County of Franklin
Solid Waste Management Authority (CFSWMA)
Proposed Landfill Expansion

Site Investigation Report

September 2008

Barton & Loguidice, P.C.
Engineers • Environmental Scientists • Planners • Landscape Architects

290 Elwood Davis Road
Box 3107
Syracuse, New York 13220

Site Investigation Report

for the

County of Franklin Solid Waste Management Authority
Proposed Landfill Expansion

Towns of Westville and Constable
Franklin County, New York

September 2008

Prepared for:

County of Franklin Solid Waste Management Authority
828 County Route 20
Constable, New York 12926

Prepared by:

Barton & Loguidice, P.C.
290 Elwood Davis Road
Syracuse, New York 13220

Table of Contents

Table of Contents – Continued

Section Page

Follows
Tables Section

Figures

Table of Contents – Continued

Figures (Continued) | Follows Section

Appendices

1.0 Introduction

The County of Franklin Solid Waste Management Authority, referred to as CFSWMA hereafter, owns and operates a solid waste management facility located in the Towns of Constable and Westville, Franklin County, New York. The Site currently consists of the active solid waste facility as illustrated in Figure 1-1. The active facility is currently permitted under 6 NYCRR Part 360 to operate as a sanitary landfill.

In order to address CFSWMA's continuing solid waste management needs, CFSWMA is pursuing a permit to construct a lateral expansion of the active facility.

A Site Investigation Report (SIR), presented herein, has been developed to supplement the previous data collected from the existing facility and to gather information pertaining to the proposed landfill expansion area. The objectives of this SIR are as follows:

- To define the hydrogeologic conditions beneath the expansion area and relate these conditions to those previously defined beneath the existing landfill facility. This includes the thickness and geologic properties of the overburden deposits, the direction and rate of groundwater movement in the overburden and underlying bedrock water-bearing zones, and the water quality characteristics within these water-bearing zones;

- To collect the data necessary to update the current Environmental Monitoring Plan (EMP) to include the proposed expansion area; and

- To provide the necessary topographic and subsurface geologic information to support the engineering report requirements of Part 360.

Section 2.0 presents the final site investigation plan for the work performed within the expansion area. This is followed by the site investigation report in Section 3.0, which describes the hydrogeologic conditions observed beneath the expansion area and relates them to those underlying the existing facility. References applicable to the text within this report are summarized in Section 4.0.

2.0 Site Investigation Plan

In order to obtain data necessary to understand the Site's hydrogeologic setting and to implement a site Environmental Monitoring Plan (EMP), various field investigations were performed. This investigatory effort included:

- Seventeen (17) exploratory borings to provide information related to the overburden thickness and to determine the physical properties of the materials encountered;

- Excavation of 35 test pits to determine the nature of the overburden materials, the depth to bedrock, where possible, and to identify large-scale structural features of the overlying materials (e.g., groundwater seeps, depositional layering, etc.);

- Installation of 20 new monitoring wells consisting of 9 top-of-rock wells and 11 overburden monitoring wells;

- In-situ hydraulic conductivity tests of the new wells;

- Water level measurements to establish groundwater elevations and flow directions; and

- Collection of groundwater samples from the newly installed monitoring wells. Each sample location was chemically analyzed, per Part 360 regulations.

2.1 Soil Borings

Seventeen (17) exploratory soil borings (EB-01 through EB-17) were advanced to refusal on bedrock at the locations illustrated on Figure 2-1. The data obtained from these locations are summarized in Table 2-1. The soil borings were continuously sampled using a 2 inch diameter, 2 foot long split-spoon sampler to refusal on bedrock. The presence of bedrock was confirmed through the collection of a minimum 5 foot length of NX core. The boreholes were sealed with a cement-bentonite grout upon completion.

2.2 Test Pits

Thirty-five (35) test pits (TP-01 through TP-35) were completed within the proposed expansion area to further define the nature of the overburden material, establish top of bedrock elevations (where possible), and to determine large-scale structural features of the overburden materials. The test pits were excavated using a backhoe capable of reaching a maximum depth of approximately 24 feet. In practice, the depth achieved was typically less than this maximum limit due to the presence of shallow bedrock, boulders, or dense glacial till. Test pit logs are provided in Appendix B and Figure 2-1 depicts the test pit locations. The data obtained from these locations are summarized in Table 2-1.

2.2.1 Geotechnical Testing

Geotechnical testing, consisting of grain-size and Atterberg limits analyses, was conducted on bulk samples collected from selected test pit locations. Locations TP-03, TP-21, and TP-30 were selected for bulk sample collection. These bulk samples were analyzed by Atlantic Testing Laboratories, Ltd. of Canton, New York. The geotechnical data were used in conjunction with the visual sample descriptions from the test pits, exploratory borings, and monitoring wells to better understand the soil properties and to provide information related to engineering design applicable to the proposed landfill expansion. In addition, the geotechnical data generated during the expansion area investigation were compared to similar data collected as part of the site investigation for the existing landfill facility. Appendix D presents the results of the geotechnical analysis, while Table 3-1 provides a summary of the geotechnical laboratory data.

2.3 Monitoring Well Installation

In order to establish an understanding of the stratigraphy and hydrogeology within the expansion area, 20 locations were selected for the installation of monitoring wells. Given the spatial distribution of the monitoring wells throughout the expansion area, coupled with a database of existing investigatory information, the stratigraphy beneath the expansion area is adequately defined. In addition, the locations at which the wells are situated are designed to confirm the direction of groundwater flow within the overburden and bedrock water-bearing zones and provide sampling points for determination of the existing groundwater quality. Figure 2-1 displays the locations at which monitoring wells were installed. Locations and elevations of the newly installed wells and borings are summarized on Table 2-1. Existing monitoring well and piezometer data are summarized on Table 2-2.

Drilling activities were performed by Northern Technical Services, Inc. of North Bangor, New York using truck-and track-mounted rill rigs equipped with hollow-stem augers, roller-bit reaming tools, and coring tools. A Barton & Loguidice hydrogeologist observed the drilling activities. Drilling and well installation methodologies for the monitoring wells are described below.

The stratigraphy of each cluster was initially defined by first completing the construction of the bedrock well. In the single instance where a bedrock well was not installed (MW-24D), a deep boring was continuously sampled to refusal on bedrock, which was then confirmed by collection of NX core. At most locations, a borehole was advanced using 6.25 inch I.D. hollow-stem augers to refusal on the top of bedrock. In areas of significant overburden or when difficult drilling conditions were encountered, a 6 inch roller bit followed by a 6 inch temporary drive casing was used to advance to bedrock. Soil samples were continuously collected from ground surface to the top of bedrock using a 2 inch diameter, 2 foot long split-spoon sampler. The samples were logged and described according to the Burmister Soil Classification System and Unified soil Classification System (USCS). Once the 6.25 inch hollow-stem augers or the 6 inch temporary drive casing were temporarily set into bedrock, a 3 inch NX core barrel was used to continuously core rock to the full depth of the borehole. The screened intervals for the top of rock wells were typically set approximately 10 to 15 feet into bedrock.

Wells were constructed using 2 inch diameter, flush-threaded Schedule 40 PVC riser casing and depending on the depth of the borehole, a 5 or 10 foot PVC continuous wire wrap screen with 0.010 inch wide slots. A sand pack (#0) was then placed in the borehole annulus to a level of 2 feet above the screen followed by a 6 inch layer of choke sand (#00). A minimum 3 foot thick bentonite-pellet seal was placed immediately above the sand layer followed by an additional 6 inches to one foot of choke sand (#00) and the remainder of the borehole annulus was filled with cement/bentonite grout using a tremie pipe.

2.3.1 Monitoring Well Development

Newly installed monitoring wells were developed following installation. To provide adequate time for the cement/bentonite grout to fully cure, each well was left undisturbed for a minimum period of three (3) weeks before development. Well development was accomplished using the method described below.

An electrically-driven inertial pump (Waterra®) was used for development of the monitoring wells. Periodic measurements of pH, Eh, temperature, specific conductance, and turbidity were recorded during the development process. Development was considered complete when there was no visible increase in the clarity of the evacuated water and/or stabilization of field parameters was achieved. Well development records are provided in Appendix F.

2.4 <u>Hydraulic Conductivity Testing</u>

The measure of hydraulic conductivity in the subsurface describes the ability of rock or soil to transmit water. Hydraulic conductivities present beneath the Site represent perhaps the most critical parameter in characterizing fluid interaction within the subsurface system. Given sufficient continuity of the strata and known hydraulic gradients, it is the hydraulic conductivity that will control the migration pathways for fluids as well as the volumetric rates of groundwater flow.

2.4.1 In-Situ Variable Head Slug Tests

In order to determine the in-place hydraulic conductivity of the unconsolidated and consolidated geologic material screened by the two-inch monitoring wells, falling head slug tests were performed on the new monitoring wells. These tests involved raising the water level in the well and measuring the change in head with respect to time as the well was allowed to recover to static conditions. Recovery was measured by means of a pressure transducer system. The data obtained from these tests were then evaluated using Aqtesolv® Software. Complete computational data for the slug tests are presented in Appendix C and are discussed in Section 3.4.1.

Duplicate slug tests of selected monitoring wells were conducted to demonstrate reproducibility of results and to determine whether well development procedures were sufficient. Duplicate slug tests were performed at all locations, although the duplicate tests were not analyzed at all locations. Duplicate slug tests for monitoring wells MW-20 and MW-25D were analyzed and indicated acceptable reproducibility.

2.5 Water Level Monitoring

Groundwater elevations within each water-bearing zone were evaluated by collection of water level measurements from each of the newly installed monitoring wells in addition to existing wells situated within or near the expansion area. In addition, measurements were taken from surface water elevation control points that were established during the field investigation to document surface water elevations within Briggs Creek and tributary waters located throughout the Site. From the compilation of these data, an understanding of groundwater and surface water interactions across the Site was achieved and is discussed in further detail in Section 3.5. Table 2-3 presents a summary of the water level measurements and calculated elevations. Table 2-4 summarizes the staff gauge location and elevation data.

The measurements were referenced to the top of PVC casing for the monitoring wells and piezometers, whereas measurements were referenced to the surface water elevation control points (i.e., top of reinforcement bar or wooden stake driven into stream bed) for the stream gauge locations.

2.6 Survey

Each of the exploratory borings, monitoring wells, exploratory test pits, and staff gauges was surveyed by a New York-licensed surveyor. The survey included location coordinates, ground surface elevation, and top of reference elevation data (for monitoring wells and staff gauges). Coordinates were referenced to a site grid system. A limited number of locations were re-surveyed in the NYS State Plane system using the North American Datum of 1983 (NAD 1983) in units of feet. These locations provided the means to convert the remainder of the locations to the NYS State Plane system. Elevations were referenced to site bench marks previously established by the surveyor in units of feet. The location and elevation data are presented in Tables 2-1 and 2-2.

2.7 Residential Well Survey

Public and private wells within one mile downgradient and one-quarter (1/4) mile upgradient of the proposed expansion area were surveyed to obtain relevant and available information prior to submittal of a permit application to NYSDEC. This information will consist of the vertical and horizontal location of the well, name of owner, age and usage of the well, stratigraphic unit screened, manner in which the well was constructed, static water levels, well yield, perceived water quality, and other relevant information. That information will then be appended to an existing residential well database, as applicable.

2.8 Groundwater Quality Sampling and Analysis

In accordance with Part 360, baseline water quality at the Site must be established prior to the deposition of solid waste at the facility. One round of sampling has been conducted to date during this investigation. The first round of sampling was performed during the period of April 7-11, 2008 and included the collection of samples from each well for analysis of the Part 360 expanded parameters. Groundwater quality samples were collected by field representatives from Barton & Loguidice. The water quality analyses for this investigation were performed by Upstate Laboratories, Inc. of East Syracuse, New York.

3.0 Site Investigation Report

In this section, the characteristics and extent of the geologic materials underlying the proposed expansion area are described.

Section 3.1 briefly explains the environmental setting attributed to the Site. A discussion of the regional geology is presented in Section 3.2 to put the Site into perspective within the larger geologic framework of the region and to describe the geologic history, which led to the formation of the strata. The following summary of geologic conditions is based on investigations conducted at the Site for CFSWMA by Barton & Loguidice as well as interpretation of data developed for the existing landfill facility by Stearns & Wheler in their report entitled *Regional Landfill Hydrogeologic Investigation – November 1991, Revised February 1993*. Section 3.3 narrows the area of interest to the geology specifically pertaining to the CFSWMA Site. Data collected during this and previous investigations both within the proposed lateral expansion area and the existing CFSWMA facility are used to characterize the site hydrogeology. In Section 3.4, the results of the hydraulic testing programs are described and summarized. The hydrogeologic conditions underlying the expansion area and their relationship to the existing facility are then discussed in Section 3.5 followed by a discussion of the groundwater quality data in Section 3.6.

3.1 <u>Environmental Setting</u>

This section presents the location and physical features of the proposed landfill.

3.1.1 Location

The landfill expansion area is located within the St. Lawrence Lowlands physiographic province (Figure 3-1). There is relatively little topographic relief in this region; the highest elevations are over 1,000 feet above mean sea level (amsl) approaching the Adirondack foothills to the south, while elevations are less than 230 feet (amsl) at the Trout River international crossing.

The natural topography in the immediate vicinity of the site is quite subtle, with total relief only on the order of thirty feet (Figure 3-2). A topographic ridge extends northeast-southwest through this area, reaching an elevation of approximately 260 feet (amsl) along portions of County Route 20 (Trout River Road), which generally follows the crest of the aforementioned ridge. Adjacent valley sections are generally less than 250 feet in elevation (amsl), with the lowest elevations occurring in the vicinity of Briggs Creek along the southwestern edge of the investigation area. In this vicinity, the lowest elevations are on the order of 232 feet (amsl).

The existing landfill facility is located generally along the crest of a secondary topographic ridge that parallels the primary topographic ridge discussed previously. Prior to development of the existing landfill facility, the secondary ridge achieved maximum elevations of slightly more than 250 feet (amsl). The secondary topographic ridge extends southwestward from the existing landfill facility for a distance of approximately 700 feet.

3.1.2 Site Hydrology

The proposed expansion area is located in the watershed of Briggs Creek, which is a tributary to the Beaver River in the St. Lawrence River drainage basin. The existing landfill facility drains into an unnamed stream that flows just east of the Site. Briggs Creek flows west/southwest from the vicinity of the Site for approximately 2.4 miles before turning north towards the U.S.-Canadian border (Figure 1-1). Briggs Creek joins the Beaver River in Canada before entering the Trout River.

3.1.3 Residential Wells

The geologic materials in the site vicinity are capable of providing modest yields to appropriately constructed water wells, and residences in the area are typically supplied by such wells. There are several residences located along County Route 20 (Trout River Road) that are located upgradient of the Site. In addition, there are approximately twelve residences within a one-mile radius south of the Site. However, these residences are located along Sand Road, which although generally in the downgradient direction from the Site, is separated from the Site by Briggs Creek, which serves as a groundwater discharge divide.

A residential well survey will be conducted one mile downgradient and a quarter (1/4) mile upgradient of the area of investigation prior to submittal of a permit application to NYSDEC. Each residential well will be surveyed for pertinent information including, to the extent possible, the location of the well, its use, depth, yield, and quality, the type of pumping apparatus, if any, and any other pertinent details of the water supply.

3.2 Regional Geologic Setting

The Franklin County region includes portions of two major physiographic subdivisions, the Adirondack Mountains to the south and the St. Lawrence Lowlands. The oldest rocks are found primarily in the Adirondacks, and include numerous types of crystalline rock. The crystalline rocks are overlain by a sequence of sedimentary rocks consisting of sandstones, dolomites, limestones, siltstones, and shales of Cambrian and Ordovician age. These sedimentary rocks represent, for the most part, marine deposits that have subsequently been solidified, slightly deformed, and uplifted to near their present position. The uplift and deformation have resulted in a slight tilting of the deposits to the north, away from the Adirondacks, at a dip of approximately 30 feet per mile. Superimposed upon this general northward trend are several sets of nearly vertical fractures, or joints. These joints provide the primary pathways for groundwater flow within the bedrock. However, they commonly are separated by masses of unfractured, relatively low permeability rock, limiting the usefulness of the bedrock as a source of significant supplies of groundwater. There are no known faults identified in the northern Franklin County region (Isachsen and McKendree, 1977).

In more recent geological times, the region has been subjected to both the erosional and depositional forces of continental glaciation. While the latter forces were dominant over the greater part of the region, the erosive action of the glacier altered many of the major drainage ways, for example, the St. Lawrence River Valley. In addition, the tributary valleys were also scoured and deepened prior to the deposition of both stratified and non-stratified glacial materials. A significant percentage of the groundwater supplies of Franklin County are derived from the unconsolidated glacial deposits. However, the deposits which are capable of yielding quantities of water sufficient for public supplies consist of stratified outwash, deltaic, and ice-contact sands and gravels that occur in the major stream valleys. The greater portion of the region, however, is underlain by relatively low permeability glacial till, which, even when fully saturated, yields water only at very slow rates.

The area under consideration for a lateral landfill expansion is situated over Ordovician-age bedrock of the Ogdensburg Dolostone of the Beekmantown Group (Rickard, et al., 1970). The Ogdensburg Dolostone consists of grey to dark blue-grey dolostone, which overlies the Theresa Formation of Upper Cambrian age. The spatial distribution of the bedrock formations in the site vicinity is depicted on Figure 3-4.

The bedrock is overlain by a mantle of glacial till deposited during the Pleistocene Epoch (McClintock and Stewart, 1965) and typically described as a brown to grey, clayey silt with some fine-to-medium-grained sand, and varying amounts of fine gravel. The spatial distribution of the surficial geologic materials in the site vicinity is shown on Figure 3-5.

3.3 <u>Site Geology</u>

Detailed descriptions of the materials encountered on-site are presented on the boring and test pit logs in Appendices A and B to this report. The soil descriptions are based upon visual examination and the results of laboratory geotechnical analyses and are in accordance with the Burmister Soil Classification System and the Unified Soil Classification System (USCS). The results of the geotechnical laboratory data are summarized in Table 3-1. The geologic strata are depicted on the geologic cross-sections A-A' and B-B' (Figures 3-6 and 3-7). Cross-section orientations are illustrated on Figure 2-1.

The general character, areal extent, and significance of the major geologic strata will be discussed in the following sections.

3.3.1 Overburden

Overburden deposits underlying the expansion area are predominantly of glacial and proglacial origin, with basal lodgement till forming the most widespread overburden deposit.

3.3.1.1 Lodgment Till

Glacial till is, volumetrically, the predominant unconsolidated earth material beneath the expansion area. Glacial till is defined as a heterogeneous, non-stratified sediment deposited directly by the action of glacial ice, and typically includes particle sizes in the range of clay to boulders. The till encountered throughout the area of investigation represents a classic example of lodgment, or basal, glacial till. The basal lodgement till is typically described as a dense grey, matrix-supported Sand and Silt, with varying proportions of Gravel and would be typically described as a CL-ML (clay to silt) to SM-SC (silty sand to clayey sand) soil in the Unified Soil Classification System (USCS). For purposes of stratigraphic mapping, this till has been termed the Lower Glacial Till, and directly overlies the bedrock across the majority of the Site. The thickness of the Lower Glacial Till, where present, typically ranges from 5 to more than 60 feet (Figure 3-8). The Lower Glacial Till was absent only in the extreme northern portions of the Site where total overburden thickness is typically less than 20 feet.

As observed in the geotechnical laboratory data (Table 3-1) as well as the visual classification of split spoon samples, the matrix of the Lower Till Unit is reasonably consistent, with the percentage of particles passing the No. 200 sieve ranging from 40 to 60% and the clay content on the order of 15 to 30%. The sand fraction ranged generally from 30 to 40%, and the gravel fraction generally ranged from 10 to 15%. These samples would be classified CL-ML to SC-SM in the Unified Soil Classification System (USCS). By way of comparison, grain-size analyses of this unit completed as part of the original site investigation yield similar results, although samples from the expansion area investigation are somewhat finer-grained on average than the samples from the original site investigation.

3.3.1.2 Ablation Till

Ablation till is typically associated with a downwasting ice margin and represents largely non-sorted, ice-contact debris derived from within the ice or debris “let down” from the surface of the ice as it melted. Ablation till is typically coarser-grained than lodgment till, and is usually much less dense. Ablation till is often intimately associated with stratified, ice-contact, meltwater deposits such as kames. Areas of ablation till are often recognized by their deranged drainage and topographic patterns, derived from the collapse of supporting ice, a feature shared with stratified ice-contact deposits.

In the upland portions of the Site above an elevation of approximately 250 feet (amsl), the Lower Glacial Till is overlain by a brown glacial till unit that represents either an ablation till and/or lodgement till that has been weathered and/or winnowed, reducing to a degree the percentage of fine-grained materials present. This till, termed the Upper Glacial Till, is typically described as a brown, loose to medium dense, matrix-supported Sand, little to some Silt, with varying proportions of Gravel, and would be typically described as an SM (silty sand) soil in the Unified Soil Classification System (USCS). Although this material typically appears dense on the basis of blow counts, test pit excavations indicated that the apparent density is due in large part to the presence of frequent tabular cobbles and boulders rather than to the density of the matrix. The thickness of the Upper Glacial Till ranges from a few feet to more than 20 feet (Figure 3-9) and is thickest to the northwest, generally along a line paralleling County Route 20.

In general, the total thickness of the overburden is inversely related to the topography of the Site. That is, the greatest total accumulations of overburden, exceeding 80 feet in total thickness, occur in the topographically lowest portions of the Site, while the thinnest accumulations of overburden occur in the topographically highest portion of the Site along County Route 20. The greatest thickness of overburden is located at the southwest end of the area of investigation at the exploratory boring designated as EB-17 on Figure 3-10, where the total overburden thickness reaches 80 feet. Within the proposed expansion area, the total overburden thickness ranges from 30 feet to 75 feet, with the lower till unit accounting for the vast majority of the total overburden thickness.

3.3.1.3 Marine Silt Unit

At elevations below approximately 247 feet (amsl), a sequence of proglacial deposits frequently overlies the glacial till. This sequence includes glaciofluvial sand, beach deposits, and marine silt and clay that formed during a period of time when the low-lying areas of the Site were inundated by an arm of the Champlain Sea. This unit has been termed the Marine Silt Unit for stratigraphic mapping purposes.

The Marine Silt Unit typically includes a massive to blocky Silt with varying proportions of Sand (ML), overlying laminated Silt & Clay (ML-CL) with dropstones. Both the massive Silt and the laminated Silt & Clay were observed in the test pit excavations to be jointed, with the walls of the test pits in these materials frequently failing along these columnar joints. The upper portion of the Marine Silt Unit sometimes includes a thin, fine-grained, moderately well-sorted Sand overlying the massive Silt.

The Marine Silt Unit typically occurs at elevations below approximately 245 feet (amsl); however, associated beach deposits, which have been assigned to this stratigraphic unit, generally occur at elevations between 245 feet and 247 feet (amsl). Although the beach deposits were directly encountered in only a single boring (MW-22), it is likely that similar deposits occur intermittently along the former shoreline in this elevation interval. In addition to its characteristic stratigraphic lithology and position, the Marine Silt Unit is frequently associated with the presence of shell fragments. Two distinct types of shells can be recognized, including *Hiatella arctica* and *Macoma balthica*, both of which are marine bivalves dating generally to the period from 10,100 years before present (BP) to 12,200 years BP. Where found in the fine sand and beach deposits, the shell fragments are typically of no more than millimeter size. Intact shell halves are frequently encountered in the fine-grained portions of the Marine Silt Unit.

The Marine Silt Unit, where present, ranges in thickness from 3 feet or less to 20 feet or more. This unit is thinner along the former shoreline and thickens to the south.

The primary shoreline features of the Champlain Sea and earlier proglacial lakes occur at elevations that are considerably higher than are present on the Site. For example, the Salmon

River formed a significant delta in the vicinity of Malone at an elevation of approximately 620 feet (amsl) during the period corresponding with the Fort Ann stage of Lake Vermont (Clark and Karrow, 1984). The upper limit of the Champlain Sea is marked by a series of beaches occurring at an elevation of approximately 492 feet (amsl) (Clark and Karrow, 1984) in the Malone vicinity, or about 246 feet higher than the beach features mapped on the Site. It is interesting to note that the upland areas of the Site bear little evidence of an extended period underwater; i.e., there are no significant deposits of stratified materials present on site above an elevation of about 250 feet. This suggests that the upper portions of the Site may have been covered by ice during much of the period between the Fort Ann lacustrine stage and the lower Champlain Sea stage. This is supported by the observation of the Upper Glacial Till overlying glaciofluvial sand in TP-20, with the upper contact of the sand occurring at an elevation consistent with the elevation of other similar sands at other locations on site. Over much of the Site, near-surface geological processes have served to alter the character of the till. This alteration has included oxidation of the upper 5 to 10 feet of the till and disturbance of the soil structure by roots and by jointing or fracturing. Of these factors, jointing is perhaps of greatest significance. Previously obtained data suggest fracture spacings on the order of 3 feet or less. These joints serve as the primary pathways for the movement of water in the upper weathered zone of the till.

3.3.2 Bedrock

The bedrock formations underlying the Site include the Ordovician age Ogdensburg Dolostone, which overlies the Theresa Formation of Upper Cambrian age. The spatial distribution of the bedrock formations in the site vicinity is depicted on Figure 3-4.

Bedrock cores obtained from beneath the proposed expansion area were that of the Ogdensburg Dolostone. The bedrock is typically described as a dark blue-grey, massive to wavy laminated dolostone with occasional styolites and fossil beds. The upper portion of the bedrock was typically more fractured than the deeper bedrock and is reflected by the higher rock quality designation index (RQD) values at depth (Table 3-2). Fractures observed in the cores were predominantly that of bedding plane fractures with occasional near vertical fractures. The bedding plane fractures or horizontal fractures in the upper five feet of the bedrock were frequently filled with clay and/or silt seams, whereas secondary mineralization was visible on the vertically oriented fracture or joint surfaces. Iron oxide staining was also evident on some of the fracture surfaces, but was more confined to the upper portion of bedrock.

Figure 3-11 depicts the spatial configuration of the bedrock surface. The bedrock surface is highest in the northeast corner of the investigation area, near the Site access road and parallel to County Route 20, where it reaches an elevation of 254.5 feet (amsl) at test pit location TP-11. The lowest elevation of the bedrock surface was observed to the southwest, in the vicinity of exploratory boring EB-17, where the bedrock surface elevation was measured at 151.4 feet (amsl).

3.4 Hydraulic Conductivity Determinations

As discussed in Section 2.4, several independent methods were employed to determine the hydraulic conductivity of the various geologic deposits found within the proposed landfill expansion area. The results of these testing programs are described in this section and are summarized by presenting the minimum and maximum values as well as the geometric mean. The geometric mean is the most widely accepted statistical parameter for representing the central tendency of log normally distributed data such as hydraulic conductivity.

3.4.1 In-Situ Variable Head Slug Tests

Hvorslev (1951) devised a method for determining the lateral hydraulic conductivity of water-bearing materials in the immediate vicinity of the well bore. This method of analysis indicates that the slug test data should plot on a straight line on semi-logarithmic graph paper. The field recovery data was evaluated by importing the data into AQTESOLV® software (HydroSOLVE, Inc., 1996-1999), in which a graphical representation along with a hydraulic conductivity value is produced. Complete recovery test analyses can be found in Appendix C and are discussed below according to each hydrostratigraphic unit. In addition to the method of Hvorslev (1951), the data were also evaluated using the Bouwer and Rice (1976) method, the Kansas Geological Survey method (Hyder, et al., 1994), and in the case of one of the bedrock monitoring wells, also with the method of Butler (1998).

3.4.1.1 Overburden Water-Bearing Zone

Slug tests were performed on the eleven (11) wells that were installed within the overburden deposits. The overall geometric mean hydraulic conductivity of the overburden unit calculated from in-situ hydraulic conductivity tests is 1.7 x 10^{-4} cm/sec and ranged from 7.1 x 10^{-6} cm/sec at MW-26S to 2.2 x 10^{-3} cm/sec at MW-27S, which is screened across a more permeable lens within the Marine Silt Unit (Table 3-3).

The geometric mean hydraulic conductivity of the Lower Till Unit ranged from 7.1 x 10^{-6} cm/sec at MW-26S to 4.0 X 10^{-4} cm/sec at MW-23I, with a geometric mean hydraulic conductivity of 1.2 X 10^{-4} cm/sec (Table 3-3). The geometric mean hydraulic conductivity values calculated during this investigation are generally higher than those reported in the above-referenced Stearns & Wheler report, where the geometric means of the various overburden units ranged from 9.93 x 10^{-6} cm/sec (upper grey till) to 8.55 x 10^{-5} cm/sec (brown “field” till).

3.4.1.2 Top-of-Bedrock Groundwater Flow Zone

Consisting of relatively weathered consolidated media, the top-of-bedrock groundwater flow zone is located at the overburden/bedrock interface and provides a preferential path for horizontal flow of groundwater.

Hydraulic conductivity values for the top-of-bedrock groundwater flow zone, based upon nine (9) in-situ slug tests, ranged from 1.0 x 10^{-4} cm/sec at MW-25D to 5.6 x 10^{-2} cm/sec at

MW-29D with a geometric mean hydraulic conductivity of 1.4 x 10^{-3} cm/sec (Table 3-3). The geometric mean hydraulic conductivity values calculated during this investigation are generally higher than those calculated in the Stearns & Wheler report entitled *Regional Landfill Hydrogeologic Investigation – November 1991, Revised February 1993*, where the geometric mean hydraulic conductivity was reported as 4.1 x 10^{-5} cm/sec.

3.5 Hydrogeologic Conditions

In this section, the conditions under which groundwater is contained within the various geologic deposits is described. Groundwater elevations for March/April 2008, which are considered representative of seasonal high water levels, are presented in Table 2-3. As discussed previously, two hydrostratigraphic zones underlie the landfill expansion area. In descending order, these zones include the overburden water-bearing zone consisting primarily of glacial till and the top-of-bedrock water-bearing zone composed of moderately weathered and fractured bedrock.

The following summary of groundwater conditions is based on the hydrogeologic investigations conducted at the Site for Franklin County by Barton and Loguidice as well as interpretation of data developed for the existing landfill facility by Stearns & Wheler in their report entitled *Regional Landfill Hydrogeologic Investigation – November 1991, Revised February 1993*.

3.5.1 Introduction

In this section, the conditions under which groundwater is contained within the various geologic deposits are described. Two hydrostratigraphic zones underlie the landfill expansion area. In ascending order, these include the top of bedrock groundwater flow zone consisting of moderately fractured bedrock, and the overburden groundwater flow zone consisting primarily of dense glacial till. Each water-bearing zone is described below.

3.5.2 Top-of-Bedrock Groundwater Flow Zone

The top-of-bedrock groundwater flow zone occurs at elevations ranging from approximately 161.08 feet (amsl) at MW-23D, to 243.73 feet (amsl) at MW-25D (top of bedrock elevation). The potentiometric surface ranged from 231.33 feet (amsl) at MW-23D, to 247.83 feet (amsl) at MW-25D in late March/early April 2008. The general groundwater flow direction in the proposed expansion area is from north to south; however, the accumulated data shows that a bedrock ridge extends northeast-southwest along portions of County Route 20 and appears to produce a hydrologic divide, causing groundwater to flow north and south of the ridge (Figure 3-12). In addition, CFSWMA operates a groundwater suppression system that causes a significant depression in the potentiometric surface beneath the existing landfill. The hydraulic gradient is variable and ranges from approximately 0.02 to 0.008. Groundwater in the top-of-bedrock groundwater flow zone occurs primarily under confined conditions. In the vicinity of Briggs Creek, artesian conditions prevail.

The volumetric flow rate (Q) can be calculated for the top-of-bedrock zone by Darcy's law as follows:

$$Q = kia$$

Where (k) and (i) are the hydraulic conductivity and the hydraulic gradient, respectively, and (a) is the cross-sectional area, perpendicular to the flow direction, through which flow occurs. The geometric mean hydraulic conductivity, based on the in situ variable head recovery testing, is 29.6 gpd/ft^2 (1.4 x 10^{-3} cm/sec) (Table 3-3). A representative hydraulic gradient (i) is 0.008 as mentioned above, and the cross-sectional area is the product of the estimated water-bearing thickness (15 feet) and the width of the downgradient Site boundary, normal to the flow direction, estimated at approximately 3,500 feet. The calculation is as follows:

$$Q = 29.6 \text{ gpd/ft}^2 \text{ x } (0.008) \text{ x } (15 \text{ feet x } 3{,}500 \text{ feet}) = 11{,}655 \text{ gallons/day}$$

The seepage velocity ($V_{s)}$, or the average speed at which a particle of water will move in the subsurface, is given by the relation:

$$V_s = ki/n_e$$

Where (k) and (i) are as defined above and (n_e) is the effective porosity.

The average linear velocity (seepage velocity, V_s) is directly proportional to the hydraulic conductivity and gradient and is inversely proportional to the effective porosity. Accordingly, as the effective porosity decreases, the seepage velocity increases. The effective porosity in unconsolidated sediments can range from a few percent to forty percent (%) or more, while the effective porosity in a fractured media may be as low as 1 x 10^{-5} (0.001%) and is usually less than 10 percent (%) (Freeze and Cherry, 1979). The seepage velocity in a fractured rock may therefore be considerably more rapid than in a porous, unconsolidated material of equivalent hydraulic conductivity.

For the purposes of the calculations and estimates presented in this report, an estimated effective porosity of five percent (%) (0.05) was used to calculate the flow velocities for the weathered top-of-bedrock groundwater flow zone.

The seepage velocity calculations are as follows:

$$Vs = 4.0 \text{ ft/day} \times (0.008)/0.05 = 0.6 \text{ ft/day}$$

Therefore, the lateral seepage velocity within the top-of-rock water-bearing zone is on the order of 217 feet per year.

3.5.3 Unconfined Overburden Groundwater Flow Zone

The overburden groundwater flow zone occurs at elevations ranging from approximately 201.59 feet (amsl) at MW-24I, to 249.72 feet (amsl) at MW-25S (Figure 3-13). Although the geologic units that constitute the overburden flow zone vary across the Site, they behave as a single hydrologic unit. Groundwater occurs within the overburden primarily under unconfined conditions.

The potentiometric surface ranged from 229.31 feet (amsl) at MW-24S to 256.63 feet (amsl) at MW-25S. The accumulated data indicates that the groundwater flow direction is generally north to south through the proposed expansion area. However, the topographic ridge which extends northeast-southwest through the expansion appears to produce a hydrologic divide, north of which the flow direction is to the north, and south of which the flow direction is to the south. The hydraulic gradient is variable and ranges from approximately 0.01 to 0.04.

The volumetric flow rate (Q) can be calculated for the overburden water-bearing zone by Darcy's law as follows:

$$Q = kia$$

Where (k) and (i) are the hydraulic conductivity and the hydraulic gradient, respectively, and (a) is the cross-sectional area, perpendicular to the flow direction, through which flow occurs. The representative geometric mean hydraulic conductivity based upon the in situ variable head recovery testing is 2.54 gpd/ft^2 (2.1 x 10^{-4} cm/sec) (Table 3-3). A representative hydraulic gradient (i) is 0.03 as mentioned above, and the cross-sectional area is the product of the estimated water-bearing thickness (60 feet) and the width of the downgradient Site boundary, normal to the flow direction, estimated at approximately 3,500 feet. The calculation is as follows:

$$Q = 2.54 \text{ gpd/ft}^2 \times (0.03) \times (60 \text{ feet} \times 3{,}500 \text{ feet}) = 4{,}267 \text{ gallons/day}$$

The seepage velocity (V_s), or the average speed at which a particle of water will move in the subsurface, is given by the relation:

$$V_s = ki/n_e$$

Where (k) and (i) are as defined above and (n_e) is the effective porosity.

For the purposes of the calculations and estimates presented in this report, an estimated effective porosity of 0.20 was used to calculate the flow velocities for the overburden water-bearing zone.

The seepage velocity calculations are as follows:

$$Vs = 0.34 \text{ ft/day} \times (0.02)/0.20 = 0.054 \text{ ft/day}$$

Therefore, the lateral seepage velocity within the overburden water-bearing zone is on the order of 20 feet per year.

3.5.4 Vertical Flow in Unweathered Glacial Till

The vertical hydraulic conductivity of the unweathered glacial till will control the volume and rate of vertical recharge to the bedrock beneath the till. However, a vertical hydraulic conductivity value was not obtained during the investigation due to the dense, stony nature of the till. Therefore, a representative vertical hydraulic conductivity value for the glacial till of 5.0×10^{-7} cm/sec (1.4×10^{-3} ft/day) obtained during the original investigation (Stearns & Wheler, Regional Landfill Hydrogeologic Investigation – November 1991, Revised February 1993) has been used for performing the volumetric flow calculation. In that the material collected for the previous investigation is comparable to the material underlying the investigation area, the value used is sufficient for estimating purposes.

Assuming a maximum vertical hydraulic gradient (i) of 0.21, as measured at the MW-26S/MW-26D monitoring well couplet and a total expansion area of 5,991,097 ft^2, the calculation is as follows:

$$Q = KiA = (1.1 \times 10^{-2} \text{ gpd/ft}^2) \times (0.21) \times (5{,}991{,}097 \text{ ft}^2) = 13{,}839 \text{ gpd}$$

Accordingly, approximately 13,839 gallons per day (5,051,393 gallons per year) move vertically downward through the glacial till. The rate at which the water travels is given by the seepage velocity equation:

$$V_s = Ki/n_e$$

(K) and (i) are as defined previously and a representative effective porosity of 0.20 is assigned to the glacial till in the following calculation:

$V_s = (1.4 \times 10^{-3}$ ft/day$) \times (0.21)/0.20 = 1.5 \times 10^{-3}$ ft/day or 0.5 ft/year

The minimum thickness of the glacial till that would underlie the proposed landfill liner system is 10 feet. In the event of a liner failure, the time required for a potential leachate release to reach the bedrock is calculated as follows:

$T = B/V_s$

Where:
$T =$ the confinement time in years
$B =$ the minimum thickness of glacial till
$V_s =$ the seepage velocity in feet/year

$T = 10$ feet$/0.5$ ft/year $= 20$ years

3.5.5 Critical Stratigraphic Section

The Site's critical stratigraphic section has previously been identified to include both the overburden and bedrock groundwater flow zones. The data collected during this investigation confirm that the critical stratigraphic section at the landfill site consists of two (2) units identified below including:

- The top-of-bedrock groundwater flow zone comprised of the upper portion of the Ogdensburg Dolostone.

- The overburden groundwater flow zone comprised primarily of glacial till.

3.6 Groundwater Quality

In order to define the groundwater quality beneath the proposed expansion area, representative groundwater samples were collected from the newly installed wells as described previously in Section 2.8. Groundwater quality samples were collected by field representatives from Barton & Loguidice. The water quality analyses for this investigation were performed by Upstate Laboratories, Inc. of East Syracuse, New York. The analytical results are discussed below and the laboratory and required data validation reports are presented in Appendix E.

The March/April 2008 sampling round includes analyses for Part 360 expanded parameters. A summary of the field parameter, indicator, and baseline metals data is presented in Table 3-4.

3.6.1 Piper and Stiff Diagrams

Groundwater quality data have been analyzed using the computer software “Rockworks 2004®” as marketed by Rockware. The software allows efficient calculation of ionic balance and generates Piper trilinear and Stiff diagrams. These diagrams are particularly useful for assessing the similarities and differences in water quality between wells and between water-bearing zones. The Stiff diagrams (Figures 3-15, 3-16, 3-18, and 3-19), in particular, often possesses a distinctive shape that is characteristic of the water in a given water-bearing zone or a portion thereof. The Piper trilinear graphs (Figures 3-14 and 3-17) permit the plotting of many analyses on a single diagram. In constructing a Piper trilinear graph, the relative percentages of cations (calcium, magnesium, and sodium) are plotted on the lower left cation triangle, while the relative percentages of anions (chloride, sulfate, and carbonate) are plotted on the anion triangle, located on the lower right side of the graph. A central plotting position is then established for each point in the central plotting rhomb by projecting the intersection of rays of the plotting positions from the cation and anion triangles. Water from the same water-bearing zone will typically plot within similar fields on the central rhomb in the trilinear graph. This technique theoretically provides the ability to determine similarity between groundwater samples to verify that each sample originated from the same water-bearing zone (Davis and DeWiest, 1966; Hem, 1985; Walton, 1984).

3.6.1.1 Overburden

The major ion data for wells screened in the overburden are presented in graphical form on Figures 3-14, 3-15 and 3-16. Figure 3-14, a Piper trilinear diagram, indicates that magnesium and calcium are the dominant cations and bicarbonate is the dominant anion. However, monitoring well MW-23I exhibits a relatively higher sodium content, with calcium, magnesium and sodium occurring in nearly equal percentages. Groundwater in the overburden may be classified as predominantly a magnesium-calcium bicarbonate type.

The Stiff diagrams (Figures 3-15 and 3-16) indicate a distinct pattern marked by relatively abundant magnesium, calcium and bicarbonate, with varying amounts of sodium, potassium and sulfate, and relatively little chloride. As mentioned above, monitoring well MW-23I departs somewhat from this pattern, in that calcium, magnesium and sodium occur in nearly equal percentages in this sample.

3.6.1.2 Bedrock

Figures 3-17, 3-18, and 3-19 present the major ion data for wells completed in the top-of-bedrock groundwater flow zone in graphical form. The Piper trilinear diagram (Figure 3-17) indicates that calcium and magnesium are the dominant cations, while bicarbonate is the dominant anion. Sodium, potassium, and chloride are generally subordinate, while sulfate occurs at higher proportions than was typical of the overburden groundwater. Thus, groundwater within the top-of-bedrock groundwater flow zone may be classified as predominantly a calcium-magnesium bicarbonate type.

Two distinct patterns are associated with the Stiff diagrams (Figures 3-18 and 3-19) generated from the top-of-rock data. The dominant pattern is marked by relatively abundant calcium and bicarbonate with varying amounts of magnesium and sulfate. Monitoring wells MW-20, MW-21D, MW-23D, MW-25D, MW-27D, and MW-28D exhibit this pattern, whereas monitoring wells MW-22D, MW-26D, and MW-29D display a pattern denoted by abundant bicarbonate, with magnesium exceeding calcium.

3.6.2 Summary of Existing Water Quality

The results of the water quality analyses indicate that existing water quality in the proposed expansion area is similar to the water quality in the vicinity of the Active Facility. Table 3-4 provides a summary of the data and a comparison to water quality standards and to trigger levels that have been established for the existing landfill for wells screened within the bedrock and lower glacial till. The water quality results do not indicate an impact from the existing landfill facility in any of the wells installed in the proposed expansion area.

3.6.2.1 Overburden Groundwater Quality

Groundwater quality in the overburden typically exhibits exceedances of water quality standards for color, turbidity, and iron, magnesium, and manganese (as totals). There are also occasional exceedances of water quality standards for total dissolved solids and sodium, and infrequent exceedances for beryllium, cadmium, and silver (as totals). It is likely that the total metals results are biased due to the elevated turbidity that is present in many of the wells despite a significant effort to sufficiently develop the newly installed monitoring wells (see Section 2.3.1 and Appendix F).

With respect to established trigger levels for the lower glacial till (the grey till zone of Stearns & Wheler), overburden water quality typically exhibits exceedances of trigger levels for turbidity, chloride, nitrate, and aluminum, iron, manganese (as totals). The aluminum, iron and manganese likely reflect a combination of natural occurrence together with the influence of the elevated turbidity. The chloride and nitrate exceedances occur at concentrations that are well below water quality standards and are more a reflection of trigger levels that have been set at very low concentrations rather than an indication that the concentrations are truly elevated. It is possible, however, that overburden water quality may be influenced by a history of agricultural use of the property within the expansion area.

3.6.2.2 Bedrock Groundwater Quality

Groundwater quality in the bedrock typically exhibits exceedances of water quality standards for color, turbidity, total dissolved solids, and total iron and magnesium. There are also single exceedances of water quality standards for manganese (MW-27D) and silver (MW-28D) (as totals). The total metals results are likely biased due to the elevated turbidity that is present in many of the wells despite a significant well development effort (see Section 2.3.1 and Appendix F).

With respect to established trigger levels for the bedrock groundwater flow zone, bedrock water quality typically exhibits exceedances of trigger levels for turbidity, hardness, nitrate, and total magnesium. Less frequent trigger value exceedances for color, total dissolved solids, and aluminum, calcium, copper, manganese and zinc (as totals) were also noted. The total metals exceedances likely reflect a combination of natural occurrence together with the influence of the elevated turbidity.

By way of summary, the water quality data for both the overburden and bedrock groundwater flow zones are generally comparable to existing water quality established for the existing landfill facility. There is no indication of a water quality impact from operations at the existing landfill and the water quality data confirm that an effective groundwater monitoring network can be established for the proposed landfill expansion area.

4.0 References

Bouwer, H., 1989. The Bouwer and Rice Slug Test – An Update, Groundwater, Vol. 27, No. 3, pp. 304-309.

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Burmister, D.M., 1958. Suggested Methods of Tests for Identification of Soils, Procedures for Testing Soils, ASTM.

Butler, J.J., Jr., 1998. The Design, Performance, and Analysis of Slug Tests, Lewis Publishers, Boca Raton, 252p.

Clark, P., and P.F. Karrow, 1984. Late Pleistocene water bodies in the St. Lawrence Lowland, New York, and regional correlations. Geological Society of America Bulletin, v. 95, p. 805-813, July 1984.

Davis, S.N., and R.J.M. DeWiest, 1966. Hydrogeolgy, John Wiley & Sons, 463 p.

Fetter, C.W., 1994. Applied Hydrogeology. Prentice Hall, New Jersey, p. 86.

Freeze, R.A., and Cherry, J.A., 1979. Groundwater. Prentice Hall, New Jersey, 604p.

Hooper Virtual Natural History Museum, 2001. The Champlain Sea. http://hoopermuseum.earthsci.carleton.ca/2001_champlain2_mb/

Hvorslev, M.J., 1951. "Time-Lag and Soil Permeability in Groundwater Observations," U.S. Army Corps of Eng., Water Exp. Stn., Bull. 36, 50p.

Hyder, Z, J.J. Butler, Jr., C.D. McElwee and W. Liu, 1994. Slug tests in partially penetrating wells, Water Resources Research, vol. 30, no. 11, pp. 2945-2957.

Isachsen, Y.W., and McKendree, 1977, Sources of information for preliminary brittle structures map of New York and generalized map of recorded joint systems in New York: N.Y. State Museum, Map and Chart Series No. 31G.

McClintock, PP and D.P. Stewart, 1965. Pleistocene geology of the St. Lawrence lowland. New York State Museum and Science Service, Bulletin 394, 1 52 pp

Rickard, L.V., Y.W. Isachsen, and D.W. Fisher, 1970. Geologic Map of New York State: Adirondack sheet. New York State Museum and Science Service, Map and Chart Series No. 15

Stearns & Wheler, 1993. Regional Landfill Hydrogeologic Investigation – November 1991, Revised February 1993.