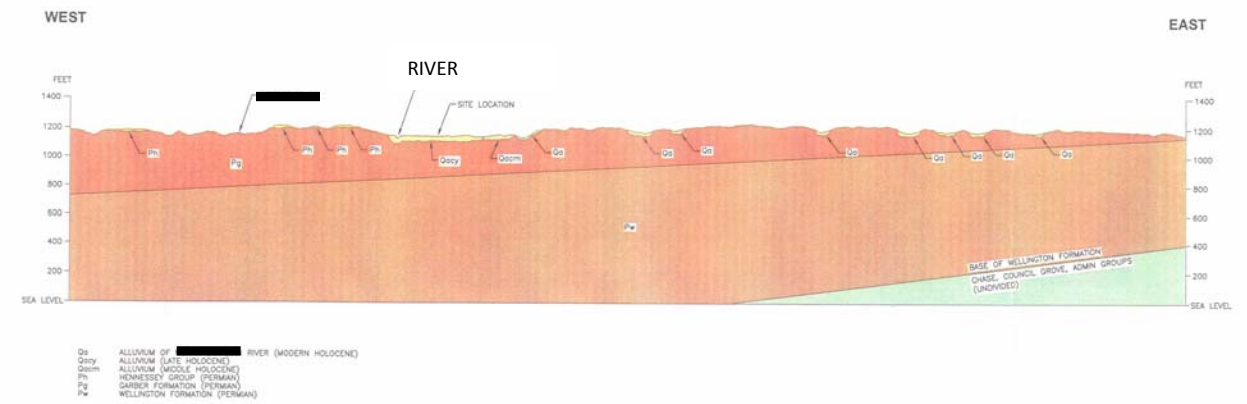
## Site Information

Geologic and Hydrogeologic Setting: A detailed Subsurface Investigation and Groundwater Study (SIGWS) report was completed in 8/2007 as part of a 45-ac lateral expansion permit application. Hydrogeologic cross sections are provided on Figures C-3 and C-4.

Regional Stratigraphy: The site is in the area of the Cherokee Platform geologic structural province. The dominant sediments are the middle to upper Pennsylvanian-age Desmoinesian, Missourian, Virgilian, and Gearyan series, and Permian-age Cimarronian series. Within a ten mile radius of the site, the Sumner and Hennessey groups are dominant. The lithologies of these groups are largely reddish-brown to orange brown sandstones, shales and siltstones. The Simmer Group was deposited in a deltaic environment by east to west flowing streams that extended into western Oklahoma and Texas. Regionally, the Sumner Group is approximately 75 percent sandstone, but to the north and south, the ratio of sandstone to shale decreases as the deltaic deposits inter-finger with and grade into marine deposits. The Sumner Group is

comprised, from oldest to youngest, of the Wellington and Garber formations. The Hennessey Group overlies the Sumner Group and is comprised, from oldest to youngest, of the Fairmont Shale, Kingman Siltstone, Salt Plains Formation, and Bison Formation. Underlying the Sumner Group are the early Permian-age, Chase, Council Grove, and Admire groups, while overlying the Hennessey Group is the Cimarronian-age El Reno Group.

*Quaternary Alluvium and Terrace Deposits* – The landfill is located on an area of mapped Quaternary alluvium along a large named river. The alluvial deposits underlying the landfill consist of sand, silt, clay, and lenticular beds of gravel deposited in the recent flood plain of the river. The alluvium is Holocene in age and is located approximately 5 to 10 feet above the modern flood plain of the river. The thickness of the alluvium is reported to range from 30 to 100 feet. Pleistocene-age terrace deposits are also located immediately above and adjacent to the modern flood plain. The terrace deposits consist of lenticular beds of sand, silt, clay and gravel. The terrace deposits are reported have a thickness of 20 to 100 feet, but average approximately 50 feet.




*Hennessey Group* – This group overlies the Garber Formation and acts as a confining unit for the Garber-Wellington Aquifer where the aquifer is fully saturated. It is reported that confined conditions due to the Hennessey Group generally begin approximately 4 miles west of the Hennessey-Garber contact outcrop. The Hennessey Group is not present at the landfill, but can be encountered on nearby hilltops to the west (see above figure). The Hennessey group is described as primarily a reddish-brown shale and siltstone with local lenticular beds of fine to very fine-grained sandstone and sandstone conglomerate. Some reports designate the Hermessey as a formation instead of a group due to the inability to map previous group subdivisions on a regional basis. The thickness of the Hennessey Group is reported to range from 0 to 60 feet.

*Garber Formation* – This is the youngest formation in the Sumner Group. The formation's contacts with the underlying Wellington Formation and overlying Hennessey Group, where present, vary from conformable to gradational. In the vicinity of the landfill, the Garber

Formation is unconformabley overlain by Quaternary alluvial and terrace deposits. The Garber Formation reportedly ranges between 150 to 400 feet or more in thickness in the vicinity. The Garber Formation is described as a mostly fine-grained, moderate reddish-brown to moderate red sandstone with some shale and siltstone, and minor conglomerate.

*Wellington Formation* – This formation underlies the Garber Formation and is the oldest formation in the Sumner Group. The Wellington Formation is described as red-brown to orange-brown shale and mostly fine to very fine-grained sandstone with maroon mudstone and chert conglomerate. The Wellington Formation ranges between 150 to 500 feet in thickness in the vicinity of the site. Regionally, the Garber and Wellington formations have very similar lithologies and can be difficult to distinguish from one another. Some reports do not differentiate between the two formations because detecting the subsurface contact between the two is virtually impossible. According to others, the principle difference between the Garber and Wellington formations is grain size. The Wellington Formation is typically finer grained than the Garber Formation; however, the basal section of the Garber tends to be finer grained than the upper sections.

Site Stratigraphy: The landfill is located upon Holocene-age river alluvium deposits. These deposits consist of clay, silt, sand and gravel that have been deposited in channels and on modern floodplains to a reported thickness of up to 40 feet. Unconformabley underlying the alluvium deposits is the Permian-age Garber Formation. This contact is not exposed at the surface within the proposed permit boundary. The following site-specific, hydrostratigraphic units were developed for the 8/2007 SIGWS based on a 2005 site investigation supplemented with data from nine earlier studies. The individual units have classifications based on lithologic characteristics and hydrogeologic functionality.

*Surface Sand Unit (SSU)* – Subsurface investigation boreholes penetrated 18 to 36 feet of a dark brown to tan SSU at the near surface. The unit consists primarily of unconsolidated, fine to coarse sand that is angular to sub-rounded quartz and feldspar grains. Seams of clay, sandy clay, and clay clasts are somewhat common within 10 feet of the ground surface, and are uncommon below 10 feet. The clay seams and clasts are typically soft to firm and plastic. The sandy clay seams are typically hard and slightly plastic to non-plastic. A basal fine to very coarse gravel was encountered immediately above the underlying Lower Consolidated Unit in eight subsurface investigation boreholes. The gravel is typically angular to subrounded, quartz and feldspar. Grain size typically ranges from fine to coarse gravel, though some cobble-size grains were encountered. Overall, the SSU displayed a fining upwards sequence across the landfill area. The SSU is dry at the surface, becoming saturated at a depth of 2 to 11 feet below the surface. This uppermost saturated zone is unconfined in the expansion area.

*Lower Consolidated Unit* (LCU) – Site exploration boreholes penetrated 2 to 21 feet of a LCU that is continuous across the landfill area. This unit consists of reddish-brown or reddish-brown and tan-banded sandstone and shale. The sandstone is composed of very fine to fine rounded grains and is often silty and/or clayey. The shale is silty and/or sandy and varies from plastic to non-plastic. The upper 6 to 10 feet of this unit is weathered. Both the sandstone and shale in this unit are very moist and saturated. Although saturated, the LCU acts as a lower confining unit to the SSU uppermost saturated zone due to its much lower hydraulic conductivity. Mean

hydraulic conductivities derived from slug test and geotechnical laboratory measurements indicate groundwater travels 160 times faster through the SSU than the LCU. None of the subsurface investigation borings penetrated the entire LCU thickness, although borings have penetrated to as much as 139 ft-bgl.

Saturated Zone: The uppermost aquifer occurs in the SSU (which is continuous beneath the permit boundary) and is unconfined. A general coarsening downward of sediments is indicated by increased porosity. The LCU is saturated and is largely comprised of dense sandstone with thin interbedded shales. Field observations during drilling campaigns in the expansion area indicated a defined shale layer in 7/10 borings at or very near the surface of the LCU but that this layer varied in thickness and is not continuous. Therefore, the LCU's groundwater is also unconfined. No perched groundwater zones have been observed.

Boring Logs: The 8/2007 SIGWS lists 10 subsurface investigations conducted between 1979 and 2005. Boring logs are available. Gamma ray and resistivity, duel induction, and compensated geophysical logs were collected from four monitoring well borings for the RCRA facility in 1994. Additional gamma ray and neutron geophysical logs were obtained from six boring in 2005 for the 2007 expansion area. The geophysical logs verified the subsurface characteristics presented in lithologic logs. Hydrogeologic cross sections are provided on Figures C-3 and C-4.

Hydraulic Conductivity: Computations of hydraulic conductivity based on slug tests and laboratory analyses performed in 2005 on the Surface Sand Unit (SSU) and Lower Consolidated Unit (LCU) at the expansion area and yielded the following results:

SSU: Six slug tests. Max k = $4.66 \times 10^{-3}$ cm/s, Min k = $1.08 \times 10^{-3}$ cm/s, geometric mean = $2.16 \times 10^{-3}$ cm/s.

LCU: One slug, seven laboratory tests. Max k = $5.4 \times 10^{-4}$ cm/s, Min k = $1.3 \times 10^{-8}$ cm/s, geometric mean = $8.5 \times 10^{-6}$ cm/s.

Groundwater: The OWRB classifies the landfill vicinity as favorable for development of groundwater supplies. According to the OWRB, the groundwater in this area is present in the Garber-Wellington and alluvial aquifers. According to the Oklahoma Geological Survey's Hydrologic Atlas No. 4, typical Garber-Wellington Aquifer yields are 150 to 300 gallons per minute in the landfill area and less than 50 gallons per minute for alluvial aquifers. Reconnaissance of nearby water resources indicates that there are six water wells within five miles of the landfill that have been utilized for studies regarding the availability and chemical quality of groundwater. The studies' wells range from 200 to 800 feet in depth and are completed in the GarberWellington Aquifer. These wells typically yield good quality groundwater. The chemical data from these wells indicates the groundwater has slightly elevated calcium, magnesium, and bicarbonate (relative to other measured constituents). In this area, the

Garber-Wellington groundwater typically has a total dissolved solids concentration of less than 300 parts per million.

Groundwater potentiometric maps indicate a bi-directional horizontal groundwater flow (which may be seasonal), majorly from S to NW and minorly from S to NE. The potentiometric surface appears to largely mirror the LCU topography. Increased friction in the more compacted LCU results in the loss of hydraulic head as groundwater moves slowly through the unit. For this reason, the unit's potentiometric surface is above the top of the LCU, but below the SSU potentiometric surface. Recharge to the SSU occurs via infiltration of precipitation and surface runoff. The LCU is believed to recharge from downward migration from the SSU.

The site's average hydraulic gradient, as measured in the vicinity of wells MW-14R and MW-225A is 0.00095 ft/ft. Vertical flow computation based on geometric mean potentiometric head difference between 12/2005 and 1/2007 at well cluster MW-226GW and MW-225A at the N boundary of the expansion area yields a slight downward flow from the SSU to LCU of 0.185 ft/ft.

Unsaturated (Vadose) Zone: See hydrogeologic description of deposits above the water table, the average elevation of which varied from 1,136 ft-msl to 1,146 ft-msl in the seven GW monitoring wells between 1992 and 2006. The ground surface ranges from 1,150 ft-msl (S of the study WMU) to 1,163 ft-msl (N of the study WMU).

Physiographical Setting: The surrounding land area is zoned agricultural and agricultural plus sand/gravel mining. Land use of the adjacent properties is mostly undeveloped woodlands and pasture areas with a sand mining operation to the S. Resident and business areas are not located particularly close to the site. There are no jurisdictional wetlands located within the property.

Potential Point(s) of Exposure: A review of the ODEQ and OWRB online water resource databases was completed in February 2007. Water resources in the area are supplied from groundwater and surface water sources (the named river and three reservoirs). The ODEQ surface water intake database indicated two surface water supply intakes are located within four miles of the site, but none are located within 3.0 miles downstream of the facility. The flood map for the area shows that the 100-yr flood plain for the river extends across the majority of the landfill; however, the waste disposal areas are/will be protected by a perimeter berm to provide at least 3 ft of freeboard between the 100-yr flood elevation and the top of the berm.

Water wells are common in the area; according to the ODEQ, 14 public water supply wells are located within two miles of the proposed permit boundary. None of these wells are located down Garber groundwater gradient from the landfill. The regional Garber Formation groundwater gradient dips toward the west. The OWEB water well database indicates there are 39 private (domestic) water wells within 1.0 miles of the proposed permit boundary. There are no on-site water wells. The uppermost aquifer in the site vicinity occurs in alluvial sediments. This groundwater flows to the northwest toward the river, where it is expected to discharge. Based on

this flow direction, all but one of the private water wells is located up gradient or west of the expected river discharge area. One reported domestic water well is located about 3,500 feet N of the landfill in an area between the landfill and the river. The OWRB listing contained no information regarding the well's producing formation or water quality. Based on the listed 120-foot well depth, the well likely produces from the Garber Formation. As such, this well is in a largely side gradient location with respect to regional Garber groundwater flow.

Climate: According to the Oklahoma Climatological Survey (OCS), the average annual rainfall at a meteorological station located 17 miles W of the landfill over the last 30 years is about 36 in. An onsite weather station exists.

## Waste Placement and Operations

General: The 11/1986 permit application estimates waste acceptance of 3,275 cy/d with estimated site life of 7.7 years assuming a maximum landfill elevation of 1,220 ft-msl. The waste stream for disposal in 2006 was estimated at 1,600 tpd for 286 days of operation per year.

Waste Placement Data: A 6/1997 GCCS design calculation provides waste placement data for the landfill from 1987 to 1996 (cumulative 2,766,377 Mg), with estimated placement through 2001 (when the originally permitted capacity of 5.22MMg would have been placed). The 3/1999 Title V permit application provides waste placement data for the landfill from 1987 to 1998 (cumulative 2,745,369 Mg), with estimated placement through 2006 of 4.37MMg. A 6/1997 topographic survey is available showing most airspace consumption to that date had occurred in the study WMU. This, it is a reasonable assumption that all waste placed through 1997 was in the study WMU. However, the maximum crest elevation in the study WMU in 6/1997 was approximately 1,250 ft-msl, this had increased to 1,290 ft-msl by 1/2006 (i.e., and additional unknown quantity of waste has been placed in the study WMU).

Waste Composition: No details are available beyond "MSW." Boring logs from installation of 13 gas wells in 2000 give brief details of waste encountered, mostly listing the material as degraded HHT, dry-damp, with some dirt.

## Closure and Post-Closure (C/PC) Plan

The most recent C/PC Plan for the landfill is contained in the 8/2007 expansion permit application. The plan is typical of a Subtitle D site with no special requirements identified. Monitoring and maintenance conditions include the final cover, SWM system, LMS, GWMS, SWMS, MMMS, and site security and access controls. An annual PCC report is required to be submitted to ODEQ.

## End Use Strategy

No specific end uses for the property are contained in either the original 11/1986 permit application or in subsequent expansion applications. However, a strategy to turn the property over the local government for use as a park is being considered.

## Liner System

Design: The pre-Subtitle D liner system in the study WMU comprises 2-ft. of compacted clay over the entire base and sideslope of the landfill. The 11/1986 permit application states the minimum liner coefficient of permeability is $1 \times 10^{-7}$ cm/s.

12/1985 design drawings show that the liner basegrades in the study WMU are sloped according to a diamond grid with three high and low points located along a centrally dividing N-S line (max elevation 1,151.7 ft-msl, min elevation 1,149.2 ft-msl) and approximately equally spaced between LCS-6 and LCS-3. All drainage is towards the perimeter of the study WMU. Liner low points (nominal elevation 1,148 - 1,147 ft-msl) are located around the perimeter where the six sumps are located.

CQA and Construction Records: N/A

As-Built Drawings: N/A

## Leachate Management System

Layout and Design: There are six leachate collection sumps in the study WMU, LCS-1 through LCS-6. 12/1985 design drawings show sump elevations at 1,147 to 1,148 ft-msl (consistent with liner basegrades shown in 8/2007 permit application). A 3-ft thick sand "granular drainage blanket" exists over the entire basal and sideslope liner (the 11/1986 permit application states that is overlain with a 2-ft protective soil layer, but this is not shown on design drawings). Leachate collection trenches (6-in. perforated SDR 11 HDPE or Sch. 80 PVE pipe in geotextile wrapped gravel V-shaped trenches at the base of the 3-ft drainage sand) run E or W from the central low points to sumps and along the perimeter to sumps at slopes of 0.2% to 1.0%. All sumps are pumped to a central storage pond (200,000 gal.) serving Phases I – VII (Phase VIII leachate is routed separately to an adjacent 80,000 gal. tank). Leachate from the pond is batch discharged to POTW (via forcemain?) when the pond is full. According to limited site records from 9/2003 to 11/2007, this has occurred 5 times in that period (indicating an average 1M gal. of leachate was generated in these seven phases over four years).

CQA and Construction Records: N/A

As-Built Drawings: N/A

Leachate Recirculation: Not practiced historically, as leachate disposal costs are very low. However, recirculation at the working face in the valley fill and new expansion areas is included in the 8/2007 permit application. No recirculation over pre-Subtitle D areas is permitted.

Leachate Generation Rate: Not routinely measured, but see comment above.

Leachate Sampling and Data:

*Leachate Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | COD | BOD |
|---|---|---|---|---|---|---|
| LCS-1 | 13 | 3/1992, 9/2004 | 99 | Y | Y | Y |
| LCS-2 | 14 | 3/1992, 8/2006 | 99 | Y | Y | Y |
| LCS-3 | 14 | 3/1992, 8/2006 | 99 | Y | Y | Y |
| LCS-4 | 14 | 3/1992, 8/2006 | 99 | Y | Y | Y |
| LCS-5 | 14 | 2/1993, 8/2006 | 99 | Y | Y | Y |
| LCS-6* | 0 | | | | | |
| POND | 9 | 7/1996, 8/2006 | 175 | Y | Y | Y |

* It is not clear whether LCS-6 was ever constructed as intended.

Compliance Issues and Community Concerns: None reported.

## Cover System

Design: Currently, the study WMU is interim-capped with 12-in of sandy loam. Sideslopes are 4H:1V, the maximum slope on the top crest is 4%. The final cover system design for the landfill is a monolithic soil ET cap comprising the existing 12-in intermediate cover layer, a 24-in vegetative support layer (store and release layer), and a 12-in vegetative topsoil layer. Vegetative cover will consist of native and introduced grasses. The alternative cap was designed to be equivalent to a Subtitle D prescriptive cover system.

The 11/1986 permit application lists daily cover as 6-in soil and intermediate cover as 12-in. soil.

A 1/2006 survey drawing shows the maximum elevation of the study WMU as about 1,290 ft-msl. It is anticipated that a 10 acre portion of the E and S sideslope to the study WMU (between LCS-2 and LCS-5) which is at final grade will be final capped in 2008/09.

CQA and Other Construction Records: N/A.

As-Built Drawings: N/A.

Topographic Surveys: 6/1997 and 1/2006 (paper only).

Cover Monitoring and Maintenance: Requirement for inspection the "verify the integrity of the cover system" and maintenance are contained in the 8/2007 C/PC Plan. Inspections shall be quarterly for the first three years of PCC, thereafter semi-annually for 2 years, thereafter annually unless additional inspections are required. Conditions to be examined include settlement, cracking, erosion, burrows, other disturbances, and state of vegetation. Mowing is required twice per growing season.

Compliance Issues and Community Concerns: 4-5 minor breakouts and some recurring E&S issues on E and S sideslopes.

## Landfill Gas Control System

Active Gas Control System: The original active Phase I GCCS in the study WMU comprised 18 wells of depth 47.5 ft – 56.5 ft installed between 10/1996 and 1/1997. A 6/1997 document provides engineering calculations and plans for a GCCS expansion from 18 to 53 wells. The system was expended by 13 wells of depth 55 ft – 98 ft installed between 9/2000 and 10/2000. The system was further expanded in 2003. A 7/2007 layout drawing of the GCCS shows 39 gas wells in the study WMU.

Gas Utilization: A limited capacity (demonstration project) for LFG-biodiesel has operated intermittently.

Passive Gas Vents: None.

Construction Details and As-Built Drawings: Phase I GCCS construction documents dated 4/1997 are available. Construction documents dated 12/2000 are available for the 13-well expansion. Four construction record drawings dated 9/2003 titled "LFG System Expansion" are also available.

Landfill Gas Data: The 2006 Title V report indicates total flow in the range of 1,100 – 2,000 scfm for a flare rated to 2,500 scfm.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Wellheads | Y | Y | Monthly records (E), mostly complete, 1/2007 through 1/2008 |
| Flare | Y | Y | Monthly records (P), Title V report 2006 |
| Surface Scans | | Methane only | Quarterly monitoring reports (P), 1997 through 2005 |

Compliance Issues and Community Concerns: The site has been issued two NOV for LFG-related issues. The first was because the initial performance test for the flare was not submitted on time; the second, in 2002, occurred after a lightning strike on the flare fused controls which took 2½ months to repair. No odor complaints have been received.

## Groundwater Monitoring System

Layout: The current GWMS at the landfill comprises seven wells, all screened in the SSU. However, MW-207R will be decommissioned as part of the lateral expansion and a new well located N of the current well location.

Monitoring Program and Groundwater Data: The current GWMP is described in the 8/2007 expansion permit application. Monitoring is currently required semi-annually. The wells of relevance to the study WMU are listed in the table below (all data electronic).

| ITEM | Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | Na | K |
|---|---|---|---|---|---|---|
| Upgradient, proximal MW-12R | 0 | | | | | |
| Upgradient, proximal MW-22R | 42 | 10/1991, 8/2006 | 98 | Y | Y | Y |
| Down/cross gradient, proximal MW-27 | 28 | 10/1995, 8/2006 | 94 | Y | Y | Y |
| Downgradient, proximal MW-25R | | 10/1991, 8/2006 | | Y | Y | Y |
| Downgradient, proximal MW-28* | | 10/1995, 8/2006 | | | | |
| Downgradient, proximal MW-29 | | 10/1995, 8/2006 | 94 | Y | Y | Y |
| Downgradient, proximal MW-207R | 14 | 3/2002, 8/2006 | | | | |

* Located directly downgradient of the leachate storage tank/pond.

Construction Details: Boring logs and well construction details are available.

Compliance Issues and Community Concerns: Some joint wells have had groundwater exceedences, mostly attributed to the adjacent RCRA landfill. Exceedences for nitrates in MW-25R are attributed to fertilizer in SWM runoff. An increase in background chloride concentrations is attributed to a leak from a brine pipeline (associated with deep-well oil derricks around the site vicinity) running along the S and E property boundary.

## Surface Water Monitoring System

Locations: Only a 100-yr storm would generate a discharge event from a sedimentation basin located to the SE of the study WMU. There have not been any discharges to date.

Monitoring Program: The post-closure SWMP is described in the 8/2007 expansion permit application. Surface water discharges will be monitored under a State PDES Multi-Sector General Permit. It is anticipated that this will generally be aimed at assuring control of sediments in water discharged. Visual monitoring will be conducted quarterly. Laboratory analysis of SW samples will be conducted annually.

Surface Water Data: None seen.

Compliance Issues and Community Concerns: In the mid-1980's the river overflowed, flooding the site to the toe of the landfill, before withdrawing.

## Methane Migration Monitoring System

Layout: The MMM network currently includes eight gas probes, GP-01 through GP-07 (installed in 10/1994) and GP-08R (installed in 2003), located along the property line at 500-1000 ft spacing, depending on location.

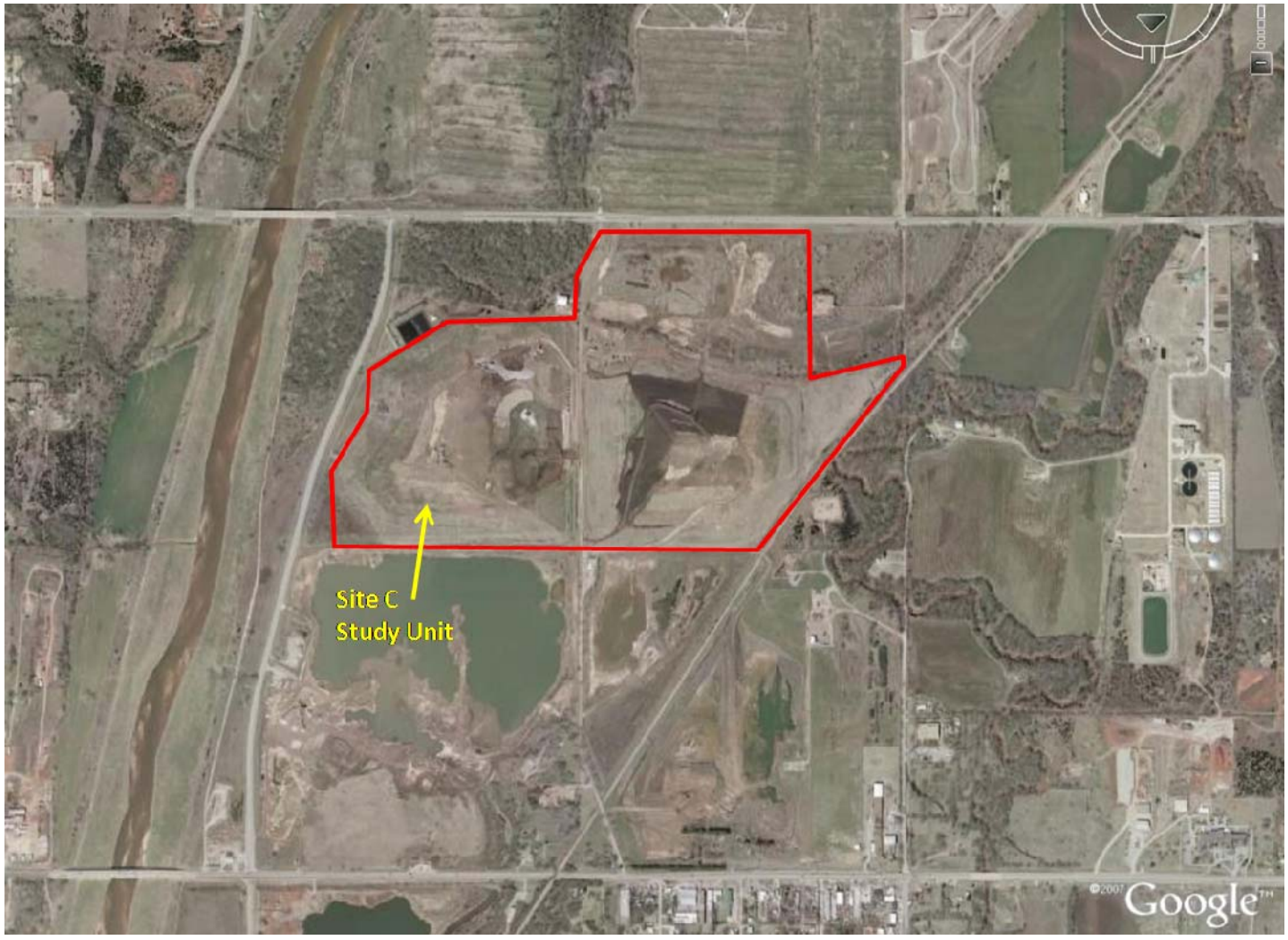
Monitoring Plan and Data: The MMMP was most recently updated in 8/2008 lateral expansion permit.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Start, End | Frequency | Notes |
|---|---|---|---|
| Perm. Probes, GP-01 – GP-07, GP-08R | | Quarterly | Only methane (as % LEL) is monitored |

Compliance Issues and Community Concerns: Some gas migration issues have occurred, twice in the last seven years. They have always responded to wellfield rebalancing.

**FIGURE C-1**
**Site C Physiographical Setting**




Red Line = Property Boundary

**FIGURE C-2**
**Site C Layout and Features**

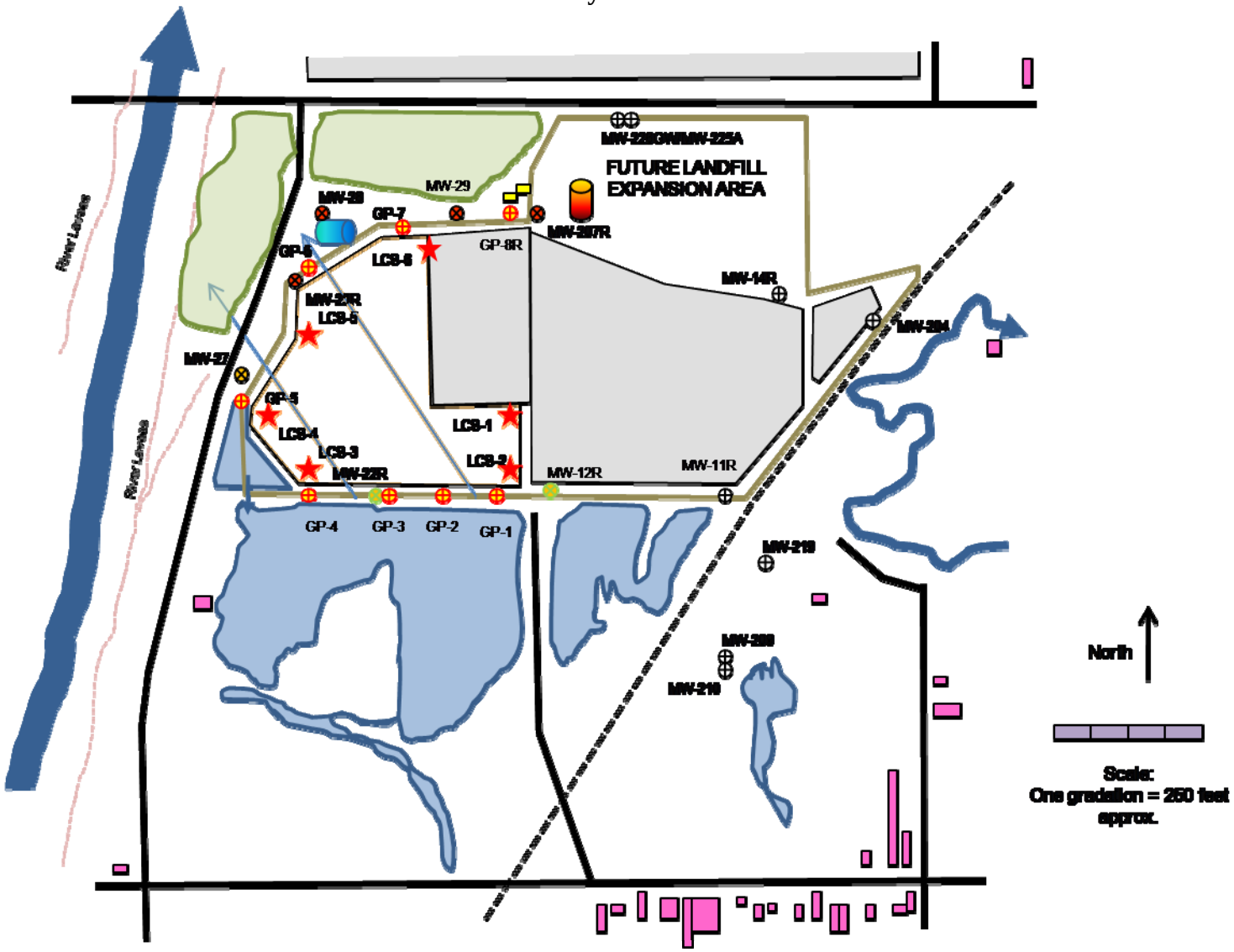


**FIGURE C-3**
**Site C Geologic & Hydrogeologic Cross Section C-C'**

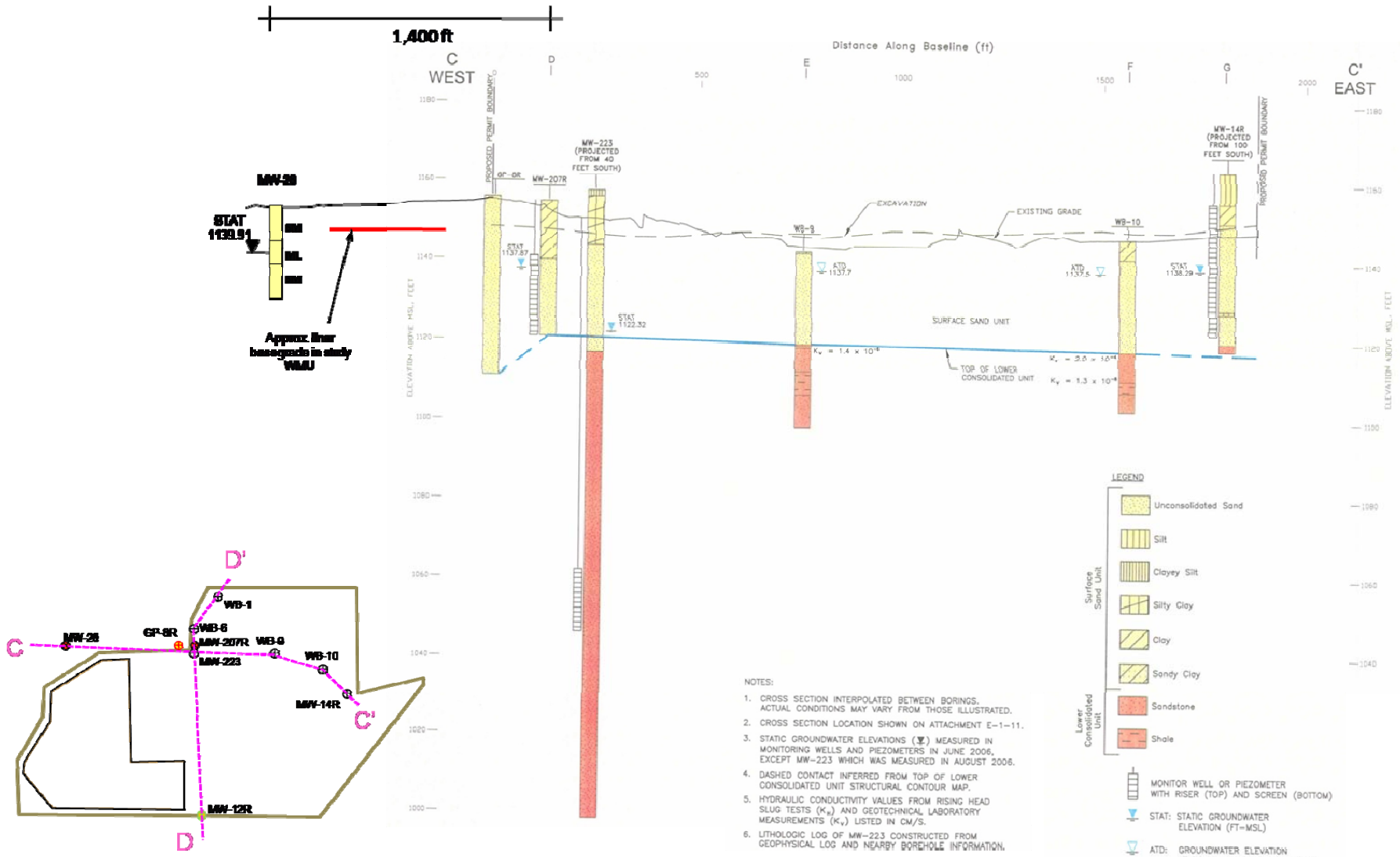
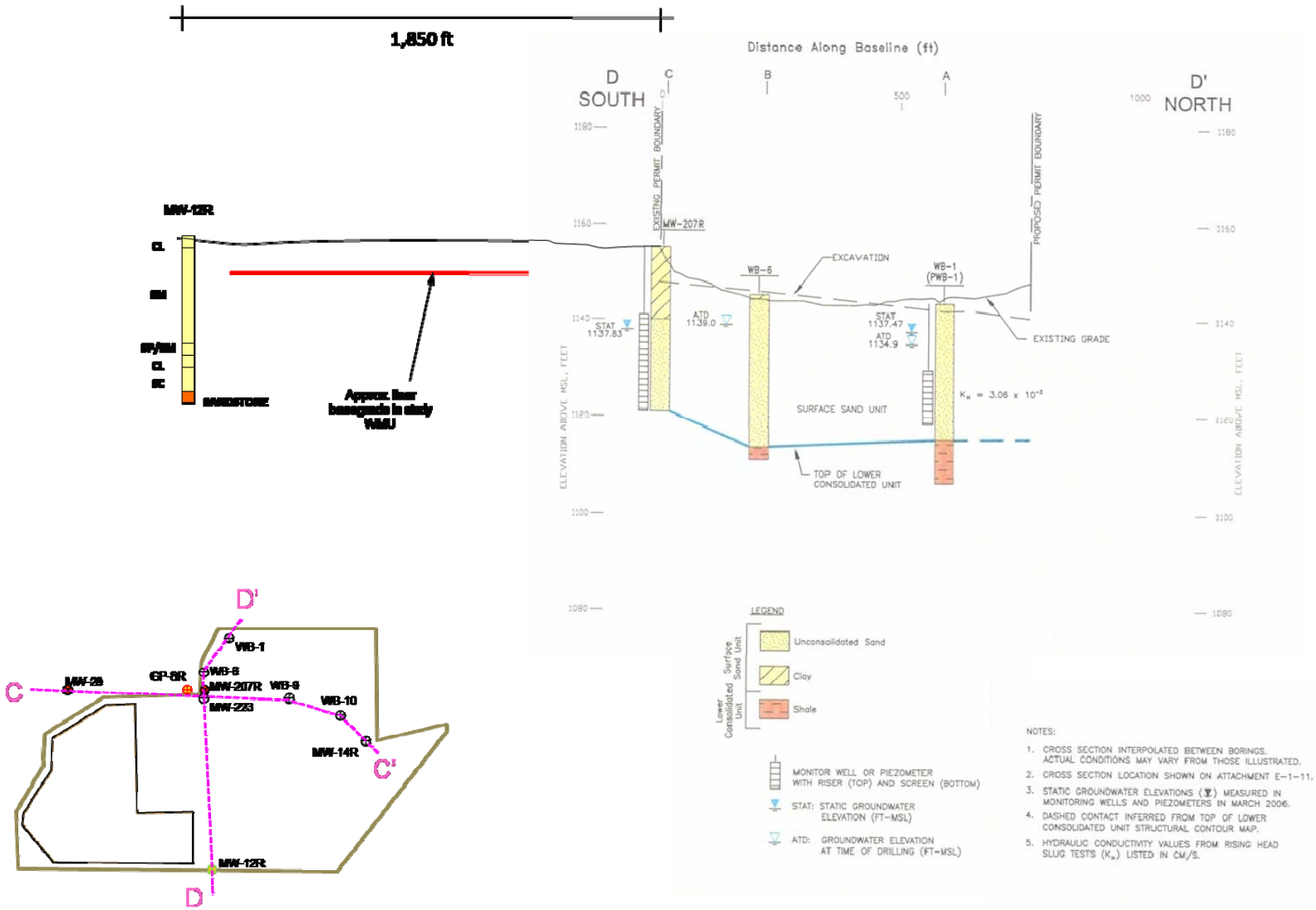


**FIGURE C-4**
**Site C Geologic & Hydrogeologic Cross Section D-D'**



## APPENDIX 2-1D

## SUMMARY – SITE D (NEBRASKA)

### Overview

Study WMU: Site D is a clay-lined (earlier phases) and composite soil and membrane liner (later phases) WMU with an approximately 170-acre footprint and constructed with about 150 feet maximum thickness of waste and 110 feet average thickness of waste. The WMU has an estimated capacity of 15 MM CY. The WMU opened in 1989 and stopped receiving waste in the Fall 2000. WMN has been the sole owner and operator.

Property: Site D is the single permitted WMU on the property. The total property size is 275 acres, of which 170 acres are permitted for solid waste disposal. An active gypsum monofill, which opened post-2004 with a maximum permitted area of approximately 20 acres, is located adjacent to the north of Site D. Site D consists of one WMU developed in eight phases of landfill construction. The earlier phases (phases 1 through 4) are underlain by three feet of low permeability earthen liner underlain by a minimum of 7 feet of in-situ clayey soil. The later phases (phases 5 through 8) are underlain by a composite soil and membrane liner. The landfill phases were excavated to about 40 feet below grade, and underwent one stage of lateral expansion which raised the maximum elevation at closure to about 150 feet above grade.

The physiographical setting of the property and WMU is shown on Figure D-1. A stylized depiction of the site layout is provided as Figure D-2.

### Site Information

Geologic and Hydrogeologic Setting: A summary of the regional and local hydrogeologic setting was presented in the Groundwater Monitoring and Reporting Plan (GMRP, AquAeTer, 2001), prepared in 4/2001, that incorporated previous investigations conducted for WMN (Site D) landfill and its expansion. The details of the hydrogeologic setting were presented in the Title 132 Compliance (1/1996). The site is located in the eastern part of the Great Plains physiographic province. The area is characterized by a broad loess-mantled upland till surface dissected by the valley of the Missouri River and its tributaries. Locally, terraces separate the valley floors from the uplands. Erosion of the loess has resulted in peaks and ridges along the Missouri River. The regional and site-specific topography is generally level to very gradually sloping. Regionally, surface water drains in dendritic patterns. Surface relief (pre-landfilling) was gently sloping to the southeast. A north-south natural surface drainage feature was well-

developed to the east of Site D. Surface water at Site D flows past the site in the natural surface drainage ditch.

The regional hydrogeologic units at Site D are characterized by consolidated and unconsolidated water-bearing geologic units that are divided into two hydrostratigraphic units. The upper hydrostratigraphic unit, between about 30 and 60 feet below ground surface (bgs), consists of Quaternary loess and alluvial sediments. The lower hydrostratigraphic unit, between about 225 and 325 feet bgs, consists of Cretaceous Dakota Group sediments. The Kansan and Nebraskan tills are low permeability aquitards that hydraulically separate the upper and lower hydrostratigraphic units.

The Quaternary sediments were deposited during various glacial advancements and retreats. Alluvial sands of the David City Formation were deposited ahead of the advancing ice sheets and later buried by Nebraskan till. The next glacial advance (Kansan) produced the alluvial sands and gravels of the Red Cloud Formation. These alluvial deposits eventually were buried by Kansan till. While the Kansan ice sheet was retreating, deep ravines were eroded into the Nebraskan till sheet and re-deposited with alluvial sediments. The next two glacial advances (Illinoian and Wisconsin) did not cover this part of Nebraska. However, wind-blown deposits coming off their outwash plains were responsible for the deposition of the Loveland Formation and Peoria Loess.

Groundwater encountered in the upper hydrostratigraphic unit is confined to the Quaternary sediments (loess and alluvium). Because of the low groundwater yields in the loess and alluvium, the upper hydrostratigraphic unit generally is not a dependable potable or irrigation water source. The regional groundwater flow direction in the upper hydrostratigraphic unit generally is toward the southeast, following area topography and surface drainage patterns.

The lower hydrostratigraphic unit is the Cretaceous-age Dakota Group. The Dakota Group consists of interbedded sandstones and shales. The sandstones are used for potable and irrigation water in the area. Regionally, groundwater flow of the sandstone is toward the east to southeast.

Saturated Zone: The GMRP (4/2001) describes the site-specific hydrogeologic setting based on 18 soil borings advanced in 2/1989. These borings penetrated to between 25 and 70 feet bgs. Previously, five monitoring wells were advanced during 1/1989 and 3/1989 as early investigations of soil and bedrock to a depth of 260 feet bgs. The surficial unit present at Site D is a silt and silty clay vadose (i.e., unsaturated) zone of Peorian and Loveland Loess. The next unit below the unsaturated zone is the very low water-yielding upper hydrostratigraphic unit, where groundwater occurs in loess between about 30 and 60 feet bgs. The base of the upper hydrostratigraphic unit is considered to be either Kansan or Nebraskan Till. The glacial till is an excellent hydraulic barrier that effectively separates groundwater within the upper hydrostratigraphic unit from the underlying Dakota Sandstone. Groundwater flow in the upper hydrostratigraphic unit is to the south and southeast. The Nebraskan Till is lowly permeable

which makes vertical leakage through the till very limited to nonexistent. Flow in the lower hydrostratigraphic unit, the Dakota Group sediments, occurs at a gradient of approximately 0.009 feet/foot in a southeast direction.

Boring Logs: The typical cross-section, included in Figure D-3, was presented in the 1994 Site Development Plan. The cross-section shows the potentiometric surface map for the shallower Loveland Loess and the deeper Dakota Group aquifer. A total of approximately 18 soil borings were advanced in early 1989. Boring logs from groundwater monitoring well installation are available for the current groundwater monitoring system consisting of 9 shallow and 5 deep monitoring wells.

Hydraulic Conductivity: Slug tests were performed in MW-101S, MW-102S, MW-103S, MW-104S, and MW-105S, completed in the shallow loess. The k values ranged between 1.1x10-3 cm/sec and 4.5x10-4 cm/sec. The average k value of rising head tests is 8.5x10-4 cm/sec, compared to the average k value of falling head tests of 4.6x10-4 cm/sec. A monitoring recovery test was performed in MW-14D, completed in the deeper Dakota sandstone. The k value (calculated from transmissivity) is 7.4x10-4 cm/sec, within the range of a sandstone. A later series of monitoring recovery tests performed in wells MW-01D, MW-02D, MW-05DR, and MW-17D, completed in the deeper Dakota sandstone, provided an average k value of 6.5x10-4 cm/sec.

| | |
|---|---|
| Loess | |
| Hydraulic conductivity (cm/sec) | 1.1 x 10-3 to 4.5 x 10-4 |
| Hydraulic gradient (ft/ft) | 0.03 |
| Porosity | 0.34 |
| Groundwater flow velocity (ft/yr) | 91 |
| Dakota Sandstone | |
| Hydraulic conductivity (cm/sec) | 6.5 x 10-4 |
| Hydraulic gradient (ft/ft) | 0.014<br>(Note: Vertical hydraulic gradient of 0.48, based on nested wells). |
| Porosity | 0.25 |
| Groundwater flow velocity (ft/yr) | 37 |

Groundwater: The design of the groundwater monitoring system accounts for zones of high hydraulic conductivity (the glacial outwash zones) by monitoring the shallow water table along the perimeter of the landfill. The average linear velocity of horizontal flow was calculated to be 91 feet per year. Potential impact to groundwater quality would be detected by the down-gradient shallow groundwater monitoring network (Permit Modification Application (PMA), 1/1996).

Unsaturated (Vadose) Zone: The vadose zone, shown on Figure D-3, is the Bignell/Peorian loess, described in boring logs as silty sand, silt, and clay. Boring logs are attached to the PMA (1/1996). The Bignell/Peorian loess overlies the uppermost aquifer (the shallow zone), which may be important to consider when completing the landfill gas and groundwater modules. In general:

| | |
|---|---|
| Elevation of lowest sump LCS-01 | Approximately 1207 feet NGVD |
| Elevation of groundwater in shallow zone well MW-201S | 1200.49 feet NGVD (June 2007) |
| Hydraulic conductivity (assume isotropic, $K_v = K_h$) | 10-3 to 10-4 cm/sec |
| Assumed porosity of loess | 0.34 (Domenico and Schwartz, 1990) |
| Assumed thickness of vadose zone | 17 feet (based on boring log data and geologic cross-sections) |

Physiographical Setting: According to the PMA (1/1996), the regional and site-specific topography is generally level to very gradually sloping with valleys developing in the glacially-derived unconsolidated deposits. Surface water drains in dendritic patterns. The highland in the area are approximately 1,300 feet NGVD and the lowlands are approximately 1,130 feet NGVD. The pre-WMU topography was a northwest-southeast oriented drainage beneath the majority of the WMU. A natural drainage ditch and intermittent creek is oriented north-south and to the east of the WMU.

Potential Point(s) of Exposure: There are no occupied structures on the WMU. Locations of off-site houses and other structures are estimated based on review of a recent Google EARTH© aerial photograph and site reconnaissance. There are no on-site water wells on the WMU. Domestic water wells are assumed to be located at the nearest residential buildings surrounding the WMU. For purposes of POE consideration, there are 10 nearby buildings assumed to have private water wells. The closest inhabited residence was located approximately 2,640 feet southeast of the WMU boundary. The 1996 Title 132 Compliance references poor groundwater quality in the uppermost unconsolidated aquifer, and no known usage of shallow groundwater. While the Kansan and Nebraskan tills (shallow groundwater source) are considered unsuitable for potable or irrigation because of low permeability and low water yield, the potential for discontinuous sand and gravel glacial outwash deposits within and between the Kansan and Nebraskan till sheets may provide a source of potable groundwater in sufficient quantity to supply a residential home (PMA, 1/1996). Water supply wells in the area usually are screened in the deeper Dakota bedrock. Municipal and community water supplies in the area are from the deeper Dakota bedrock.

Climate: The PMA (1/1996) characterizes the climate as continental with warm summers, cold winters, and moderate rainfall. Temperatures vary between an average daily maximum temperature during the warmest month (July) of 88 degrees F and average daily minimum

temperature in July of 67 degrees F, and an average daily maximum temperature during the coldest month (January) of 31 degrees F and average daily minimum temperature in January of 13 degrees F. Precipitation varies seasonally, with approximately three-quarters (21 inches) of the annual precipitation (28.4 inches) falling between April through September.

## Waste Placement and Operations

General: The Site D WMU consists of 8 disposal cells. The original WMU design (2/1989) was for 87 acres. The original cells (Phases 1 through 6) typically were excavated to about 20 to 40 feet below grade, or 1,240 to 1,255 feet NGVD, between years 1989 and 1998. A major expansion of 30.5 acres and occurred between 1999 and 2000 (Phases 7 and 8) adjacent to the northwest of the original cells. The initial design of the WMU was to a maximum elevation of 1,390 feet NGVD, based on the earliest available (2/1989) as-built pit bottom plan. The lateral expansion was to a maximum elevation of 1,380 feet NGVD.

Waste Placement Data: Waste receipts are available for the life of the landfill. Some early scale tickets are held by the county. In the early 1990s, a "blue bag" program was started to allow for on-site steam separation and recycling; however, the program was not actively promoted. A summary of annual waste receipts is available from the Landfill Gas Production Data Sheet. The site operated between 1989 and 2000. Annual waste placement is reported to have been between 530,000 and 690,000 tons. Total estimated waste-in-place is 6,720,768 tons in place, including sludge.

Waste Composition: The PMA (1/1996), revised May 2003, indicates that the waste stream is municipal solid waste, bulky waste, C&D waste, and small dead animals. A minor permit modification in May 2003 allowed for liquid waste solidification (i.e., mixing of a bulking agent with non-hazardous liquid prior to disposal as solid waste). Material to be used for solidification included fly ash, kiln dust, and saw dust.

## Closure and Post-Closure (C/PC) Plan

The Closure/Post Closure Plan was submitted 8/2008, but a copy was not available at the time of the WMU data review. The closure of the western portion of the WMU beneath an alternative final cover system (65 acres) was submitted 12/07 and 5/08, and was approved by the regulatory agency on 5/08.

The C/PC plan for the eastern side of the WMU was included in the PMA (1/1996), and included completion of the WMU's final cap and cover system as each area reached final grade. The LFG system was expanded during or after placement of the final cap. Final closure activities began within 30 days of final receipt of refuse. Final cap and cover were placed within 180 days if climatic conditions allowed. Final covered areas were seeded and stabilized as soon as conditions allowed after placement of final cover. C/PC care and maintenance was to continue

for 30 years after closure. Maintenance was to be conducted to preserve the integrity and effectiveness of the final cover, including repairs to the cap and cover as necessary. Visual inspection of the entire final cap and cover system, and the surface water run-off management system, was to be performed quarterly for the first five years of the PC period, and annually thereafter. Operation of the leachate collection, groundwater monitoring, LFG monitoring, and LFG venting systems was to continue during PC period. Maintenance on the leachate collection pipes included being jet-cleaned every 10 years during PC period. The cover is mowed twice each year.

### End Use Strategy

As included in the Proposed Operating Plan (1988), the end use plan was for general recreational use or open green space. The PMA (1/1996) indicated that low impact open green space uses may be made of the WMU. Post-closure usage will not disturb the integrity of the final cap and cover system.

### Liner System

Design: Base Grades Plan (9/1994) shows the early phases of Site D construction consisting of Phase 1 (13.2 acres), Phase 2 (14.1 acres), Phase 3 (13.6 acres), and Phase 4 (14.5 acres). The early phases of Site D construction (constructed from 1989 through 1994) have a minimum of 3 feet low permeability earthen liner underlain by a minimum of 7 feet of in-situ clayey soil layer. The in-situ clayey soil layer has an average permeability of 2.3x10-6 cm/sec. The compacted low permeability soil has an average permeability of 3.0x10-8 cm/sec. The later phases of Site D construction consist of Phase 5 East and West (15.8 acres), Phase 6 East and West (15.8 acres), Phase 7 North and South (15.9 acres), and Phase 8 North and South (14.6 acres). The later phases of Site D construction (constructed from 1996 through 2000) have a composite liner consisting of a 12-inch thick granular leachate drainage layer with a minimum permeability of 1x10-2 cm/sec, underlain by nonwoven geotextile cushion, underlain by a 60-mil, high density polyethylene (HDPE) geomembrane (as the upper component of the composite liner) underlain by 3 feet of low permeability earthen liner with a maximum permeability of 1x10-7 cm/sec (as the lower component of the composite liner).

From boring logs, there is typically 30 to 50 feet of separation between the bottom of the waste cells and the top of the upper hydrostratigraphic unit (loess and alluvial material). There is a basegrade low point (1,212 feet NGVD) at the lowest sump (Sump #1) located on the southeast corner of the WMU. Figure D-2 show the lowest point near Sump #1 and a basegrade line. Based on review of groundwater elevations in the two proximal shallow down-gradient wells, which range between 1,200 and 1,203 feet NGVD, groundwater levels historically have been 9 to 12 feet lower than the WMU basegrades.

CQA and Construction Records: The CQA report for the soil liners constructed in Phases 1 through 5 East are included in the Title 132 Compliance (Rust, 1/1996). Nine subsequent CQA reports for the liners constructed in Phases 5 West through Phase 8 South are available on-site.

As-Built Drawings: A Base Grading Plan (Figure 3, 2/1989, WMN) includes pit-bottom grades and leachate collection plan for phases 1 through 5. A Base Grading Plan (Figure 9, 9/1994, Rust) includes pit-bottom grades and leachate collection plan for phases 5 West and 6 East and 6 West. A Base Grading Plan for subsequent phases 7 and 8 was not found.

## Leachate Management System

Layout and Design: The leachate collection system consists of 14 sumps located around the perimeter of the WMU and leachate collection system. The leachate collection system is designed to prevent head build-up at the lowest point in the collection system to less than 6 inches. The top of the cohesive soil liner is sloped toward the sumps, providing positive drainage. Six parallel lines of perforated piping was placed from north to south, extending between the six pairs of LCRS sumps LCRS-1 through LCRS-12. The two parallel lines of perforated piping placed from north to south beneath Phases 7 and 8 extend to LCRS-13 and LCRS-14 located along the north side of the lateral expansion. Details on construction of the LCRS installed in Phases 1 through 5 East were not found. Construction of the LCRS installed in Phases 5 West through 8 along the west sides of the WMU included a 12-inch thick granular leachate drainage layer with a minimum permeability of $1x10^{-1}$ cm/sec placed over the nonwoven geotextile cushion over the HDPE geomembrane and earthen liner, to provide additional porous media to transmit leachate to the sumps.

During the active life of the WMU, leachate was collected from all phases and recirculated in Phases 5W, 6E, and 6W, the composite lined phases. Excess leachate unable to be recirculated was stored on-site in a pair of 20,000-gallon aboveground storage tanks until it could be recirculated or transported to a local WWTP for final disposal. After the WMU was closed, all the leachate was pumped to a tanker truck and stored on-site in aboveground storage tanks prior to disposal (PMA 1996).

CQA and Construction Records: N/A

As-Built Drawings: Leachate LCRS-1 through LCRS-12 collection sump schedule (invert and collection line inverts) are included on the Base Grading Plan (2/1989).

Leachate Generation Rate: Paper data are available of leachate generation by LCRS in gallons per month, between 1993 through 2005.

Leachate Recirculation and/or Disposal: State approval for leachate recirculation was requested at the end of 1995, for areas that have a composite liner system. These areas were to include Phase 6 and the west half of Phase 5. Leachate was to be pumped from the collection sumps,

transported to the infiltration area, and discharged. Temporary infiltration areas were to be placed on selected lifts of waste, in areas of 50 feet by 30 feet cut into the daily cover, and a one-foot high soil berm around the windowed area.

Leachate Sampling and Data: Under the Leachate Management Plan (5/1991), leachate within the leachate storage tanks was composited from all available leachate collection sumps, sampled quarterly for two years (2Q1991 through 2Q1993), and sampled annually in the 3Q thereafter. Leachate sample data exist for one location, LCTK, which is a composite sample of untreated leachate. An electronic data set includes 21 sampling events between 6/1991 and 12/2007 for 123 analytes, including chloride, COD, and BOD. Monthly measure of leachate levels exist for 2004 in site files.

*Leachate Data (Electronic)*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Composite Sample (untreated), LCTK | 21 | 6/1991, 12/2007 | 123 | 1000 | 100-5000 | 500-2500 |
| LCS-01 through LCS-14 | 7 | 8/2001, 12/2007 | 3 | -- | -- | 10 |
| LCS-02 | 2 | 8/1996, 2/2000 | VOCs & metals | -- | -- | 10 |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: None reported.

## Cover System

Design: The 9/1994 Final Cover Plan drawing shows the original soil cover over the oldest portion of the WMU along the east side as in-place, and the plan for the cover to be placed progressively toward the west and central portion of the WMU, covering Cells 1 through 4. The areal extent of the original final cover is approximately 55 acres. The original final cover is described in the PMA (1/1996) as overlaying areas with a clay liner, and consisting of (from top to bottom), a minimum 18-inch thick topsoil/vegetative cover, and a minimum of 24-inch thick recompacted cohesive soil having a maximum permeability of <1x10-7 cm/sec. The original soil cover was constructed in 1990, 1991 through 1994, 1996, 1998, and 2000.

The PMA (1/1996) describes the newer cover system over the newer portion of the WMU, covering the west half, over Cells 5 through 8. The areal extent of the newer final cover is approximately 65 acres. The newer final cover is described in the PMA (1/1996) as overlaying areas with a composite liner, and consisting of (from top to bottom), 18-inch thick vegetative cover and protective soil; a drainage layer consisting of geocomposite drainage blanket; a 40-mil HDPE geomembrane, textured on both sides, cap as the upper component of a composite cap

system on 25 percent final grades (smooth on both sides on 5 percent final grades); and 24-inch thick, low permeability earthen cap having a maximum permeability of <1x10-55 cm/sec as the lower component of a composite cap system. The geomembrane and recompacted cohesive soil would serve as the composite cap system.

CQA documents and certification of Phases 1 through 5, dated 11/1989 through 4/1994, are available on-site. Other CQA documentation of Phases 5 through 8, dated 5/1994 through 1/2002, also are available. The "2000 Final Cover Construction" shows the year of construction of the newer cover system, and tie-in to existing cover, as constructed in 1994, 1995, and 1998.

The 1/2004 Final Capping Plan drawing shows the new cap over the newer portion of the WMU along the west side of the original cells (Cells 5 and 6) and over the lateral expansion cells (Cells 7 and 8). An area of overlap and tie-in to previously capped areas occurred along the west portion of Cells 2 and 4. The areal extent of the new cap is approximately 65 acres. The new alternate final cover (AFC) is described in the Quality Assurance report – Final Cover System constructed in 2006 as consisting of three layers (from top to bottom), a 6-inch thick vegetative soil cover layer; a 48-inch thick clay layer; and a intermediate soil cover layer of either 6 inches or 12 inches (depending on location) placed over the daily soil cover. The original place for the final cover was a 30-inch clay layer. In actuality, a 48-inch clay layer was constructed.

Soil placed prior to the 2006 final capping system was referred to as existing intermediate soil cover. The 2006 Final Capping System requirements for the intermediate soil cover layer of either 6 inches or 12 inches (depending on location) was based on a minimum of 6 inches of intermediate soil cover on the side slopes (slopes > 10 percent), and a minimum of 12 inches of intermediate soil cover on areas < 10 percent. The 1/2004 design details show that in areas of transition between the old final cover and the new final cover, that existing vegetative cover soil was to be removed to expose the recompacted clay layer, and a stepped transition was to be constructed into the existing recompacted clay layer.

The maximum design elevation was to be 1,400 feet NGVD over the center (crest) of the WMU. The final design elevation over the western portion of the WMU is between 1,380 and 1,390 feet NGVD.

CQA and Other Construction Records: The Quality Assurance Report for the Final Cover System Constructed in 2006, dated 4/2007, was reviewed. However, the Closure/Post-Closure Plan, which includes a Final Cover System Performance Monitoring Plan and new CQA Plan addressing the new CQA requirements for the AFC system for Phases 5 through 8 was not available for review, but was to have been submitted to the State by 5/2008 and to be available by 8/2008. In lieu of reviewing the C/PC Plan and CQA Plan, previous documents were available, as follows. Final closure was completed in stages commencing in 11/1989 and completed by 2006, in accordance with the following sequence: Certification of Phase 1 (11/1989), Phase 2 (8/1990), Phase 3 (8/1992), Phase 4 (4/1994), East Half Phase 5 (5/1994),

West Half Phase 5 (9/1996), East Half Phase 6 (11/1995), West Half Phase 6 (11/1987), Phase 7 (10/1999), North Phase 8 (10/2000), South Phase 8 (1/2002).

Final cover soil testing of the 48 inch clay soil layer was conducted using in-place density and moisture content tests using a nuclear densitometer, and using Shelby tubes (for laboratory testing of hydraulic conductivity). The results of soil testing are appended to the Quality Assurance Report for the Final Cover System Constructed in 2006 (4/2007) but were not reviewed or obtained. Closure certification was to be included in the 5/2008 report. Closure certification has not been issued by the State to date.

As-Built Drawings: Not available.

Topographic Surveys: No topo surveys were available. A fly-over of the final cap was to have been done in 2007, but was not available.

Cover Monitoring and Maintenance: The cover is regularly mowed twice each year. All gas collection and control system (GCCS) components except wellheads are buried. Monthly Title V wellhead monitoring program includes visual inspection of cover vegetation and erosion. Quarterly surface scans for fugitive methane emissions have been conducted since 2000. The cap does not have erosional issues or geotechnical instability, according to the site engineer. It was noted that fill was placed around one gas well (#18) due to settlement. A settlement analysis has not been performed. Monthly cover integrity inspections conducted during 2001 indicated that fill was placed around gas well #18 and #39 in the summer months.

Compliance Issues and Community Concerns: None reported.

## Landfill Gas Control System

Active Gas Control System: Installation of a network of approximately 23 wells was completed by prior to 2004 in Phases 1 through 6. An additional 37 wells and gas collection header and associated piping installation was completed by 4/2006 in Phases 7 through 8. This timing is based on a Gas System Location Plan, dated 4/2006, indicating that gas well locations on the original Phases 1 through 6) are estimated, and gas well locations on the lateral expansion Phases 7 and 8 are accurately located. The landfill GCCS was expanded as part of NSPS requirements for the vertical expansion. Based on an example wellfield log from December 2001, the system consisted of 39 active wells at the end of 2001. The system consisted of approximately 56 wells in 2008.

Gas Utilization: LFG extracted from the WMU is collected and processed at a Landfill Gas-to-Energy (LFGTE) Plant, located near the southeast corner of the WMU. The LFGTE Plant was built in 2001. The WMU currently produces enough gas to run seven generator engines. All the gas is being used to generate electricity. Gas can be flared at a single location located west of the LFGTE plant. The gas flare was installed 10/1998. The estimated average flow from the flare in

2000 was 1130 cfm. The estimated gas produced in 2000 was 3,173,665 scfd, or the fuel equivalent of 47.0 mm BTU/hr.

Passive Gas Vents: None.

Construction Details and As-Built Drawings: As-built information for the active GCCS is provided on a single sheet dated 4/2006. A table of well bore depths was not available.

Landfill Gas Data: Monthly Title V wellhead monitoring is performed at all current (in 2000) 39 wells. Total flow is recorded monthly and ranged from 15 to 97 cfm in 12/2001.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Wellheads | Semi-annual reports of monthly flow (not obtained) (P – 1997-2001); (E – from 2005 to present) | Semi-annual reports of composition (not obtained) (E – from 2005 to present) | |
| Surface Scans | N/A | Quarterly, incomplete, Observed 1Q01, 2Q01 (P) | Methane content only |

Compliance Issues and Community Concerns: None reported.

## Groundwater Monitoring System

Layout: Two hydrostratigraphic units are monitored at the WMU, designated "S" for shallow hydrostratigraphic (unconsolidated) and "D" for deep hydrostratigraphic (Dakota bedrock). Fourteen wells are included in the monitoring system, including: three up-gradient wells (MW-102S, MW-106S, MW-18D); seven cross-gradient wells (MW-10S, MW-101S, MW-104S, MW-105S, MW-13S, MW-16D, MW-17D); and four down-gradient wells (MW-201S, MW-202S, MW-14D, MW-15D). Most of the shallow wells were installed in 1989. As part of the lateral expansion, shallow well MW-106S was installed in 12/1998. Deep wells MW-14D and MW-15D were installed in 9/1990 and 10/1990, and MW-16D and MW-17D were installed in 6/1991. The final two shallow wells (MW-201S and MW-202S) were installed in 1/2001 to replace two older shallow wells.

Monitoring Program: The Groundwater Monitoring and Reporting Plan (4/2001) indicates that the wells are monitored semi-annually for primary leachate indicator parameters (Ammonia Nitrogen, Chloride, Sodium, Iron, TDS, TOC, TOX, and COD) and annually for 15 metals and 47 VOCs.

Construction Details: Boring logs for MW-201S and MW-202S, and well completion details for all wells, are available for all wells in the Groundwater Monitoring and Reporting Plan (4/2001),

Table 6-2, Monitor Well Completion Details. Boring logs for older wells are in the PMA (1/1996), Appendix B.

Groundwater Data: A summary of analytical data is provided in the table below. Data are available for all parameters for which monitoring is required by the State.

*Groundwater Data (Electronic)*

| ITEM | Number of Wells, Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* |
|---|---|---|---|---|---|
| Up-gradient, proximal MW-102S | 1, 32 | 5/1990, 6/2007 | 101 | 1 | 10 |
| Up-gradient, proximal MW-106S | 1, 13 | 4/1999, 6/2007 | 78 | 1 | 10 |
| Up-gradient, proximal MW-18D | 1, 15 | 4/1999, 6/2007 | 77 | 1 | 10-100 |
| Cross-grad., proximal MW-10S | 1, 27 | 5/1990, 6/2007 | 95 | 1 | 10 |
| Cross-grad., proximal MW-13S | 1, 33 | 5/1990, 6/2007 | 95 | 1 | 10 |
| Cross-grad., proximal MW-101S | 1, 34 | 5/1990, 6/2007 | 95 | 1 | 10 |
| Cross-grad., proximal MW-104S | 1, 16 | 10/1994, 6/2007 | 78 | 10 | 10 |
| Cross-grad., proximal MW-105S | 1, 16 | 10/1994, 6/2007 | 84 | 1 | 10 |
| Cross-grad., proximal MW-16D | 1, 27 | 9/1991, 6/2007 | 96 | 1 | 10 |
| Cross-grad., proximal MW-17D | 1, 27 | 9/1991, 6/2007 | 95 | 1 | 10 |
| Down-grad., proximal MW-201S | 1, 14 | 3/2001, 6/2007 | 79 | 10 | 0 |
| Down-grad., proximal MW-202S | 1, 14 | 3/2001, 6/2007 | 79 | 10 | 0 |
| Down-grad., proximal MW-14D | 1, 35 | 1/1991, 6/2007 | 95 | 1 | 10 |
| Down-grad., proximal MW-15D | 1, 30 | 1/1991, 6/2007 | 95 | 1 | 10 |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: No compliance issues or community concerns were reported.

Landfill gas effects to groundwater occurred at the WMU in 1992 at well MW-08S. The VOC Dichloro-difluoromethane (DCDFM) was reported in groundwater from well MW-08S in an

original sampling event, and two subsequent sampling events. DCDFM was not found in leachate data from the nearby sump for the previous two years. Methane was found in nearby barhole probes. Two assessments were conducted 3/1994 and 1/1995 and both reached the same conclusion: the logical source of DCDFM in the groundwater was landfill gas. An additional well was installed down-gradient of well MW-08S. No exceedances were measured in new well MW-105S. Well MW-08S was abandoned.

More recent SSIs were reported to the State, based on an initial exceedance of ammonia from well MW-13S in June 2007, and TOC from well MW-202S. Both initial SSIs were within the range of historical values, and were determined to be due to natural geochemical changes in the groundwater or some other natural cause, and not indicative of a release from the WMU. Detection groundwater monitoring continues at the WMU.

### Surface-Water Monitoring System

Locations: Surface water at the WMU is limited to the floodplain and intermittent stream, referred to as a drainage ditch, and located to the east of the WMU. Drainage flows onto the WMU at the north boundary (sample point SWS01), and flows from the WMU at the south boundary (sample point SWS02). A sedimentation pond exists between the surface drainage and the WMU near the southeast corner. Surface water from the WMU collects in a rip-rap lined channel, which discharges into the sedimentation basin. The sedimentation pond will discharge to the intermittent stream. Surface-water samples were collected at the sedimentation pond in 1999.

Monitoring Program: According to the Groundwater Monitoring and Reporting Plan (4/2001), surface-water monitoring is performed if water is flowing. Monitoring frequency is semi-annual for TOC, Chloride, Iron, Nitrate, Nitrite, Ammonia as N, and TKN. Surface-water samples were collected semi-annually in 2003, 2004, and 2007 at points SWS01 and SWS02, but are not available electronically.

The electronic surface-water data set for Site D includes data for the sedimentation pond for 5/1999 and 12/1999.

Surface-Water Data: Available data from the electronic database are summarized in the table below.

*Surface-Water Data (Electronic)*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Pond NW | 1 | 12/1999 | 15 | 10 | -- | -- |
| Pond SW | 1 | 12/1999 | 15 | 10 | -- | -- |
| Sedimentation Pond | 1 | 5/1999 | 25 | 10 | -- | -- |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: None reported.

## Methane Migration Monitoring (MMM) System

Layout: A methane migration monitoring plan was not identified, but the WMU has four permanent gas probes (GP-1 through GP-4) located on the four sides of the WMU. Total depths of the gas probes were not found. Quarterly monitoring has been conducted since 2002 through the present. Prior to 2002, data were collected quarterly at 21 barhole locations (BH-1 through BH-21) between 5/1991 through 1/1994. The locations and total depths of the barholes were not found.

Monitoring Plan and Data: Methane migration monitoring of perimeter gas probes and buildings is required quarterly (Groundwater Monitoring and Reporting Plan, 4/2001). Quarterly monitoring data exist for 2002 through 2005, and likely through the present.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Start, End | Frequency | Notes |
|---|---|---|---|
| Perimeter Probes, GP-1 to GP-4 | 2002, 2007 | Quarterly | P, incomplete (likely complete Electronically) |

Compliance Issues and Community Concerns: None reported.

**FIGURE D-1**
**Site D Physiographical Setting**

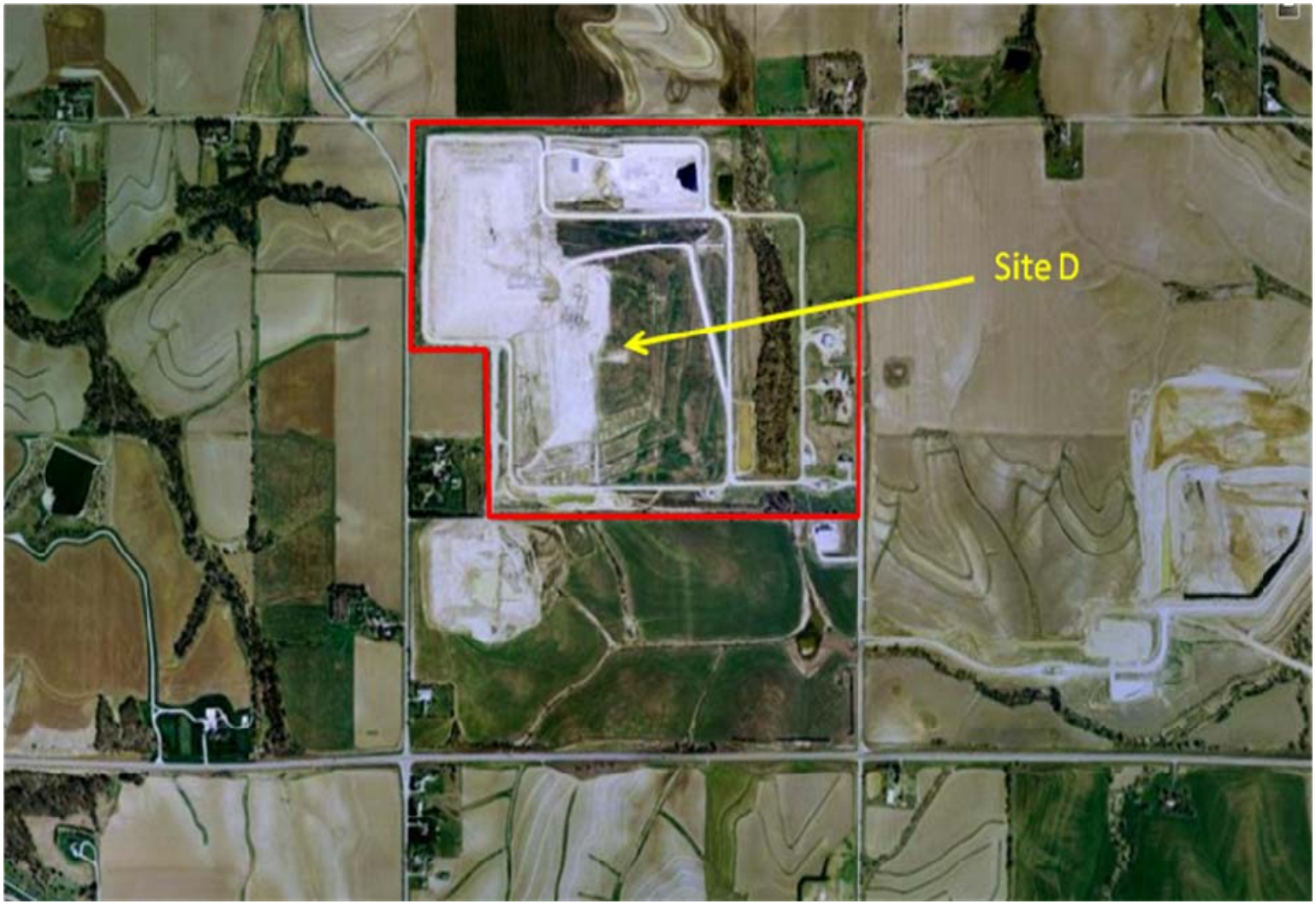


**FIGURE D-2**
**Site D Layout and Features**

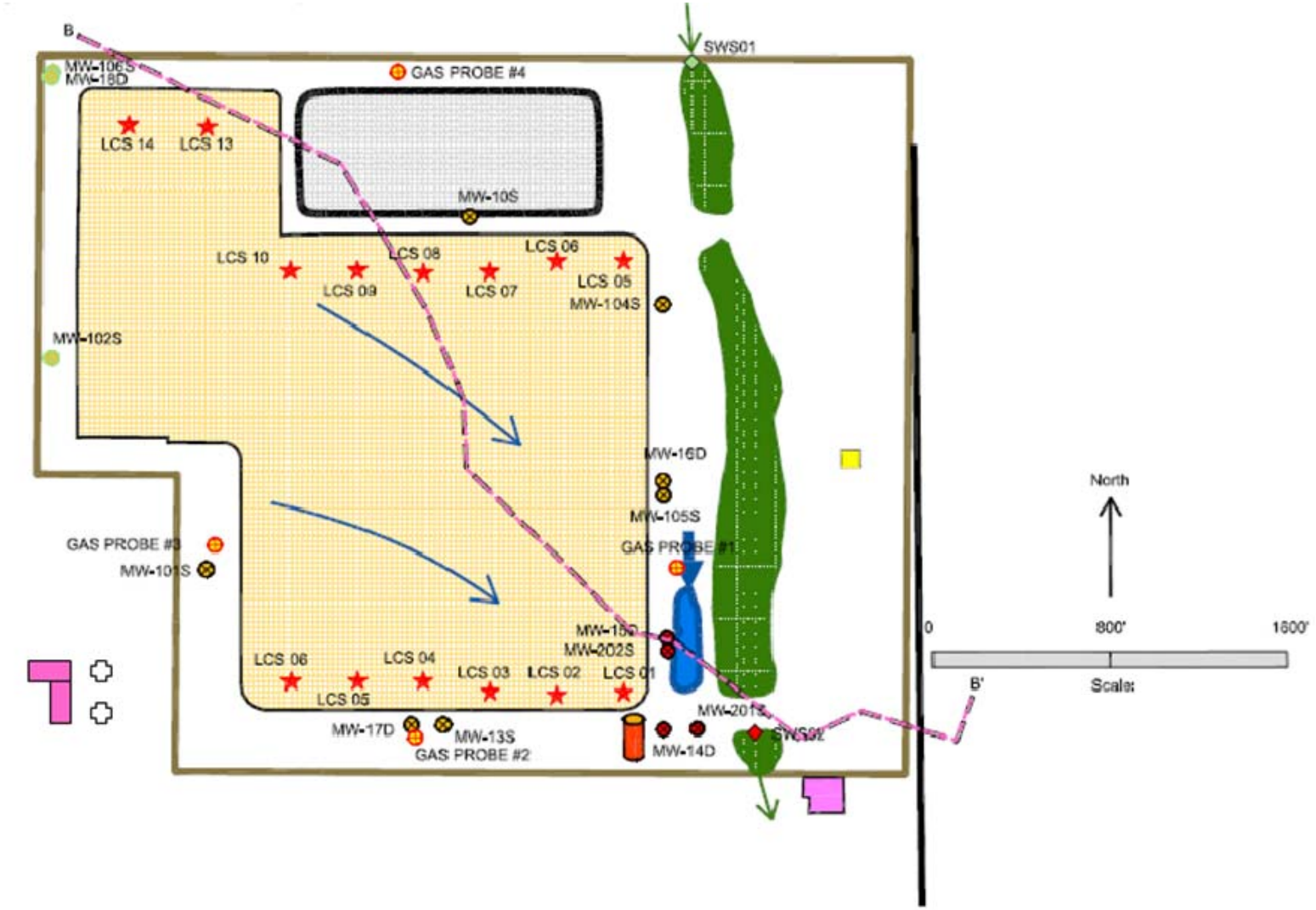
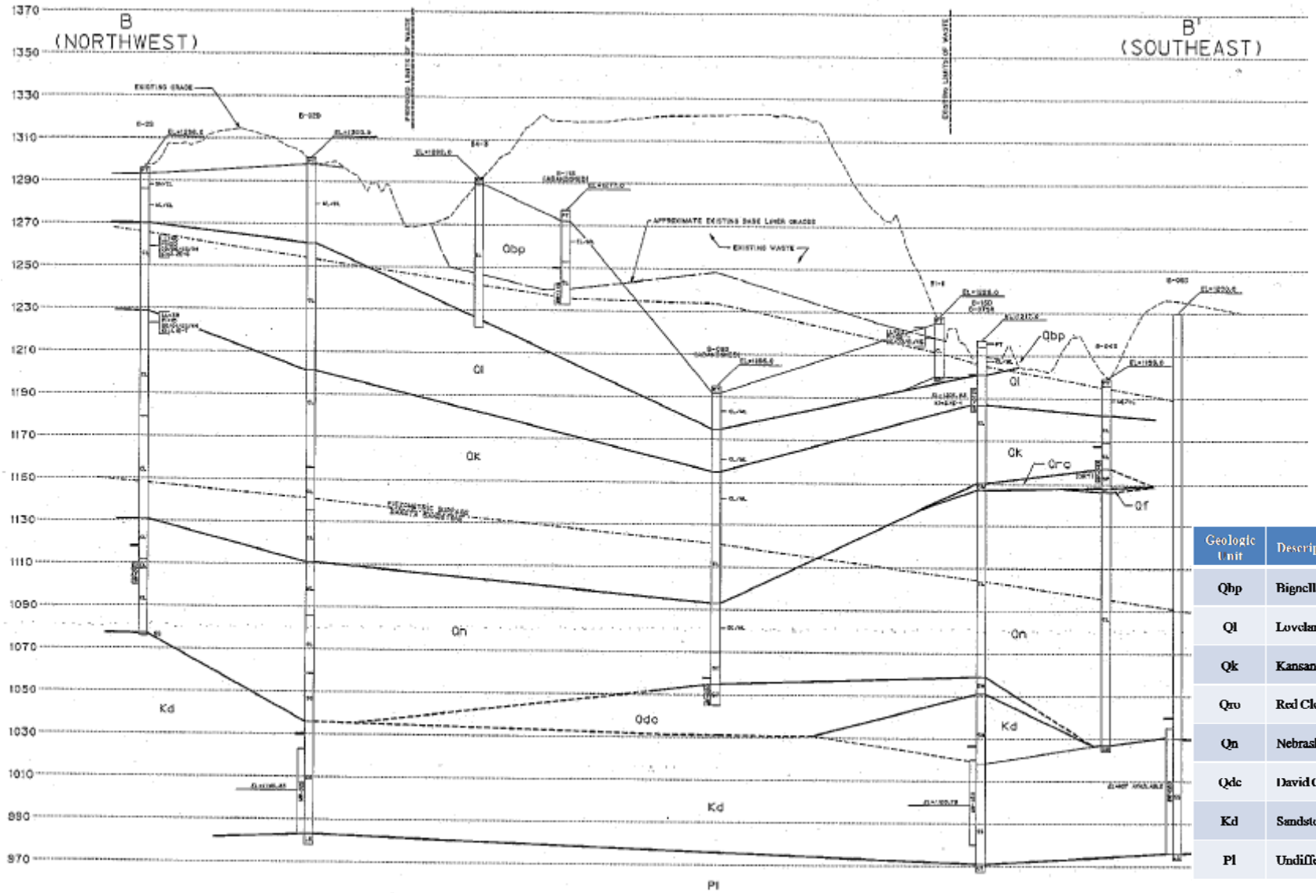


**FIGURE D-3**
**Site D Geologic & Hydrogeologic Cross Section**




| Geologic Unit | Description |
|---|---|
| Qbp | Bignell/Peorian loesses |
| Ql | Loveland loess |
| Qk | Kansan till |
| Qro | Red Cloud sands and gravels |
| Qn | Nebraskan till |
| Qdc | David City formation |
| Kd | Sandstone shale |
| Pl | Undifferentiated limestone |

## APPENDIX 2-1E

## SUMMARY – SITE E (MICHIGAN)

### Overview

Study WMU: Site E is an unlined WMU with an approximately 77-acre footprint and constructed with about 180 feet maximum thickness of waste and 100 feet average thickness of waste. The Title V Operating Permit Application dated 5/1997 states that the WMU has an estimated capacity of 11 MM CY. The WMU opened in 1983 and stopped receiving waste in June 1994. WMI has been the sole owner and operator.

Property: Site E is the single permitted WMU on the property. The total property size is 105 acres, of which 77 acres are permitted for solid waste disposal. An older 61-acre WMU, which closed in 1983, is located to the north of Site E, separated by a major rail. An active 148-acre WMU, which opened in 1994 with a maximum permitted area of 148 acres, is located to the south of Site E, separated by a major road. Site E consists of 12 disposal cells underlain by a natural clay liner of less than $10^{-7}$ cm/s permeability. The landfill was excavated to about 30 feet below grade, and underwent three stages of vertical expansion which raised the maximum elevation at closure to about 160 feet above grade.

The physiographical setting of the property and WMU is shown on Figure E-1. A stylized depiction of the site layout is provided as Figure E-2.

### Site Information

Geologic and Hydrogeologic Setting: A comprehensive Hydrogeologic/Geotechnical Investigation (H/GI) was prepared in 3/1990 that incorporated previous investigations conducted for the adjacent landfill to the north and its expansion, for the WMU (Site E) landfill and its expansion, and for the adjacent landfill to the south. The H/GI was revised in 11/1990 and again in 3/1991. An Environmental Impact Assessment was prepared in 11/1992 in support of the third and final vertical expansion of the WMU. The 3/1990 comprehensive H/GI provides a review of regional geology and hydrogeology.

The site is located in a relatively flat-lying glacial till plain. Surface relief (pre-landfilling) was gently sloping to the northeast. Typical of clayey glacial terrain, surface drainage features were not well developed. Surface water at Site E has been configured to flow around the site in two surface drainage ditches. Both drains flow from south to north.

The geologic units at Site E are subdivided into three major hydrogeologic units: a homogeneous silty clay till from ground surface to about 70 feet below ground surface (bgs); underlain by a very dense coarse-textured basal till (early Wisconsin or late Illinoian); underlain by bedrock units of either Devonian Antrim Shale or Antrim Group. The bedrock formation consists of shale, limestone, and dolomite, and is encountered at depths ranging between 85 and 110 feet bgs. The silty clay till is not considered to be an aquifer because of very low permeability. The basal till is considered the uppermost aquifer, in which groundwater occurs within strata described as ranging from sand with some silt and some gravel, to hard clay and silt with some fine-grained to coarse-grained sand and some gravel within the overall "hardpan" till. The bedrock is a water-bearing unit beneath the adjacent WMU north of Site E, but is not monitored beneath Site E.

Saturated Zone: The H/GI describes a site-specific hydrogeologic study based on 8 soil borings advanced in 1990. These borings penetrated to between 68 and 98 feet bgs. Previously, approximately 20 boreholes and four monitoring wells had been advanced during 1981 through 1983 as early investigations of soil and bedrock. The surficial unit present at Site E is a veneer of lacustrine clay and loam. The groundwater surface is present at 1.0 to 2.5 feet bgs, and is locally affected by discharge to surface drainage ditches on the WMU perimeter.

The predominant glacial unit (silty clay till) underlying the site extends from the ground surface to a typical depth of about 70 feet bgs. The silty clay till ranges in thickness from 68 to 72 feet. The uppermost sediments generally consist of 5 to 15 feet of weathered brown and gray mottled silty clay which is underlain by an unweathered gray till stratum. Both the weathered and unweathered silty clay till units contain some sand and gravel. Although the silty clay till is relatively competent stratum, it is significantly less consolidated than the underlying coarser basal till unit. The unweathered silty clay till is reported to have horizontal and vertical hydraulic conductivities of less than 1x10-7 cm/sec. Lenses and seams of sand and silt present within the silty clay till range in thickness from less than one inch to 34.4 feet. These more permeable sand lenses and seams are generally discontinuous and average less than five feet thick. The sand lenses and seams are reported to have hydraulic conductivities of about 4x10-4 cm/sec.

The silty clay till is underlain by 21 to 38 feet of relatively coarse-textured basal till, referred to as "hardpan." The basal till thickness increases from northwest to southeast across the site. The basal till ranges from a hard gray silty clay with some fine to medium sand and a trace of fine gravel (CL) to a very dense gray fine to medium sand with some clay and silt and a trace to some gravel (SM). Cobbles and boulders are occasionally present. The hydraulic conductivity of the basal till ranges between 3x10-7 to 4x10-5 cm/sec.

The basal till is underlain by bedrock at 85 to 110 feet bgs. The bedrock consists of interlayered shale, dolomite, and limestone of the Traverse Group, and also the Antrim shale. The shale is

slightly weathered to unweathered, dark gray to black, soft to very soft, and contains limestone stringers. The limestone is slightly weathered to unweathered, gray to dark gray, unfractured, fossiliferous, and contains occasional shale lenses. The variation in the amount of weathering produces a range of hydraulic conductivity values (for the adjacent WMU properties) between 1x10-5 and 4x10-8 cm/sec.

Boring Logs: A typical N-S cross-section, included as Figure E-3, was presented in the 1991 H/GI Report. Boring logs from groundwater monitoring well installation are available for all 12 monitoring wells (in the 2001 revision to the Hydrogeologic Monitoring Plan). These include two wells on the adjacent WMU to the north that are used to distinguish between off-site and on-site up-gradient groundwater quality.

Hydraulic Conductivity: Although the predominant glacial unit underlying the Site E WMU is a silty clay till, the underlying basal till is sufficiently permeable relative to the overlying silty clay till unit to be considered the uppermost aquifer beneath the site. The basal till stratum is the primary pathway for horizontal groundwater flow beneath the site. Field tests performed in the basal till beneath the adjacent WMU to the north provided hydraulic conductivity values ranging from 3x10-7 to 4x10-5 cm/sec. Field tests performed in the basal till beneath Site E provided hydraulic conductivity values ranging between 1x10-5 to 2x10-4 cm/sec. Field tests performed in the basal till beneath the adjacent WMU to the south provided hydraulic conductivity values ranging between 2x10-6 and 3x10-5 cm/sec.

Groundwater: Groundwater elevations are recorded during groundwater monitoring events and flow beneath the property is well-characterized. The original eight monitoring wells were installed in the silty clay till stratum. These original site wells provided inconsistent water-level elevation data based on a wide variation in completion depths, and poor hydraulic communication between different sandy zones and thin sand seams being monitored. Groundwater data from piezometer clusters completed at the adjacent WMUs found a vertical component of hydraulic gradient which was downward through the silty clay till toward the underlying basal till. The average vertical gradients were between 0.14 and 0.23 ft/ft. Because the silty clay till stratum has low hydraulic conductivity and thin, discontinuous sand units, the silty clay till was determined to not provide a laterally extensive groundwater flow path beneath the WMU. The eight original wells were abandoned when it was recognized that it was unlikely that a release from Site E would be detected by the wells completed in silty clay till.

Eight new groundwater monitoring wells were installed and completed in basal till in 1990. Groundwater is present in the upper portion of the basal till unit under confined conditions. Potentiometric data indicate that the lateral component of groundwater flow within the basal till, which is the uppermost aquifer beneath Site E, is toward the south and southeast. The average horizontal component of hydraulic gradient is 0.006 ft/ft.

Groundwater data from the adjacent WMUs show that groundwater also occurs under confined conditions within the bedrock underlying the basal till. Potentiometric levels in the bedrock in the vicinity of Site E often are higher than in the basal till in the WMU north of Site E, and lower than the basal unit in the WMU south of Site E. This suggests that the basal till may locally be either a recharge or a discharge zone for the underlying bedrock.

Potentiometric maps for 1991 to 1999 show minor variation in the potentiometric surface and flow directions beneath Site E. Groundwater elevations range from 654 to 665 feet NGVD in proximal up-gradient wells GA-33C and GA-34A, and from 635 to 660 feet NGVD in proximal down-gradient wells MW-104, MW-105, MW-106, MW-109 and MW-110. This means that the seasonal high GW elevation is consistently above the minimum base of waste elevation (633 feet NGVD) at down-gradient Sump LCR-6.

Unsaturated (Vadose) Zone: The vadose zone, shown on Figure E-3, is the upper part of the weathered and unweathered silty clay till that overlies the uppermost aquifer (the basal till). Details regarding vadose zone soil description are available on boring logs attached to the Groundwater Monitoring Plan, 9/1994, which may be important to consider when completing the landfill gas and groundwater modules. In general:

| | |
|---|---|
| Elevation of lowest sump LCR-06 | Approximately 630 feet msl |
| Elevation of groundwater | 635 to 644 feet msl |
| Hydraulic conductivity (assume isotropic, $K_v = K_h$) | 10-5 cm/sec |
| Assumed porosity of till | 0.10 to 0.20 (Fetter, 1988) |
| Assumed thickness | Zero (based on boring log data and geologic cross-sections) |

Physiographical Setting: The pre-WMU topography was flat, glaciated terrain. The Environmental Impact Assessment Addendum No. 3 (11/1992) describes the natural drainage for the site as being toward the north and into a river located approximately one-half mile away. Two surface drainage ditches, locally called drains, are adjacent to the site, and divert surface-water flow around the WMU. The two drains discharge into the river. The WMU is not located in a floodplain and is outside of any 500-year floodzone. The WMU includes the two surface-water drains and one small stormwater pond, but does not contain any natural wetlands areas.

Potential Point(s) of Exposure: There are no occupied structures on the WMU. Locations of off-site houses and other structures are estimated based on review of a recent Google EARTH© map aerial photograph and site reconnaissance. There are no on-site water wells on the WMU. There are no known domestic water wells located within one mile of the WMU. For purposes of POE consideration, the nearest buildings are assumed to have private water wells. The closest inhabited residence was located approximately 230 feet southeast of the WMU boundary in 1991 (Engineering Report for the Vertical Expansion, 3/1991). The 1994 Hydrogeologic Monitoring

Plan references poor groundwater quality in the county and rare local usage of groundwater. Water supply wells in the area usually are screened in sand and gravel outwash zones within glacial drift deposits. Such glacial outwash zones typically are horizontally discontinuous and not considered to be regionally significant. The basal till aquifer beneath Site E is not considered to be such a zone. Municipal and community water supplies in the area are from surface water sources.

Climate: Meteorological data included in an appendix to the Environmental Impact Assessment Addendum No. 3 (11/1992) indicate that the prevailing wind direction is from the southwest at an average of about 10.4 mph); the annual mean precipitation is 32.29 inches; and the annual mean temperature is 48.5 degrees F. Meteorological data are collected at a private weather station located adjacent to the WMU.

## Waste Placement and Operations

General: The Site E WMU consists of 12 disposal cells, typically excavated to about 30 feet below grade, or 640 feet NGVD, between 1983 and 1989. The original WMU design (10/1987) was updated (5/1989). The initial design of the WMU was to a maximum elevation of 740 feet msl, based on the earliest available (1/1983) as-built pit bottom plan. A series of vertical expansions in 3/1990, 3/1991, and 11/1992 brought the final maximum WMU elevation to 830 feet NGVD.

Design plans for vertical expansion of Site E provide some operations details (3/1991). Refuse was to be placed in multiple 2-feet lifts with 6-inches of daily cover. A 12-inch intermediate cover was required over any area would be inactive longer than one month.

Waste Placement Data: A summary of annual waste receipts is available from the Landfill Gas Collection and Control System (GCCS) Design Plan dated 5/1997. The site operated between 1983 and 1994. The site did not have a scale so there are no waste weight receipt records. Annual waste placement is reported to have been between 450,000 and 820,000 tons. Total estimated waste-in-place is 6,700,000 tons or 11MM CY.

Waste Composition: Details of waste composition are mostly unknown. The EIS (11/1992) indicates that the waste stream is classified as nonhazardous and consists of municipal refuse and commercial and industrial waste. Nonhazardous industrial wastes disposed at this WMU consisted primarily of fly ash and industrial and municipal sludges.

## Closure and Post-Closure (C/PC) Plan

The certification of final closure was submitted April 1999.

A C/PC Plan (5/1995), mostly concerning sequencing of closure and post-closure events, was revised 5/1996, but has not yet been approved by the regulatory agency. The C/PC Plan was

revised to modify the closure schedule and delay placement of the final cover based on landfill gas concerns and installation of a new gas flare. The post-closure use of the WMU acknowledged in the C/PC landfill is intended as a "gas generation area" with "no public access."

Gas extraction was expected to occur for at least 15 years after closure (End Use Plan, 1992). Methane gas management was controlled by in-place perimeter clay sidewalls, naturally existing cohesive soil, and an active gas extraction system. The gas management system consists of 44 gas extraction wells connected by 12-inch header lines. The wells were installed by drilling through the waste to a depth of approximately 5 to 10 feet above the top of the liner. Vacuum is supplied to the wells through a header pipeline which originates at a compressor station located northeast of the landfill. The gas is either processed for use at a nearby industrial complex or flared if not needed. Landfill gas monitoring is conducted weekly at a minimum to assess the quality and effectiveness of the gas extraction system, and to monitor changing gas quality and production levels.

The cover is to be inspected quarterly for 30 years after certification of final closure. In addition, surface-water control structures, groundwater monitoring wells, and the leachate system are to be inspected regularly. Site access control is to be provided by fencing.

The C/PC Plan (5/1995) specifies that, for 30 years following closure: groundwater monitoring at 12 wells will be done semi-annually; leachate level and leachate monitoring will be done annually; leachate volumes discharged will be recorded quarterly; landfill gas monitoring at 15 barhole probes will be done quarterly, and the facility will be inspected annually. There are no PC monitoring requirements for surface water, although surface water data exist for the period of 12/1984 through 5/2007.

### End Use Strategy

As included in the Post Closure Plan (5/1995), there are no end use plans for the WMU other than as greenspace. Therefore, it is not expected that post-closure use of the WMU after landfill gas production will damage the integrity of the cap, monitoring systems, or other site features.

### Liner System

Design: Site E is a naturally lined facility. The liner system consists of 10 feet of natural cohesive soil with a permeability of less than 1x10-7 cm/sec. Excavation of 12 cells from 1983 to 1989 was to have been certified to leave a minimum of 10 feet of clay beneath waste, certified by drilling to verify thickness. A total of 101 soil borings were advanced at the base of the cells and sidewalls, and reported along with laboratory testing results (Engineering Report, 3/1991). Based on the hydrogeologic investigation, the natural clay thickness ranges between 36 and 53 feet. Of the 36 permeability tests conducted on the clay liner, results ranged between a

maximum of 1.0x10-7 cm/sec to a minimum of 3.9x10-9 cm/sec, with an average of 3.3x10-8 cm/sec. A 1983 "As-built pit bottom plan" shows the locations of the soil testing, as included in the 3/1991 report table summarizing the certification laboratory data.

From boring logs, there is typically 40 to 50 feet of separation between the bottom of the waste cells and the top of the uppermost aquifer (basal till) (Hydrogeologic Monitoring Plan, rev. 4/2001). There is a basegrade low point (633 feet NGVD) at the lowest sump (Sump #6) located on the south side and near the southwest corner of the WMU (see Figure E-2). Based on review of groundwater elevations in the five proximal down-gradient wells, which range between 635 and 660 feet NGVD, groundwater levels historically have been above the WMU basegrades.

CQA and Construction Records: Engineering Report (3/1991) contains Table 1, Summary of certification laboratory data, for a total of 161 soil tests, and Table 2, Summary of liner certification reports, for a total of 16 reports submitted from 1/1983 through 5/1989 for cells 1 through 12.

As-Built Drawings: An as-built pit bottom plan (Figure 4, 1/1983, Midwestern Consulting, Inc.) was updated and included in As-built pit bottom and leachate collection plan and proposed berm at entrance (Drawing 3, 4/1990, Waste Management).

## Leachate Management System

Layout and Design: The leachate collection system consists of six sumps located around the perimeter of the WMU and leachate collection system. The leachate collection system is designed to prevent head build-up at the lowest point in the collection system to less than 6 inches. The top of the cohesive soil liner is sloped toward the sumps, providing positive drainage. Perforated piping was placed around the perimeter of each cell, and radially outward from each of the six sumps. Along four cells on the north side of the WMU, slightly compacted refuse was placed around the collection pipes to promote drainage to the sumps. At the one cell at the southeast corner of the WMU, gravel was placed around the leachate collection piping. In the remaining seven cells along the south and west sides of the WMU, a 12-inch thick drainage blanket was placed over the cohesive liner and leachate collection piping, to provide additional porous media to transmit leachate to the sumps.

Leachate fluid levels can be measured at the individual sumps, and the sumps have the ability to be pumped or sampled individually. However, the operational practice is for leachate to be pumped from each of the leachate manholes to one location. A gravity sewer at that location conveys the leachate to a metering station, located at the southwest side of the WMU, and the leachate is piped to the public water treatment plant for disposal. Composite samples are collected from a Parshall flume at the southwest side of the WMU, and tested in accordance with a discharge permit issued by the city.

CQA and Construction Records: N/A

As-Built Drawings: Leachate pipe details (Figure 6, 2/1983, Midwestern Consulting, Inc., a single sheet, not attached to any report or referenced in the Engineering Report, 3/1991.)

Leachate Generation Rate: Electronic data are available of leachate generation in gallons per day, between 1994 through the present.

Leachate Recirculation and/or Disposal: Leachate is piped to the public water treatment plant for disposal; composite samples are collected and tested in accordance with a discharge permit issued by the city.

Leachate Sampling and Data: Leachate sample data exist for one location, MHOLT, which is a composite sample of untreated leachate. An electronic data set includes 92 sampling events between 10/1984 and 11/2007 for 207 analytes, including chloride and COD. No BOD data exist.

*Leachate Data (Electronic) –*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Composite Sample (untreated), MHOLT | 92 | 10/1984, 11/2007 | 207 | 1000 | 3000 | |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: None reported.

## Cover System

Design: The 12/1988 design drawings show 30-inch thick cover soil on the east side slope (7.33 acres); 24-inch thick cover soil on the north side (3.44 acres) and on a portion (4.27 acres) of the interior side slope; and 18-inch thick cover soil on the south side, west side, and WMU crest (total of 59.49 acres). The 30-inch and 24-inch cover material is described as “final clay”. The 18-inch cover soil is described as “infiltration clay-soil”. The Engineering Report (3/1991) shows that the final cover would consist of a 4.5-feet thick composite soil and geomembrane cap, as follows: 22-inch thick compacted clay/silt soil layer; 40-mil sheet of HDPE geomembrane over the cushion layer; 12-inch soil drainage layer; additional 12-inch thickness of soil; and minimum 6-inches of topsoil. The 12/1988 design drawings indicate that, in general, the infiltration layer-soil was overbuilt by an additional 3 inches during 1992 through 1995 to accommodate vegetative growth. The vegetative growth was removed prior to geomembrane installation. The maximum design elevation was to be 800 feet NGVD. The 12/1998 design

drawing shows that the maximum elevation at the crest of the WMU actually reached 842 feet NGVD.

CQA and Other Construction Records: The Construction Documentation Report (Final Closure Report, or FCR) for Site E was submitted to the State in April 1999. The FCR certifies that the final cover satisfied State requirements. Final closure was completed in stages commencing in 5/1988 and completed by 2/1999, as follows:

- In 1988, initial placement of recompacted infiltration layer soil material occurred over 7.3 acres along the bottom of the east slope and portions of the bottom of the north and south slopes.
- In 1992, final closure activities resumed with placement of infiltration layer soil placement over 3.4 acres of the north slope.
- In 1993, infiltration layer soil was placed over 4.3 acres on the south slope.
- In 1994, 32 acres of final cover was constructed and gas management system was installed.
- In 1995, final cover construction continued with infiltration layer soil placement over 23.9 acres, and erosion layer placement, stormwater control structure construction, and downslope pipe construction. 26 acres of geomembrane was placed on the east slope.
- In 1996, a new blower and landfill gas flare was constructed ton control fugitive gas emissions during placement of the FML on the site.
- In 1997, final cover construction continued with installation of 22.8 acres of geomembrane on the north and south slopes, and erosion layer placement and berm construction.
- In 1998, final cover construction was completed with placement of infiltration layer soil over 3.5 acres, erosion layer placement, and berm construction. In 1998, 25.7 acres of geomembrane was placed on the west slope and crest of the WMU. Perimeter fence installation was completed in 2/1999.

Cover soil testing was conducted using nuclear density testing and moisture content testing of recompacted infiltration layer soil, and using Shelby tubes (for laboratory testing of hydraulic conductivity). The results of soil testing are appended to the Construction Documentation Report (3/1999), but were not reviewed or obtained. Closure certification was included in the 3/1999 report. Closure certification has not been issued by the State to date.

As-Built Drawings: An as-built final cover survey map dated 12/1998 is provided in the FCR.

Topographic Surveys: No topo surveys are available, other than the topo survey included in the 12/1998 as-built final cover contour map. Post-closure subsidence of the final cover is known to be occurring and has necessitated periodic repairs to surface-water ditches on the final cover.

Cover Monitoring and Maintenance: Although the post-closure plan has not been approved by the State, the cover is regularly mowed. All gas collection and control system (GCCS) components except wellheads are buried. Annual Title V wellhead monitoring program includes visual inspection of cover vegetation and erosion. Occasional settlement around well shafts, minor downslope erosion gullies, and occurrence of small bare areas has been reported. The Post-Closure Plan (3/1995) indicates that damage to the gas system that allows direct venting of gas to the atmosphere will be repaired immediately. According to the site engineer, all minor cover issues are promptly repaired. Quarterly surface methane monitoring scans have been done since 1999.

Compliance Issues and Community Concerns: None reported.

## Landfill Gas Control System

Active Gas Control System: Installation of a network of 47 wells was completed in 8/1994. Gas collection header and associated piping installation was completed by 12/1994. About 26 original wells were installed along the older, northern side of the WMU. Five new gas extraction wells were installed in 8/1993, and 16 new gas extraction wells were installed in 8/1994. The landfill GCCS was expanded as part of NSPS requirements for the vertical expansion. One old gas well, GW-10, was destroyed by fire in 10/2001. This gas well was replaced by GW-10R in 4/2003. Three gas extraction wells have been abandoned, and therefore the current system consists of 44 wells.

Gas Utilization: LFG extracted from the WMU is collected and processed for use at a nearby industrial complex. In the event that the manufacturing facility does not need the gas, the gas is flared at a single location located along the west side of the WMU.

Passive Gas Vents: None.

Construction Details and As-Built Drawings: As-built information for the active GCCS is provided on a single sheet dated 12/1998. The gas well schedule is provided in the Construction Documentation Report (3/1999), with well bore depth varying from 42 to 80 ft bgs.

Landfill Gas Data: Monthly Title V wellhead monitoring is performed at all current 44 wells. Total flow is composited from Site E and two adjacent WMUs. Gas is piped to an industrial complex. Unused or excess gas is flared. Total flow is recorded monthly and ranged from 1,100 to 1,400 cfm between 1/2004 and 3/2008. According to the site engineer, approximately 800 to 900 cfm comes from Site E.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Wellheads | Total to manufacturing facility, monthly records 1/2004-3/2008 (E) | Monthly, incomplete 9/2007 – 3/2008(P) | |
| Surface Scans | N/A | Quarterly, incomplete, Since 1999 (not observed) (P) | Methane content only |

Compliance Issues and Community Concerns: None reported.

## Groundwater Monitoring System

Layout: Twelve wells are included in the monitoring system, including: two offsite up-gradient wells (GW-33C and GW-34A); two WMU-specific up-gradient wells (MW-101 and MW-108); three side- or cross-gradient wells (MW-102, MW-103, and MW-107); and five down-gradient wells (MW-104, MW-105, MW-106, MW-109, and MW-110). The two offsite wells (GW-33C and GW-34A), installed in 8/1985, were incorporated into the WMU network to distinguish the water quality related to the adjacent WMU to the north and the Site E up-gradient groundwater quality. The ten site-specific wells were installed in 1990 and 1991. These ten wells replaced a series of eight wells that monitored only the silty clay till above the basal till. The original eight wells had been completed at a variety of depths based on the presence of transmissive zones of thin sand seams, which were later found to be neither laterally extensive nor hydraulically connected. These eight wells were abandoned. The shallow silty clay till has a predominantly downward groundwater flow regime, and therefore the basal till stratum is the primary pathway for horizontal groundwater flow beneath the WMU. All current 12 wells are completed in the basal till stratum.

Monitoring Program: The Hydrogeologic Monitoring Plan (rev. 4/2001) indicates that the wells are monitored semi-annually for primary leachate indicator parameters (Ammonia Nitrogen, Chloride, Magnesium, Potassium, Barium, and pH) and heavy metals (Arsenic and Zinc), and annually for primary (44) and secondary (11) VOCs.

Construction Details: Boring logs and well completion details are available for all wells in the Hydrogeologic Monitoring Plan, App. C (rev. 4/2001).

Groundwater Data: A summary of analytical data is provided in the table below. Data are available for all parameters for which monitoring is required by the State.

*Groundwater Data (Electronic)*

| ITEM | Number of Wells, Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* |
|---|---|---|---|---|---|
| Up-gradient, proximal (offsite) GA-33C | 1, 113 | 2/1986, 11/2007 | 191 | 100 | 10 |
| Up-gradient, proximal (offsite) GA-34A | 1, 133 | 2/1986, 11/2007 | 183 | 100 | 10 |
| Up-gradient, proximal MW-101 | 1, 74 | 10/1990, 11/2007 | 94 | 100 | 10 |
| Up-gradient, proximal MW-108 | 1, 73 | 1/1991, 11/2007 | 94 | 100 | 10 |
| Cross-grad., proximal MW-102 | 1, 30 | 1/1991, 6/1999 | 93 | 100 | 10 |
| Cross-grad., proximal MW-103 | 1, 74 | 10/1990, 11/2007 | 94 | 100 | 10 |
| Cross-grad., proximal MW-107 | 1, 73 | 1/1991, 11/2007 | 94 | 100 | 10 |
| Down-grad., proximal MW-104 | 1, 73 | 1/1991, 11/2007 | 94 | 100 | 10 |
| Down-grad., proximal MW-105 | 1, 32 | 1/1991, 3/2000 | 93 | 10 | 1 |
| Down-grad., proximal MW-106 | 1, 74 | 10/1990, 11/2007 | 94 | 10 | 1 |
| Down-grad., proximal MW-109 | 1, 69 | 11/1991, 11/2007 | 94 | 10 | 1 |
| Down-grad., proximal MW-110 | 1, 68 | 11/1991, 11/2007 | 94 | 10 | 1 |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: No compliance issues or community concerns were reported.

One possible SSI was reported to the State, based on a verified exceedance of Dissolved Barium at cross-gradient well MW-102 in 10/1998. Because Site E continues in detection monitoring, it is assumed that either an alternate source demonstration or other determination was subsequently provided to the State's satisfaction, showing that the exceedance resulted from a sampling error, laboratory analysis error, natural variation in groundwater, or a source unrelated to the WMU.

## Surface-Water Monitoring System

Locations: Surface-water samples were collected at four monitoring locations around the perimeter of the WMU. The samples are obtained from the perimeter drainage ditches which convey offsite irrigation water and surface-water runoff from the WMU. Two samples are obtained from each drainage ditch, one upstream (designated with a "U" and one downstream (designated with a "D"). Sample locations S01U and T03U are located where the drainage ditches enter the WMU property, and sample locations S02D and T04D are located where the drainage ditches leave the WMU property. In addition, surface-water monitoring location T05D is the outflow from the sedimentation basin at the southeast corner of the WMU.

Monitoring Program: Monitoring frequency is annual for VOCs; semi-annual for Barium, COD, Chromium, Mercury, Nickel, and Selenium; and quarterly for about approximately 17 other constituents including Ammonia, BOD, Chloride, DO, Iron, Nitrate, TDS, and TSS.

The electronic surface-water data set for Site E includes data for the drainage ditch sample locations for 12/1984 through 5/07, and for the sedimentation basin outfall location for 8/1995 through 5/2007. Samples were collected quarterly for Turbidity, Fecal Coliform, Dissolved Oxygen, Phosphates, pH, BOD, TDS, Nitrate-Nitrogen, and Temperature.

Although the Closure/Post Closure Plan (5/1995) indicates that there are no post-closure monitoring requirements for surface water, surface water have been collected after the WMU closure date of 6/1994 at the five locations included on a figure in the Closure/Post Closure Plan.

Surface-Water Data: Available data from the electronic database are summarized in the table below.

*Surface-Water Data (Electronic)*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Up-grad., S01U | 82 | 12/1984, 5/2007 | 88 | 100 | 10 | 1 |
| Down-grad., S02D | 77 | 12/1984, 5/2007 | 88 | 100 | 10 | 1 |
| Up-grad., T03U | 78 | 12/1984, 5/2007 | 88 | 100 | 10 | 1 |
| Down-grad., T04D | 77 | 12/1984, 5/2007 | 88 | 100 | 10 | 1 |
| Sedimentation Basin Outfall, T05D | 41 | 8/1995, 5/2007 | 61 | 10-100 | 10 | 1 |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: None reported.

## Methane Migration Monitoring (MMM) System

Layout: A methane migration monitoring plan was not identified, but 15 barhole locations are approximately equally spacing around the perimeter of the WMU. The total depth of the barhole probes is not known. Prior to 12/2003, data were collected at 13 barhole locations.

Monitoring Plan and Data: Methane migration monitoring is required quarterly (Closure/Post-Closure Plan, 5/1995). Quarterly monitoring data exist for 1994-1996, 1998-2000, and 2003 through the present. The missing data for 1997 are bracketed by zero methane detections in 1996 and 1998.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Start, End | Frequency | Notes |
|---|---|---|---|
| Barhole Probes, BH-1 to BH-15 | 1994, 3/2008 | Quarterly | P, incomplete (missing 1997, 2001, and 2002) |

Compliance Issues and Community Concerns: None reported.

**FIGURE E-1**
**Site E Physiographical Setting**

**FIGURE E-2**
**Site E Layout and Features**

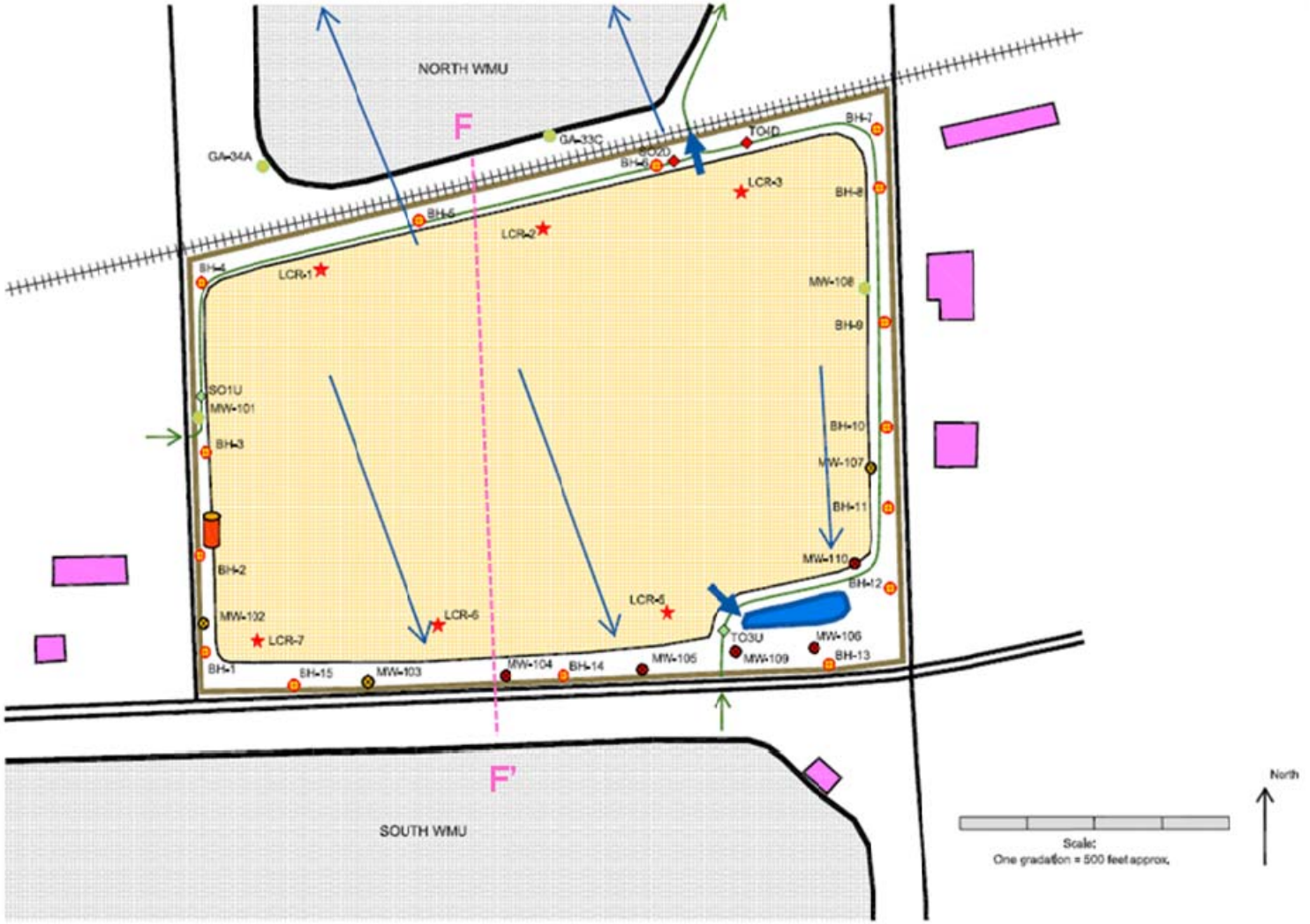
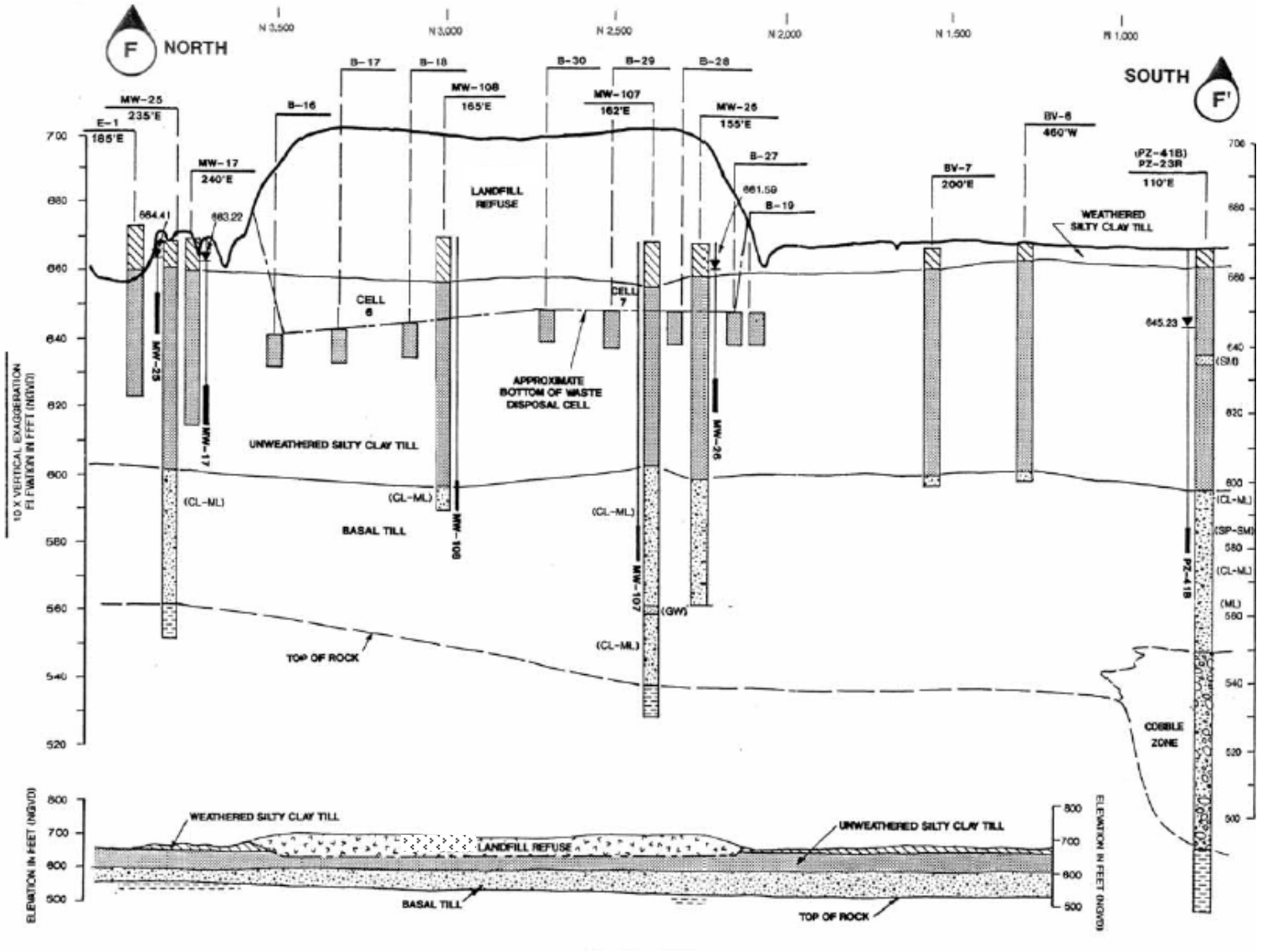


**FIGURE E-3**
**Site E Geologic & Hydrogeologic Cross Section**



# APPENDIX 2-1F

# SUMMARY – SITE F (OHIO)

## Overview

Study WMU: The site comprises 534 acres, of which 160 are currently permitted for landfill. According to the application for a permit to install (PTI), dated 10/1986, rev. 3/1989, solid waste disposal at Site F commenced in 1972 at a 34 acre area in the NW section of the site. Between 1982 and 1985, a 4-ac. cell in this area was permitted to accept hazardous waste and is now a closed RCRA facility. In 1983, the main NW area was closed for landfill and non-hazardous solid waste was accepted for disposal at a new landfill area in the S section of the site. The total size of the S section permitted for landfill was 78 acres (3/1989 PTI) expanded to 126 acres according to a subsequent vertical expansion modification permit to install application (originally dated 3/2002, rev. 2/2004, rev. 4/2005). The total permitted airspace of the S section was on the order of 21.1Mcy in the 3/1989 PTI, increased to 24.7Mcy in the 4/2005 PTI. Although technically on the same property, the old NW landfill area and the RCRA cell are generally considered separate from the S area MSW landfill.

The study WMU comprises eight contiguous cells with total footprint 38.8 ac. in the S section which were closed between 1990 and 2004. The last cell is contiguous with the expanded operational landfill.

Property: Nearly 70% of the site is drained to the north by an unnamed tributary to a larger named creek. The remaining area is drained to the south by a named creek. The surface topography, in general, is characterized as flat, sloping gently towards either creek. Non-landfilled surface elevations vary between 610 and 620 ft-msl across the site. The closed N landfill area rises about 40 to 50 feet above surrounding undisturbed land, reaching 664 ft-msl. The maximum elevation of the study WMU is at approximately 720 ft-msl.

The physiographical setting of the property and study unit is shown on Figure F-1. A stylized depiction of the site layout is provided as Figure F-2.

## Site Information

Regional Geologic and Hydrogeologic Setting: A comprehensive hydrogeological Investigation (HI) was conducted at the site (included as Volumes III/IV of the 4/2005 PTI).

Regional Geology: The region surrounding the site is underlain by unconsolidated glacial deposits and glacially derived soils that overlie Silurian age carbonate bedrock. Glacial

sediments are primarily fine grained lacustrine deposits and till that are the result of continental glaciation during the Pleistocene Epoch. Bedrock units of importance in the region are identified as undifferentiated Salina Dolomite, Tymochtee Dolomite, Greenfield Dolomite, and the Lockport Dolomite.

Site Hydrogeology: Site-specific hydrogeologic data for the Site have been generated from 1971 to present. Unconsolidated deposits consist predominately of silt and clay lacustrine deposits and clayey till deposits with very isolated sand partings and thin sand lenses. Topsoil is virtually absent. The defined unconsolidated deposits at the site fall within an established stratigraphic sequence consisting of topsoil, upper till/lacustrine deposits, middle till, and lower till. Isolated sand partings and lenses, if present, generally occur within transition deposits (non-till) that occur between the middle till and lower till. In some areas the transition deposits are not present and the middle till directly overlies the lower till. The underlying bedrock is composed of Silurian age dolomite.

*Natural Soils* – Native soils have largely been removed or altered across most of the site. The predominant soil series across the site are/were the Toledo and Fulton Series which developed from lacustrine silts and clays. The composition of the soil probably varied between clayey silts and silty clays with trace amounts of sand and gravel. Unit thickness was probably between two to three feet.

*Upper Till/Lacustrine Deposits* – These deposits are encountered below native soils at the Site. The unit is believed to represent a transition from till deposition to lacustrine deposition as Pleistocene glaciation was coming to an end in Ohio. Some of the till-like deposits may represent deposition resulting from large blocks of the ice sheet, floating and melting within a large lake setting. The unit forms a thin (generally less than 15 feet) relatively continuous deposit across the site. Field descriptions typically characterize the unit as a weathered silty clay with a trace to no gravel. Generally, the unit varies from weakly stratified to laminated to unsorted and massive. Laboratory soil analyses show that the unit typically is a silty clay (CL). Contact with the underlying middle till is distinguished by a change to a consistent massive till. This contact is often transitional and may extend across several feet of strata.

*Middle Till* – This is an extensive, compositionally consistent unit encountered below the upper till/lacustrine deposits. The upper five to 10 feet of the unit is moderately weathered with desiccation fractures/joints. Below the weathered upper surface the unit is unweathered with very little compositional variation. The thickness of the unit varies from 30 to 55 feet. The unit is at its thinnest within the southwestern part of the site where the bedrock surface rises. Laboratory analyses indicate a relatively consistent grain size distribution for the unit with USCS classification as a lean clay (CL). Field descriptions vary from clay to clayey silt with little sand and a trace of gravel, and usually indicate decreasing gravel and sand content near the base of the unit. Often the deposit grades into a lacustrine silty clay or clay which marks the base of the unit.

*Transition Sediments* – These are a relatively thin, discontinuous, interbedded, silty sand, silt and clay zone that, in places, separates the middle till from the underlying lower till. Transition deposits appear to be associated with subaqueous or lacustrine sedimentation resulting from stagnation of an ice sheet or an interstadial glacial event. The lack of any associated weathering features indicate that middle till and lower till deposits were probably deposited contemporaneously. Because of its discontinuous nature and the fact that it is often difficult to distinguish any difference from the base of the middle till, the transition materials are not considered to be a mappable unit, rather it represents a transitional contact between units. Roughly half the Site borings do not encounter these transitional sediments and the middle till rests directly over the lower till. The thickness of the sediments, when encountered, varies from zero to as much as 7.0 feet, but usually no more than one foot. Field descriptions typically characterize the materials as variable sandy silt/silty sand and gravel, silt, or clay lenses. Silt or clay seams frequently are described as laminated, having some deformation features and a reddish coloration. Laboratory data for the materials have been collected where the deposits are sandy and should not be considered representative of the zone as a whole. Laboratory data indicate that transition materials are highly variable, fine grained deposits varying from a silty sand/sandy silt to a sand (SM, SM-SP). Conversely, field descriptions indicate USCS classifications in the CL and ML range.

*Lower Till* – The lower till is the lower most unconsolidated unit encountered at the site. The lower till is compositionally distinct when compared with overlying tills at the site. In general, the lower till is sandy, indurated, and field descriptions typically characterize the unit as containing a comparatively high percentage of gravel and cobble size rock fragments. Sandy silt and silty sand partings and thin lenses are occasionally encountered. The unit varies in thickness from 5.0 feet to 20.0 feet. The very dense nature of the lower till and the overall high percentage of rock fragments combine to produce difficult soil sampling conditions. Often soil sampling recovery drops below 60 percent. However, the abundance of data for the site provides enough information for characterization. Laboratory analyses indicate that the composition of the unit is highly variable. USCS classifications of CL, CL-ML, and ML have been determined for the unit; however, the unit is typically classified as a lean clay (CL).

*Silurian Dolomite Bedrock* – The deepest stratigraphic unit investigated at the site, this bedrock is identified as the basal part of the Silurian age Greenfield Dolomite and possibly the upper part of the Lockport Dolomite. Regional data as well as site data suggest that the bedrock underlying the site represents a transition from sediments generated at the flanks of reefs (Lockport) to the shallow reef sedimentation of the Greenfield. Regionally the unit is described as an olive gray to yellow brown argillaceous dolomite with sedimentary breccia zones. Bedding varies from thin to massive. Formation thickness ranges from 0 to 80 feet. The upper part of the bedrock (± 15 feet) has been intensely investigated at the site. The deepest borings at the site extended about 50 feet below the top of the unit (to about 498 feet MSL). The bedrock is typically described as a blue gray dolomite with variable shaley partings, stylolites, and vuggy zones. The upper part of the unit (± 10 feet) is characterized as weathered with increased solutioning (vugs up to one-

half inch in diameter) and common horizontal and vertical fracturing. Generally the bedrock surface slopes to the north between 20 to 40 feet per mile.

Saturated Zone: The hydrogeologic regime at the site is relatively simple, consisting of surficial weathered unconsolidated deposits overlying an unweathered unconsolidated silty clay/clay silt aquitard which in turn overlies and confines the Silurian bedrock aquifer. Figure F-3 is an illustration that graphically displays the relationship of the lithology at the site to the hydrostratigraphic units and their significance. The silty clay/clayey silt aquitard consists of the unweathered part of the middle till, and the lower till. Transition deposits, which generally occur between the middle till and lower till, have been identified by the Ohio EPA as a zone of increased horizontal permeability. Site investigations have been performed to investigate the hydraulic properties of transition deposits and associated silty sand lenses/partings. Investigations have concluded that hydraulic properties of the transition deposits are similar to the unweathered middle and lower till. A simplified cross-section is provided as Figure F-4.

The lower till (LT) monitoring zone at the site targets sandy zones/lenses associated with the transition materials that occur near the contact between the middle till and the lower till. Field descriptions as well as laboratory geotechnical data indicate that sandy silt, sand, or sandy zones associated with the transition materials, where encountered, may have higher permeabilities than the surrounding middle and/or lower till. However, in-situ permeability testing of 10 LT monitoring wells at the site show very low values, ranging from $3.6 \times 10^{-6}$ to $2.4 \times 10^{-9}$ cm/s with a geometric mean value of $1.1 \times 10^{-7}$ cm/s. The low values along with boring log data define the isolated nature of the transition deposits.

The uppermost aquifer beneath the site is the Silurian Dolomite. This is the first unit encountered below the proposed base of waste that is laterally-continuous and is a hydraulically-significant ground-water producing zone. The bedrock unit is encountered below 60 to 80 feet of low permeability silty clay/clayey silt unconsolidated sediments. Ground-water occurrence within the bedrock primarily occurs within secondary openings in the rock, primarily fractures/joints, vugs, and small solution cavities. The upper 15 feet of the bedrock encountered under the proposed Site is the targeted uppermost-aquifer monitoring zone.

Two horizons are monitored as significant saturation zones (SSZs). The upper SSZ is the base of surficial weathering (UT-zone) which generally occurs near the contact between the upper till/lacustrine and middle till stratigraphic units. Discharge from the UT significant saturated zone is to adjacent surface water features. During wet periods, the UT zone may discharge locally to ditches and low lying areas. Stagnation zones are common because of the flat topography and standing water in low lying areas. During periods of low precipitation where ditches are dry, the only discharge from the UT zone is to the surface via evapotranspiration.

The lower SSZ (LT-zone) is the sand lenses, sand partings, and sandy zones associated with the transition materials that occur near the contact between the middle till and the lower till.

Recharge to the LT-zone strata is the result of precipitation and very slow infiltration through the overlying strata. Discharge from the unit is to underlying deposits. Vertical discharge to underlying units is supported by site water level data for the zone. Additionally, strong downward vertical gradients from the LT-zone to the uppermost aquifer suggest a strong vertical flow (discharge) potential.

Unsaturated (Vadose) Zone: See discussion above and Figures F-3 and F-4.

Boring Logs: The 3/1989 PTI includes 58 boring logs. Of these, 10 were made at the base of excavated Cells 5, 6, and 7, and seven were performed at the base of Cell 8. In total, 88 USCS tests, 89 Atterberg limits, over 200 natural moisture content tests, two specific gravity tests, and seven unconfined compression tests were performed on select samples.

Hydraulic Conductivity: The 3/1989 PTI includes data for 11 constant head permeability tests performed on soil samples retrieved from the expansion area borings. The results of these tests ranged from $1.19 \times 10^{-8}$ cm/s to $3.7 \times 10^{-8}$ cm/s. The 4/2005 HI provides the following geometric mean values for both laboratory tests and in-situ slug tests for the unconsolidated deposits at the site: Upper Till = $1.5 \times 10^{-8}$ cm/s (lab), Middle Till = $1.6 \times 10^{-8}$ cm/s (lab), UT/MT transition = $1.5 \times 10^{-5}$ cm/s (slug), Lower Till = $6.6 \times 10^{-9}$ cm/s (lab), MT/LT transition = $1.1 \times 10^{-7}$ cm/s (slug), LT/Bedrock transition = $8.8 \times 10^{-8}$ cm/s (lab).

The 4/2005 HI includes data from 14 monitoring wells developed in the Silurian bedrock aquifer which were evaluated by slug test analysis. Hydraulic conductivity values were found to vary from $2.1 \times 10^{-2}$ to $6.3 \times 10^{-7}$ cm/s with geometric mean of $1.5 \times 10^{-4}$ cm/s.

Groundwater: Within the region, the carbonate bedrock (Silurian age dolomite bedrock) is the regional aquifer. In general, unconsolidated glacial sediments have very low permeabilities and are not considered aquifers. The base of the carbonate aquifer is defined as the base of the Silurian age bedrock. The thickness of the carbonate aquifer is estimated to be between 300 to 400 feet. Ground water primarily occurs within joints/fractures, along bedding features and where solution activity has enlarged openings in the rock. Typically, primary porosity within the carbonate bedrock is low.

Recharge-discharge relationships for the aquitard conceptually are relatively simple. A small percentage of precipitation or surface water at the site infiltrates surficial soils and the unsaturated part of the upper till/lacustrine deposits to recharge the UT-zone. Generally, ground-water within the UT-zone moves laterally because the underlying aquitard (unweathered middle till) has a considerably lower permeability. However, a vertical flow potential from the UT-zone to the underlying aquitard does exist. A small percentage of groundwater may continue on a downward path into the aquitard. Flow within the aquitard is through the matrix of the deposits. The uniform, fine-grained, impermeable nature of the aquitard precludes any significant movement of groundwater through the unit on a scale relevant to the site. A very small percentage of ground water discharges from the aquitard to the underlying Silurian dolomite

aquifer. However, within the immediate vicinity of the site the overlying aquitard is thick, generally greater than 60 feet, and is not a significant recharge area.

A vertical gradient through the aquitard was estimated in the 4/2005 HI by evaluating ten UT-zone and LT-zone well pairs. Formation thickness between well pairs was calculated by taking the difference between the midpoint of the effective screen interval at each well pair. Based on 10/1999 groundwater levels, the vertical gradient varies between 0.35 ft/ft to 1.07 ft/ft. The geometric mean vertical gradient is 0.67 ft/ft.

The potentiometric surface of the uppermost aquifer plotted for April 2001 and October 2003 shows a general east-northeast flow direction. The primary groundwater flow direction is horizontal, vertical flow is expected to be minimal. The horizontal groundwater gradient varies between 0.006 ft/ft near MW-15 to 0.0005 ft/ft within the north-central part of the site. Groundwater flow velocities for the Silurian dolomite uppermost aquifer were estimated at 0.73 ft/yr using the geometric mean hydraulic conductivity of $1.5 \times 10^{-4}$ cm/s (3.2 gpd/ft$^2$), an average hydraulic gradient estimated at 0.001 ft/ft within the south-central part of the site, and an effective porosity of 0.20.

Reliable groundwater level data have been collected since 1990. Hydrographs of uppermost aquifer water level data show seasonal variation (one foot) from 1991 through 1994. After 1994 the hydrographs show a general increasing water level trend through April 1996. From April 1996 through 2005 water levels declined with more pronounced seasonal differences between measurements. Water levels at the site appear to be controlled by regional groundwater use which appears to have increased after April 1997.

Physiographical Setting: The facility borders several road and railroad right-of-ways, although none transect the site. No known easements exist in current or future disposal cell areas. The facility is not located within a 100 year flood plain. The site is located in an agricultural/industrial area and is bounded by commercial operations and a few residences (particularly to the SE).

The region surrounding the site is within the Lake Plains section of the Central Lowlands physiographic province. The area is characterized as relatively flat with very poor natural drainage. Most of the region was originally deciduous swamp forest that was cleared and tiled for agriculture. Surface water in the region flows into one of the great lakes. The site is within two small lake drainage basins (creeks). Just northwest of the site is a dominant river basin. Two other river basins are located to the south.

Potential Point(s) of Exposure: The site is not located within an area designated by the Federal government as a sole source aquifer (SSA). Significant sand and gravel resources are not present in the region, and site-specific drilling and permeability data clearly show that a 100 gpm unconsolidated aquifer is not present at the site (4/2005 HI). The minimum vertical isolation

distance between the uppermost aquifer system and the bottom of the recompacted soil liner is 16.6 ft, based on data from 12/2001 borings (4/2005 PTI).

The closest public water supply is located 1.5 miles up/cross gradient (S) and 2.4 miles downgradient of the limits of waste. The 4/2005 HI reports that a total of 31 well records were identified within a one mile radius of the site. However, a 9/2001 door-to-door survey found no active wells or springs located within 1000 ft of the limits of waste. Only the carbonate bedrock aquifer is utilized as a groundwater resource. Residential wells typically penetrate between 40 to 100 feet of the carbonate bedrock. Reported well yields vary between 4.5 and 25 gpm (average 13 gpm), although one well log reported a well yield of greater than 100 gpm. Higher yields are typically achieved with greater depths; however, ground-water quality generally decreases with depth.

Climate: Average annual precipitation is 36 in, which includes about 26 in of snow (10 in of snow is about equivalent to 1 in of water). Total annual evaporation is 25 in. The prevailing wind direction is from the W-SW and averages 5 MPH. Temperatures range from highs over 100 deg F to lows below -10 deg F. Minimum frost depths range from 3-4 feet.

## Waste Placement and Operations

General: According to the 2/1996 Part 70 Air Emission Assessment (AEA), the maximum permitted waste acceptance rate was 7,500 tpd, while the average acceptance rate was 1,500-2,000 tpd in 1995. The AUF is calculated quarterly at the site, records through 1Q2002 are available. Recent values range from 1,650 tcy in 1Q2006 to 1,910 tcy in 4Q2007.

According to the 3/1989 PTI, daily cover is 6-in soil or an Ohio EPA approved equivalent. Intermediate cover of 12-in compacted soil is applied to any area inactive for more than 30 days.

Waste Placement Data: Annual waste acceptance records for the period 1973 through 2005 are available from a 11/2006 Title V permit reapplication calculation.

Waste Composition: According to the 2/1996 AEA, the composition of the waste in place (both N and S areas) is about 50% industrial waste, 30% inert waste (boiler ash and other materials), and 20% MSW. The relative proportion of MSW is probably higher in the study WMU.

## Closure and Post-Closure (C/PC) Plan

A final C/PC plan was developed as part of the 4/2005 PTI. The plan is typical of a Subtitle D site with no specific post-closure uses of the site identified.

## End Use Strategy

An imaginative conceptual end-use plan for the site was developed in 4/2008, as illustrated on Figure F-5. The plan calls for the site to be redeveloped as a broad-based community open-space featuring nature trails, a learning center, sports fields, playgrounds, and parks.

## Liner System

Design: Cells 1-8 were not constructed with a Subtitle D liner. However, falling head permeability tests were conducted on samples retrieved during the certification process of Cell 8 with ranging from 1.19 x $10^{-8}$ cm/s to 1.7 x $10^{-8}$ cm/s. This data, coupled with uniform gradations, sand content below 30%, high densities, and strengths that increase with depth indicated that on-site clays were suitable for construction of the landfill (3/1989 PTI).

According to the 3/1989 PTI, the bottom grades slop at 2% towards collection laterals which are sloped at 1% towards the three leachate collection manholes. The bottom contours across the eight cells range from about 586 to 597 ft-msl, corresponding to depths below initial grades of about 20 to 30 ft. Sides slopes range from 1:1 to 2:1 (H:V).

CQA and Construction Records: None seen.

As-Built Drawings: Basegrade drawing available with some details, not as-built.

## Leachate Management System

Design: Cells 1-4 were constructed with 6-in perforated PVC collection laterals on cell bottoms draining to manholes (sumps) located in the cell. Cells 5-8 have a 12-in thick 1 x $10^{-2}$ cm/s granular drainage blanket placed on the cell bottom to facilitate drainage to the collector pipes. The three basal collection manholes (LMH#1, LMH#2, and LMH#3) are sequentially interconnected, gravity draining to pump station PLS-1. From there, leachate is either recirculated or pumped via forcemain to a central master sump for the site (MHOLS) prior to sewer discharge.

According to the 3/1989 PTI, leachate generation HELP modeling predicted 4.27 in/yr for daily cover, 3.19 in/yr for intermediate cover, and 0.91 in/yr for final cover (3-ft clay) assuming a maximum elevation of 705 ft-msl.

CQA and Construction Records: None seen.

As-Built Drawings: Layout drawings available with some details of leachate collection system and manholes, not as-built.

Leachate Recirculation: No recirculation has occurred in the study WMU; however, leachate from these cells is included in that recirculated in some newer operational cells. The

recirculation system was initially constructed in 9/1995 (expanded 2007) and comprises subsurface horizontal distribution field and vertical injection wells. No surface spraying is allowed.

Leachate Sampling and Data: Leachate generation and recirculation volumes are available from 1994-2006 (monthly site-wide total). Annual monitoring for Appendix I parameters is required for a leachate composite sample (unless it is demonstrated through monitoring that a parameter is consistently absent from leachate, in which case it may be removed from the approved monitoring list per an Ohio EPA letter dated 12/1999).

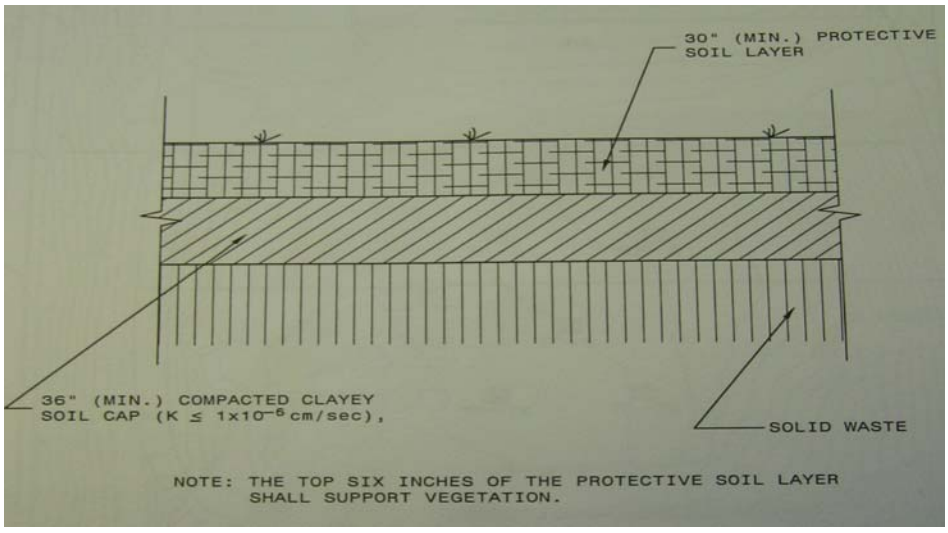
*Leachate Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | COD | BOD |
|---|---|---|---|---|---|---|
| MHOLS | 12 | 10/98, 10/07 | 114 | Y | Y | N |

Compliance Issues and Community Concerns: None known.

## Cover System

Design: Initially, an interim final cover design for the study WMU was designed (as described in a CQA report dated 8/1996) and comprised 24-in. of recompacted clayey soil. This cover was applied over the E, S, and SW side slopes of the study WMU between 1987 and 3/2000 (probably reflecting about one half of the WMU footprint) as well as the top crown. In 2004, a revised cover design was developed as shown below (from a 1/2005 CQA report).




This was applied to improve the top crown area of the study WMU in 2004 (a further one third of the WMU footprint), but not seeded. In 2005, the remaining NW side slope area was covered,

and the entire cap seeded. In a 5/2004 alternation request, the above cover design was modified to reflect BAT by including a double sided geocomposite drainage layer between the two soil layers. However, the modified design appears not to have been installed at the study WMU.

CQA Reports and As-Built Survey Drawings: The closure capping system was applied in various stages. Certified sections of sideslope cap are shown on survey drawings dated 1987 (minor), 4/1990, 8/1991, 10/1993, and 8/1996. CQA reports are available dated 8/1996 and 1/1997. A CQA report dated 3/2000 and a 4/1999 survey drawing show installation of crown cover. A CQA report dated 1/2005 describes improvements to this top crown cap. A CQA report dated 11/2005 describes application of final portions of cap to the study WMU.

Topographic Surveys: Four available: 11/1998, 12/2001, 3/2005, and 12/2007.

Cover Monitoring and Maintenance: The 3/2005 C/PC plan specifies quarterly inspection of, and contingency measures for dealing with, vegetative cover (bare spots, cracks, erosion, , ponding, and protruding objects), differential settlement, and leachate seeps and breakouts.

Compliance Issues and Community Concerns: Some minor, rare seeps and "wet areas of cap soil" reported. Also, rare washout and minor E&S problems with the cover have occurred after heavy storms, mostly affecting downchutes and diversion berms.

## Landfill Gas Control System

Active Gas Control System: 24 gas wells were installed in the study WMU in 1998 as Phase I of a GCCS (including the N landfill). The Phase II GCCS expansion into the rest of the S landfill occurred in 2003. All wells are linked to a single site wide flare/blower station. The current Title V permit for the facility was issued in 4/2008. A flare emission report dated 7/2007 gives the total flow rate on 5/31/2007 as 2,000 scfm.

Gas Utilization: None.

Passive Gas Vents: A passive venting system with 18 passive vents was proposed for the study WMU in the 3/1989 PTI. It is not clear whether this passive system was ever installed.

Construction Details and As-Built Drawings: A CQA report and as-built survey, including a well schedule, for the study WMU gas wells is available dated 9/1998.

Landfill Gas Data: None seen. However, Title V assessments have been conducted in 2/1996, 2002, and 2006.

Compliance Issues and Community Concerns: None known.

## Groundwater Monitoring System

Layout: The groundwater monitoring system at the site includes the uppermost aquifer system (limestone aquifer/bedrock, LA) and two horizons (UT and LT) that are monitored as significant zones of saturation. The base of surficial weathering defines the UT monitoring zone and sand lenses/partings associated with the transition materials, where encountered, define the LT monitoring zone. According to the 3/1989 PTI, 14 monitoring wells were originally installed at the site. Four wells (MW-1, MW-2, MW-14, and MW-15) were intended to monitoring the study WMU; these were all installed to monitor the uppermost aquifer and monitored semi-annually for a limited list of analytes.

The current GWMP for the study WMU was developed in 10/2007 and supersedes all previous programs. The 10/2007 GWMP provides good overview details of historical GW monitoring at the site. Currently, there are 21 GW monitoring well locations within the above three screening levels. Because flow in the till is predominantly downward, all UT and LT wells are considered downgradient due to the lack of a definitive groundwater flow system within the UT and LT zones (i.e., there are no background or upgradient wells for these zones). All UT and LT wells are directly proximal to the landfill.

Monitoring Program and Groundwater Data: The current GWMP is described in the 10/2007 document. Monitoring is required semi-annually and annually for different parameters in different zones. The 12 well clusters (LA, UT, or LT) of relevance to the study WMU are listed in the table over.

Construction Details: Well development details are available in the 10/2007 GWMP document.

Compliance Issues and Community Concerns: During the 10/2006 monitoring event, exceedences for chloride were detected at two LA wells and four UT wells. Re-sampling in 11/2006 showed that three of the UT well results were statistically significant. However, an ASD was submitted to Ohio EPA arguing that this was the result of winter salt application to site haul roads and did not represent leakage from the landfill to groundwater.

*Groundwater Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chl. | Na | K |
|---|---|---|---|---|---|---|
| LA Upgradient, distal MW9A | 23 | 10/98, 10/07 | 83 | Y | Y | Y |
| LA Upgradient, proximal MW13 | 19 | 10/98, 10/07 | 235 | Y | Y | Y |
| LA Downgradient, prox. MW14 | 28 | 10/98, 12/07 | | | | |
| LA Downgradient, prox. MW15 | 21 | 10/98, 12/07 | 87 | Y | Y | Y |
| UT, proximal MW13UT | 18 | 10/98, 12/07 | 88 | Y | Y | Y |
| UT, proximal MW23UT | 25 | 6/99, 10/07 | | | | |
| UT, proximal MW14UT | | 10/98, 10/07 | | | | |
| UT, proximal MW15UT | | 10/98, 10/07 | | | | |
| LT, proximal MW13LT | 18 | 10/98, 10/07 | 87 | Y | Y | Y |
| LT, proximal MW14LT | | 10/98, 10/07 | | | | |
| LT, proximal MW15LT | 17 | 10/98, 4/03 | | | | |
| LT, proximal MW15LTR | 17 | 3/03, 12/07 | | | | |

## Surface Water Monitoring System

Locations: The 3/1989 PTI describes three SW monitoring points (outfalls from sedimentation ponds) 001, 002, and 003 which have been monitored since 1981. SW discharges are now controlled and monitored under a NPDES permit, effective 12/2003. Monitoring point 001 (now 802) is of relevance to the study WMU as a downstream monitoring point on the creek to which the south sedimentation pond discharges. Point 902 is the upstream monitoring point on the creek.

Monitoring Program: SW monitoring is required annually per the 12/2003 NPDES permit.

Surface Water Data: None seen.

Compliance Issues and Community Concerns: None known.

## Methane Migration Monitoring System

Layout: The explosive gas migration monitoring program was first described in a 1/1989 document and included 3 permanent probes. This was revised in 7/1991 to include 4 permanent probes (10 ft deep, 5 ft screen at the bottom, boring logs reported all soils as CL or ML). This was revised again in 3/1995 to include 6 permanent barholes and monitoring of onsite structures. This was revised again in 8/2001 to include 7 permanent barholes and monitoring of additional onsite structures. The most recent revision (1/2005) PTI describes 9 permanent barhole "Testing Station" locations BH-1 through BH-9, monitoring of which consistently provides readings of 0.0% methane.

Four barholes are relevant to the study WMU: BH-3, BH-4, BH-5, and BH-6.

Monitoring Plan and Data: Monthly monitoring is required during active landfilling; this will convert to quarterly during first 5 years of PCC, then semi-annually thereafter.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| BH-3, BH-4, BH-6 (proximal) BH-5 (distal) | -- | Monthly, 5/1994 – 3/2008 (P) | |

Compliance Issues and Community Concerns: None known.

**FIGURE F-1**
**Site F Physiographical Setting**

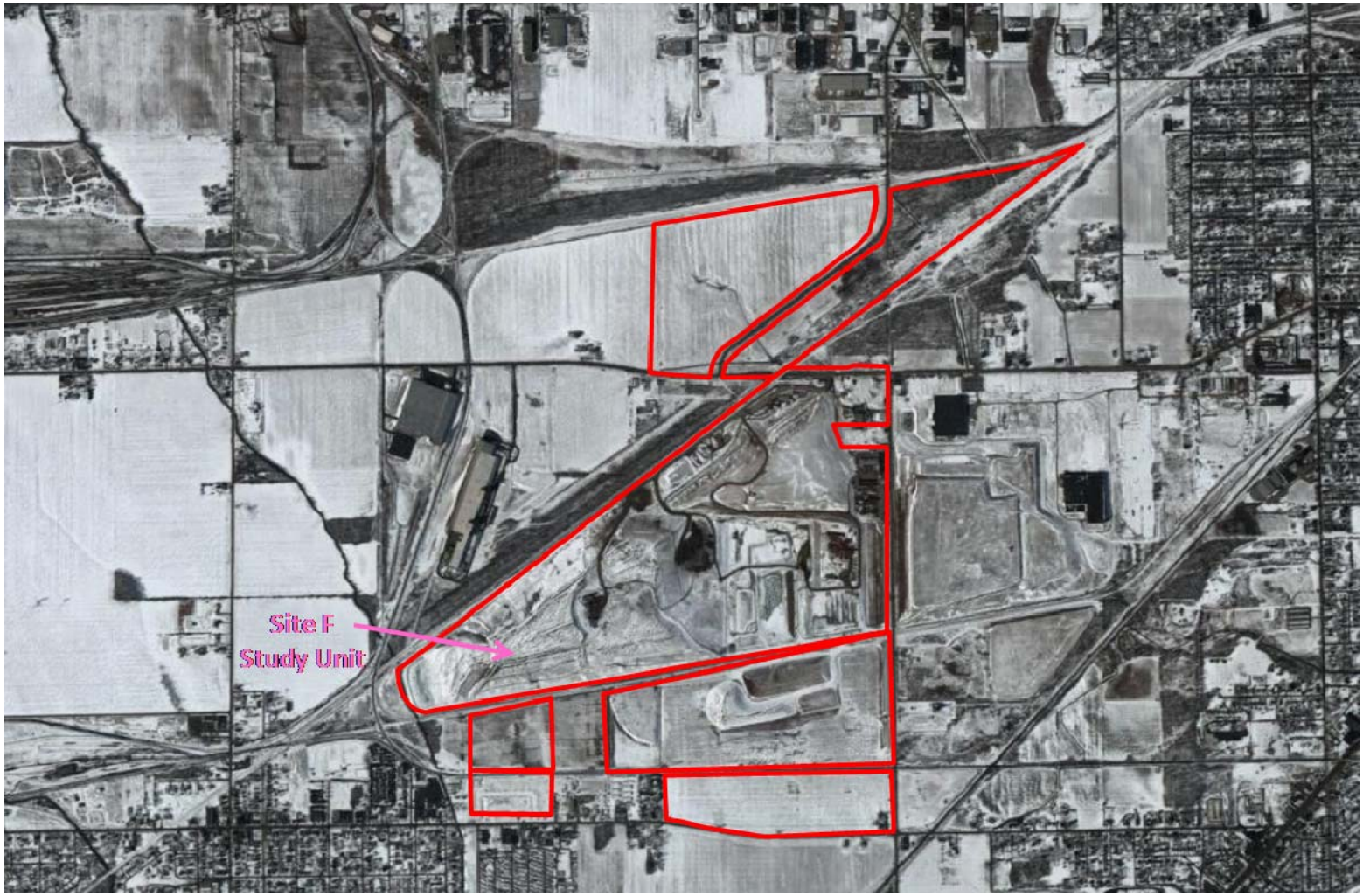


**FIGURE F-2**
**Site F Layout and Features**

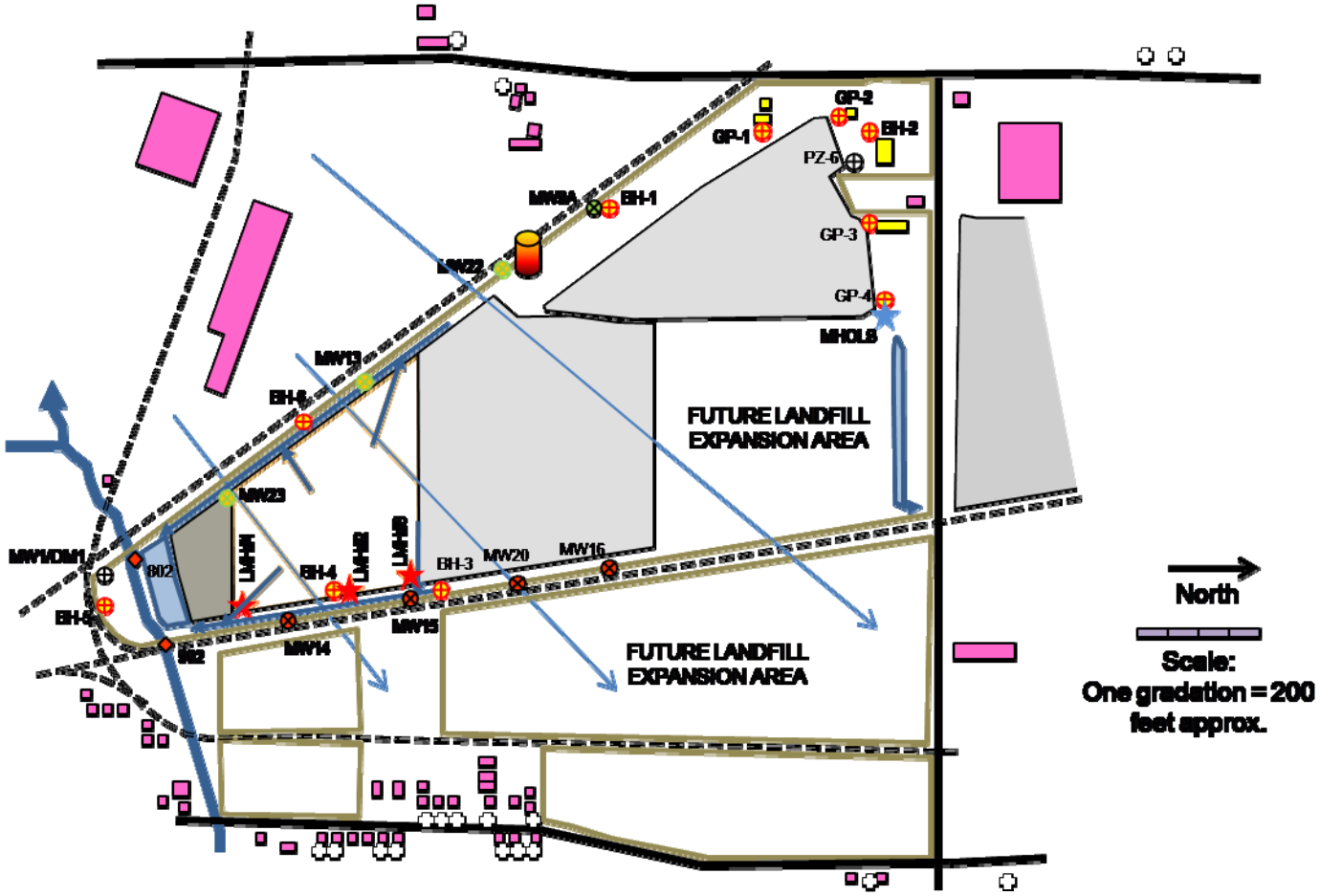
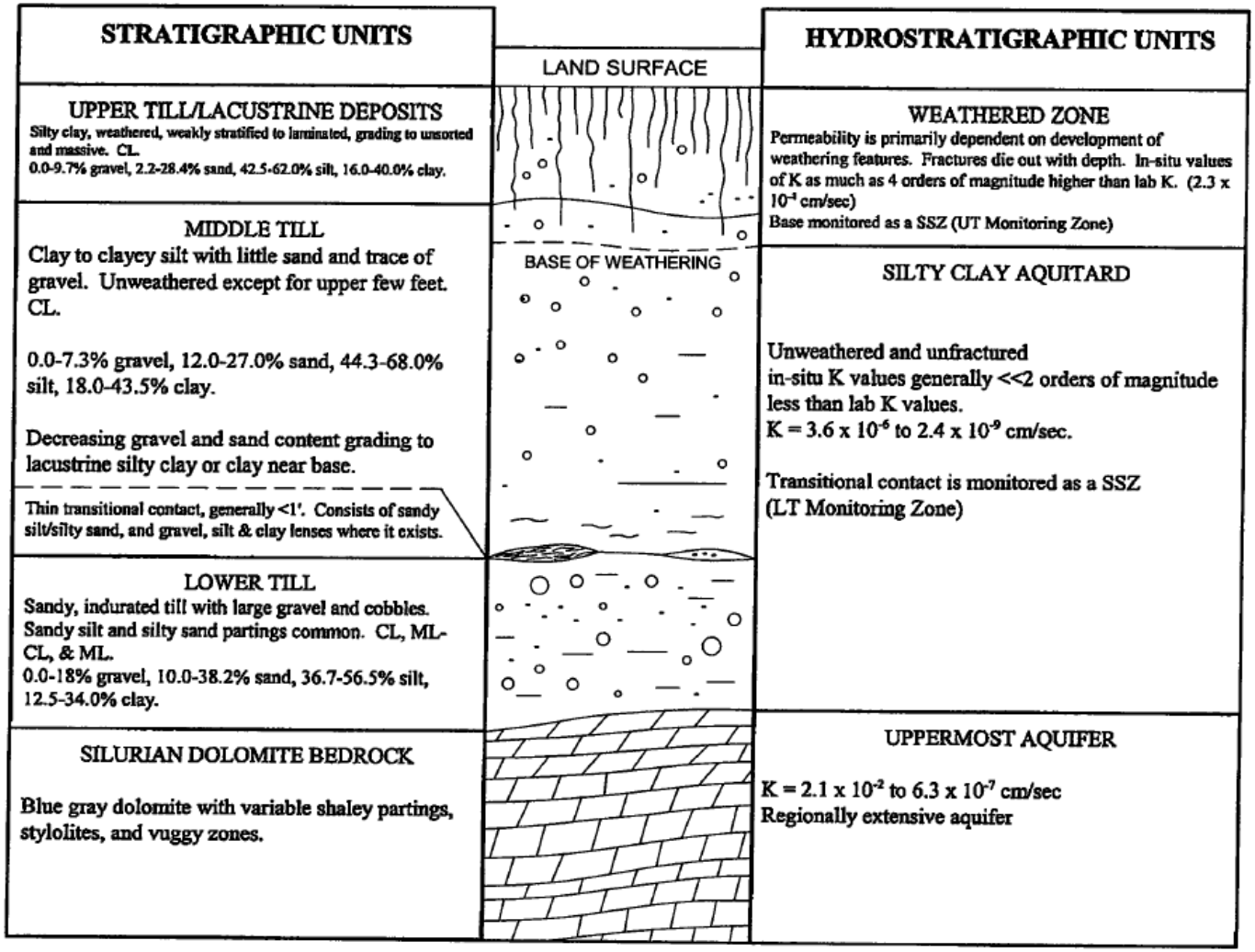
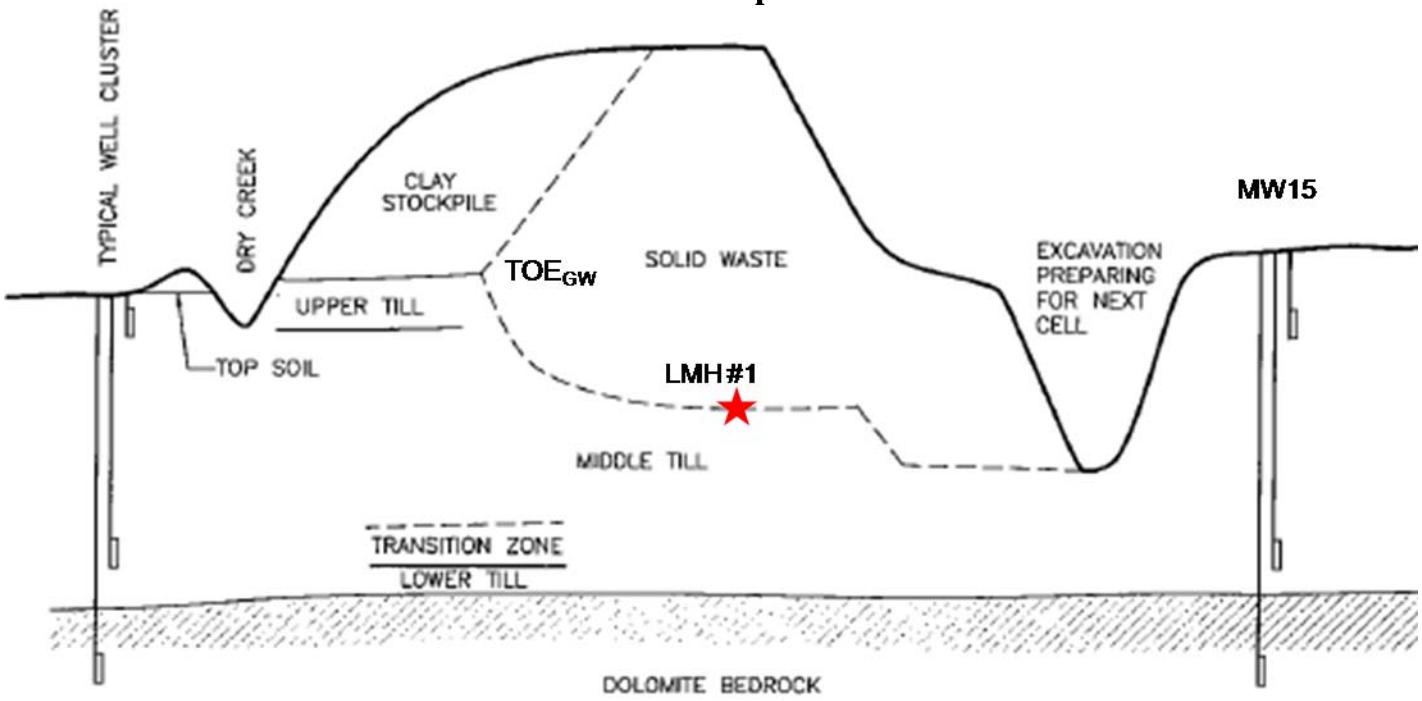


**FIGURE F-3**
**Site F Hydrogeological Column**



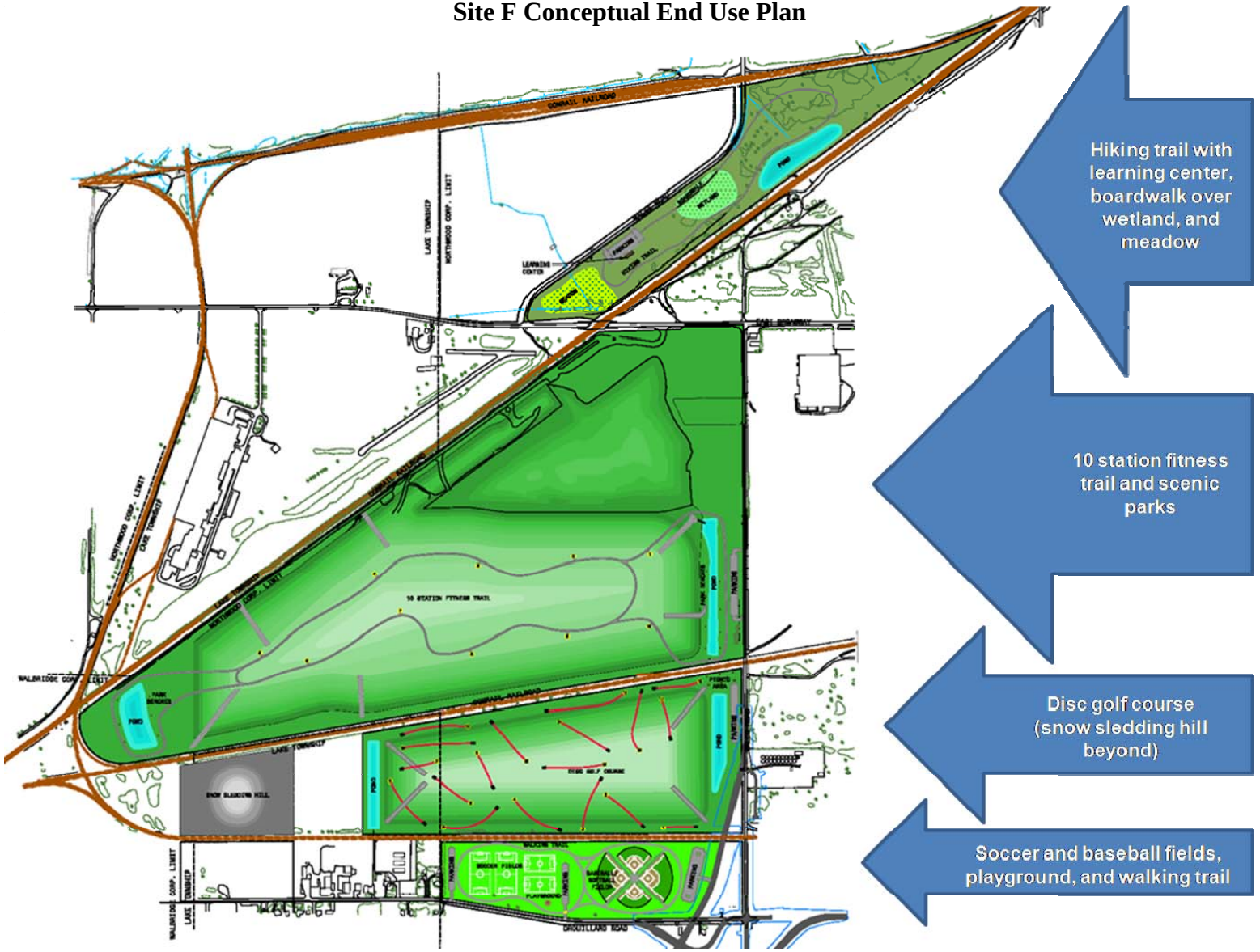

SSZ - Significant Saturated Zone
K - Hydraulic Conductivity

**FIGURE F-4**
**Site F Simplified Cross Section**




| Item | Top Elevation (ft-msl) | Bottom Elevation (ft-msl) | Thickness (ft) |
|---|---|---|---|
| LMH #1 | – | 586 | – |
| TOE$_{GW}$ | 620 | – | – |
| Upper Till at MW15 | 615 | 605 | 10 |
| Middle Till at MW15 | 605 | 565 | 40 |
| Lower Till at MW15 | 565 | 545 | 20 |

**FIGURE F-5**
**Site F Conceptual End Use Plan**



## APPENDIX 2-1G

## SUMMARY – SITE G (ILLINOIS)

### Overview

Landfill Property: The original development permit for a 175 acre site with capacity of 27.22 Mcy (2,000 tpd) was issued in 2/1997. In 2/2002, an application for a major permit modification (MPM) to allow vertical and lateral expansion was submitted to IEPA, approved in 7/2004. The vertical expansion increased the maximum filling height by up to 50 ft. The lateral expansion permitted an additional 76 acres for landfilling in a contiguous area S of the original footprint. With the expansion, the total permitted capacity of the 251-ac, 14-phase landfill is 45.37 Mcy.

Study WMU: The study WMU comprises inactive Phase IV (liner footprint = 25.7 acres, consumed airspace = 3.69 Mcy) of the active landfill. Despite being part of the original landfill permit, Phase IV was not constructed until 2002. The phase comprises two modules; operating authorization for Phase IV was received in 1/2003 (Module 1) and 9/2004 (Module 2). Waste placement in Phase IV occurred between 1/2003 and 11/2005. Because of the location and geometry of Phase IV on the property, it will not be affected by the vertical expansion and was closure capped in 2006.

The physiographical setting of the property and study unit is shown on Figure G-1. A stylized depiction of the site layout is provided as Figure G-2.

### Site Information

Geologic and Hydrogeologic Setting: A detailed Phase I, II, and III Hydrogeological Investigation (HGI) was conducted prior to initial development of the landfill in 1996 and describes a comprehensive desk study of the local region and site investigative work conducted between 1963 and 1993. The landfill is located in an area which is relatively straightforward in terms of hydrogeological characteristics but is quite complex in terms of its geological history and processes. Deep valleys were carved into the bedrock surface and subsequently filled with an assortment of glacial till, outwash, fluvial, alluvial, lacustrine, and aeolian deposits. Repeated erosional and depositional events, throughout four glacial epochs, had their impact upon the resulting stratigraphic record. Such events have left high terraces filled with sediments that may be older than sediments found within deeper portions of the buried bedrock valleys. Geologic and hydrogeologic cross sections are provided in Figures G-3 and G-4.

Regional Geology: The landscape of the region is underlain by Quaternary System, Pleistocene Series glacial drift which overlies Paleozoic bedrock. At the site, glacial drift deposits are composed predominantly of Esmond Till underlain by glacial outwash and older glacial deposits. The clay content of the Esmond Till generally ranges from 30 to 50 percent and forms the groundmass or matrix for the coarser particles.

*Bedrock Geology* – Topographic maps of the bedrock surface show a deeply entrenched system of bedrock valleys. These include the Sugar, Pecatonica, Rock, and Troy Bedrock Valleys. The site is located just east of center over the Rock Bedrock Valley. The valley walls range from elevation 750 ft-msl in the higher reaches, to an elevation of 450 ft-msl at the valley floor. The Geologic Map of Illinois shows bedrock to consist of Ordovician Galena-Platteville Group dolomites and limestones over most of the region, with the underlying Ordovician Glenwood and St. Peter Sandstones outcropping in the floors of the bedrock valleys. Older Ordovician and underlying Cambrian rocks are exposed at the bedrock surface approximately 18 miles south of the site region. Younger Ordovician Maquoketa Shales are found at the bedrock surface east of the site. Shales occur in patches and even younger Pennsylvanian strata, with associated coal deposits, occur south of the site.

*Regional Pleistocene Geology* – Glacial deposits fill the bedrock valleys and blanket the bedrock surface outside of the valleys. The drift ranges in thickness from absent to as much as 400 ft in portions of buried bedrock valleys. The geology of the region is the result of four major glacial stages that served to shape the bedrock surface and were responsible for overburden deposition and morphology. The first was the Nebraskan Stage, evidence for which consists predominantly of brown chert gravels found in terraces above the deeper floors of bedrock valleys. The second was the Kansan Stage, which left a record of extensive sand deposits in buried bedrock valleys as well as glacial till deposits. The Illinoian Glacial Stage represents the third Pleistocene glaciation. Deposits from this stage include the greater portion of sediments found and include tills and associated outwash sediments collectively included in the Illinoian Glasford Formation. The fourth Wisconsinan Stage was responsible, through a series of substages, for further deposition of till, silts, clays, loess, and outwash deposits of sand and gravel. A map of surficial geology shows the site to be located on Illinoian Esmond Till.

Site Geology: Based on the log for Boring PB-1 in the geographic center of the study WMU, in geological terms the base of the study WMU (approx. 720 ft-msl) is located over 5 ft of Esmond Till (Phase II), which in turn overlies 18 ft of Esmond Till (Phase III), overlying 10 ft of Fine Sands/Quiet Water, then several tens of feet of Second Outwash sands and gravels. As described below, the Second Outwash is considered to represent the uppermost aquifer. These units are described below.

*Esmond Till* – The Esmond Till occurs as a blanket over most of the site. It occurs in three phases. Phase I occurs primarily in the upper portion, but interfingers with, and sometimes is present below, Phase II material. Phase I consists of grey silt with variable clay content and

occasional traces of organics. The organics occur as a fine smearing along laminae and the silt interfingers with silty clay. This material has been labeled as disturbed kettle deposits. Phase II consists of a silty clay with traces of coarse sand and small to large gravel and is considered to be meltout till. In some areas the till contains traces of fine to medium sand. It is grey to dark grey in color, and may contain hairline silt or fine sand partings. Occasional lamination or foliation is found in this unit. Phase III is the basal phase of the Esmond Till. It is included as part of the Esmond Till classification primarily because the Phase Il/Phase III contact is transitional, and this basal phase occurs everywhere below the other two phases. Phase III is not, however, a till-like material as it consists primarily of clay, or in some places silty clay with rare to no sand or pebble content, and has a greater plasticity than the silty clays of Phases I and II. It is primarily distinguished for its lamination and occasional foliation. The lamination actually appears as horizontal foliation and the clay has been described on the logs as being "thinly deeply laminated." At the base of this deposit, numerous very thin fine sand and silt seams are present, as if incorporated from underlying fine sand/quiet water deposits through structural shearing.

*Fine Sands/Quiet Water Deposits* – A relatively thin unit occurs above the second outwash just below the Esmond Till which is referred to as "fine sands" or "fine sands/quiet water." This unit is composed predominantly of a very well sorted fine to medium sand. Included within this deposit are silty fine sands, sandy fine silts, and thin clay seams. Organics are present in this unit and it variously displays characteristics of quiet water and aeolian sedimentation. The unit is absent to thin in southern portions of the site, becoming thicker with an irregular upper surface in northern portions of the site. At the northern extreme of the property the fine sand unit merges with fine sands and lacustrine deposits which occur beyond a point where the Esmond Till pinches out. At some locations, barely discernable laminae were noted in the fine sand unit in its upper portion just below the Esmond Till. Also noted were bedding planes and cross bedding, sometimes with concentrations of dark mineral grains along the bedding planes.

*Second Outwash* – The second outwash is composed predominantly of fine to coarse sands and small to large gravels in crude beds having a coarsening downward sequence. Occasional beds of fine to medium sand with a trace to some coarse sand and gravel and rare, relatively thin, silt beds occur within the deposit. The outwash gravel is composed predominantly of dolomite and silicified dolomite and includes brown chert, igneous rock, and fine grained black rock with occasional traces of jasper, coal, and rare pyrite.

Regional Hydrogeology: Compared to the complex regional geology, the regional hydrogeology is relatively straightforward. A printout from the Illinois State Water Survey database reports transmissivities and hydraulic conductivities derived from specific capacity tests conducted in wells penetrating deeper portions of the valley. Transmissivities are reported between 100,000 and 770,000 gallons per day per foot for the full thickness of the aquifer, with lower values more common. Hydraulic conductivities reported are on the order of $10^{-1}$ cm/sec.

In the site region, the aquifer group known variously as the Cambrian Ordovician and the

Midwest Aquifer Group is present below glacial drift. The Ancell Aquifer, which includes the St. Peter Sandstone and the overlying Glenwood Sandstone where present, is one of the principal aquifers of this group. It averages 200 feet in thickness. The Ancell Aquifer is overlain by the Galena-Platteville unit which often forms a confining layer above the Ancell Group, but locally may yield large water supplies. The confining Maquoketa Shale is absent in the site region; consequently, the Galena-Platteville is directly recharged through glacial drift. The Ancell Group also is in direct communication with glacial drift where it is exposed in the floors of the buried bedrock valleys.

Because of direct communication between bedrock and drift aquifers contained within the walls of the bedrock valleys, and the lack of a bedrock confining layer, the piezometric surface reported for the Midwest Aquifer Group should reflect general regional groundwater flow. The piezometric surface at the site, both in bedrock and in the more permeable valley sediments, should occur somewhere between 700 and 750 ft-msl, being closer to 700 ft-msl. In the site vicinity, the topographic high of the morainal ridge, and more locally the north-south trending portion of that ridge, forms a local recharge area. The named creek to the east and north, and the unnamed tributary to the west, defines local discharge areas. The high point of the north-south trending portion of the ridge forms a local groundwater divide which separates the site from the eastern segment of the creek, thus rendering the northern segment more influential as a discharge area with respect to the site. The site is topographically high to the southeast and lower to the north and west. Topographic control of groundwater would indicate a northerly and/or westerly direction of flow. Because the creek to the north of the site forms the lowest nearby topography, flow is expected to be more northerly than westerly.

Groundwater is expected to flow vertically at a very slow rate through the till and horizontally at a much higher rate through sands and gravels, again in a general northerly direction. Sands and gravels occurring below or adjacent to the Esmond Till form the uppermost aquifer at the site. Glacial deposits are saturated below the water table. Several site specific studies in Illinois glacial tills have indicated that the water table varies seasonally, typically occupies a position between ground surface and approximately 12 feet below ground surface, and generally parallels topography. While flow through till deposits is at a very slow rate in a predominantly vertical direction, the configuration of the water table imparts a slight horizontal component of flow to the north and west.

Boring Logs: The Phase I site investigation was conducted by researching available literature and evaluating water well logs within one mile of the study area. Water wells within one mile of the site were inventoried in order to determine aquifer useage in the site vicinity. Twenty-four well logs were obtained from the Illinois State Geological and State Water Surveys. These logs are available. The well logs show varying amounts of clay, sand and gravel, and bedrock. One well clearly penetrated Rock Bedrock Valley sediments, whereas several wells located farther from the site penetrated bedrock at relatively higher elevations which places them outside the bedrock valley. The Phase I study encompassed work on the existing site which began in 1989,

for which an initial background report was prepared, and extended through additional existing and proposed site investigations through 1993. Boring logs and test pit profiles from the 1993 investigations are available. Applicable boring log data are used to generate the geologic and hydrogeologic cross sections provided in Figures G-3 and G-4.

Hydraulic Conductivity: The geometric mean hydraulic conductivities of the four main units of interest at the site as measured in the field (F) and laboratory (L) are: (i) Esmond Till (Phase II), $1.97 \times 10^{-7}$ cm/s (F), $4.22 \times 10^{-8}$ cm/s (L); (ii) Esmond Till (Phase III), $1.69 \times 10^{-7}$ cm/s (F), $3.63 \times 10^{-8}$ cm/s (L); (iii) Fine Sands/Quiet Water, $3.17 \times 10^{-3}$ cm/s (F); and (iv) Second Outwash (Aquifer), $2.67 \times 10^{-2}$ cm/s (F).

Groundwater: In the strictest sense of the regulatory language, the uppermost aquifer must be interpreted to include all sands or sands and gravels within the Rock Bedrock Valley as well as underlying and adjacent Galena-Platteville bedrock, lower St. Peter Sandstone, and the entire thickness of the Cambrian-Ordovician aquifer. Detailed characterization of hundreds of feet of geologic formations is neither practicable nor useful for a site located over a much more localized hydrogeologic regime.

During establishment of GW monitoring requirements for the site, based on regional data, existing site data, and deep boring G1G3D log, there was evidence that an upper outwash sand and gravel layer occurred below the Esmond Till, overlying an 80 foot thickness of fine sand, which in turn was underlain by clayey gravels and bedrock. The sand and gravel outwash, with its much higher hydraulic conductivity with respect to that of the underlying fine sand, was expected to dominate in terms of groundwater flow and contaminant transport below the site. Low vertical gradients observed in existing wells and regional groundwater flows supported this expectation. Consequently, the upper sand and gravel outwash portion of the uppermost aquifer was determined to be the most important layer for hydrogeologic characterization, and is hereinafter referred to as the outwash aquifer or the sand and gravel aquifer to distinguish it from the more extensive uppermost aquifer as defined by 35 IAC 811/812. This outwash portion of the uppermost aquifer became the subject of extensive site investigation during 1992, and the entire unconsolidated portion of the uppermost aquifer was explored to depths 300 feet below ground surface during the 1993 site investigation.

Physiographical Setting: Topographically the site is located on the shallow slopes of a broad flat valley formed by a named creek. The creek is located approximately one mile east of the site where it flows through the valley to the north. It curves westward and passes just under one mile north of the site toward its confluence with a reasonably large river approximately 1.5 miles northwest of the site. The higher topography in the southeast portion of the site is part of a north-south trending ridge. This ridge, defined by the creek to the east, and an unnamed drainage tributary to the west, is part of a much larger ridge which trends slightly south of west to slightly north of east.

Potential Point(s) of Exposure: Farming is the predominant land use in the site vicinity, but landfills and gravel pits are present as well. In addition to the study site and existing adjacent closed landfill is a landfill located just less than one mile ENE of the site. Gravel pits are located just under one mile to the ENE and N, respectively. A major railroad runs N-S along the W property boundary. The 1996 HGI reports that a gas main is aligned E-W through the northern portion of the property, although the current status of that gas line is not clear.

Water wells within one mile of the site were inventoried by the 1996 HGI in order to determine aquifer usage in the site vicinity. Twenty-four well logs were obtained from the Illinois State Geological and State Water Surveys. Several residences are located near the site. These residences, as well as other residences within one mile of the site, likely have wells, but no logs were available for these locations. All are located over 500 feet from the proposed landfill boundaries. Five wells are located on the adjacent landfill property. A well located in the southeast portion of the site is understood from conversations with the previous landowner to be almost 200 feet deep, but little else is known about it. Wells to the north and southwest are said to be shallow.

No community water supplies are known to be present within one mile of the proposed landfill. The nearest recorded community wells are two wells located a little over four miles west. Both draw water from the St. Peter Sandstone at levels of 300 and 445 feet, respectively. The nearest communities are located approximately two miles to the N and S of the site. Neither is documented to have community wells and is either on public water supply or is supplied from private wells.

The location of the facility with respect to water wells and groundwater is such that no part of the unit is located within a setback zone nor is any part of a unit located within the recharge zone or within 1200 feet vertically or horizontally of a sole source aquifer.

Climate: The climate of the study WMU is typical for northern Illinois. Based on a review of NOAA records for the period 1951 through 1980, reported mean temperatures throughout the year range from 18.3 to 73.0 degrees Fahrenheit, with a mean annual temperature of 47.8 degrees. Normal precipitation ranges from a February low of 1.18 inches to a June high of 4.58 inches, with an average annual precipitation of 36.78 inches. The prevailing wind direction, averaged over a ten year period, is from due south, 180 degrees on the compass. Average wind speed for the same period is reported as 8.9 knots.

## Waste Placement and Operations

Waste Placement Data: In 2002, the site was receiving about 3,600 tpd of MSW, commercial refuse, and nonhazardous permitted special wastes. Annual site records indicate that 3.46 million tons of waste was disposed of between 1 Oct 2002 and 1 Oct 2005. Waste placement in Phase IV began in February 2003 and ceased in October 2005. Approximately 2.77 million tons

of waste was placed in the WMU during that period. This number was estimated by the site manager, as some wastes received during that period were placed in other areas of the facility.

Waste Composition: Between 10/2006 and 3/2007, waste disposed of at the landfill comprised 60% MSW, 26% C&D, 4% special, and 11% contaminated soil (by weight). Between 4/2007 and 4/2008, waste disposed of at the landfill comprised 62% MSW, 32% C&D, 5% special, and 3% contaminated soil (by weight).

## Closure and Post-Closure (C/PC) Plan

The most recent C/PC Plan for the site is included in the 2/2002 permit application. The PCC period is assumed to be 30 years after final closure of the entire site. PCC activities include inspection and maintenance of final cover, vegetation, drainage ditches, sedimentation basins, and access roads. Initially, cover inspection will be required quarterly; if, after 5 years, settling has stopped and there are no E&S problems, the frequency will be reduced to annual. GW and gas monitoring will continue for 30 years, and the provisions of the SWPPP implemented. The LCRS and recirculation system will be monitored and maintained at least monthly.

## End Use Strategy

The end use strategy is for the site to be used as greenspace set-aside.

## Liner System

Design: Phase IV was constructed in 2 modules; a temporary delineation berm separated the two modules during construction. Module 1 abuts Phase III and is about 50% larger than external Module 2. The liner system basegrades in Module 1 run from W-E across the module (max top of GDL elevation at W edge = 728 ft-msl, min elevation at E near sumps = 714 ft-msl). The liner system basegrades in Module 2 run from W-E across the module (max top of GDL elevation at W edge near Module 1 boundary = 726 ft-msl, min elevation at NE corner near sump = 714 ft-msl). Liner subbase grades were set to maintain at least 10 ft of in-situ clay (Esmond Till) beneath the bottom of the liner.

The liner system for Phase IV (see section below) comprises, from bottom to top: 4-ft of recompacted clay, 60-mil HDPE smooth geomembrane, and 8-oz nonwoven geotextile cushion. The geotextile is overlain by a 12-in thick granular drainage layer. The liner slopes at 1% W-E (along the main leachate collection pipes) and at 3-5% perpendicular to the pipes.

CQA and Construction Records: An 11/2002 construction acceptance report is available for Module 1. An 8/2004 construction acceptance report is available for Module 2.

As-Built Drawings: Construction acceptance drawings (plans and details) dated 10/2002 and 8/2004, respectively, are available for Modules 1 and 2.

## Leachate Management System

Design: Phase IV was constructed in 2 modules; Module 1 abuts Phase III and is about 50% larger than external Module 2. Three leachate collection pipes run W-E across the length of Module 1, equally dividing the basal area. A leachate collection sump with external clean-out riser is located at the E end of the N and S leachate collection pipes. The N sump is designated L-306 and the S sump is designated L-305. The central pipe drains to both sumps in pipes along the E internal toe. In Module 2, two leachate collection pipes run W-E across the length of the module. A leachate collection sump (designated L-307) with external clean-out riser is located at the E end of the N leachate collection pipe. The S pipe drains to both sumps L-307 and L-306 in pipes along the E internal toe. Leachate is pumped from all three sumps via a forcemain and series of transfer manholes to a 100,000 aboveground central storage tank for truck disposal to POTW.

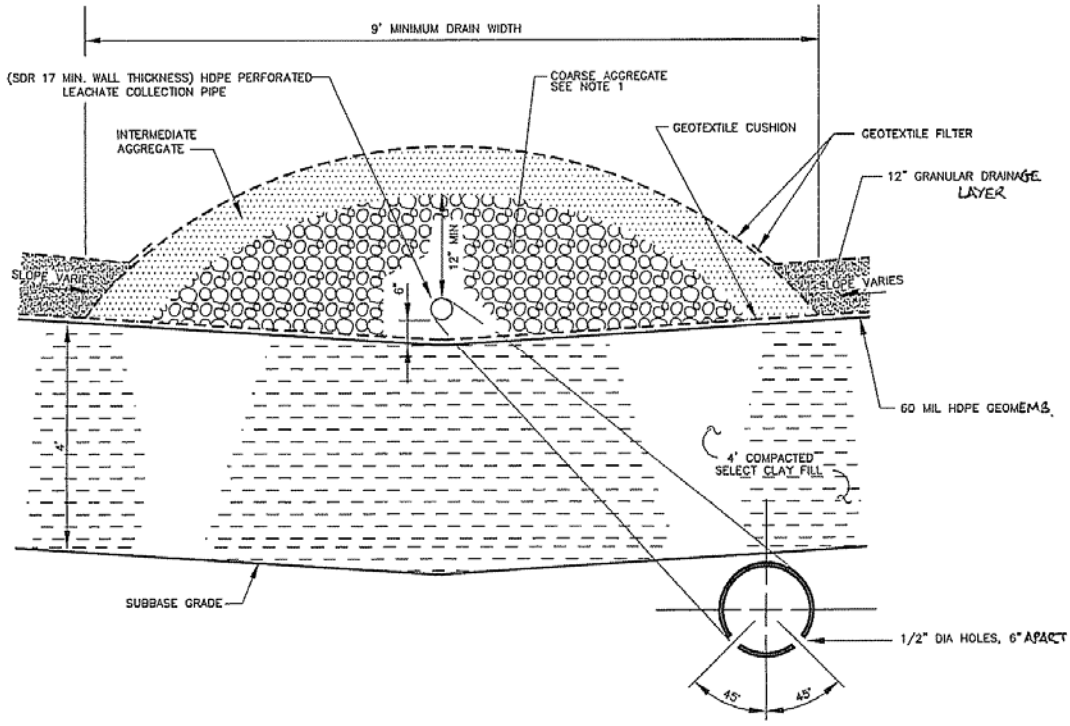
The leachate collection system comprises 12-in granular drainage layer (GDL) above the liner, sloping at 3-5% perpendicularly to the 6-in dia. leachate collection pipes. The GDL is overlain by a 6-oz nonwoven geotextile filter. A cross section through the leachate collection pipes is shown overleaf. The min base elevation at the sumps is at about 708 ft-msl. Leachate is pumped from all three sumps via a forcemain and series of transfer manholes to a central storage location.

Leachate Recirculation: A total of 13 equally-spaced, horizontal E-W orientation leachate recirculation lines were placed in Phase IV in two lifts: Lift 1 comprises 5 lines, LRL15 – LRL19, Lift 2 comprises 8 lines, LRL22 – LRL29. Construction acceptance reports and drawings (plans and details) for the recirculation system are dated 2/2004 and 5/2005 for Modules 1 and 2, respectively.

Operating authorization for leachate recirculation in Phase IV was received in 4/2004. Recirculation in Phase IV began in 7/2004. Leachate has also been recirculated in Phase I-III since mid-2003 and surface application at the working face is currently practiced. Leachate recirculation volumes are recorded monthly and injection quantities tracked by phase. Recirculation logs for 2005-2008 are available. Recirculated leachate is not phase-specific.

CQA and Construction Records: An 11/2002 construction acceptance report is available for Module 1. An 8/2004 construction acceptance report is available for Module 2.

As-Built Drawings: Construction acceptance drawings (plans and details) dated 10/2002 are available for Module 1. Construction acceptance drawings (plans and details) dated 8/2004 are available for Module 2.




**Leachate Collection System and Liner**

Leachate Sampling and Data: Leachate monitoring is required quarterly at nine sumps and the storage tank. Data are reportedly available through 1999 (some paper records from 2003 through 2007 were obtained). Two monitoring lists are required: List L1 (68 parameters) must be monitored quarterly, List L2 (202 parameters) must be monitored semi-annually. Further an annual "representative sample" (LREP) must be collected and tested for List L3 described as "analysis for RCRA characteristics and toxicity," not seen.

Leachate flow at the sumps has been recorded monthly since about 2003. Electronic data are available for 2005 and 2006.

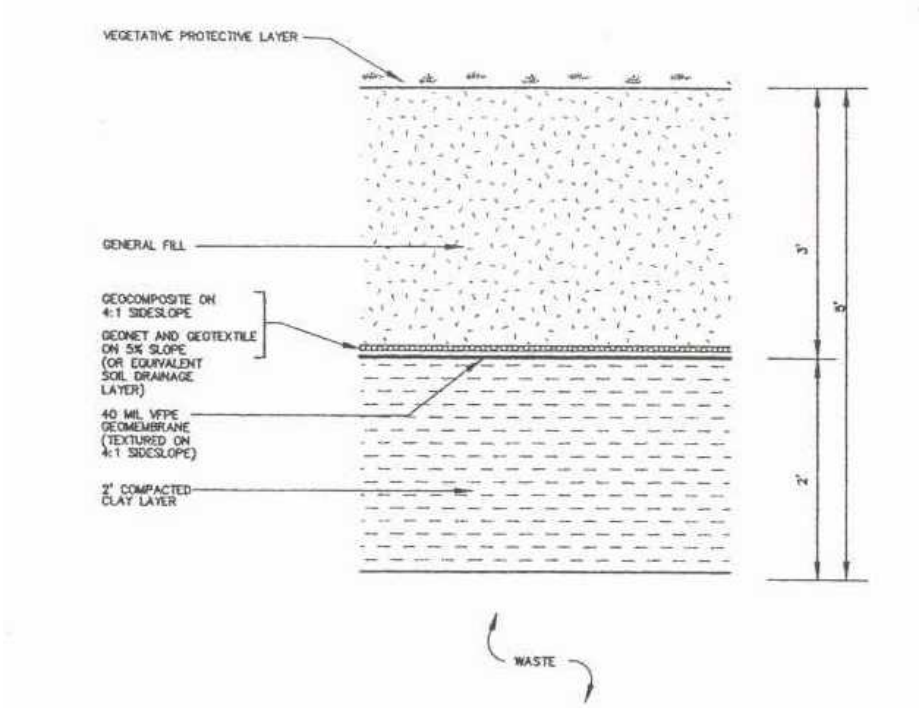
*Leachate Data (Paper)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | COD | BOD |
|---|---|---|---|---|---|---|
| L-305 | 28 | 2003, 2007 | 202 | Y | Y | Y |
| L-306 | 28 | 2003, 2007 | 202 | Y | Y | Y |
| L-307 | 28 | 2005, 2007 | 202 | Y | Y | Y |
| L-310 (Tank) | 28 | 2003, 2007 | 202 | Y | Y | Y |
| LREP | 7 | 2003, 2007 | List L3 | | | |

Compliance Issues and Community Concerns: None reported.

## Cover System

Design: Capping of Phase IV began in April 2006 and was completed in October 2006. The final cover system comprises, from bottom to top, 2-ft compacted clay overlain by geosynthetics (see below) overlain by 3-ft general fill vegetative protective layer.




**Composite Final Cover System**

CQA and Other Construction Records: A construction acceptance report for the composite cover system for Phase IV is dated 1/2007.

As-Built Drawings: A construction acceptance drawing (top of grading layer plan) for the composite cover system for Phase IV is dated 1/2007 for cover system construction completed in 2006.

Topographic Surveys: Whole-site aerial topo surveys dated 10/2006, 4/2007, and 4/2008 are available, although the site manager reports that annual survey from 1997 to 1999 and quarterly surveys thereafter were flown. The latter shows the maximum crest elevation in Phase IV as 863 ft-msl.

Cover Monitoring and Maintenance: Cap has a history of requiring minor repair as a result of E&S damage.

Compliance Issues and Community Concerns: None.

## Landfill Gas Control System

Active Gas Control System: 17 new wells in Phase IV (#10-26) are shown on an 8/2006 gas system construction acceptance drawing. No existing wells in Phase IV are shown on that drawing. All GCCS features on the landfill are buried beneath the final cover except wellheads. Well depths vary from 45-55 ft around the perimeter to 140 ft at the crest. All well end at least 10 ft above the granular drainage layer above the liner. Operating authorization for the gas system in Phase IV was received in 4/2004.

The entire GCCS for the facility currently comprises a total of 35 wells and various connections to LR lines and risers (for odor control) across the landfill.

Gas Utilization: None, although LFGTE is under consideration.

Passive Gas Vents: None.

Construction Details and As-Built Drawings: A construction acceptance report and drawings (plan and details) for new gas wells and piping in Phase IV and northern portions of Phase III are dated 8/1996. The new system ties into an existing GCCS in Phases I – III.

Landfill Gas Data: Various GCCS monitoring has been ongoing since 2004.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Flare Log | Yes | Yes | Monthly monitoring and annual Title V reports (not seen). |
| Wellheads | Yes | Composition ($CH_4$, $O_2$, $CO_2$, balance), temperature, and differential pressure | Monthly monitoring. Monthly data (E) available for 2006-2008. |
| Surface Scans | | Methane | Per Title V permit |
| Four internal gas probes | | $CH_4$, $N_2$, $O_2$, $CO_2$ and pressure | To provide representative sampling of composition and build up of gases as required by IEPA. |
| Ambient air, AA-1 to AA-3 | | Methane (%) measured in air at 3 locations 100 ft downwind of site or at property line. | Monthly data (E) available for 2007-2008. |

Compliance Issues and Community Concerns: None.

## Groundwater Monitoring System

Layout: In accordance with IEPA regulations, analytical contaminant modeling was conducted in 1996 and 2002 to determine necessary well spacing for the landfill. The calculated well spacing for Phase IV is 280 ft screened in the uppermost aquifer within a 100-ft zone of

attenuation (ZOA) that extends horizontally around the landfill. In addition, a ZOA well is required 100-ft downgradient of the landfill.

Monitoring Program: GW monitoring is conducted quarterly at all wells for List G1 and annually for List G2 since 1Q 1998. List G1 includes 24 parameters, List G2 includes 140 parameters. A statistically significant, site-specific Maximum Allowable Predicted Concentration (MAPC) and Applicable Groundwater Quality Standard (AGQS) is calculated for each parameter, based on pooled data from upgradient GW wells. The MAPC is applied at the side- and down-gradient wells within the ZOA. The AGQS is applied at the ZOA well.

Construction Details: All well construction details are reportedly available, not seen. All GW monitoring wells for Phase IV are screened in the Second Outwash.

Groundwater Data: A summary of available analytical data for wells pertinent to the study WMU is provided in the table below. GW monitoring has ongoing at these wells since 1Q 1998 (upgradient) and 1Q 2003 (downgradient). Some additional wells and piezometers may also provide additional GW elevation data.

*Groundwater Data (Paper)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | Na | K |
|---|---|---|---|---|---|---|
| Upgradient, distal G01M, G01D, G04D, G27D/MW-114 | 28 | 2003, 2007 | > 140 | Y | Y | Y |
| Sidegradient, proximal G17D, G18D, G23D | 28 | 2003, 2007 | > 140 | Y | Y | Y |
| Downgradient, proximal G19D, G20D, G21D, G22D, | 28 | 2003, 2007 | > 140 | Y | Y | Y |
| Zone of Attenuation Well G52D | 28 | 2003, 2007 | > 140 | Y | Y | Y |

Compliance Issues and Community Concerns: None.

## Surface Water Monitoring System

Monitoring Program and Locations: Two sedimentation basins exist, sized to store runoff from the 25-year, 24-hr storm and with emergency spillways to safely handle runoff resulting from the 100-yr, 24-hr storm. All runoff from the study WMU is routed to the NW Sedimentation Basin No. 1 (5.5 acres, 9 ft deep). Currently, all SW discharges from the site are covered under individual NPDES permits.

Surface Water Data: SW monitoring records are available (quarterly) since 1997, not seen.

Compliance Issues and Community Concerns: None reported.

### Methane Migration Monitoring System

Layout: The spacing of gas migration monitoring probes around the site is approximately 1,000 ft. Three probes are relevant to Phase IV: GMP22 (east), GMP23 (north), and GMP24 (west).

Monitoring Plan and Data: Monthly monitoring has been ongoing since 1998.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| 10 perimeter probes | | $CH_4$, $N_2$, $O_2$, $CO_2$ and pressure | Monthly monitoring data are available (E) for 2007 and 2008. |
| 4 on-site structures | | $CH_4$, $N_2$, $O_2$, $CO_2$ | Monthly monitoring, also continuous monitoring for methane in indoor air. |

Compliance Issues and Community Concerns: Occasional exceedences up to 50% LEL for methane were occasionally recorded on the W boundary (not adjacent to the study WMU) prior to installation of the GCCS.

**FIGURE G-1**
**Site G Physiographical Setting**

**Red Line = Property Boundary**

**FIGURE G-2**
**Site G Layout and Features**

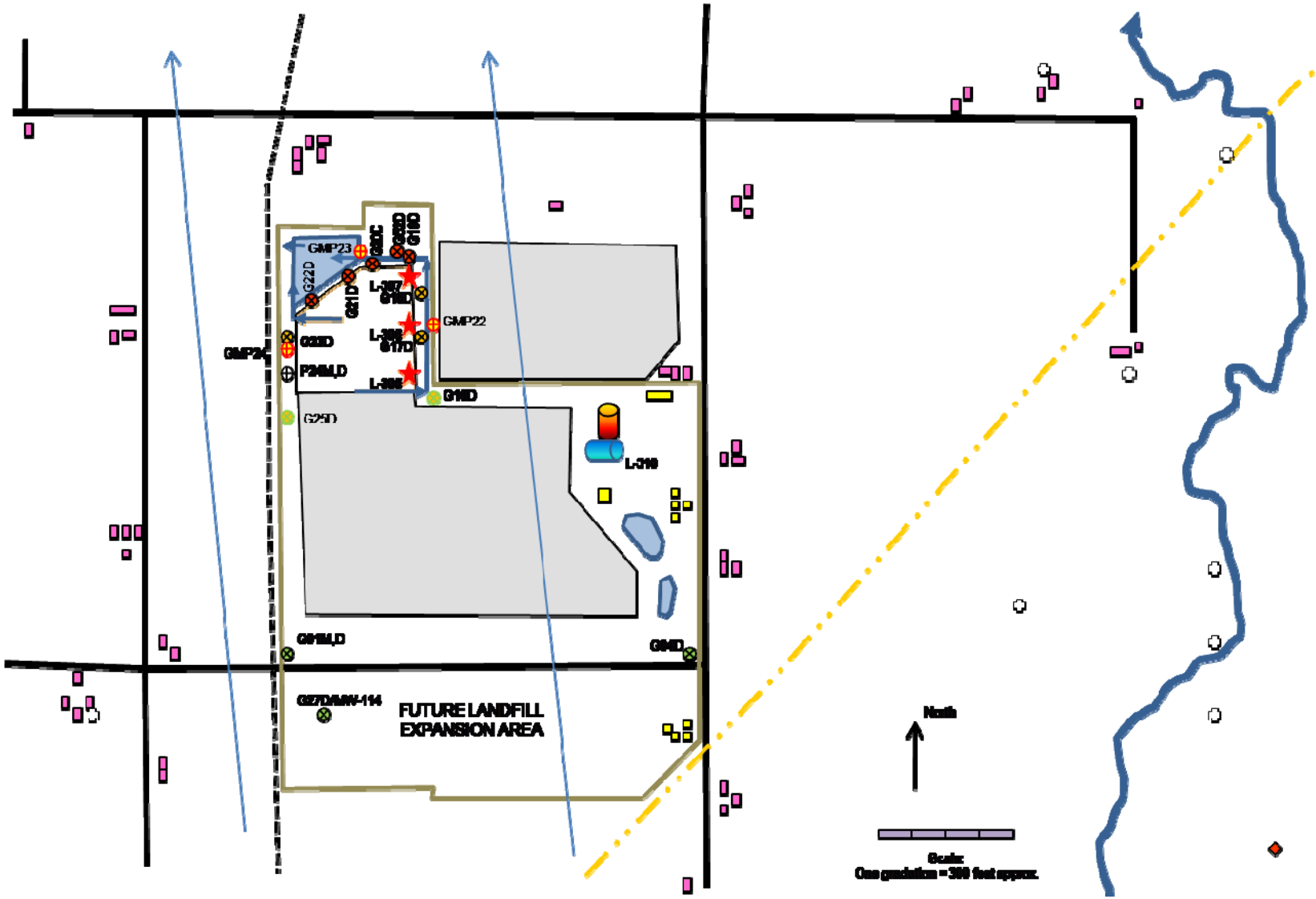


**FIGURE G-3**
**Site G Geologic & Hydrogeologic Cross Section A-A'**

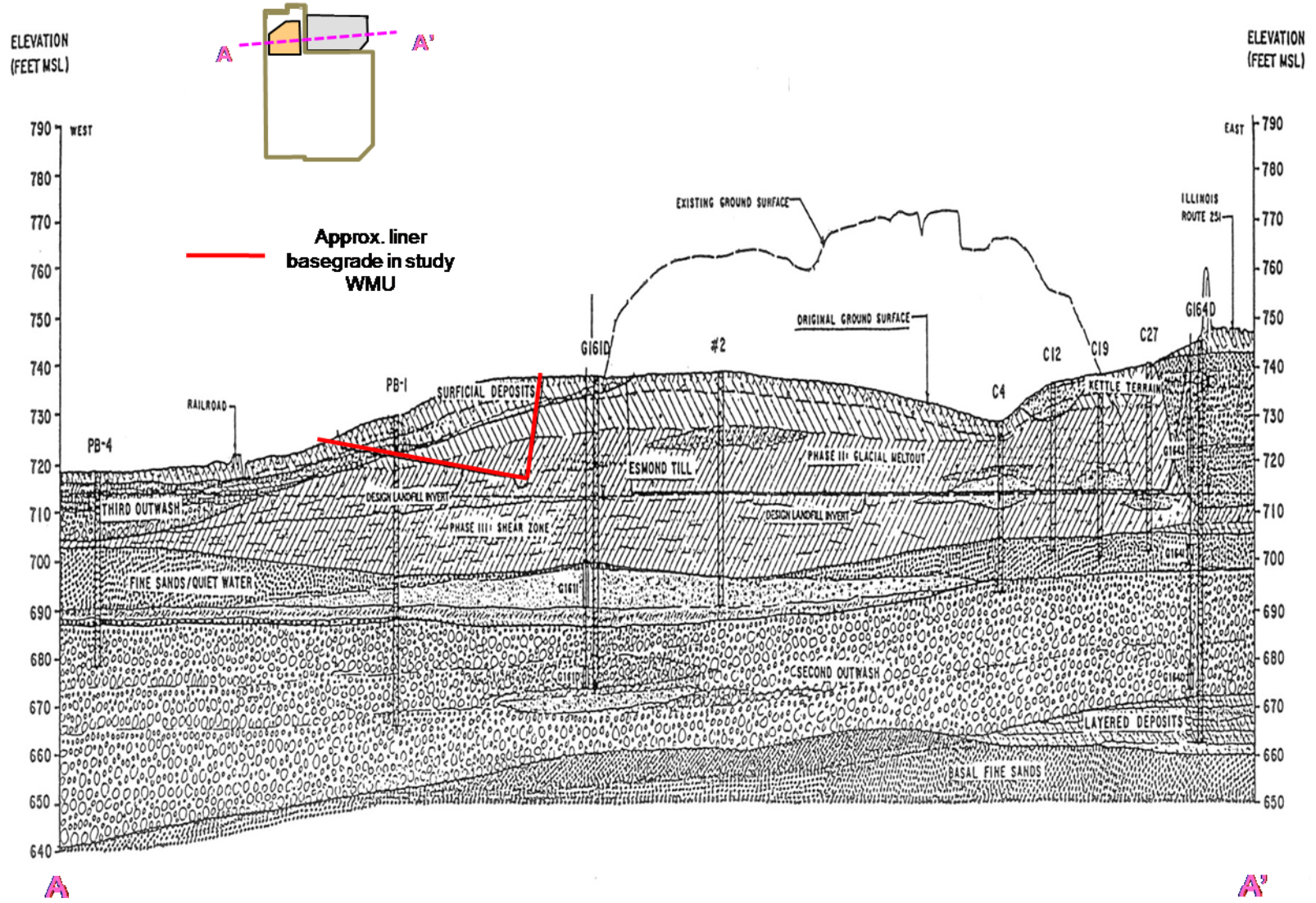
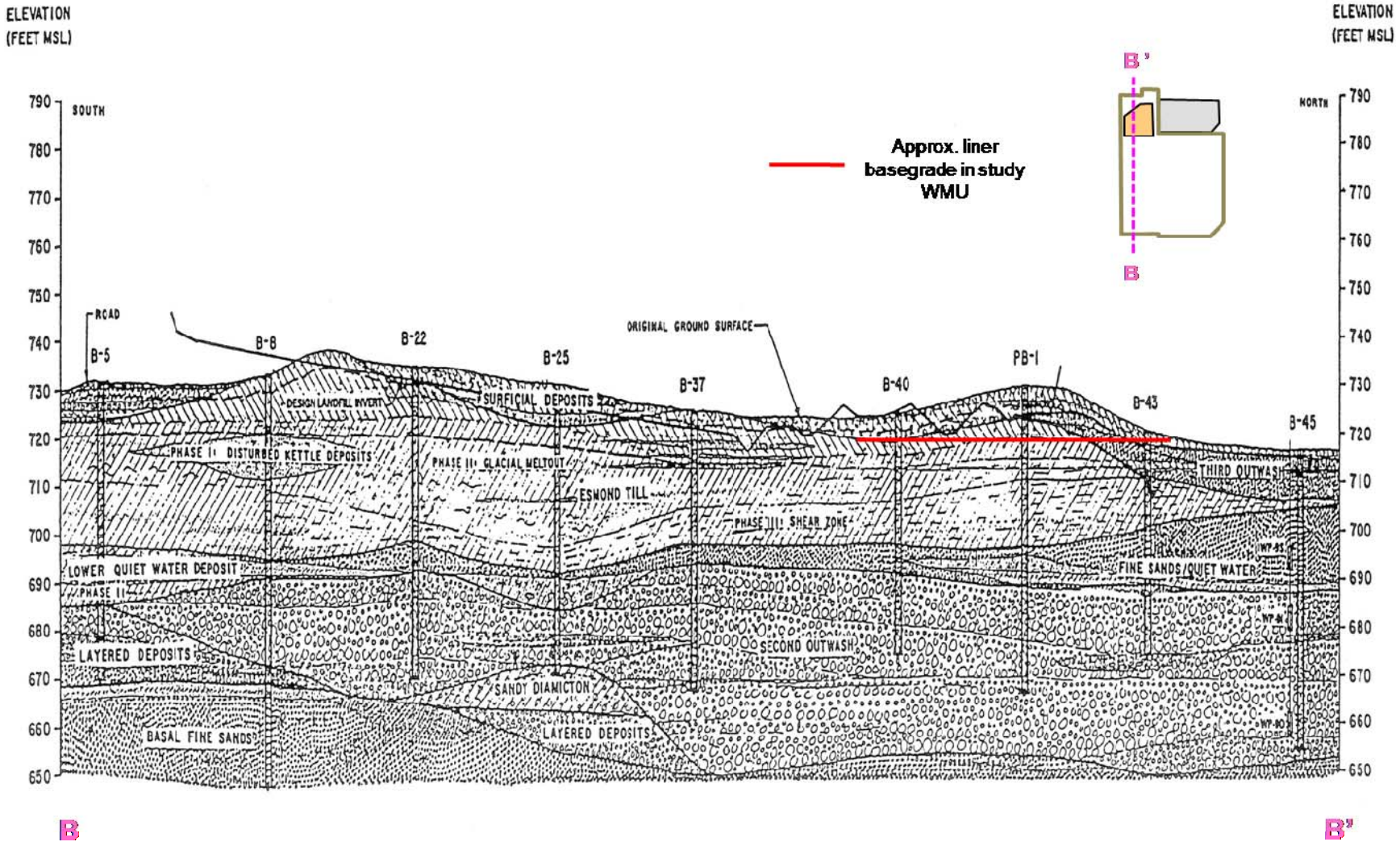


**FIGURE G-4**
**Site G Geologic & Hydrogeologic Cross Section B-B'**



## APPENDIX 2-1H

## SUMMARY – SITE H (MINNESOTA)

### Overview

Study WMU: Site H is an old unlined WMU with an approximately 42-acre footprint and new Phases I, II, and III of approximately 26.5 acres that are "piggy-backed" on the old WMU. The old WMU was privately owned and operated. The active Phases have been owned and operated by Waste Management, Inc. (WMI) and its predecessors since 1990. The most recent approved design includes 10 phases of development, of which Phases I through VII have been constructed.

The old WMU was opened in 1969 on property that was a gravel operation in the 1950s. The permit for the old WMU was issued 4/1970, amended 9/1983 with a hydrogeologic assessment and updated engineering plans. A re-permitting application (3/1988, revised 2/1992) was filed for continued operation. The operating permit was granted 6/1993. The last waste was placed 9/30/1993. Final closure was obtained in 1994. An application for a 125-acre vertical and lateral expansion above the footprint of the existing waste was filed 11/1990, including expanding vertically above the old landfill, and laterally onto the adjacent unlined portion. A re-permitting application was filed 1/1998. Site H participated in a three-year leachate recirculation study from mid-1997 through 6/2000, and a second leachate recirculation pilot study from 8/2001 through the present, in the new Phases I, II, and III of WMU.

Estimates of the original WMU construction are about 56 feet maximum thickness of waste and 20 feet average thickness of waste (Liesch, 10/1990). The original permit (1993 to 2006) was for 3,325,035 CY of waste and daily/intermediate cover. The re-permit (2008) is for an additional 8,353,835 CY. The 42-acre WMU has an estimated waste-in-place of 2,072,708 CY (from WMU site manager). This includes about 95,625 CY of liner material between the final cover of the original unlined WMU and the top of the sand drainage layer for Phases I, II, and III.

Property: The total property size is approximately 225 acres, of which 42 acres were the old WMU, 26.5 acres are Phases I, II, and III of the 60.95-acre active lined waste area, 19.55 acres are a future lined waste area, and 101.5 acres are on an adjacent property to the north of Site H separated by an unpaved county road. Site H consists of the old 42-acre WMU, and the total 26.5-acre Phases I, II, and III that are piggy-backed on the old WMU. The three phases were constructed in 1993, 1994, and 1996. Phases I through III of the expansion are included in this WMU study because Phase I is a control area, and Phases II and III are leachate recirculation study areas.

The Phase I and II disposal cells are underlain by the final cover of the old WMU. The old WMU has undergone one vertical expansion (i.e., Phases I and II) which raised the maximum elevation at closure to about 90 feet above grade. Where possible, Phases I and II are evaluated separately from the original WMU, specifically for control (no leachate recirculation) (Phase I) and bioreactor/recirculation area (Phase II) versus the original WMU.

The physiographical setting of the property and WMU is shown on Figure H-1. A stylized depiction of the site layout is provided as Figure H-2.

## Site Information

Geologic and Hydrogeologic Setting: A summary of the geologic and hydrogeologic setting is included in the Permit Application (Liesch, 3/1988, rev. 2/1992). In addition, a comprehensive Hydrogeologic (HG) Evaluation Report (Geomatrix, 3/2005) was prepared for the adjacent 101.5-acre property to the north.

The site is located in an area of Des Moines Lobe glacial outwash deposits, associated with a drainageway presently expressed as the South Fork of the Crow River, along the southeast side of the WMU. The outwash deposits are bounded on the north and south by glacial deposits associated with the Altamont Moraine. Surface relief (pre-landfilling) probably was fairly flat-lying, based on the previous land use for agriculture prior to gravel mining.

The Des Moines Lobe undifferentiated till deposits are approximately 300 to 400 feet thick, overlying a slightly sloped bedrock surface. The till is unsorted and unstratified gray, calcareous silty tills containing buried sand and gravel deposits of variable shape and thickness.

Bedrock is Cambrian Mount Simon Sandstone and Precambrian Hinkley-Fond du Lac Sandstone of a combined thickness of over 330 feet. The bedrock slopes southeastward.

An important aquifer in the area is a buried outwash sand unit within the undifferentiated till of the Des Moines Lobe. The aquifer is confined sand and gravel over 30 feet thick, at elevations between 805 and 870 feet NGVD. In addition, smaller, more localized buried sand aquifers exist within the till. A deeper aquifer in the Mount Simon-Hinkley Fond du Lac bedrock lies beneath approximately 300 to 400 feet of glacial deposits. This deeper aquifer generally is undeveloped because of the availability of shallower water in the outwash sand units in the glacial till (Liesch, 3/1988, rev. 2/1992).

Shallow groundwater flow generally is from the high moraines and drift areas toward the river (to the southeast beneath Site H). Deep groundwater flow in the bedrock aquifer also is toward the east-southeast. Establishment of a surface-water compliance boundary for the WMU is based on the site-specific hydrogeologic conditions, which are that potentially impacted groundwater beneath the WMU ultimately would discharge to the river. Therefore, water-quality standards for the WMU are intended to be protective of the river.

The geologic units at Site H are subdivided into three units: a black sandy clay loam topsoil ranging from zero to six feet thick, thickest in the lower elevations adjacent to the river, and absent were removed prior to gravel mining; a sand and gravel with varying amounts of clay ranging from less than three feet to 20 feet thick, depending on the undulating surface of the underlying clay till; and a blue-gray, relatively stiff clay till with varying amounts of sand and gravel, ranging from 85 to 190 feet thick, based on the on-site and off-site water-supply wells.

Saturated Zone: All of the WMU groundwater monitoring wells are screened across the surficial sand aquifer. The surficial sand and underlying clay till control the migration of potential impacts from the WMU.

Site HG investigations have determined that the deeper glacial and bedrock aquifers are separated from the WMU by the continuous clay till layer. No shallow water supply wells are located between the WMU and the river. Potential impacts from the WMU are limited to the surficial sand (water table) aquifer and ultimately discharge to the river. There a surface-water compliance boundary and water-quality standards protective of the surface water are approved for this WMU.

Boring Logs: The HG describes site-specific hydrogeologic data based previous investigations by the State highway department to identify sand deposits for road construction (39 shallow soil borings); a soil borrow study to locate near-surface clay deposits for landfill cover; and HG investigations in 1984 (eight piezometers, and four monitoring wells MW-1 through MW-4), 1990 (11 soil borings, four of which were completed as MW-5 through MW-8), and 1993 (15 soil borings drilled beneath Phases I and II). The 1990 efforts reportedly were included in the "Hydrogeologic and Engineering Report", 11/1990, but the report was not found. Three additional piezometers and one additional monitoring well (MW-9A) were installed and reported in the "Hydrogeologic Report Addendum", but the report could not be found. The 15 boring logs from the 1993 effort are included in the "Subsurface Exploration for the Phase I and Phase II Lined Disposal Facility" (STS Consultants, 5/1993). In 1993, the WMU-specific borings penetrated to between 10.4 and 24 feet below ground surface (bgs). The deeper soil borings intentionally penetrated the upper five feet of basal clay. All of the borings encountered groundwater at depths ranging between 2.4 and 6.4 feet below existing grade (nominally, 912 feet NGVD). One on-site water-supply well drilled to 215 feet deep, and some logs for off-site private water-supply wells, provide soil descriptions to total depths as deep as 472 feet bgs. The typical cross-section, a portion of which is included in Figure H-3, was presented in the HG report (Geomatrix, 3/2005). Boring logs from the original groundwater monitoring well installation are available. These include former MW-4A, abandoned in 2001 prior to landfilling in the area. Boring logs for the 15 soil borings drilled in the Phase I/Phase II area are included in the STS letter report (5/1993).

Hydraulic Conductivity: The average horizontal hydraulic conductivity of the surficial sand is 4x10-2 cm/sec. The average vertical hydraulic conductivity of the underlying clay till is 1x10-8 cm/sec. The vertical seepage velocity through the clay till was calculated to be between 0.0016 and 0.0034 ft/year. Based on the higher seepage estimate of 0.0034 ft/year through 85 feet of clay till (clay till thickness in MW-5), impacted water would take 25,000 years to reach deeper aquifers. Horizontal flow velocities through the surficial sand aquifer were estimated to range between 80 and 320 ft/year. Based on the relatively permeable surficial sand and lowly permeable underlying clay till, horizontal groundwater movement through the surficial sand is the predominant path of groundwater movement beneath the WMU.

Groundwater: Groundwater elevations are recorded during groundwater monitoring events and flow beneath the property is well-characterized. All of the monitoring wells were installed with screens across the surficial sand aquifer. The designation of "A" indicates that the well is screened at or near the water table. The wells were installed and completed in 8/1984 (MW-1A through MW-4A), 7/1990 (MW-5A through MW-8A), 4/1991 (MW-9A), and 8/2003 (MW-10A). Well MW-4A was sealed and abandoned before landfilling in the area. Well MW-5A was sealed and abandoned, and replaced by MW-5A(06). A table of well completion data is included in the Engineering Report (ER, Leisch, 8/2002). Total depths range between 8 and 20 feet below ground. Groundwater is present under water-table conditions. Potentiometric data indicate that groundwater flow is toward the south beneath the northwestern portion of the WMU and toward the south-southeast beneath the eastern portion of the WMU. The average horizontal component of hydraulic gradient ranges between 0.001 and 0.0007 ft/ft, based on a 9/2004 groundwater flow map.

Potentiometric maps for 10/96, 9/2004, and 10/2004 show minor variation in the potentiometric surface and flow directions beneath Site H. Groundwater elevations range from 1004 to 1007 feet NGVD in up-gradient well MW-1A; from 1004 to 1007 feet NGVD in side-gradient well MW-8A, and from 1001 to 1008 feet NGVD in down-gradient wells MW-9A, MW-2A, MW-3A, MW-5A(06), MW-7A, and MW-10A. The seasonal high GW elevation is approximately 4.5 feet below the base of waste elevation (1013.5) at up-gradient Sump LCR-3, located midway across Phase I.

Physiographical Setting: The pre-WMU topography was fairly flat, glaciated terrain, sloping towards the South Fork of the Crow River, which flows from west to east and northeast, past the WMU southeastern boundary. The property under development as a WMU located adjacent to the north includes natural wetlands areas. The land surface northwest of the WMU and south of the river is characterized by low rolling topography with subtle, elongated ridges in a northwest-southeast orientation. The orientation of the elongated ridges is indicative of the prevailing direction of ice movement during the most recent glaciations (Late Wisconsin).

Ground-surface elevations at the WMU range from 1,010 feet NVGD in the northwest corner and 1,010 feet NVGD near the river along the southeast side of the WMU.

Unsaturated (Vadose) Zone: The vadose zone is the upper part of the surficial sand that overlies the clay till. Details regarding vadose zone soil description are available on soil boring logs (STS, 5/1993), which may be important to consider when completing the landfill gas and groundwater modules. In general:

| | |
|---|---|
| Elevation of lowest point on liner (at a sump in Phase I) | 1013.50 feet NGVD (base of sump 1010.50) |
| Elevation of lysimeter (equivalent to base of clay liner beneath a sump in Phase I) | 1008.50 feet NGVD |
| Elevation of highest seasonal groundwater in well MW-1A | 1008.96 feet NGVD (4/1997) |
| Hydraulic conductivity (assume isotropic, $K_v = K_h$) | 4x10-2 cm/sec |
| Assumed porosity of surficial sand and gravel | 0.20 to 0.35 (Fetter, 1988) |
| Assumed thickness | 4.5 feet (based on boring log data and geologic cross-sections) |
| Assumed thickness | Zero (based on boring log data at former well MW-4A and geologic cross-section) |

Potential Point(s) of Exposure: There is one continually occupied structure/scalehouse and one storage structure, located near the northwest corner of the WMU. The closest off-site POE is the Landfill Gas to Energy (LFGTE) plant located near the northwest corner WMU. Locations of off-site houses and other structures are estimated based on review of a recent Google EARTH© map aerial photograph and site reconnaissance. There is one on-site water well. There are approximately 30 known domestic water wells located within one mile of the WMU, including the on-site water well. For purposes of POE consideration, the nearest buildings are assumed to have private water wells. The closest inhabited residence in 2002 was located approximately 500 feet northwest of the WMU boundary (ER, Leisch, 8/2002). The deeply-buried (confined) sand and gravel deposits are used as a potable water source for water supply wells in the area, including the Site H water supply well. Well depths range between 100 and 200 feet deep, and static water levels range between 10 and 20 feet bgs.

Monitoring of the WMU water-supply well is a permit requirement to verify proper well construction to prevent downward migration of impacts to lower groundwater units. The original site water-supply well was 215 feet deep and located near the southwestern corner of the WMU. When the office was relocated to the northwest corner, a new water-supply well was drilled to 195 feet deep, and the old well was sealed and abandoned. In addition, some private water wells in the vicinity are sampled voluntarily for good community relations and historical purposes. Historically, the concentration of arsenic in groundwater was of concern. In this area, the source of arsenic is from the glacial material, specifically the Des Moines Lobe.

Climate: Precipitation data have been collected for the past 10 to 20 years by a private individual at an off-site meteorological station. Site meteorological data have been collected on the top of the WMU for the past two years.

## Waste Placement and Operations

General: The Site H WMU consists of the original 42-acre landfill, plus the three Phase I, II, and III disposal cells. Waste yardage records do not exist for the original WMU. Waste receipt records exist after 10/1/1993 when the new landfill was opened. In 1993, the waste was composed of 50 percent residential, 24 percent commercial; 25 percent industrial; and 1 percent rural. Currently, waste comes from a 50-mile radius, including a major metropolitan area. The typical MSW waste characterization for 1993 and 1994, according to the State, was 70 percent urban and 30 percent rural.

Waste Placement Data: No on-site stream separation or recycling is known to have occurred at the WMU until a minimal effort when Phases I, II, and III were receiving waste between 1993, and then 2002 to present. An aerial photo from 1990 showed the current conditions as filling from west to east, and recycling drop-off bins for the public located near the WMU offices near the northwest corner. Prior to 2002, MSW, industrial waste, and a small amount of C&D debris was placed in Phases I and II. After 2002, MSW waste is placed in Phase III and later phases. The WMU used 355,000 CY airspace in 2006, and 480,000 CY in 2007 (2006 and 2007 Annual Reports).

The permit for the original WMU (issued 4/1970) was for 15 MM CY. The 1993 permit reduced the original capacity to 8,290,888 CY. Approximately 2.2 MM CY of waste and cover had been landfilled as of 2/1992. The application for vertical expansion (10/1990) planned for compacted waste volume in the vertical expansion of 752,000 CY with 93,000 CY of daily and intermediate cover. A horizontal expansion onto the liner/leachate collection system was planned for additional 5,763,500 CY of waste and daily/intermediate/final cover (PA, 2/1992). The waste-in-place was 6,455,556 CY (2008), as included in permit application in the Request for Permit Modification (RPM) (Leisch, 10/2008).

The old WMU accepted waste on a yardage basis only prior to 10/1/1993. Waste receipts were not kept prior to 10/1/1993. An example of a yearly report of refuse delivered to the old WMU was found for 1988 (included in the Permit Application, Liesch, 12/1992). In 1998, between 37,000 and 51,000 CY were delivered per quarter, totaling 178,910 CY of waste.

Waste density data are available for the Phase I (control) and Phase II (recirculation) areas. In the 1Q08, wet densities of the waste ranged between 1,800 and 2,640 lbs/CY. The average density was 2,210 lb/CY.

Waste Composition: The Permit Modification Application (PMA, Leisch, 10/2008) indicates that the waste stream is classified as non-hazardous and consists of municipal refuse and C&D waste. MSW volumes have averaged 225,000 CY per year. Demolition/industrial waste volumes have averaged 200,000 CY per year. In 2007, of the 480,000 CY, 307,000 CY (64 percent) was MSW and 173,000 CY (36 percent was Demolition/Industrial.

## Closure and Post-Closure (C/PC) Plan

The Closure Plan for existing conditions included a final cover design of four feet thick, from bottom to top, as follows: a 2-feet barrier layer of <2x10-6 cm/sec, a 6-inch sand drainage layer, a 12-inch general fill layer, and a 6-inch inch topsoil layer (Liesch, 10/1990). An average of five percent and 20 percent slopes were modeled to approximate the existing conditions at the WMU. The Closure Plan for the final cover design of the vertical expansion also is four feet thick: 2-feet clay barrier, of <2x10-6 cm/sec; a 12-inch drainage layer of >1x10-2 cm/sec; a filter fabric; and a 12-inch topsoil layer (Liesch, 10/1990).

A new C/PC Plan included in the PMA (10/2008) requested a design modification for the final cover system to be an evapotranspiration (ET) cover system. The ET cover design is a four-feet thick, monolithic soil layer of 2 feet of brown clay, a 12-inch thick layer of compacted wetland or topsoil stockpiled soil, and a 12-inch thick topsoil layer.

The C/PC Plan (10/2008) specifies that the leachate management system will be inspected for pump functionality, leachate level in the storage tank; recirculation of leachate will continue and might continue into post-closure to allow for additional accelerated waste decomposition; the LGMS will be maintained under Title V air permitting, including monitoring each gas well monthly, groundwater monitoring and landfill gas monitoring will continue, and sedimentation basins will be maintained, and sampled in conjunction with groundwater monitoring.

Routine inspection and maintenance of the erosion/surface water control features will be performed during closure. Inspections and repair, as necessary, will be performed under the existing NPDES permit. The exposed final cover over the old WMU (exposed along the west side of the active WMU) is inspected in May and October, including an evaluation of LFG migration, soil erosion, settlement, vegetative cover maintenance and monitoring activities.

## End Use Strategy

As included C/CP Plan (dated 2/1992, rev. 9/1992, 12/1992), the end use strategy for the WMU in 1992 was an open area with limited access to authorized personnel. The 10/2008 post-closure use of the WMU is possibly development as a mixed-use recreational area for the surrounding community.

## Liner System

Design: The old unlined WMU, closed in 1993, was covered with a minimum of 12-inch buffer layer over the waste; 24-inch clay barrier layer; 6-inch sand drainage layer; 12-inch general fill layer, and 6-inch topsoil layer. Construction of the new liner over the previously closed areas of the WMU included stripping and stockpiling the topsoil layer, and stripping the general fill, sand drainage layer, and upper portion of the 2' feet thick clay barrier layer. The upper surface of the clay was re-compacted, then covered with GCL.

Basegrades for cells in Phases I through III placed on the old unlined WMU are designed with a herringbone pattern. Each of the Phases is divided into three cells. The cell width ranges from 160 to 190 feet. The slope of the basegrade allows the flow path of leachate across the base liner from the edge of the cell to the center leachate collection line at a slope greater than two percent. The slope of the central leachate collection line within each cell is 0.5 percent. The Phase I top of liner and final site grades (on the old WMU) are shown on Leisch (5/1993).

The liner system layout for Phase I through VII are shown on the Final Contour Plan (Liesch, 10/2008). The liner design (2/1990) for the horizontal expansion was to be a composite base liner: 2 feet of compacted clay, with maximum permeability of 1x10-7 cm/sec; overlain by 60-mil HDPE flexible membrane liner (FML); overlain by 1-foot sand drainage layer to convey leachate to the collection system and act as a buffer layer between the waste and the liner, minimum permeability of 1x10-3 cm/sec.

From boring logs, there is typically four feet of separation between the bottom of the Phase I cells and the average seasonal groundwater level. There is a basegrade low point (1013.5 feet NGVD) at the lowest sump located along the north side of Phase I. Figure H-2 shows the lowest point near LCR-3. Based on review of groundwater elevations in the nearest up-gradient well (1008.50 feet NGVD at MW-1A), groundwater levels historically have been below the WMU basegrades.

CQA and Construction Records: Phase I Construction Documentation Report (Liesch, 9/1993) contains a summary of density test results, and clay liner laboratory testing results. Subsequent CQA documentation for later phases are available.

As-Built Drawings: An as-built "Phase I top of liner and final site grades" plan is Figure 11 (Leisch 5/1993). The final site grades of the old WMU and the top of sand contour, leachate collection plan, anchor trench, and berm of the Phase I expansion are shown.

## Leachate Management System

Layout and Design: A Leachate Management Plan was prepared for the original WMU (2/1992, revised 8/1992, 12/1992). Annual leachate flow data by phase exist since 1997. The leachate collection system consists of two sumps located around the southeast perimeter of the WMU,

and 15 sumps located along the north perimeter of the WMU, and leachate collection system. Each of Phases I through III has three sumps, located along the northern edges of the cells comprising the Phases. Perforated leachate collection pipes drain from the south to the north for phases along the north perimeter, including Phases I through III, and drain from the north to the south for phases along the east side of the WMU. The sumps along the north perimeter of the WMU represent the low area of the liner, and were used for the time of travel (TOT) calculations pertaining to the Site H study area. Although the sumps along the southeast perimeter also represent the low end of the WMU, these are not related to the Site H study area and are not used in the TOT calculations.

The leachate collection system is designed to collect and convey leachate along the base liner of the cell by gravity drainage. The collection pipes prevent head build-up at the lowest point in the collection system to less than 6 inches. The top of the cohesive soil liner is sloped toward the sumps, providing positive drainage. The collection pipes are 6-inch Sch. 80 perforated PVC pipe placed at a 3:1 slope. The collection pipes are in slots excavated into the clay barrier layer. The liner and LCRS components in the slots are seamed 40-mil FML, a geotextile filter fabric layer, the collection pipe and sand bedding material, and the filter fabric folded and over-lapped over the top of the bedding sand mound.

The WMU liner and slope of the basegrade promotes leachate flow to a collection point. Leachate is removed from the liner area by submersible pumps. Leachate is pumped up the access pipe to a collection header draining to a collection wet well. Leachate in the collection wet well is pumped to a 100,000-gallon epoxy coated above-ground concrete tank, located along the west side of the WMU. The State required lysimeters to be constructed below leachate collection sumps. The lysimeters are 25 feet wide and 50-feet long, and located along the main axis of each cell. The lysimeters consist of a 60-mil HDPE liner and drainage net, a 6-inch perforated drain pipe to collect liquid, and a solid 6-inch pipe to convey liquid to the lysimeter collection well. The lysimeter collection well is a 4-foot drop leg and stand pipe reaching above ground surface. Details of leachate collection system, including lysimeter piping and liner, are available (Liesch, 8/2002).

Leachate has been generated and collected in the lined portion of the WMU since 1993, and hauled for treatment at a POTW. Since 1997, leachate is collected in an on-site tank, and recirculated in Phases II and III, and more recently (since 2007) in Phase VII via lateral distribution lines (LDLs). Leachate is loaded from the 100,000-gallon storage tank into a tanker, weighed, and transported to the south end of the LDLs for distribution. Leachate drains into the LDLs via a flexible hose from the tanker to the cleanout of the LDL. Between 1997 and 2002, the volume of leachate recirculated was between 600,000 and 1,600,000 gallons per year. From 1997 to 2002, approximately 5.7 MM gallons of leachate were recirculated. During this same time period, approximately 700,000 gallons of leachate were hauled to the POTW (Engineering Report, 8/2002). In 2007, 3.7 MM gallons of leachate was recirculated, 1.3 MM gallons was

placed in the bioreactor cell (Phase VII), and 3.4 MM gallons were hauled to the POTW for treatment (2007 Annual Report).

Leachate data for the existing lined waste area have been collected quarterly since 1997. Composite samples from the leachate storage tank are collected and analyzed quarterly, in accordance with POTW requirements. Leachate volumes pumped from each cell (Cells 2 through 10) are monitored weekly using flow meters. The monthly volume of leachate recirculated is recorded.

Leachate head levels are monitored weekly on the control panels, which output the water head above a pressure transducer within the sump on the north end of each cell. Leachate levels are monitored quarterly on the south cleanout risers since 10/1998.

Leachate in Phase I (control) versus Phases II and III (recirculation): Recirculation of leachate has occurred in Phase II since 1998 through the present. Cell-specific leachate (and LFG generation) have been studied. Compared to Phase I, the waste in Phase II is more degraded, and more LFG is generated.

Leachate recirculation is done using pipes embedded in gravel-filled trenches buried in the waste mass. The LDLs are 4-inch diameter solid and perforated polyethylene piping. The trenches are about 24-inches deep and wide. The pipes are sloped 0.5 percent downward from the south to north. The gravity feed leachate recirculation delivery system includes seven lateral distribution lines (LDLs). Two of the LDLs (LDL1 and LDL2) were installed in Phase II in 1997. Two LDLs (LDL 3 and LDL4) were installed in Phase I in 1998. Three LDLs (LDL5, LDL6, and LDL7) were installed in Phase II in 1998. After installation of the LDLs in Phase I, Phase I was designated as a control area and the two LDLs have not been used.

CQA and Construction Records: N/A.

As-Built Drawings: Leachate pipe details are included in Liesch, 5/1993.

Leachate Generation Rate: Leachate volume has been recorded monthly since 1997, and is available through annual reports for leachate recirculation.

Leachate Recirculation and/or Disposal: Sixteen recirculation trenches are installed in Phases I through III. The trenches are oriented north-south, as shown on Landfill Gas Collection and Control System (Shaw, 1/2006). Leachate is piped from the leachate storage tank located at the west side of the WMU.

Leachate Sampling and Data: Leachate monitoring is included in the Sampling and Analysis Plan (Liesch, 2/2006). In addition, a Lysimeter Monitoring Plan is dated 4/2001. Lysimeter data (flow and water chemistry) are collected four times a year. Flow (in gallons) is included in annual reports. Water chemistry for LYS-2 through LYS-16 include analysis for VOCs, total

metals, leachate indicators, ammonia, and TSS. Monthly (COD, pH, and TSS) and quarterly (inorganics, VOC, and SVOCs) leachate sample data during the Phase 1 Pilot Study (conducted from mid-1997 to 6/2000) exist for the leachate tank.

Leachate chemistry is also available since 1997, and available through annual reports.

Leachate chemistry is available since 6/1999 through 5/2002 for the No Recirculation (Phase I cells 2, 3, and 4), Recirculation (Phase II cells 5, 6, and 7), and Leachate tank in the ER (Leisch, 8/2002).

*Leachate Data (Electronic) –*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Leachate Tank | 50 | 10/2000, 12/2007 | 201 | 100-1000 | 100-1000 | 100-1000 |
| YL-1 through YL-16** | 14 | 7/2004, 12/2007 | 91 | 10-100 | -- | -- |
| Phase I - Cell 2 | 1 | 11/2002 | 105 | 100 | 100 | 10 |
| Phase I - Cell 3 | 1 | 11/2002 | 105 | 10 | 10 | 1 |
| Phase I - Cell 4 | 1 | 11/2002 | 105 | 100 | 100 | 10 |
| Phase I - Cells 2, 3, and 4 | 12 | 10/2002, 6/2005 | 132 | 100 | 100 | 10 |
| Phase I - Control Cell 2, 3, 4 | 14 | 9/2004, 12/2007 | 106 | 100-1000 | 100-1000 | 10-100 |
| Phase II - Cells 5, 6 | 1 | 3/2002 | 105 | 1000 | 1 | 100 |
| Phase II - Cells 5, 6, 7 | 11 | 10/2002, 6/2005 | 132 | 1000 | 1000-10,000 | 1000-10,000 |
| Phase II – Recirc. Cells 5, 6, 7 | 14 | 9/2004, 12/2007 | 106 | 1000 | 1000 | 100-1000 |
| Phase III - Cells 8, 9, 10 | 2 | 6/2004, 6/2005 | 111 | 1000 | 1000 | 10 |
| Phase III - Recirc 8, 9, 10 | 14 | 9/2004, 12/2007 | 106 | 1000 | 1000 | 100-10,000 |

* Concentration (order of magnitude, in mg/l).

** Chemistry data exist for these sample points, but the sample point type/location was not found .

Compliance Issues and Community Concerns: None reported. The WMU has no evidence of current impacts caused by leachate at the groundwater POC, or at surface water sampling locations.

## Cover System

Design: Daily cover information for the original WMU does not exist. The original WMU has a final cover. The CQA for the 1993 Closure Construction (Leisch, 10/1993) provides details on

the June 1993 construction of the clay-barrier layer. Prior to placement of the final cover component of the clay barrier layer, existing intermediate cover was graded to suitable slopes, compacted, and smoothed. A buffer layer which was a minimum of one-foot thick compacted sandy clay and clayey sand was placed. Clay for the barrier layer came from the property to the northeast of the WMU. The clay was sampled every 5,000 CY, graded in not greater than 6-inch compacted lifts. Testing of the clay barrier layer (density testing) and Shelby tube sampling is included in the 10/1993 CQA report. The clay tested at less than 2x10-6 cm/sec. The granular drainage layer placed over the clay was a one-foot thick sand, with permeability greater than 1x10-3 cm/sec. Placement details and soil testing are included in the 10/1993 CQA report. No topsoil layer was placed on the granular fill on the portion of final cover constructed in 1993, because the area was included in the Phase I liner construction completed in 9/1993. Geogrid for the Phase I liner over the existing waste was placed directly on the general fill layer of the final cover.

The CQA of the Phase I clay liner, lysimeter construction, geogrid installation, and leachate collection system are included in the Construction Documentation Report (Leisch, 9/1993).

A sand-clay mix was used as the daily (interim) cover Phases I, II, and III. The final cover proposed 2/1992 was to be 4.5-feet thick: 2-feet compacted low-permeability clay; overlain by 12-inch drainage layer of high-permeability sand, minimum permeability of 1x10-2 cm/sec; overlain by non-woven geotextile fabric; overlain by 12-inch general fill layer; overlain by 6-inch topsoil. The final cover proposed in the C/PC Plan (10/2008) will be a four-feet thick, monolithic soil layer (from the bottom to the top) of 2 feet of brown clay, a 12-inch thick layer of compacted wetland or topsoil stockpiled soil, and a 12-inch thick topsoil layer.

CQA and Other Construction Records: Phase I Construction design drawings are dated 5/1993. The Construction Documentation and Certification Report for the 1993 Closure Construction of the McLeod Landfill is dated 10/1993. The McLeod Landfill Phase I Construction Documentation Report is dated 9/1993. The 1992 Closure Area is shown on the Existing Landfill Gas Site Plan (1/2006). Other drawings include the 2008 Landfill Repermit (10/2008).

As-Built Drawings: An as-built final cover survey map dated 10/1993 is provided in Leisch, 10/1993.

Topographic Surveys: Annual flyovers to collect topographic survey data have been flown since approximately 1995. The most recent aerial survey was flown in 6/2008. A review of cap performance was completed in the first five to 10 years of cap construction. A settlement analysis is performed in the area of the Phases I and II. Plates were installed between 10/1997 and 7/1999. Electronic data exist for plate elevations taken 12/1998, 7/2000, 12/2004, and 4/2008.

Cover Monitoring and Maintenance: According to the site engineer, no maintenance issues such as seeps, breakouts, or slope failures have occurred over the original WMU. Monthly Inspection Checklists are included in the annual operating reports. The checklists include active portions of the landfill, leachate management, final/interim cover, surface water, LFG management, and the environmental management system. Monthly inspections have been conducted since 1993 (i.e., including Phases I and II).

Settlement plate analysis has been collected from both the control area (Phase I) and the study area (Phase II) since 1997. These data exist in paper form for approximately 11 plates, as included in quarterly "Leachate Recirculation and Bioreactor – Operational Summary" reports. Five plates remain in Phases I and II as of the first quarter 2008.

Compliance Issues and Community Concerns: None reported.

## Landfill Gas Control System

Active Gas Control System: The layout of the gas collection system is shown on Landfill Gas Collection and Control System (GCCS) (Liesch, 10/2008). An active gas control system consists of a system of seven horizontal perforated PVC pipes (ET-1 through ET-7), oriented north-south, and approximately 37 vertical collection wells (EW-1 through EW-37) tied into the horizontal network via a main header. The horizontal trenches are located beneath the liner in areas where the lined cells piggy-back on the old unlined portions of the WMU. Phase I includes six vertical gas extraction wells. Phase II includes 13 wells and four horizontal gas extraction trenches. Phase III includes five wells and three trenches. Installation of a network of 37 wells was done in 1996, 1997, and 1998. The GCCS was connected to an on-site flare in 1996. 14 vertical wells were installed in the western portion of the unlined WMU in 1996. In addition, the seven recirculation laterals installed in Phases I through III were connected to the GCCS in 8/2000.

Gas Utilization: LFG extracted from the WMU is collected and processed at a LFGTE plant, located near the northwest corner of the WMU. The LFGTE plan was built in 2007 and began operation in 2008, running three engines. Previously, LFG was burned at a single gas flare, installed in 1996 and located along the west side of the WMU, and since 2008 used for emergency flaring only.

Passive Gas Vents: None.

Construction Details and As-Built Drawings: As-built information for the active GCCS is provided on Leisch, 10/2008.

Landfill Gas Data: Monthly wellhead monitoring has been performed at all current 11 wells (5 groundwater/gas wells and 6 gas probes). Monthly flow rates are included in Annual Operating Reports, Appendix C, for methane. A paper copy of monthly gas composition and depth to water in groundwater/gas wells for 2007 was obtained. LFG quality, and well and header

vacuum, from each of the Phase I (control) gas wells (EW-15 through EW-19) and Phase II (recirculation) gas wells (EW-20 through EW-24) have been recorded monthly since 1/1998 and 12/1998, respectively. Well-specific gas flow rates have been measured since 8/2000. Flow is recorded weekly at individual wellheads. Average gas flow is 1.3 cfm per foot of screen for gas wells installed in the recirculation area, and 0.7 cfm per foot of screen for gas wells installed in the control area. According to the site engineer, the amount of gas flow from the study WMU can be separated from the whole-site flow, by knowing the current gas volume and using the gas curve and volume of waste to back-calculate the volume coming from Site H specifically.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Wellheads | Monthly records, since 1996 | Monthly, since 1996 (E) | E |
| Surface Scans | N/A | Quarterly, (E) | Methane content only (E) |

Compliance Issues and Community Concerns: None reported. There is no evidence that gas migration has caused impacts at the gas migration POC or groundwater POC.

## Groundwater Monitoring System

Layout: The approved groundwater monitoring system incorporates both shallow groundwater monitoring wells and surface water monitoring locations in the river. Point of compliance (POC) groundwater wells include MW-2A, MW-3A, MW-5A(06), MW-7A, MW-9A, and MW-10A, as shown on the Request for Permit Modification (Liesch, 8/2005). Eight wells are included in the monitoring system, including: one up-gradient well (MW-1A); one side- or cross-gradient well (MW-8A); and six down-gradient wells (MW-2A, MW-3A, MW-5A(06), MW-7A, MW-9A, and MW-10A). All of the existing eight monitoring wells were installed with screens across the surficial sand aquifer. The wells were installed and completed in 8/1984 (MW-1A through MW-4A), 7/1990 (MW-5A through MW-8A), and 4/1991 (MW-9A), and 8/2003 (MW-10A). A table of well completion data is included in ER (Leisch, 8/2002). Total depths range between 8 and 20 feet below ground. Groundwater is present under water-table conditions.

Monitoring Program: Groundwater monitoring is included in the Sampling and Analysis Plan (Liesch, 2/2006). The wells are monitored three times a year in the Spring, Summer, and Fall. The 2008 Sampling and Analyses Plan (Leisch 2/2008) indicates that the wells are monitored for VOCs and field parameters pH, specific conductance, temperature, DO, eH, and turbidity. In addition, the wells are monitored for metals and inorganic parameters annually during the summer event. None of the POC wells have exceeded VOC intervention limits. Semi-volatiles were eliminated from the sampling program after being below detection in 1994 through 1997. Chloride has been noted in up-gradient well MW-1A, and in general, indicator parameter

concentrations in some down-gradient wells are higher than in the up-gradient well. The spatial variability of natural groundwater chemistry is observed in greater variability of mineralization in wells closer to the river in which groundwater and surface water interactions occur.

Lysimeters are monitored quarterly for the presence of adequate volume of water to be collected and analyzed for anions (alkalinity, chloride, and sulfate) and cations (calcium, magnesium, sodium, and potassium).

Construction Details: Driller's sampling descriptions are available for MW-1A through MW-4A. Boring logs and well completion details for the later wells are available, and were provided, but do not appear to be an appendix to any particular report.

Groundwater Data: A summary of analytical data is provided in the table below. Data are available for all parameters for which monitoring is required by the State. The wells have been monitored since approximately the 1980s.

*Groundwater Data (Electronic)*

| ITEM | Number of Wells, Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* |
|---|---|---|---|---|---|
| Up-gradient, proximal MW-1A | 1, 21 | 10/2000, 10/2007 | 103 | 10 | -- |
| Cross-grad., proximal MW-8A | 1, 21 | 10/2000, 10/2007 | 100 | 10 | -- |
| Down-grad., proximal MW-2A | 1, 21 | 10/2000, 10/2007 | 102 | 10 | -- |
| Down-grad., proximal MW-3A | 1, 21 | 10/2000, 10/2007 | 99 | 10 | -- |
| Down-grad., proximal MW-5A(06) | 1, 15 | 10/2000, 10/2007 | 99 | 10 | -- |
| Down-grad., proximal MW-7A | 1, 21 | 10/2000, 10/2007 | 101 | 100 | -- |
| Down-grad., proximal MW-9A | 1, 15 | 10/2000, 10/2007 | 100 | 1 | -- |
| Down-grad., proximal MW-10A | 1, 13 | 4/2004, 10/2007 | 34 | 100 | -- |
| Lysimeters LYS 1 through LYS 10 | 1 | 10/2000 | 115 | 10 | 1 |

* Concentration (order of magnitude, in mg/l)

A 12/1994 analysis of VOCs from the old site water supply well is available in paper.

Compliance Issues and Community Concerns: No compliance issues or community concerns were reported. The WMU has always been free of impacts to groundwater.

## Surface-Water Monitoring System

Locations: Surface-water samples were collected at three monitoring locations along the river. SW-1 is an upstream sampling point, SW-3 is a downstream sampling point, and SW-2 is a midway sampling point.

Monitoring Program: Surface-water monitoring is included in the Sampling and Analysis Plan (Liesch, 2/2006). Surface-water data are available prior to 1992. Monitoring frequency is three times a year in the Spring, Summer, and Fall. Wells are sampled for Ammonia as Nitrogen, Chloride, Iron, Nitrate + Nitrite as Nitrogen, Sulfate, and TDS, and field parameters Ph, specific conductance, and temperature.

Surface-Water Data: Available data from the electronic database are summarized in the table below.

*Surface-Water Data (Electronic)*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Up-stream, SW-1 | 20 | 7/2001, 10/2007 | 27 | 10-100 | -- | 1 |
| Mid-stream, SW-2 | 20 | 7/2001, 10/2007 | 25 | 100 | -- | 1 |
| Down-stream, SW-3 | 20 | 7/2001, 10/2007 | 26 | 10 | -- | 1 |
| Sedimentation Basin Outfall | 7 | 4/2001, 10/2002 | 20 | 1 | -- | -- |
| SB-1 (continued) | 7 | 7/2004, 10/2007 | 21 | 10 | -- | -- |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: None reported.

## Methane Migration Monitoring (MMM) System

Layout: The MMM consists of five dedicated locations (gas probes GP-1 through GP-5) and four combined groundwater/gas monitoring locations (monitoring wells MW-5A, MW-7A, MW-8A, MW-9A, and MW-10A), shown on Figure H-2. The MMM exists for the whole site, and not for the WMU specifically. The gas probes consist of 5-ft slotted PVC screen positioned in the middle of the upper sand and gravel layer, which is generally 15 feet thick. Therefore, the total depth of gas probes is approximately 7.5-feet bgs.

Monitoring Plan and Data: Methane migration monitoring is required quarterly. Quarterly monitoring data exist since 1993 through the present.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Start, End | Frequency | Notes |
|---|---|---|---|
| Gas Probes GP-1 through GP-6, Groundwater Wells MW-5A, MW-7A, MW-8A, MW-9A, MW-10A | 1993, 12/2007 | Quarterly | P |

Compliance Issues and Community Concerns: None reported. The WMU has received no odor complaints and detected no significant concentrations in the gas monitoring system since monitoring was initiated in 1997.

**FIGURE H-1**
**Site H Physiographical Setting**

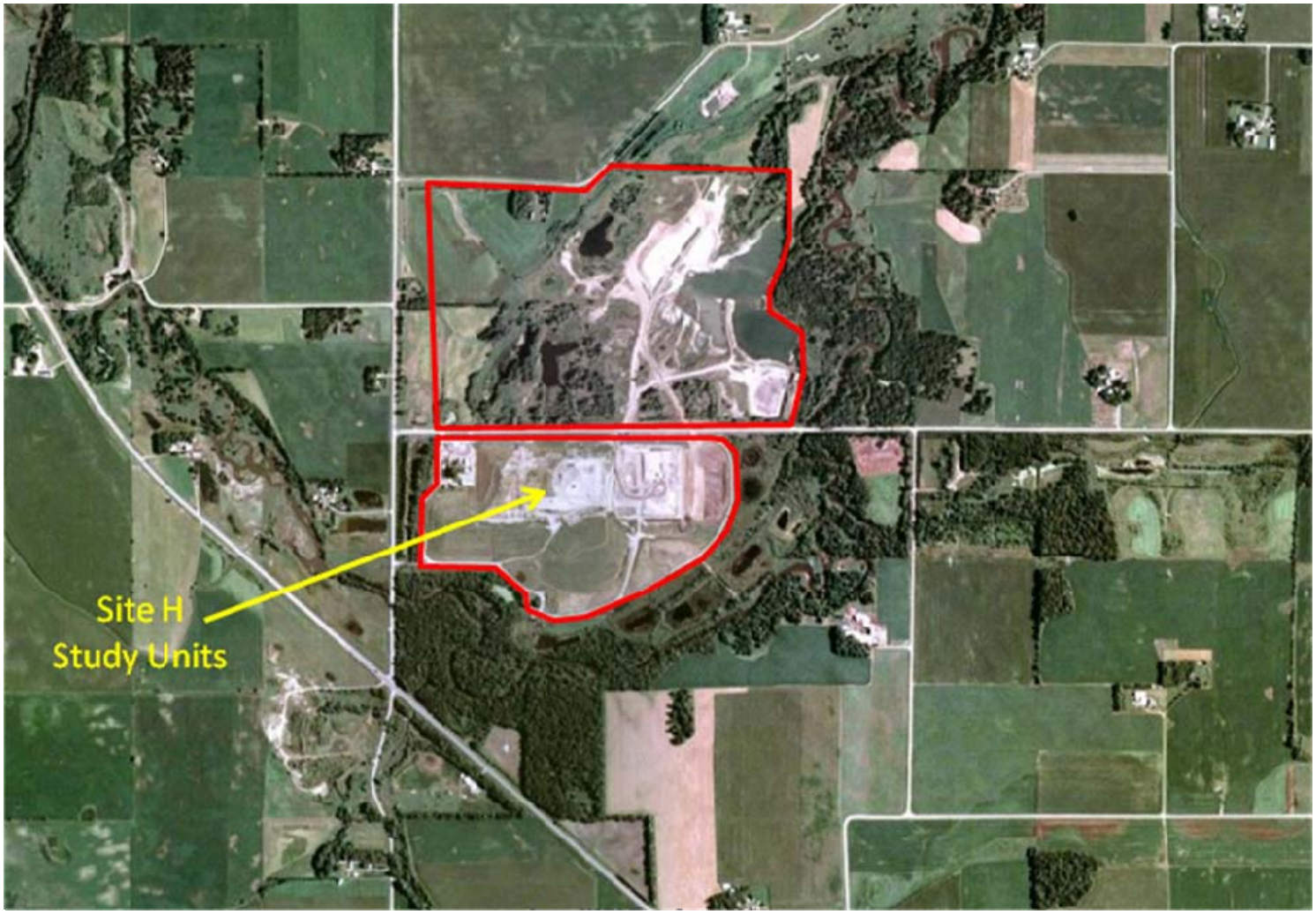


**FIGURE H-2**
**Site H Layout and Features**

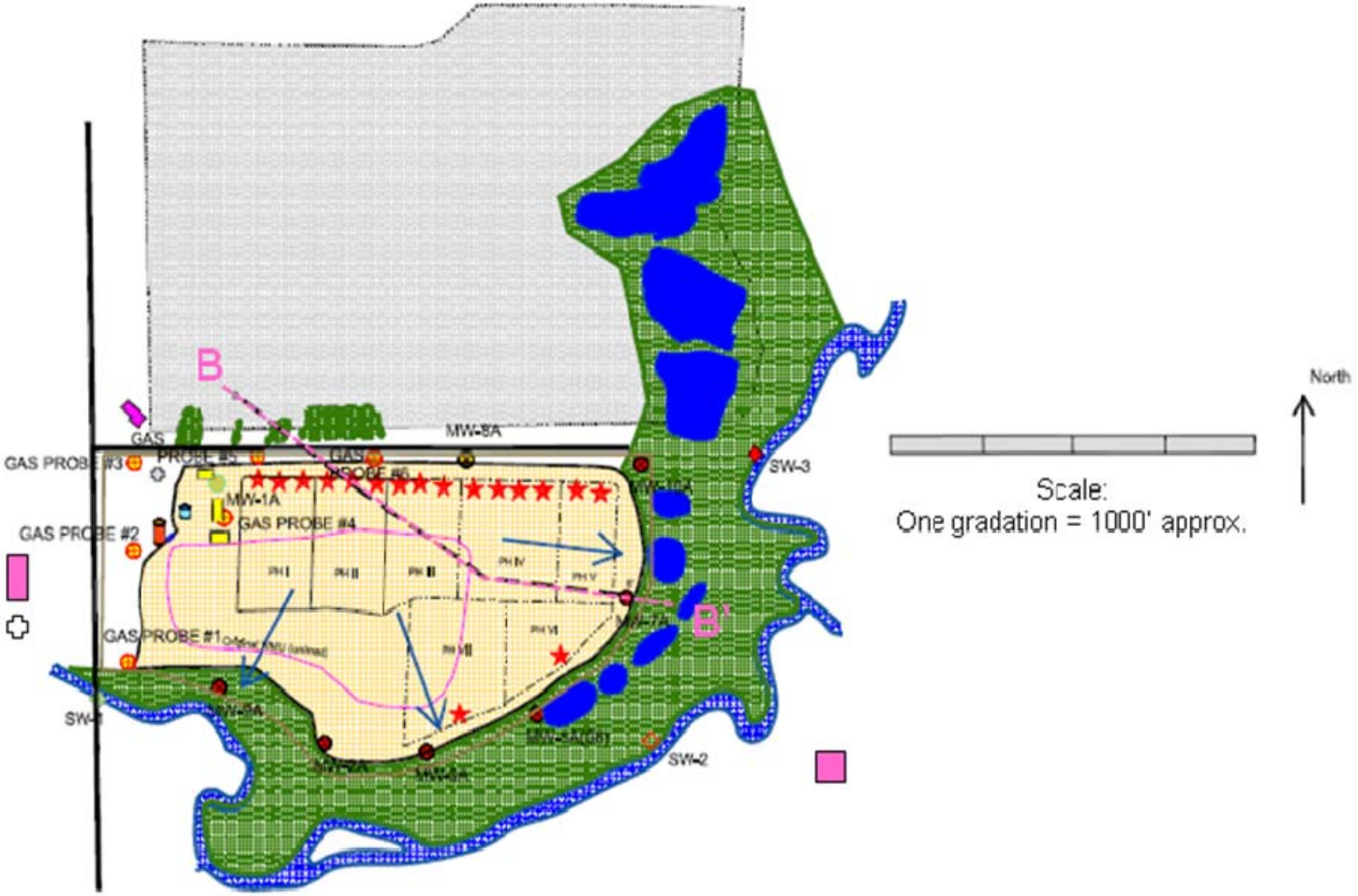
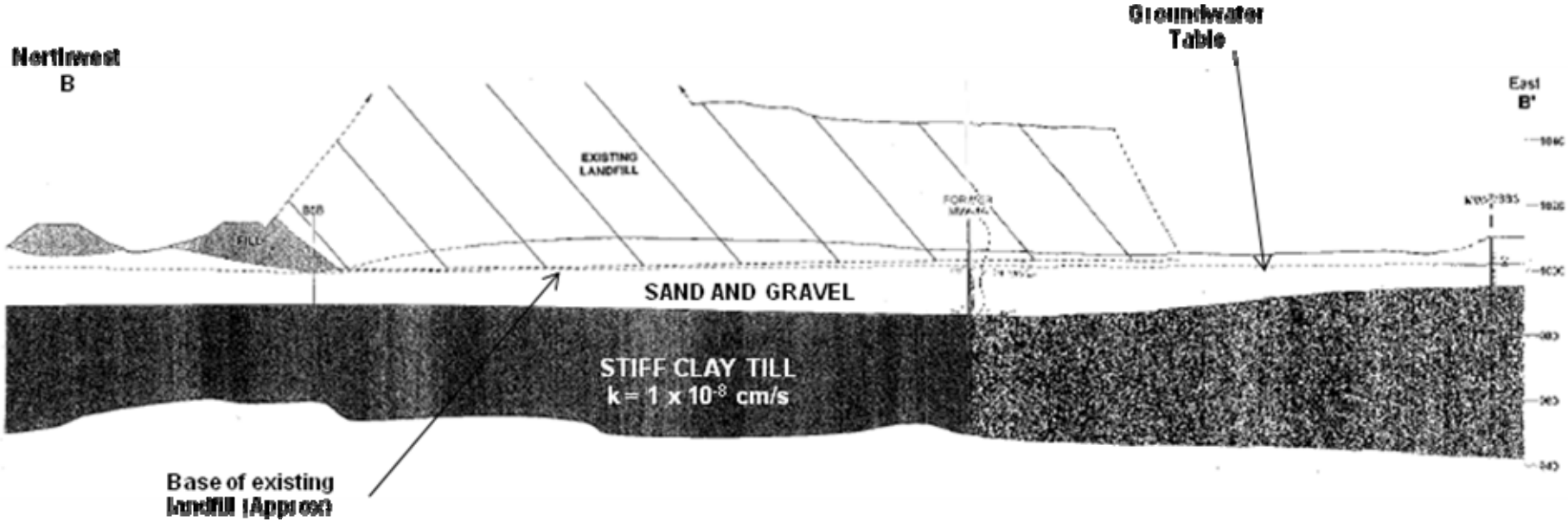
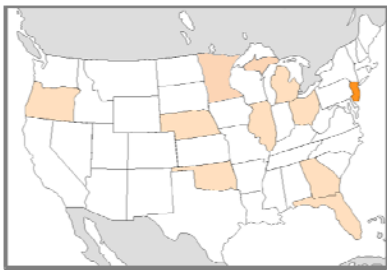


**FIGURE H-3**
**Site H Geologic & Hydrogeologic Cross Section**



## APPENDIX 2-1I

## SUMMARY – SITE I (NEW JERSEY)



### Overview

Study WMU: Site I was officially closed in 3/1989. The last area to receive solid waste (approximately 25 acres) was covered by a geosynthetic cap in 1991. The older parts of the landfill were clay capped in previous years. A naturally occurring clay liner underlies the landfill. There is an active landfill gas (LFG) extraction system and leachate collection system in place. The facility is completely fenced. The site is in the 30-year post-closure period in accordance with the New Jersey Department of Environmental Protection (DEP) Closure and Post-Closure Care (C/PC) Plan, dated 2/1990.

Property: The properly on which the landfill is located was originally the site of a brick factory. The properly was purchased in 1976 by a private waste management company and developed as a landfill in 1977. Waste filling commenced in 1/1978. Waste Management Inc. (WMI) acquired the site in 1984. The facility property consists of 93 acres of which 73 acres were permitted for disposal activities. Stormwater runoff is directed to one of three sedimentation ponds via a series of channels and outfalls.

The physiographical setting of the property and WMU is shown on Figure I-1. A stylized depiction of the site layout is provided as Figure I-2.

### Site Information

Geologic and Hydrogeologic Setting: The landfill is situated within the Atlantic Coastal Plain Physiographic Province. The Coastal Plain is characterized by several thousand feet of sediments underlain by Precambrian and Early Paleozoic bedrock. The sediments beneath the landfill range from Late Cretaceous to Recent in age and were deposited as a southeastwardly thickening wedge of estuarine, fluvial, deltaic, and marine deposits. A generalized schematic cross section through the New Jersey section of the Coastal Plain is presented in Figure I-3. The Cretaceous Coastal Plain sediments generally dip southeastward between 10 and 60 feet per mile. The overlying Pleistocene and Recent sediments are essentially horizontal.

The aquifers of the Coastal Plain are the primary source of water supply in the region. The aquifers crop out in irregular bands which trend NE to SW. Recharge to the Coastal Plain aquifers is largely by infiltration of precipitation on the outcrop areas. Leakage from the overlying surface water bodies also contributes to recharge of the aquifers as does leakance through the confining aquitards. At several locations, this recharge is induced by the lowering of

potentiometric heads in the aquifers due to over-pumping of the major Potomac Raritan Magothy (PRM) Aquifer. Water is discharged from the Coastal Plain aquifers, from surface water bodies (i.e., Black Creek), evapotranspiration, and by withdrawals from wells.

The facility is underlain by Woodbury and Merchantville Formations (see Figure I-4). These formations are unconsolidated deposits of Cretaceous Age consisting chiefly of micaceous clay. The Woodbury and Merchantville Formations have similar permeabilities and water-bearing properties. Both units are described as aquicludes and function as confining beds separating the underlying Raritan and Magothy Aquifer from the overlying landfill. Prior to development of the site, a thin veneer of Pleistocene deposits known as the Pensauken Formation covered the entire facility. Past clay mining activities removed most of this surficial mantle. In the vicinity of the facility the Pensauken Formation is characteristically a sandy clay to clayey sand. A brief description of the site geology and hydrogeology are presented below:

*Pennsauken Formation* – The uppermost geologic unit is the Pensauken Formation, which is Pleistocene in age. The Pensauken Formation varies in thickness from about three feet to twelve feet. The formation generally contains a high but variable percentage of clay and silt. Though most of this formation was removed or reworked during the course of clay mining and/or landfilling activities, some remnants of this material exist on the northern edges of the site. The Pennsauken Formation unconformably overlies the Cretaceous-age Woodbury Clay.

*Woodbury Clay* – The Woodbury clay is typically an unconsolidated, massive-bedded, black to dark gray, lignitic, micaceous clay with small amounts of glauconite near its base. The thickness of the formation on-site varies from approximately 10 feet to 40 feet. The Woodbury clay in turn lies over the Merchantville Formation. The contact between the Woodbury and underlying Merchantville Formations is gradational and conformable.

*Merchantville Formation* – The Merchantville Formation consists of alternating layers of sand and silt of variable thickness in an interbedded sequence of thin to thick layers of sands and silt. It is very clayey, unconsolidated, and typically greenish-black in color. This unit is approximately 55 feet to 60 feet thick on-site. The contact with the underlying Magothy Formation is well defined and unconformable.

*Magothy Formation* – The Magothy Formation, also Cretaceous Age in age, is the upper member of the combined Raritan-Magothy Aquifer. It consists of an unconsolidated, interbedded sequence of thin to thick sands and clays. The sand is very dense and consists chiefly of angular quartz grains with lignite and some mica. This stratum is the oldest strata intersected by borings completed at the site and the thickness of this formation is believed on regional geologic information to be approximate 50 feet.

Saturated Zone: Three water bearing units have been identified at the site on the basis of the stratigraphy identified from on-site borings and screened intervals of site investigations, regional geologic and hydrogeologic information, and the location of recharge and discharge points on the

Geological Map. In general, the hydrogeology and potentiometric head distribution in specific water bearing units beneath the facility are consistent with local area and regional hydrogeological conditions. The site is underlain by a sequence of interbedded aquifers and aquitards. These hydrogeologic units conform to the regional system defined by the USGS for the Coastal Plain of New Jersey. None of the aquifers beneath the site (to the depths investigated) can be classed as productive. They are better described as water bearing units; either discontinuous, low yielding, or both. Each hydrostratigraphic unit is described below in order of increasing age.

*Pennsauken Water Bearing Unit* – It is reported that groundwater may occur as a shallow perched water table (at depths of approximately one to ten feet) in the remnants of the Pennsauken Formation clay and sand, which overlie Cretaceous sediments. The Pennsauken Formation is not documented as containing important aquifers in the New Jersey Coastal Plain At the site isolated perched water bodies in this formation are recharged by precipitation and discharge to a creek on the N and NE sides of the landfill and to a lake on the W, S, and SE sides of the landfill. This pattern may be influenced on the S side of the facility by local heterogeneous zones, such as alluvial deposits or the sewer line trench which traverses this area. Consequently, actual flow directions in the Pennsauken Aquifer in this area may vary to some degree.

It should be noted that though three of seven shallow monitoring wells (MW01, MW05, and MW07) were installed with the gravel packs that extend upward from the Merchantville Aquifer to the lower portion of the Pennsauken perched water bearing unit, none of the monitoring wells at the site were intended to monitor the Pennsauken. The water levels measured for the shallow water bearing unit represent a composite level between the Pennsauken perched water bearing unit and Merchantville Aquifer; seasonally the water levels present a high in the month of April of each year (55 – 65 ft-msl), ten feet above the average level.

*Merchantville Aquifer* – Beneath the Pennsauken Formation is the Cretaceous-age Merchantville-Woodbury Formation which hydrogeologically is classed as a confining unit. The upper section of this unit, the Woodbury Clay, has a very low hydraulic conductivity and yields virtually no water: it is essentially dry. Beneath the Woodbury Clay, the Merchantville water bearing zone (the Sandy Horizon) is a low yield “aquifer” that has progressively higher moisture content with increasing depth below the Woodbury Clay. A review of the geologic map indicates that the Merchantville Aquifer is recharged in the outcrop areas located approximately ¼-mile W of the site. Groundwater in the aquifer flows generally eastward beneath the site area toward a creek, the natural area of discharge, located approximately ¼-mile E of the site. In the vicinity of the site, the elevation of the recharge area is about 70 ft-msl and the elevation of the creek is approximate 20 ft-msl.

Based on a detailed study in 7/1996, groundwater seepage is toward the landfill. This seepage pattern is consistent with the impact of lowering the water pressure in the Woodbury Clay (due

to excavation of the clay pit and continued extraction of leachate). Actual seepage into the landfill is estimated to be extremely low, on the order of one tenth of one gallon per minute or less for the entire clay pit excavation.

Magothy Aquifer – The Magothy Formation is saturated and forms the upper zone of the PRM Aquifer. It has been reported to be artesian with respect to its upper surface. The groundwater flow direction of the aquifer under the site is generally reported as SE to NW towards the Delaware River.

Boring Logs: Boring logs for 26 wells/boreholes from four subsurface investigations at the site dating from 1976 to 1996 are available. The stratigraphic intersections in each boring clearly show that site subsurface conditions fit the regional model. Two geotechnical boring logs to support the foundation design for the flare pad were also generated in 5/1991.

Hydraulic Conductivity: Hydraulic conductivity values reported for the Merchantville Formation from laboratory permeability tests indicated an average hydraulic conductivity of about $2.0 \times 10^{-5}$ cm/s (0.05 feet/day) for the Upper Zone (Sandy Horizon) and $1.8 \times 10^{-7}$ cm/s for the Lower Zone.

Groundwater: Because the Woodbury and Merchantville Formations have poor water bearing properties, few wells are known to tap either formation. Very few wells tap the small discontinuous sandy lenses of the Merchantville Formation. Yields of these wells are quite low. The Raritan-Magothy Aquifer is the most productive aquifers in the region. Most industrial and public water supply wells in the region utilize the aquifer.

Groundwater flow in the Merchantville aquifer is generally towards SE. However, locally flow in this formation is radially inwards towards the landfill. This flow pattern is caused by seepage of moisture towards the clay pit resulting from extraction of leachate. As reported by the original 1976 engineering report, the groundwater flow direction of the Magothy aquifer under the landfill facility is generally from SE to NW towards the Delaware River. However, a review of groundwater elevation measurements collected during 1992 and 1993 indicates that groundwater flow in the Magothy Formation beneath the site is toward the E or SE.

Unsaturated (Vadose) Zone: See discussion above.

Physiographical Setting: The topography of the region is characterized by gentle hills with less than 100 feet of relief. The facility is approximately 1,000 feet SW of a named creek and located within the creek's watershed which drains into the Delaware River some distance NW of the landfill area. Several ponds are located within the creek drainage basin, the largest has a surface area of approximately seven acres and is approximately one-half mile SW of the facility.

The facility gently slopes to the SW from an elevation of 100 ft-msl to a low of 60 ft-msl. There are no streams on site, although drainage ditches have been constructed along the W and S

boundaries of the landfill. The drainage ditches direct surface water runoff into one of three sediment basins located in the NW and SW corners of the facility. This surface water is periodically discharged to a drainage ditch that discharges to a lake, which is located approximately one mile W of the facility.

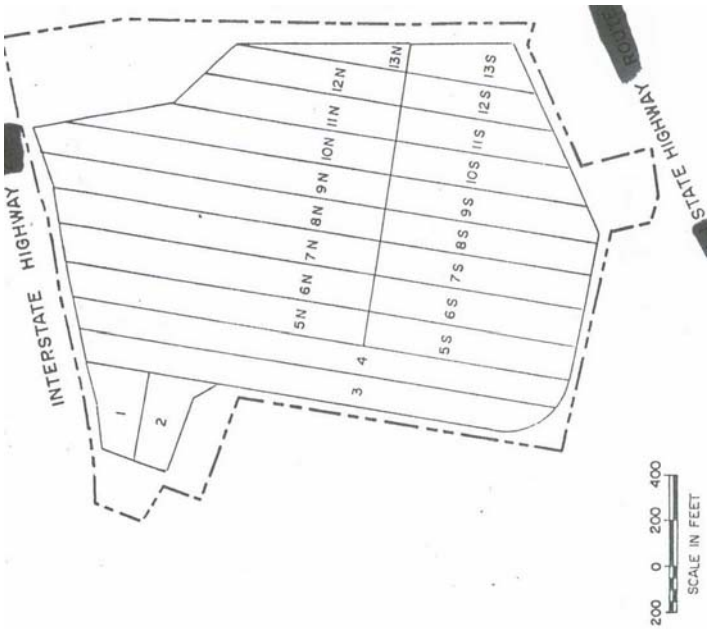
Potential Point(s) of Exposure: Site I is bounded by highways on the E and W and local roads on the N and S. Properties adjacent to the facility include a high school at the NW corner, a motel along the E highway, and truck stop facilities to the S. A sanitary sewer line runs with 50 ft of the SE and S boundary (between the landfill and truck stop) and is suspected of leaking.

The landfill is located in an industrial/commercial zone. Area businesses are served by public water and sewer. Historical GW data does not indicate contamination. The 6/1994 EMP identifies 18 private water wells located within 0.5 miles of the site (based on 1984 records), all but one screened in the Magothy Aquifer. One municipal well is located within 1.5 miles of the facilty.

Climate: No on-site weather station.

## Waste Placement and Operations

General: Landfill operation was by the trench method (see figure below). Trenches 1 and 2 were not developed for waste disposal. Waste filling commenced in 1/1978 at a rate of 500-900 tpd in Trenches 10-13 which were closed prior to 12/1987. The next trenches filled were N portions of Trenches 3-9. S portions of Trenches 3-9 were filled starting in 1987 under a vertical expansion plan and continued until closure of the site in 1989.



An airspace survey reports a total of 4.63Mcy consumed as of 17 March 1989 at an estimated in place density of 1,475 lb/cy. The remaining volume for refuse and daily cover at the date was estimated at 120,000 cy (total = 4.75 Mcy). A 4/2001 Final Control Plan puts the volume at 6.7 Mcy (3.3 Mcy placed prior to 3/1986) with equivalent weight of waste of 3.26 million Mg and states the landfill is 120 ft deep in some areas. However, most recent site documents (e.g., second semi-annual GW monitoring report, 2008) cite the total airspace volume as 3.1 Mcy.

Waste Placement and Composition Data: Little data are available. Sewage sludge disposal occurred through 1984, thereafter only MSW and C&D allowed. Gas well boring logs from 1990 are available for Wells # 44-57, but give little detail of waste encountered.

## Closure and Post-Closure (C/PC) Plan

The C/PC Plan is dated 12/1988 and briefly describes final cover, vegetative cover, E&S control, SWM drainage controls, GW and SW monitoring, gas control, leachate handling, controlling facility access, and measures to conform the site to the surrounding area (focused on minimizing the visual impact of the completed landfill, providing moderate slopes that grade gently to surrounding terrain, and maintaining good cover with visual compatibility with surroundings).

The official cessation date for site operations is 3/1989. The C/PC Plan was approved in 2/1990. All closure activities were completed by 10/1991 in accordance with the C/PC Plan. 30 years of PCC are required. The post-closure EMP was initially dated 12/1988, updated in 6/1993, 6/1994, and most recently in 1/2005.

## End Use Strategy

No specific end use is identified.

## Liner System

Design: The landfill was designed in 1976 to be developed in an excavation in the Woodbury Formation clay. Maximum liner basegrades are generally between 50 and 60 ft-msl approximately. The last two trenches (5S and 6S – see below) were excavated to 30 ft below the original design elevations to provide additional disposal volume. A synthetic liner system (50-mil PE liner with fused seams) was used in these trenches. In several areas, the natural thickness of clay was less than 10 ft and the excavation intersected a sandy horizon within the Merchantville Formation. In these areas, additional clay was emplaced prior to landfilling to achieve the required minimum thickness of 10-ft underlying clay. An upper cutoff wall was constructed from in-situ Woodbury clay around the entire perimeter of the landfill excavation to reduce groundwater seepage.

The hydraulic conductivity of the Woodbury clay is reported as approximately $10^{-7}$ cm/s and provides the facility with a natural clay base for leachate containment.

CQA and Construction Records: None seen.

As-Built Drawings: As-built survey for 4.45-acre Trench 5/6 only (10/1987).

## Leachate Management System

Design: According to the 3/1998 O&M Plan, the LCS consists of a network of perforated PVC and HDPE pipes to 11 interconnected concrete manholes with risers that extend through the cover. Leachate from eight of the manholes gravity drains to MH-9 from where it is pumped to a 20,000 gallon aboveground storage tank. Leachate also gravity drains into MH-TE-3-4 from where it is also pumped to the tank. The post closure permit for the site requires that the pumping system and levels controls keep the leachate level no higher than one foot above the base of the manholes. Leachate is conveyed from the storage tank to POTW by tanker truck.

A compacted clay cutoff wall into the Woodbury Formation clay was installed around the entire side-gradient and downgradient toe of the landfill in 1986.

CQA and Construction Records: None seen.

As-Built Drawings: The LCS was built in several phases with minimal as-built documentation available. An as-built drawing of leachate transmission piping dated 1/1990 is available.

Leachate Recirculation: Not practiced.

Leachate Sampling and Data: Leachate is monitored in accordance with the current POTW agreement, effective 6/2002. Flow and pH are reported monthly. Various other macro parameters and metals are reported semi-annually. VOCs are reported annually. A total toxic organic (TTO) analysis is required prior to each permit renewal.

The 9/1992 estimates that approximately 16,000 gal of leachate is generated per week. Monthly leachate flow data are available for 1996 and 2003 through Nov 2008. Flow in 2007 ranged from 12,000 to over 100,000 (ave 57,700) gallons per month.

*Leachate Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | COD | BOD |
|---|---|---|---|---|---|---|
| TTANK, TANK, or LTANK | 89* | 3/1985, 8/2007 | 168 | Y | Y | Y |

* Older events have limited data.

Compliance Issues and Community Concerns: The site received an NOV for high TKN in leachate that exceeded acceptance criteria at the POTW, 1/1995.

## Cover System

Design: The landfill was capped with a clay cap over the older 44 acres (Trenches 10-13 and N portions of Trenches 3-9) and a geosynthetic cap over the newer post-1985 area (S portions of Trenches 3-9, approx. 29 acres). Final capping was completed in 1991. The clay cap profile includes two feet of $10^{-7}$ cm/s compacted clay (no intermediate cover) overlain by 6-in sand drainage layer covered by six inches of topsoil. The geosynthetic cap profile includes 12-in intermediate cover, overlain by 8-oz non-woven geotextile, overlain by a 40-mil HDPE membrane, geonet, and 8-oz non-woven geotextile, overlain by an 18-inch thick clean fill layer and six inches of top soil. A system of drainage swales and surface water runoff channels is maintained on the surface and around the edges of the landfilled area. The swales and ditches lead water to sedimentation basins located at the northwest and southeast corners of the facility.

CQA and Other Construction Records: Construction details showing 1989-1991 capping system cross sections are available. A closure certificate was issued in 6/1992 for the Phase I clay cap system installation (completed in 12/1990), enclosed flare installation (8/1991), and Phase II/III geosynthetic cap system (completed 1/1992).

As-Built Drawings: An as-built survey drawing for the Phase II/III cap showing a maximum crest elevation of 118.1 ft-msl is available dated 11/1991. Final grade contours over the older sections of the landfill are shown on a number of plan drawings.

Topographic Surveys: No recent topo surveys seen, beyond the above as-built surveys.

Cover Monitoring and Maintenance: According to the C/PC Plan, to provide for drainage of precipitation and reduction of infiltration, positive drainage must be maintained from the cap. To this end, as the cap subsides differentially due to subsidence of the refuse materials, runoff is maintained by leveling and filling in any subsided areas with sand and a six inch layer of topsoil. Erosion of the side slopes of the cap and swales requires repair as do the drainage ditches following heavy storm events. The drainage system and sedimentation basins have to be cleared of vegetation growth and debris periodically to ensure free drainage.

Compliance Issues and Community Concerns: The site received NOVs for a leachate and gas seep at the toe of the landfill (2/1991) and inadequate E&S control (12/1990). A subsidence repair to the Cell 5/6 cap was reported in 4/2002.

## Landfill Gas Control System

Active Gas Control System: 21 passive gas vents were installed in 1983 but replaced in 1984 with an active system with candlestick flaring (expanded in 1985 to include 24 wells, at least 10 of which exceeded 50 ft in depth). In 1990, 14 additional wells (#44-57) were installed. The permit to construct for the enclosed flare is dated 4/1991. The original Title V permit is dated 4/1997, most recently re-issued in 10/2002. By 3/1998, the GCCS is described as comprising 50

vertical wells, 2 extraction trenches, 7 condensate collection tanks and an enclosed flare rated for 2,000 scfm. The candlestick flare remains as a backup to the enclosed flare. The gas system is also tied into the 11 leachate manholes. Landfill gas is conveyed by pipeline to a main flare for combustion. Condensate that develops within the gas collection lines drains to a series of tanks for collection and disposal at POTW.

Although the site is subject to NSPS/EG since submission of an initial design capacity report to USEPA and DEP in 4/2001 (based on calculated NMOC emissions using default inputs), WMI submitted a report to DEP in 6/2007 demonstrating that the NMOC concentration in raw LFG data collected between 1996 and 2007 would never have resulted in the site exceeding the 50 Mg/yr NMOC emission threshold for NSPS.

Gas Utilization: None. Various schemes have reportedly been investigated in the past, most significantly a power co-generation system in mid-1994.

Passive Gas Vents: 21 passive gas vents were installed in 1983 but replaced one year later.

Construction Details and As-Built Drawings: An as-built drawing for installation of 24 wells dated 4/1986 is available. A construction certification for the flare was issued by DEP in 8/1991.

Landfill Gas Data: Limited historic data on total flow to the flare are reported: 756 scfm in 8/1987, 664 scfm in 1/1988, 599 in 8/1988, 1,016 in 1/1989, 559 in 2/1989, 868 in 1/1990, and 859 in 8/1990. A 2005 compliance report puts flow to the flare at 300-500 scfm with methane content at 48-50 (% dry volume) and NMOC at 1979-2321 ppmvd. Monthly monitoring reports for the flare put the flow rate at 200-300 scfm from Jan-Oct 2008.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Flare Log | Continuous recording of total flow at flare inlet | $CH_4$, TNMHCs, $H_2S$, HCl, $CO_2$, $O_2$ | Flow testing is monthly, composition is annual. Annual stack test required. Monthly flow summaries (P) available, 2003-2008. |
| Wellheads | Bi-monthly monitoring and balancing. | $CH_4$ (%) and pressure | Monthly reports (P) available, 2002-2008 |
| Surface Scans | | $CH_4$ only, quarterly monitoring | Annual reports (P) available 2002-2008, one exceedance reported 4Q 2004 |

Compliance Issues and Community Concerns: The site received numerous odor and bird nuisance complaints from local residents and the adjacent school, and was taken to court five times between 1983 and 1986. These complaints contributed significantly to the site's earlier-

than-necessary closure. Two NOVs for odor and the flare being down were issued in 6/1990 and 8/1990. A flare explosion was reported in several local and state newspapers in the late 1990's.

## Groundwater Monitoring System

Layout: Originally, 11 monitoring wells surrounded the landfill. However, a 7/1996 "Reduction in Monitoring Requirements Report" was successful in demonstrating that six wells were redundant or should be replaced, and that three new wells should be installed, thereby reducing the total number of wells to the eight currently located around the perimeter of the facility. The current monitoring locations, frequency, and modified parameter list were approved by DEP in 9/1996.

Monitoring Program: The site is in Detection Monitoring. GW monitoring is required on a semi-annual basis (1Q and 3Q) for a reduced parameter list, and annually (in 1Q) for an extended parameter list. The presence of iron pyrite in the Merchantville and Magothy Formations has resulted in historically low pH in GW which gives rise to elevated Fe, Mg, TDS, and $SO_4$ around the site.

Construction Details: Construction details and certification forms are available for all GW wells.

Groundwater Data: A summary of analytical data from current wells is provided in the table below. Data dating to 1985 are also available for seven discontinued wells.

*Groundwater Data (Electronic)*

| ITEM | No. Monitoring Events | Start, End Dates | Total No. Analytes | Chloride | Na | K |
|---|---|---|---|---|---|---|
| Upgradient*, Kmv/s MW03 | 74 | 1/1985, 7/2007 | 180 | Y | Y | Y |
| Side-gradient*, Kmv/s MW05R | 23 | 7/1998, 7/2007 | 76 | Y | Y | Y |
| Upgradient, Kmv/s MW06 | 68 | 4/1985, 7/2007 | 91 | Y | Y | Y |
| Upgradient*, Kmv/s MW07R | 22 | 7/1998, 7/2007 | 76 | Y | Y | Y |
| Downgradient, Km MW08 | 74 | 1/1998, 7/2007 | 180 | Y | Y | Y |
| Downgradient, Km MW10 | 74 | 1/1998, 7/2007 | 180 | Y | Y | Y |
| Upgradient, Kmv/s MW11R | 6 | 1/2002, 7/2007 | 64 | Y | Y | Y |
| Downgradient, Km MW12 | 22 | 7/1998, 7/2007 | 76 | Y | Y | Y |

* Radial flow in Kmv/s due to localized effects of leachate extraction in landfill.

Compliance Issues and Community Concerns: The site received a NOV for a GW and SW discharge violation in 4/1989. Semi-annual monitoring since 1Q 2002 has shown elevated benzene and VC in MW05R (sidegradient, Kmv/s) in 1Q 2006 and 1Q 2007. PCE is also elevated in GW. However, these constituents are marginally above DEP standards for Class II Aquifers and continue to show decreasing or stable trends. No action is required.

## Surface Water Monitoring System

Locations: A surface water sampling point exists at the off-property outfall of Sedimentation Basin No. 3 which is located at the southwest corner of the facility.

Monitoring Program: Stormwater is monitored in accordance with a DEP "Discharge to SW General Permit." The permit does not require stormwater sampling; however, an annual inspection report of the facility and a recertification application must be submitted to DEP certifying that BMPs contained in the SWPPP (originally developed 10/1993, most recently revised 9/2007) are being properly implemented.

Surface Water Data: None seen, although SW data back to 1992 is reportedly available.

Compliance Issues and Community Concerns: The site received NOVs for a SW discharge violation in 4/1989 and multiple SW exceedences between 4Q 1989 and 3Q 1990.

## Methane Migration Monitoring System

Layout: The original MMMP dates from 1/1992, an update to more generic requires for gas migration monitoring in the 12/1988 C/PC Plan. The MMMP was updated in 4/2001 and again in the 1/2005 EMP which describes two permanent probe locations on the N property line adjacent to nearby homes. A further 29 barhole probe locations are distributed at approximately equal spacings around the facility boundary.

Monitoring Plan and Data: The probes, barholes, and seven onsite structures are monitored on a quarterly basis. Quarterly monitoring reports are available from 1Q 2002 through 3Q 2008.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Permanent Probes<br>P-1 and P-2 | -- | $CH_4$ (%) and pressure | On an annual basis, water levels are also recorded |
| Barhole Probes<br>B-1 to B-29 | -- | $CH_4$ (%) | |
| Structures<br>S-1 to S-7 | -- | $CH_4$ (%) | |

Compliance Issues and Community Concerns: The site received a NOV for a gas seep at the landfill toe in 2/1991. Semi-annual GW monitoring prior to 1/2002 showed elevated VOCs in MW05 and MW05R (sidegradient, Kmv/s), attributed to LFG migration. No methane detections above 0.0% have been recorded since 1Q 2002.

**FIGURE I-1**
**Site I Physiographical Setting**

**FIGURE I-2**
**Site I Layout and Features**

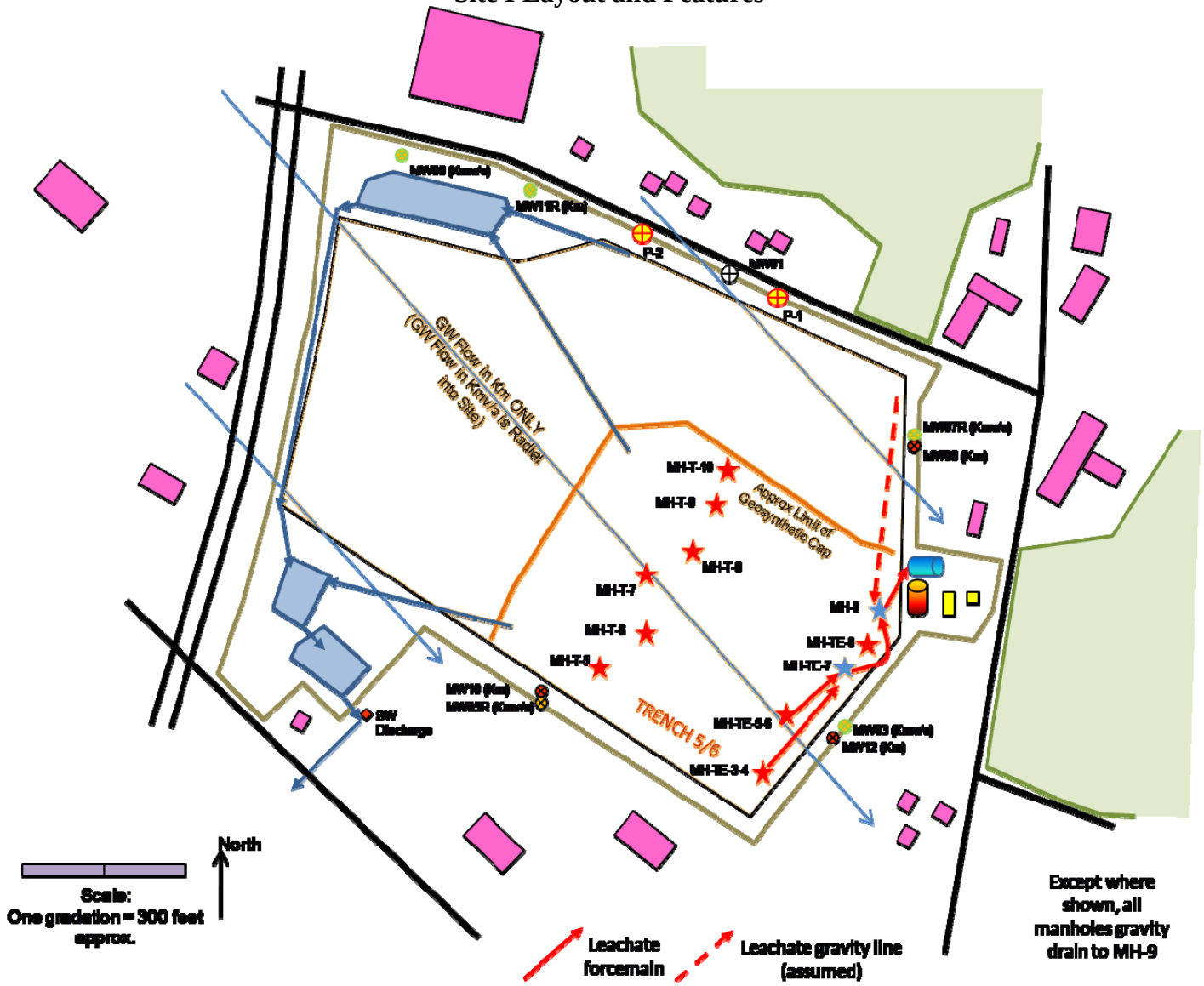


**FIGURE I-3**
**Site I Regional Geologic & Hydrogeologic Setting**

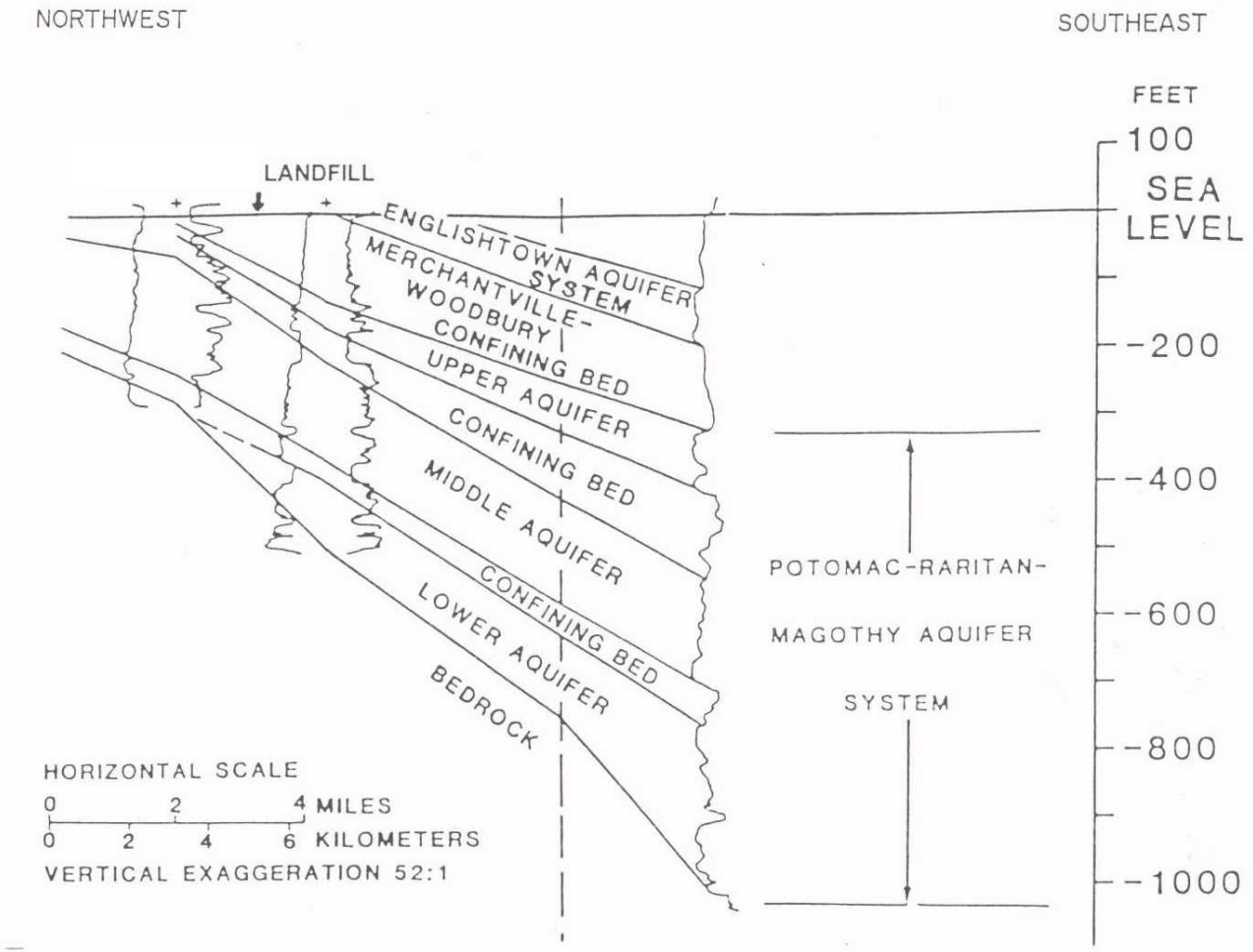
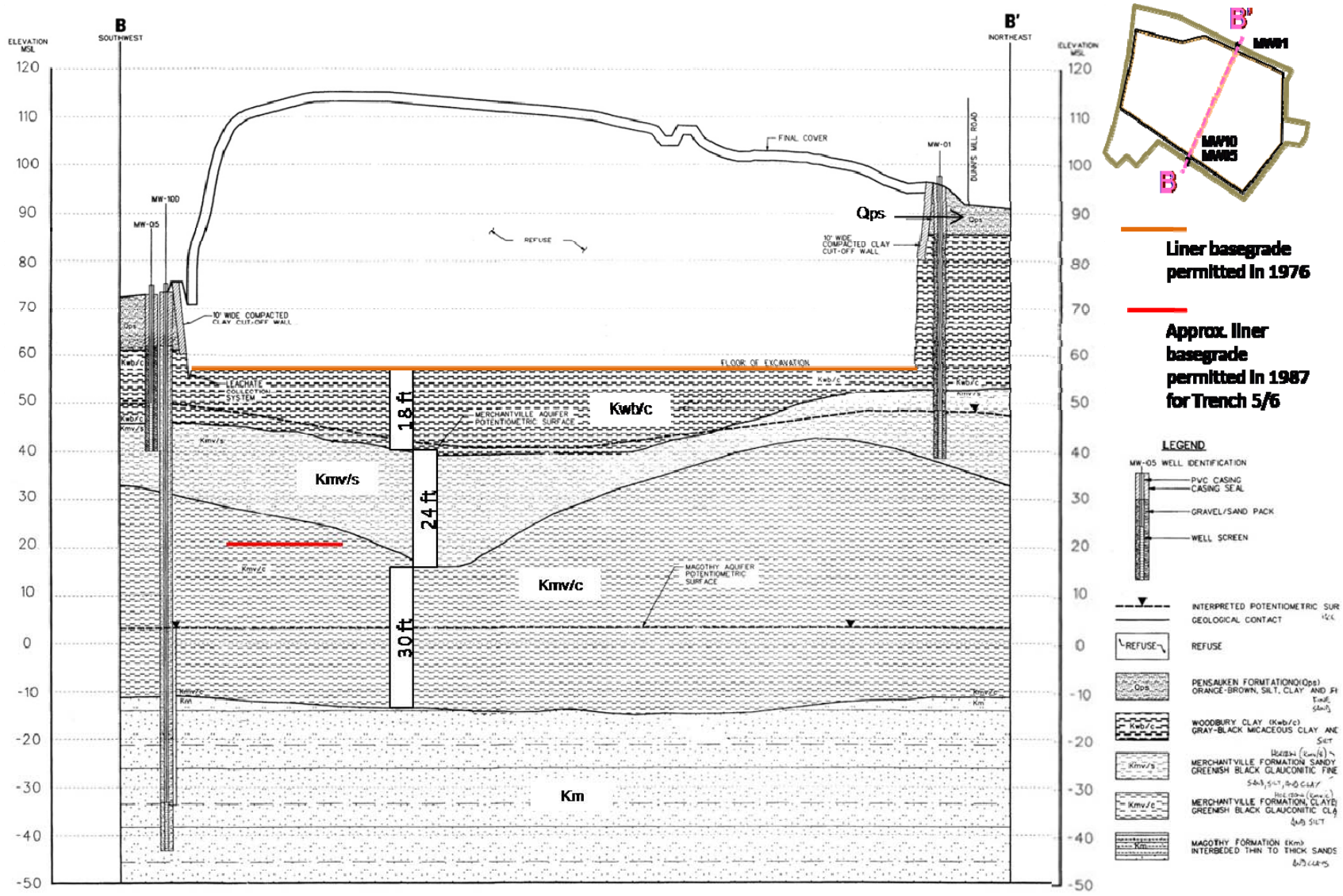
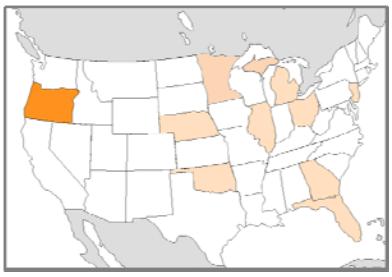


**FIGURE I-4**
**Site I Geologic & Hydrogeologic Cross Section**



## APPENDIX 2-1J

## SUMMARY – SITE J (OREGON)



### Overview

Study WMU: Site J is a composite-lined WMU with an approximately 244-acre footprint, including 39 MMCY of waste in-place at a thickness of about 125 to 150 feet. The WMU opened in 1/1990 and has been constructed in stages or modules. Approximately 32 acres of the sideslope of the earliest three modules to receive waste have received final cover.

Property: Site J is the single permitted WMU on the property. The total property size is 2,036 acres, of which approximately 650 acres are approved for solid waste disposal. Site J consists of one WMU developed to date in 11 modules of landfill construction. The earlier phases (modules 1 through 8) are underlain by a minimum of two feet compacted soil liner. The later phases (modules 9 through 11) are underlain by a composite liner consisting of 60-mil, high density polyethylene (HDPE) geomembrane underlain by a geosynthetic clay liner (GCL). Ultimately, 22 modules are planned for the estimated total capacity of 356 MM CY at a thickness of approximately 250 feet of waste and four feet of final cover.

The physiographical setting of the property and WMU is shown on Figure J-1. A stylized depiction of the site layout is provided as Figure J-2.

### Site Information

Geologic and Hydrogeologic Setting: A summary of the regional and local hydrogeologic setting was presented in the Environmental Monitoring Plan (EMP, HWA GeoSciences, 8/2000; Rev. CH2M Hill, 12/2007), that incorporated previous investigations conducted for WMN (Site J) landfill. The details of the hydrogeologic setting were presented in the Site Characterization Report (Sweet, 1989) and the Supplement to Site Characterization Report (Sweet, 11/1991). The site is located within the Columbia Plateau physiographic province, on a desert plateau approximately six miles south of the Columbia River. The area is characterized by a thick sequence of extensive and thick basalt flows that are locally interbedded with sediments. The WMU is located on a broad, gentle dipslope extending from the mountains south of the WMU to the Columbia River. The dipslope is formed by flows of the Columbia River Basalt Group. The dipslope has been dissected by streams, creating plateau-like relief. The dipslope is locally folded into discontinuous east-west trending anticlines and synclines. A canyon immediately south of the WMU follows an eastward-plunging anticline.

The regional geology is characterized by a layered sequence of flood basalt and sedimentary interbeds, overlain by fluvial and lacustrine volcanoclastic sediments, glaciofluvial sediments, and eolian deposits. Basaltic rock forms the regional bedrock for thousands of square miles in the area. The basalt is characterized by alternating layers of hard competent rock and less-competent layers of flow breccias and vesicular basalt (called interflow zones). The basalt flows dammed existing drainages, forming broad shallow lakes that were filled with interbedded sedimentary deposits. Surface deposits were locally sculpted by catastrophic glacial floods during the Pleistocene. Folding and minor faulting of the area resulted in the dominant structural features which are the east-west trending anticlinal ridges. The geologic units dip gently (approximately 1 degree) toward the south.

The stratigraphy of the WMU is, from youngest to oldest: loess, alluvium, glaciofluvial deposits of the Missoula Floods; siltstone, sandstone, and conglomerate of the Dalles Formation; tuffaceous sandstone of the Rattlesnake Ridge Member; vitric tuff and clayey silt of the Selah Member of the Ellensburg Formation; and basalt of the upper flow of the Columbia River Basalt Group.

The regional hydrogeologic units are interflow zones in the Grande Ronde and Frenchman Springs Basalts of the Columbia River Basalt Group. The vadose zone beneath Site J includes the siltstone, sandstone, and conglomerate of the Dalles Formation, the tuffaceous sandstone of the Rattlesnake Ridge Member, and the upper part of the vitric tuff and clayey silt of the Selah. The lower part of the Selah, a highly stratified siltstone interbedded with sandy silt and clay, is the uppermost hydrostratigraphic zone; however, the limited water yield (less than one to 10 gallons per minute) is not considered an aquifer for water supply purposes. Groundwater beneath Site J flows northeast to southeast, toward the canyon and valley to the south and east, respectively.

Saturated Zone: The EMP (12/2007) describes the Selah and site-specific hydrogeologic setting based on three soil borings advanced in 1987 and four soil borings advanced in 1988. These borings penetrated to between 250 and 450 feet bgs. These borings were completed as monitoring wells MWS-01 through MWS-04, and MWS-05 through MWS-07. Horizontal conductivity (k) in the hydrostratigraphic unit ranges between 1x10-3 and 7x10-6 cm/sec based on rising head tests. Vertical conductivity typically is two or more orders of magnitude lower. The laminated nature and contrast in hydraulic conductivity result in primarily horizontal flow, with minimal to no vertical movement of groundwater. The saturated zone is unconfined to partially confined because of the fine-grained nature. An average k of 6x10-5 cm/sec, and a gradient between 0.008 and 0.011, provides a horizontal seepage velocity of 0.004 to 0.006 per day.

Boring Logs: The typical cross-section, included in Figure J-3, was presented in the 11/1991 Supplement to Site Characterization. Boring logs are included in the EMP. The cross-section

shows the potentiometric surface map for the Selah hydrostratigraphic unit. Boring logs from groundwater monitoring well installation are available for the current groundwater monitoring system consisting of 7 monitoring wells.

Hydraulic Conductivity: Rising head tests were performed in all seven monitoring wells. The k values ranged between 1.1x10-3 cm/sec and 7x10-6 cm/sec.

| | |
|---|---|
| Hydraulic conductivity (cm/sec) | 1.1x10-3 to 7x10-6; average 6x10-5 |
| Hydraulic gradient (ft/ft) | 0.008 to 0.011 |
| Porosity | 0.30 |
| Groundwater flow velocity (ft/yr) | 1.5 to 2 |

Groundwater: Groundwater appears to occur under unconfined conditions beneath most of the WMU. Groundwater is encountered between 200 and 250 feet below ground surface. The design of the groundwater monitoring system accounts for quasi-radial flow direction ranging from flow to the east-northeast beneath the northern portion of the WMU to flow to the south-southeast beneath the southern portion of the WMU. The saturated thickness of the Selah ranges between 10 and 75 feet, with saturated thickness beneath the northern half of the WMU between 60 and 70 feet. The saturated thickness decreases to 10 feet in well MWS-06, just outside the southern WMU boundary. The hydraulic conductivity ranges between 1x10-3 and 7x10-6 cm/sec. Potential impact to groundwater quality would be detected by the down-gradient groundwater monitoring network including point of compliance wells MWS-04 and MWS-05.

Unsaturated (Vadose) Zone: The vadose zone, shown on Figure J-3, is the upper portion of the Selah Member, approximately 200 to 250 feet thick, described as light grayish-green to white colored, weathered tuffs and fluvial tuffaceous silt. The facies of the Selah (from bottom to top) are basal air-fall tuffs; lacustrine claystone and siltstone; tuffaceous siltstone and sandstone of reworked tuffs; and airfall tuff. A distinctive vitric (glassy) tuff locally occurs at the top of the Selah. The Dalles formation siltstone and conglomerates, Rattlesnake Ridge member tuffs, and unsaturated Selah Member tuffs overly the uppermost aquifer (the basal zone of the Selah Member), which may be important to consider when completing the landfill gas and groundwater modules.

| | |
|---|---|
| Elevation of lowest point on LCRS trench (2' below lowest point of liner, 890 feet NGVD) | Approximately 888 feet NGVD |
| Elevation of groundwater in MWS-2 | 760.70 feet NGVD (9/2007) |
| Assumed porosity of tuff (from "Supplement to Site Characterization Report" (Sweet, 11/1991) | 0.20 |
| Assumed thickness of vadose zone | 127 feet (based on boring log data, geologic cross-section, and base grade drawing) |

Physiographical Setting: According to the EMP (12/2007), the regional and site-specific topography is characterized by gently rolling uplands of desert, separated by moderately to deeply incised drainages and long east-west trending anticlinal ridges. A canyon located at the south end of the WMU approximately marks the property boundary. This canyon is oriented east-west. Toward the east of the WMU, the canyon trends into a north-south oriented valley. The WMU lies on an upland plateau, which rises abruptly to the north, to about 250 feet above the canyon floor. The WMU lies generally in an erosional trough, interpreted to the result of Pleistocene floods. The trough floor lies at an elevation of about 900 to 950 feet NGVD. Seasonally, surface water drains from the north portion of the WMU toward an ephemeral stream. The south portion of the WMU drains toward the closed basin-playa lakes that form in the winter or early spring in the canyon to the south of the WMU.

Potential Point(s) of Exposure: There are no occupied structures on the WMU. Locations of off-site houses and other structures are estimated based on review of a recent Google EARTH© aerial photograph and site reconnaissance. There are two water wells on the WMU (Wells 1 and 6), which have a maximum combined yield of about 600 gallons per minute (gpm) from the basalt units below the Selah. These wells are located in the canyon south of the WMU. A third well (Well 3) produces water used for dust control only, and is not tested for water quality. Wells 1 and 3 are tested quarterly for coliform bacteria; annually for nitrate; and triennially for lead, copper, VOC, and SVOC. Groundwater use on-site is for potable water, dust suppression, construction, and other site needs. The nearest domestic water wells are assumed to be located at the residential buildings nearest the WMU. For purposes of POE consideration, there is one residential building assumed to have a private water well. The residential building and well are located approximately five miles southwest of the WMU boundary. Water supply wells in the area are screened in the deep basalt zones and the overlying alluvial material. Groundwater use in the area includes irrigation, industry, livestock, domestic, and public supply.

Climate: The Base Liner and Final Cover Alternative Design Performance Demonstration (Rust, 10/1993) characterizes the climate as very arid with low precipitation, low humidity, high temperatures, high evapotranspiration, and strong winds. Average daily temperatures range from 33.5 to 75.5 degrees F. Average annual precipitation is approximately 9 inches per year. Average annual pan evaporation is approximately 50 inches. Meteorological data is collected at the upper scale house, located immediately south of the WMU.

## Waste Placement and Operations

General: The Site J WMU consists of 11 modules. The original cells (Modules 1 through 8) typically were excavated to about 80 feet below grade, or 880 feet NGVD, between years 1989 and 2000. The newer cells (Modules 9 through 11) were constructed between years 2002 and 2005).

Waste Placement Data: Waste receipts are available for the life of the landfill, starting in 1990. On-site steam separation and recycling has occurred. A summary of tonnages by year (for 1990 through 2007) is available in Title V Annual Reports. Annual waste placement is reported to have been 2,525,000 tons during the period between 5/2007 and 4/2008 (2008 Annual Report for Liquid Addition RD&D Project). Total estimated waste-in-place is 38,996,000 CY.

Dredged sediment, leachate, stormwater runoff, and other liquids have been added to the WMU since 12/2003 to reduce the stabilization period of the waste, and to accelerate generation of landfill gas. Annual reports of liquid addition have been filed since 2004. A monthly log of liquid added to the landfill is available. More than 93 percent of the liquid addition in 2008 was from leachate pumped from the evaporation pond at the north end of the site. In 2008, 2.8 MM gallons of leachate and other liquid was added. During the same period, 2.5 MM tons of MSW and industrial (special) waste was landfilled.

Waste Composition: The waste stream is 80 to 90 percent municipal solid waste, and special waste including ACM and auto fluff.

## Closure and Post-Closure (C/PC) Plan

The Closure/Post Closure Plan is Appendix I to the Operations Plan (11/2005, Rev 4/2007). Approximately 32 acres of the WMU were closed in 2006. The final grades of the WMU are designed with a 3.3H:1V sideslopes around the perimeter, and a relatively flat top (approximately 10 percent slope) covering the center of the WMU. The maximum elevation of the WMU will be 1,500 feet NGVD. Because of the long active life of the WMU, the final grading design is conceptual. The final cover will be an evapotranspiration (ET) cover.

## End Use Strategy

As included in the C/PC Plan (4/2007), the end use plan is for open, grassed land. The return of the site to its original use for grazing cattle will be considered after the PC care period. Also, enterprises that can be established without jeopardizing the integrity of the containment systems or endangering public health will be considered.

## Liner System

Design: Base Grade Plan (8/2006) shows the base of the WMU designed in a herringbone pattern with perforated leachate collection pipes and granular drainage material just above the composite liner. The pipes, which are spaced 300-feet apart, drain toward collection and removal points at the perimeter of the landfill. Early phases of Site J construction consisting of Modules 1 through 8 were constructed from 1989 (pre-Subtitle D) through 2000 and have a minimum of 2 feet compacted soil liner with permeability of 1x10-6 cm/sec. The later phases of Site J construction (Phases 9 through 11) (constructed 2002 through 2005) have a composite

liner consisting of 60-mil, high density polyethylene (HDPE) geomembrane underlain by a geosynthetic clay liner (GCL).

In addition to the composite liner and LCRS system, the WMU has a leachate monitoring system (LMS) beneath portions of the base liner. The monitoring system consists of HDPE-lined troughs located immediately below the compacted soil liner of the LCRS pipe troughs. Each trough is approximately 22 feet wide, lined with 60-mil HDPE, and contains a 4-inch diameter perforated HCPE pipe surrounded by drainage material. The pipes lead to a perimeter monitoring pipe (located below the perimeter LCRS pipe) to conduct liquid to collection points at the north (and ultimately, the south end) of the WMU.

From boring logs, there typically is 150 feet of separation between the bottom of the waste cells and the top of the upper hydrostratigraphic unit. There is a base grade low point (lowest point of liner, 890 feet NGVD) at the northern edge of the liner. Figures J-1 shows the lowest point at the northern edge of the liner.

CQA and Construction Records: The CQA reports for the soil liners were not available.

As-Built Drawings: A Base Grading Plan (Drawing 2) and Base Liner Details (Drawing 8) are available (Site Development Plan Design Report (Environmental Information Logistics, 9/2006).

## Leachate Management System

Layout and Design: The leachate collection and removal system (LCRS) comprises the entire base and below-grade sidewall areas of the landfill footprint. The north half of the LCRS discharges leachate by gravity to a lined evaporation pond. The LCRS design includes riser pipes that daylight on the north side of the WMU. The LCRS is monitored at these risers for potential head buildup on the liner system. Liquid levels are measured at riser L-4. Leachate flow is measured at leachate discharge headers L0-1 and L0-2. Leachate samples are collected at the discharge points L0-1 and L0-2 at the leachate evaporation pond. Leachate analytical data are compared to basin lysimeter data to evaluate evidence of a leachate release.

Details on construction of the LCRS are available in the Site Development Plan Design Report (Environmental Information Logistics, 9/2006).

A leachate monitoring system (LMS) supplements the LCRS with an additional liner and collection system beneath portion of the composite base liner. The LMS design for Modules 1 through 11 includes riser pipes that daylight on the north side of the WMU. The LMS design includes 10 monitoring points (designated BL-module number, or BL-Manhole, or BL-Perimeter Trench) at the north end of the WMU where the LMS pipes terminate at the leachate evaporation pond.

In addition, a secondary leachate collection system is present beneath the leachate evaporation pond. This is a separate system not connected to the LMS of the WMU. The leachate pond LCRS includes monitoring points BL-P1 and BL-P2.

CQA and Construction Records: N/A

As-Built Drawings: Leachate monitoring system details are included on Drawing 10 of the Site Development Update (Environmental Information Logistics, 9/2006), and on Figures 7A, 7B, and 7C of the EMP (HWA, 8/2000, Rev. CH2M Hill, 12/2007).

Leachate Generation Rate: Electronic records of leachate system modification and maintenance are available. Leachate flow data have been collected daily since the beginning of leachate production. Leachate flow is measured at manhole BLM. Leachate generation since 5/2003 through the present is available in the 2008 Annual Report for Liquid Addition RD&D Project (Environmental Information Logistics, 6/2008).

Leachate Recirculation and/or Disposal: State approval for liquid addition to the WMU was requested and approved at the end of 2003. In 2007, two infiltration trenches were used to recirculate leachate. One trench is located in waste near the north end of the landfill within the footprint of Module 4. The other trench is located in waste further south on the top deck of the landfill near the locations of previous trenches within the footprint of Modules 1 and 2. A map of previous and current trenches is available (Figure 1, annual liquid addition reports). Leachate flow rate was measured weekly at the LCRS discharge to the leachate evaporation pond. Leachate flow for 2008, and a summary of liquid added to the WMU since 12/2003, is available in the 2008 Annual Report for Liquid Addition RD&D Project (Environmental Information Logistics, 6/2008).

Leachate Sampling and Data: Leachate is sampled and analyzed semi-annually. Leachate is sampled at L-01 and L-02. Prior to the construction of Module 11, header L-01 conveyed leachate from Modules 1 through 10. After 9/2005, header L-01 conveys leachate from Modules 1 through 5. A second header, L-02, was installed as part of Module 11 construction in 9/2005, and conveys leachate collected from Modules 6 through 11 to the leachate evaporation pond. Under the EMP, leachate is monitored at the pond weekly for discharge rates into the evaporation pond, and liquid levels in riser L-4. Leachate grab samples are analyzed semiannually for inorganic and indicator parameters, and annually for VOCs. The LMS is monitored monthly for the presence of liquid, and the volume of liquid removed. If liquids are present, they are collected and analyzed semi-annually for inorganic and indicator parameters and annually for VOCs.

*Leachate Data (Electronic)*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Semi-annual sampling, leachate discharge point, L01 | 39 | 11/1990, 4/2008 | 115 | 100-1000 | 10-1000 | 100-1000 |
| Semi-annual sampling, leachate discharge point, L02 | 6 | 10/2005, 10/2007 | 108 | 1000 | 1000 | 1000 |
| Semi-annual sampling, LMS monitoring point BLP (perimeter) | 32 | 12/1989, 4/2005 | 194 | 100-1000 | 10-100 | -- |
| Special monitoring, BLPSP1 | 1 | 10/1991 | 67 | 100 | 10 | -- |
| LMS monitoring point BLManhole, BLM | 9 | 12/1989, 7/1992 | 185 | 100 | 10 | -- |
| BL6 | 3 | 9/1997, 1/1998 | 66 | 100 | 10 | -- |
| BL6B | 1 | 9/1998 | 28 | 100 | 10 | -- |
| BL6-E | 1 | 4/2004 | 28 | 1000 | 10,000 | -- |
| BL6W | 1 | 2/2003 | 63 | 100 | 10 | -- |
| BL7/8East | 1 | 4/2003 | 30 | 100 | 100 | -- |
| BL7/8W | 1 | 2/2003 | 63 | 100 | 10 | -- |
| BL9E | 5 | 1/2006, 1/2007 | 63 | 100 | 100 | -- |
| BL9W | 14 | 2/2003, 1/2007 | 63 | 100 | 10 | -- |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: None reported. There is no past or current evidence of current leachate impacts at the groundwater point of compliance (POC).

## Cover System

Design: The WMU has an interim cover, with the exception of an ET cover over the western slopes of Modules 1 through 3. Final cover and landfill closure will be far in the future. Currently, waste is placed to an elevation of approximately 1,100 feet NGVD. The final cover will be at an elevation of approximately 1,500 feet NGVD. Steep sideslopes (30 percent) will lead to a flat top.

The areal extent of the existing final cover is approximately 32 acres. This section of final cover is described in the CQA Certification Report for 2006 Landfill Closure Construction (Thiel Engineering, 3/2007) as a minimum of 18-inches of pre-existing soil that was smoothed, then

covered with 30-inches of cover soil and three inches of compost. The final cover was constructed between 9/2006 and 11/2006.

CQA and Other Construction Records: The Construction Quality Assurance (CQA) Certification Report for the 2006 Landfill Closure Construction, dated 3/2007, was reviewed.

As-Built Drawings: A record survey of landfill closure is included in the 3/2007 CQA report.

Topographic Surveys: Topographic surveys are available. The most recent topographic survey is 3/2008. Surveys from 2005 and earlier are flown annually and are available in the Airspace Utilization Reports. Also, aerial topographic surveys of the landfill were performed in 4/2004, 5/2005, 5/2006, 5/2007, and 3/2008 as part of the RD&D, to observe for an increase in settlement in the liquid addition areas.

Cover Monitoring and Maintenance: The C/PC Plan describes semi-annual inspections of the final cover surface to be performed for a minimum of five years after closure of an area, and annually thereafter as vegetation becomes well established and the rate of differential settlement of the final cover decreases. The WMU has a cap monitoring and maintenance program in compliance with the existing permit conditions. No maintenance issues such as seeps, breakouts, or slope failures were reported. An example of a monthly inspection report for 11/2008 of the final cover over portions of Modules 1, 2, and 3 was obtained.

Compliance Issues and Community Concerns: None reported.

### Landfill Gas Control System

Active Gas Control System: A gas migration monitoring system, completed in phases, exists for the whole WMU. Installation of a network of 16 vertical wells (WELL0001 through WELL0016) was completed in Phase 1 in 6/1998. Subsequently Phase 1B was completed in 2004; Phase 1C was completed in 2006; and Phase 1D was completed in Fall 2008. The landfill gas collection system includes a series of vertical and horizontal wells connected to a network of header piping. A blower/flare system provides vacuum to the wells via the header piping. Gas that is currently extracted from the WMU is burned in the flare. A LFG system map for 2008 is available (SCS, undated).

A record of gas system compliance as part of NSPS requirements is available. The history of operation, modification, maintenance, and wellfield balancing is available for Phases 1 through 1D. Wellfield balancing data is quarterly. The GCCS is connected to a flare. The flare was installed in approximately 1/2000. The monthly average flow at the flare (in cfm) is available in the 2008 Annual Report for Liquid Addition RD&D Project (Environmental Information Logistics, 6/2008). Monthly fugitive gas emissions through the cover system range between 50 and 52 percent.

Gas Utilization: A landfill gas-to-energy (LFGTE) system is planned to be installed in 2009. The gas flare was installed 10/1998. The estimated average flow from the gas flare in 2008 was 2700 cfm.

Passive Gas Vents: None.

Construction Details and As-Built Drawings: The construction report for Phase 1B GCCS is available (SCS, 6/2006). Gas header and gas collection pipe details are available on Drawing 9 (Site Development Plan Design Report, 9/2006).

Landfill Gas Data: Monthly Title V wellhead monitoring has been performed at individual wellheads since 1998. Total flow is recorded monthly at the flare and ranges from 250 to 3,000 cfm (in Annual Report for Liquid Addition RD&D Project, Environmental Information Logistics, 6/2008).

Gas composition data exist for bulk gases (CH4, CO2, N, H, O2). Under AP-42, the flare is tested every 18 months prior to permit expiration, and 18 months after permit renewal.

*Landfill Gas Data (E = Electronic, P = Paper)*

| ITEM | Flow | Composition | Notes |
|---|---|---|---|
| Wellheads | One month of flow obtained (E – 2003 and 2004 spreadsheets; 2005 through present on LGMS) | One month of flow obtained (E – 2003 and 2004 spreadsheets; 2005 through present on LGMS) | |
| Surface Scans | N/A | N/A | |

Compliance Issues and Community Concerns: None reported. There is no evidence that gas migration currently causes impacts, or has caused impacts in the past.

## Groundwater Monitoring System

Layout: The uppermost hydrostratigraphic unit is monitored at the WMU. Seven wells are included in the monitoring system, including: two up-gradient wells (MWS-02 and MWS-03, designated as background wells); two down-gradient wells (MWS-04 and MWS-05, designated as compliance wells); and down-gradient wells for future site development (MWS-01, MWS-06, and MWS-07). Wells MWS-01 through MWS-03 were installed 6/1987. Wells MWS-04 through MWS-07 were installed 4/1988. Four wells are sampled for groundwater quality, and all wells are measured for depth to groundwater.

Monitoring Program: The EMP (12/2007) indicates that the two background wells (MWS-02 and MWS-03) are monitored every two years, and the two compliance wells (MWS-04 and MWS-05) are monitored semi-annually for primary leachate indicator parameters (Ammonia

Nitrogen, Chloride, Sodium, Iron, TDS, TOC, TOX, and COD) and annually for 15 metals and 47 VOCs.

Construction Details: Boring logs for all seven wells, and well completion details, are available in the EMP in Appendix 5 and Table 2, well completion summary information.

Groundwater Data: A summary of analytical data is provided in the table below. Data are available for all parameters for which monitoring is required by the State.

*Groundwater Data (Electronic)*

| ITEM | Number of Wells, Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* |
|---|---|---|---|---|---|
| Background: Up-gradient, proximal MWS-02 | 1, 26 | 3/1989, 10/2007 | 193 | 10 | 10 |
| Background: Up-gradient, proximal MWS-03 | 1, 25 | 1/1989, 10/2007 | 193 | 10 | 10 |
| Future: Down-grad., proximal MWS-01 | 1, 2 | 2/1989, 1/1990 | 184 | 10 | 10 |
| Compliance: Down-grad., proximal MWS-04 | 1, 38 | 2/1989, 4/2008 | 217 | 10 | 10 |
| Compliance: Down-grad., proximal MWS-05 | 1, 35 | 1/1989, 4/2008 | 217 | 10 | 10 |
| Future: Down-grad., proximal MWS-06 | 1, 2 | 1/1989, 1/1990 | 184 | 10 | 0 |
| Future: Down-grad., proximal MWS-07 | 1, 2 | 1/1989, 1/1990 | 184 | 10 | 10 |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: No compliance issues or community concerns were reported.

## Surface-Water Monitoring System

Locations: There is no surface water monitoring at Site J. However, stormwater monitoring is conducted under an NPDES permit. Stormwater monitoring and data are discussed, primarily because of the configuration of the north end of Site J where a leachate evaporation pond exists between WMU and the intermittent surface drainage located down-gradient. Stormwater sample point SWPPP-01 is located down-gradient of the pond at the approximate point where water would flow in an intermittent stream. This sample point has been called by a variety of names,

including “stormwater pond” or “stormwater discharge” or “stormwater monitoring point” in the table below. Stormwater flows from the WMU at the north boundary (sample point SWPPP-01), and flows from the WMU at the south boundary (sample points SWPPP-02 and SWPPP-03).

Monitoring Program: When stormwater is flowing, water is collected and analyzed for Copper, Lead, Zinc, TSS, and color, odor, and oil and grease. Stormwater samples have been collected between 1997 and 2006. A full-suite of parameters was measured in a sample from a stormwater pond in 1997.

Surface-Water Data: Available data from the electronic database are summarized in the table below.

*Surface-Water Data (Electronic)*

| ITEM | Number of Monitoring Events | Start, End Dates | Total Number of Analytes | Chloride* | COD* | BOD* |
|---|---|---|---|---|---|---|
| Stormwater Pond | 1 | 12/1997 | 65 | 1000 | 100 | -- |
| Stormwater Discharge | 2 | 3/2002, 4/2003 | 5 | -- | -- | -- |
| Stormwater Monitoring | 3 | 12/1999, 2/2000 | 5 | -- | -- | -- |
| SWDMP 1 | 3 | 12/2002, 12/2006 | 6 | -- | -- | -- |
| SWPP2 | 2 | 2/1998, 5/1998 | 5 | -- | -- | -- |
| SWPP3 | 4 | 2/1998, 10/2001 | 5 | -- | -- | -- |

* Concentration (order of magnitude, in mg/l)

Compliance Issues and Community Concerns: None reported.

## Methane Migration Monitoring (MMM) System

Layout: Site J has seven permanent perimeter gas probes (GP-1 through GP-4, and GP-11 through GP-13) located along the northwest-north-northeast sides of the WMU. The probe numbering corresponds to the closest module number. The original gas probe, GP-1, was installed in 1991; probes GP-2 through GP-4 were installed 1993; and the newer probes GP-11 through GP-13 were installed 2007. Probe installation logs are in Appendix 6 of the EMP (12/2007). Screens are placed between about 25 and 100 feet in GP-1, GP-2, and GP-3, and between 10 and 30 feet in GP-4. Screens are nested in GP-11, GP-12, and GP-13 to monitor shallow, middle, and deep intervals, as follows: GP-11 (between 10-20, 40-50, 70-80 feet bgs), GP-12 (between 25-35, 45-55, 65-75 feet bgs), and GP-13 (between 10-20, 45-55, 76-86 feet bgs). Quarterly monitoring has been conducted since 1991 in the older probes (and since 2007 in the newer probes) through the present.

Monitoring Plan and Data: Methane migration monitoring of perimeter gas probes and buildings is required quarterly (EMP, 12/2007). Quarterly monitoring data exist for 1997 through the present.

*Methane Migration Monitoring Data (E = Electronic, P = Paper)*

| ITEM | Start, End | Frequency | Notes |
|---|---|---|---|
| Perimeter Probes, GP-1 to GP-4 | 1991, 2008 | Quarterly | Electronic |
| Perimeter Probes, GP-11 to GP-13 | 2007, 2008 | Quarterly | Electronic |

Compliance Issues and Community Concerns: None reported.

**FIGURE J-1**
**Site J Physiographical Setting**

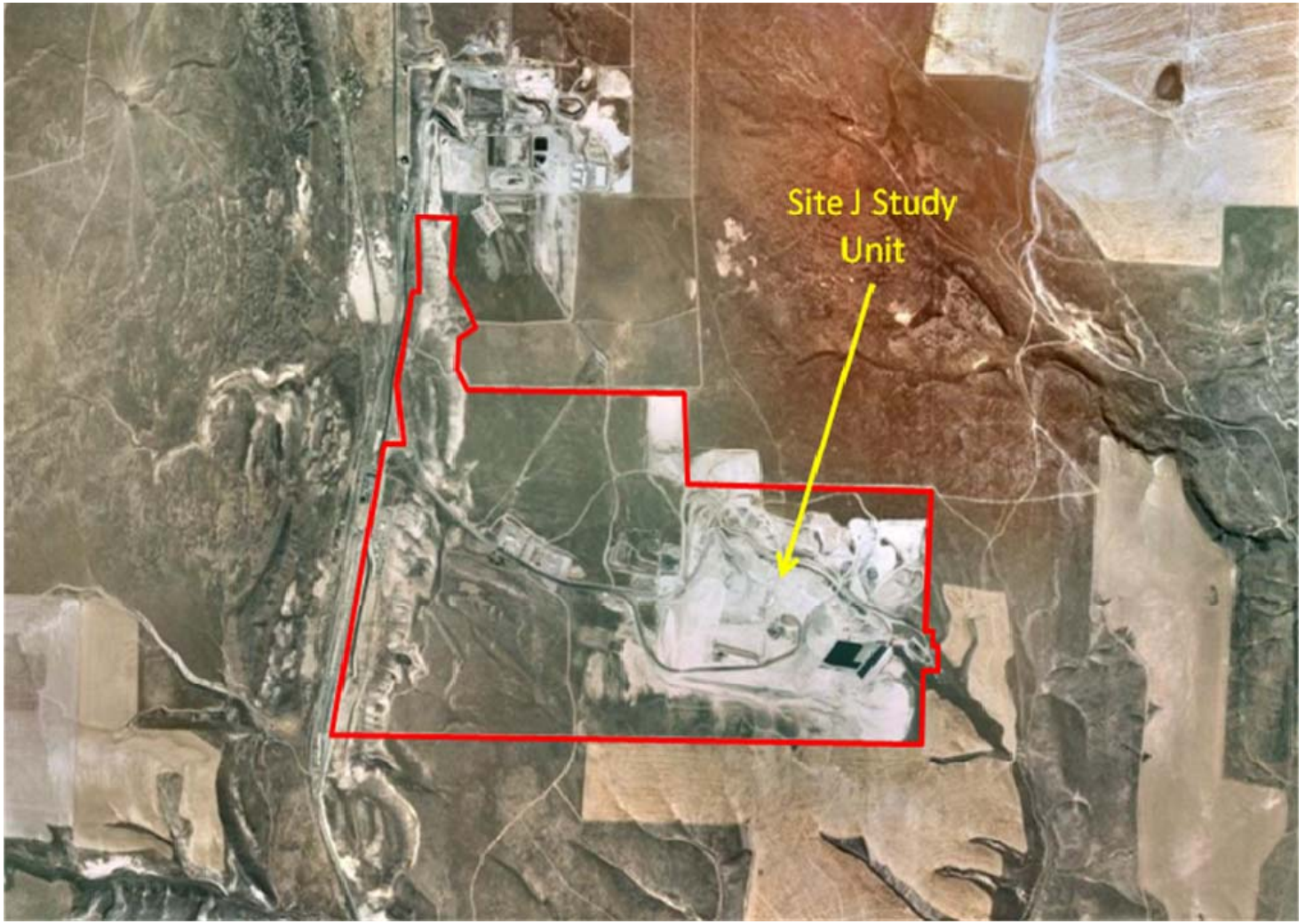


**FIGURE J-2**
**Site J Layout and Features**

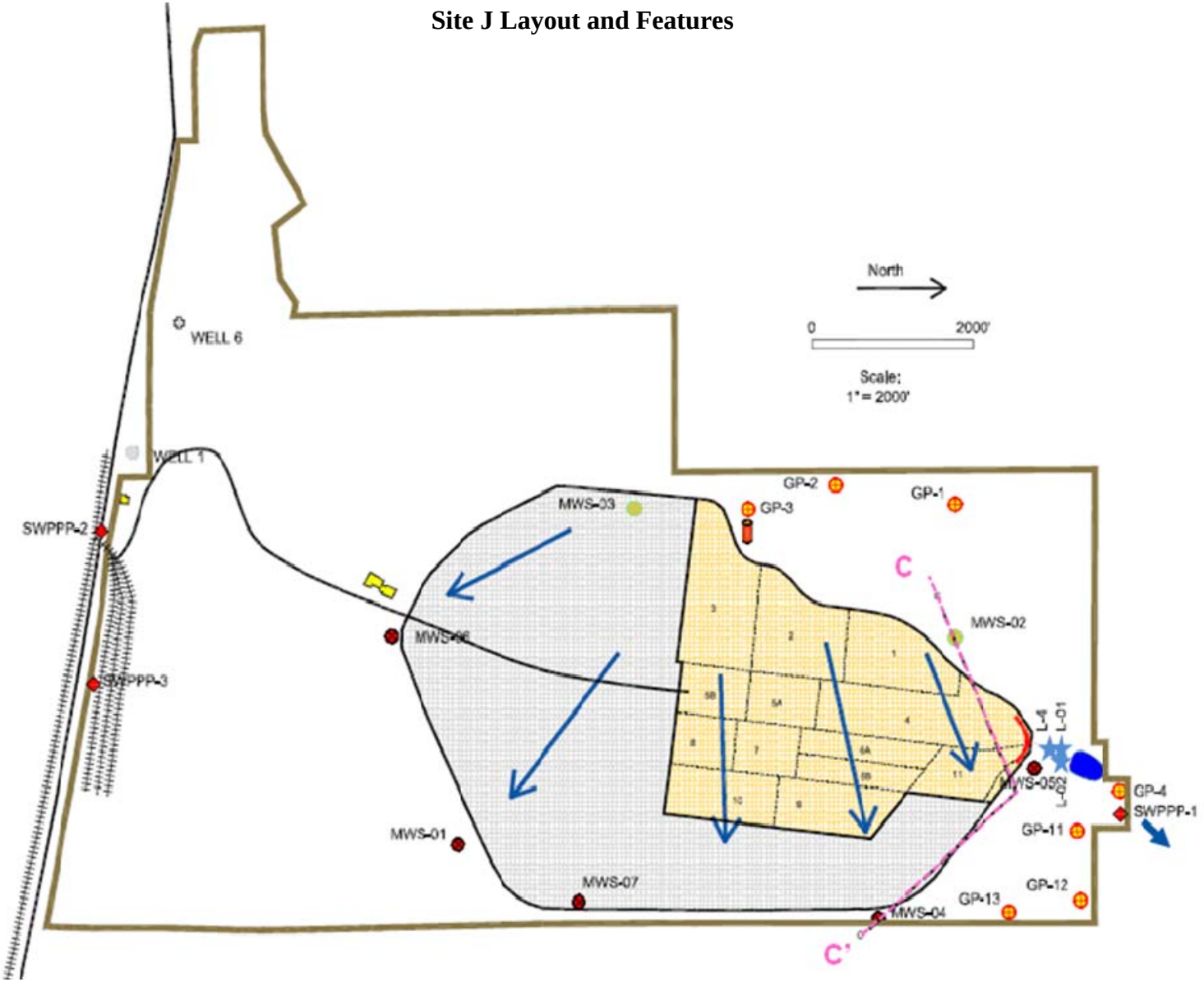
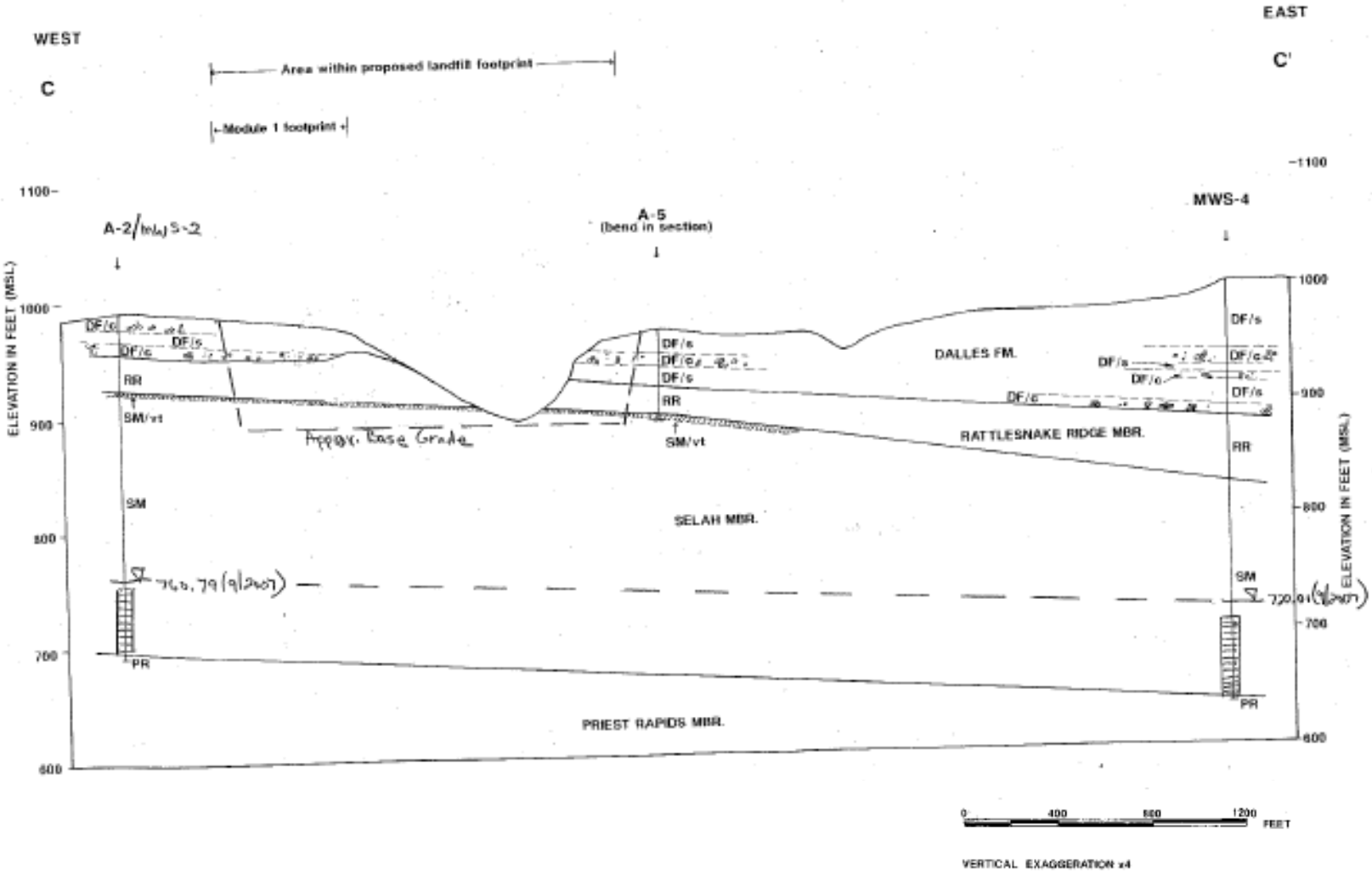


**FIGURE J-3**
**Site J Geologic & Hydrogeologic Cross Section**



# APPENDIX 2-2
# KEY TO SYMBOLS USED IN SITE LAYOUT FIGURES*

## Determining Critical Data Requirements for Implementation of the EPCC Methodology Prerequisites Module
## Environmental Research and Education Foundation

### Land Use and Site Features

Study WMU

Other Landfill/WMU

Soil Stockpile

Surface Water Body or Stormwater Pond

Natural Woodland

Natural Wetland or Wooded Swamp

Constructed / Mitigation Wetland


Surface Water Flow Direction in Swamp or Wetland


Public Road


Railroad

Private Offsite Water Supply Well

Public Offsite Water Supply Well

Onsite Water Supply Well


Generalized Groundwater Flow Direction in Uppermost Aquifer

Property Boundary / WMU Parcel Boundary (Dashed)

Stormwater Conveyance from Study WMU

River / Stream / Canal

Leachate Collection Sump


Low Point on Base of Liner

Plan Center on WMU Base (Assumed Low Point)

Leachate Composite Sump / Metering Station

Leachate Storage Tank(s)


Leachate Recirculation Trench

Flare / Gas Utilization Station


Gas Migration Cut Off Trench / Vent Line

Onsite Structure

Offsite Structure

### Monitoring Features

Upgradient Surface Water Monitoring Location

Downgradient Surface Water Monitoring Location

Distal Upgradient Groundwater Monitoring Well

Proximal Upgradient Groundwater Monitoring Well

Cross Gradient Groundwater Monitoring Well

Downgradient Groundwater Monitoring Well

Piezometer / Boring / Other Well

Methane Migration Monitoring Probe

Proposed (Virtual) Well/Probe for Confirmation Monitoring

* Including all figures in Appendices 2-1A through 2-1J, and Figure 5-2A through 5-2J