FINAL DRAFT:
Geoarcheological Assessment of Geotechnical Borings for the Onondaga Lake Remediation Project, Wastebeds 1-8, Town of Geddes, Onondaga County,
New York.

Prepared for:

Public Archeology Facility
State University of New York at Binghamton
P.O. Box 6000
Binghamton, NY

Assembled by:

Juan C. Urista, M.A.,
Project Geoarcheologist

Michael J. Aiuvalasit, M.A.,
Staff Geoarchaeologist

and

Joseph Schuldenrein, Ph.D.
Principal Investigator

Geoarcheology Research Associates
92 Main Street, Suite 207
Yonkers, NY 10701

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TABLE OF CONTENTS

Description	Page
List of Figures	iii
List of Tables	iii
1. Introduction	4
2. Geological Background and Cultural Context	6
3. Methods	11
4. Results	12
Boring Descriptions	12
Review of Boring Logs	20
5. Geoarcheological Interpretations and Recommendations	24
References Cited	27
Appendix A. Geotechnical Boring Descriptions	29

Description		Page
Figure 1.	Boring location map	5
Figure 2.	Overview of project area along the shoreline of Onondaga Lake	6
Figure 3.	Shaded relief map of Onondaga Lake with the project area	7
Figure 4.	Reconstructed model of Ninemile Creek channel locations	10
Figure 5.	Drill rig and extracted split spoon sample placed on table for sampling and description	11
Figure 6.	Photographs of surface soil and Solvay waste	13
Figure 7.	Photographs of marl unit with sands of Ninemile Creek and interbedded peats	14
Figure 8.	Photographs of transmarl and close-up of glacio-lacustrine silts	15
Figure 9.	Stratigraphic cross section of the project area	21
Figure 10.	Selection of the Geologic Cross-section A-A' of Wastebeds 1-8	23

LIST OF TABLES

Description		Page
Table 1.	Summary descriptions of stratigraphic units	12

INTRODUCTION

Geoarcheology Research Associates (GRA) was contracted by the Public Archeology Facility (PAF) to conduct a geoarcheological investigation at the Wastebeds 1-8 in Onondaga County. At an earlier stage of the project, Parsons contracted PAF to undertake archeological investigations of properties owned by the State of New York and Onondaga County. These properties are slated for environmental remediation work, which in many cases will impact underlying deposits of potential archeological sensitivity. Phase IA investigations by PAF (Hohman 2004) recommended that a geomorphological evaluation of several properties should be performed to assess whether or not the properties subject to deep impacts preserve buried surfaces that could contain archeological materials. GRA's investigation (Aiuvalasit and Schuldenrein 2010) proposed several recommendations, including a determination for potential of deeply buried shoreline deposits on the northern shore of Wastebeds 1-8 along Onondaga Lake (Figure 1). Geotechnical borings by O'Brien and Gere, also under contract to Honeywell, Inc., provided initial observations of the stratigraphy along the northern shore of Wastebeds 1-8 (Figure 2). While the purpose of the borings was to situate locations for peizometers and to gather hydrological data, they also previewed the structure of deep stratigraphic sequences along the shoreline. Sediments from a total of seven borings were either observed first-hand while in the field, or as grab samples collected by O'Brien and Gere for our review. Fieldwork was undertaken between October 27 and November 11, 2010. Follow-up review of nearby boring logs facilitated correlations with field observations of the core sequences.

This report details the results of our geoarcheological investigation. The report consists of a thorough review of the project area geology; the results of field investigations; a composite stratigraphy of the project area; and interpretations of the geomorphic setting with a focus on the potential for buried archeological deposits.

This study found extensive and thick lacustrine (lake) deposits, as well as alluvial deposits associated with the delta formed at the confluence of Ninemile Creek (NMC) with Onondaga Lake. The borings did not identify deeply buried soils that could have served as living surfaces for pre-contact inhabitants. Instead, the stratigraphic sequence along north shore of Wastebeds 1-8 appears to register predominantly offshore settings with some evidence of fluctuating shore and nearshore locales associated with variable channel patterns at the confluence of Ninemile Creek and Onondaga Lake.

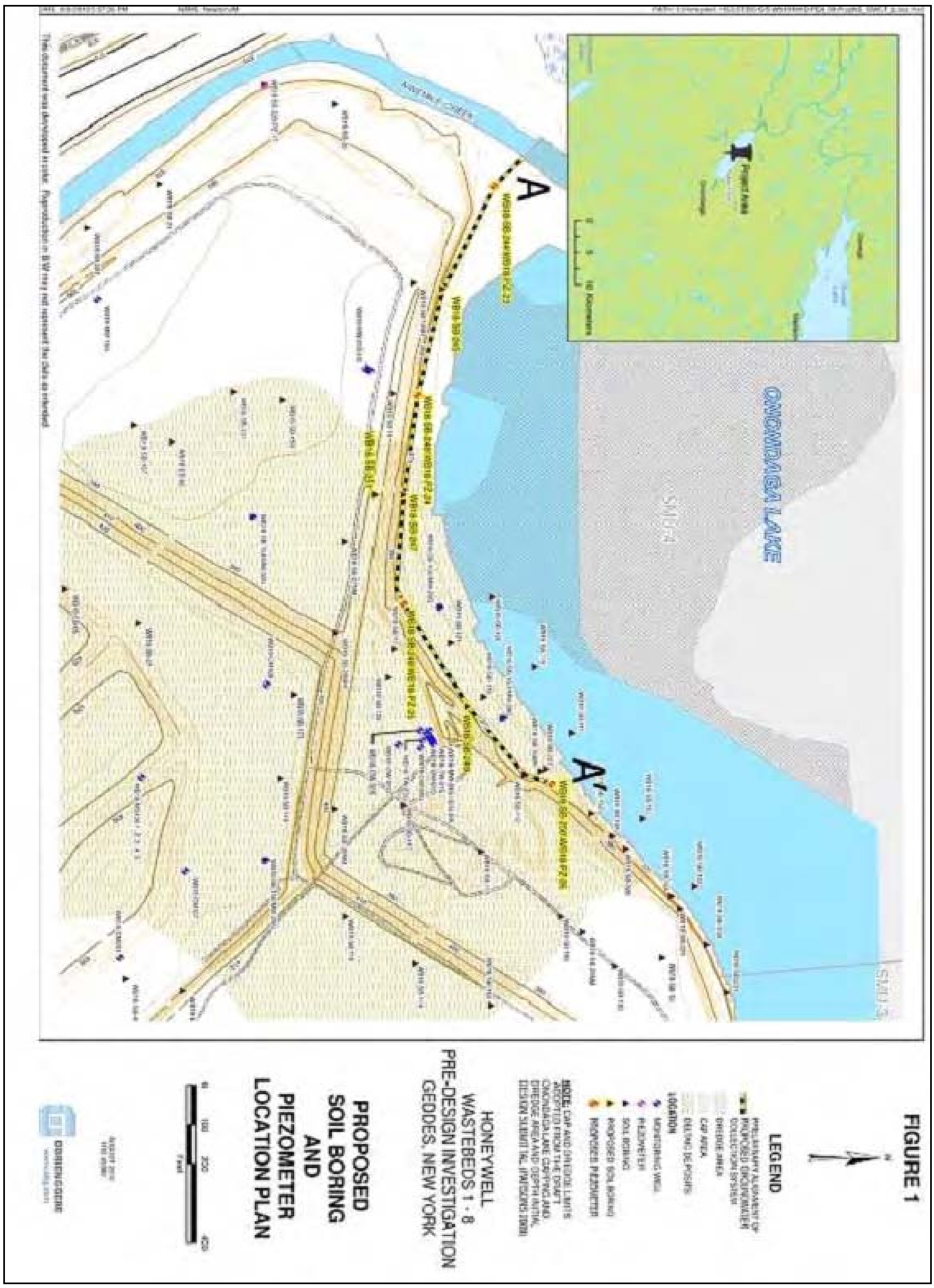

Figure 1. Boring Location map. Borings examined for this project are highlighted in yellow (Crawford 2009: Figure 1).

Figure 2. Overview of project area and landscape at the shoreline of Onondaga Lake; sampling locality is in the background.

GEOLOGIC BACKGROUND AND CULTURAL CONTEXT

Onondaga Lake lies within the Allegheny physiographic region. Specifically, it is set in the Onondaga Trough, at the base of the Onondaga Escarpment. Elevations range from 110.6 meters above MSL (median sea level) at the surface of Onondaga Lake to greater than 300 meters above MSL along the highest terrain of the escarpment (Figure 3). The lowlands of the Onondaga Escarpment are composed of glacio-fluvial sediments that overlie the Silurian Age Vernon Shale at the base. The uplands are mantled by unconsolidated deposits, predominantly glacial drift and valley train distributions. The Syracuse, Helderberg, and Onondaga formations compose the bedrock grading up the escarpment (see Fisher et al. 1970, Cadwell and Muller 1986, and Kappel and Miller 2005).

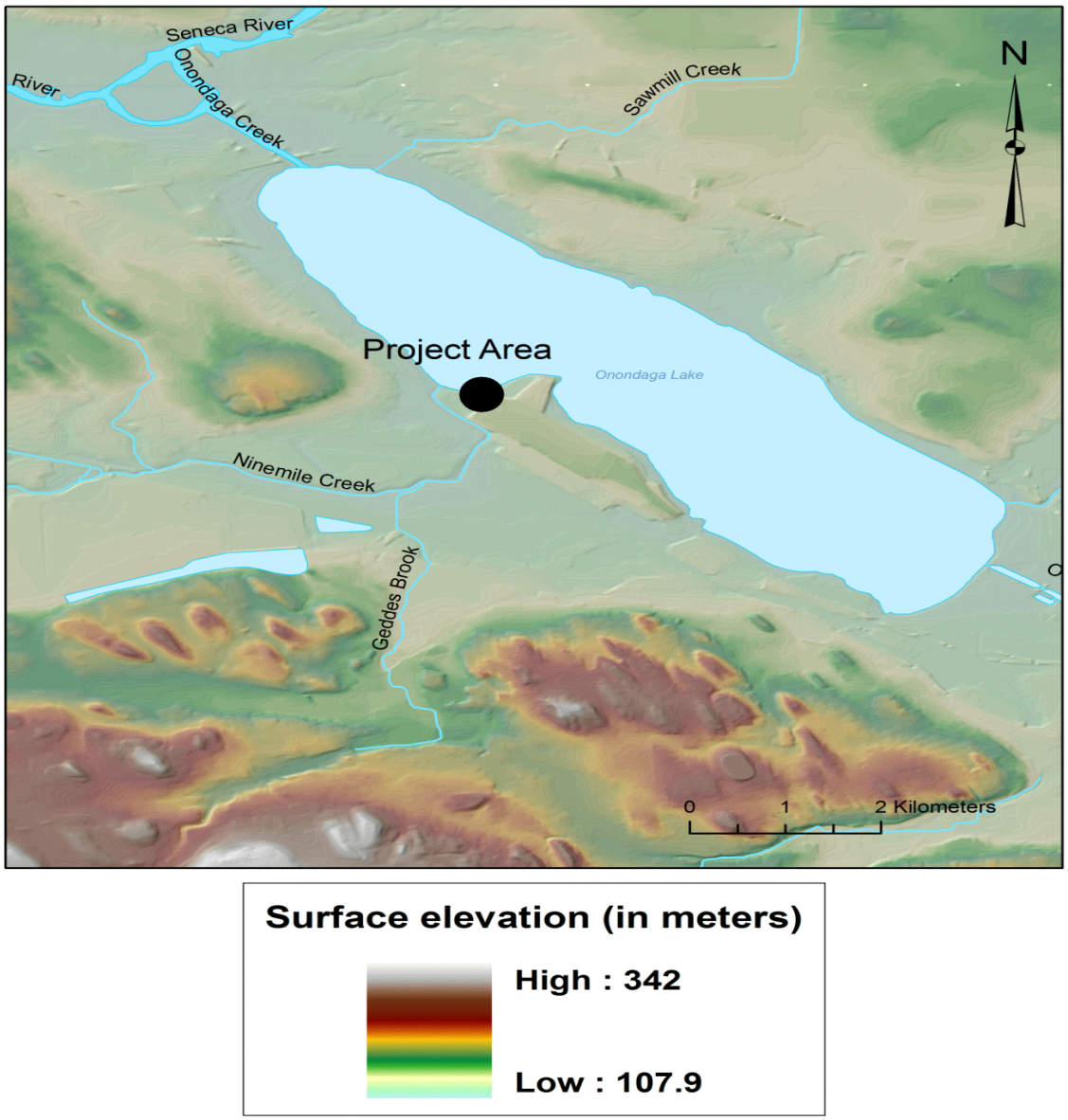

Figure 3. Shaded relief map of Onondaga Lake highlighting the project area.

Onondaga Lake formed within the Onondaga Trough after a complex succession of landscape changes associated with cycles of glacial advances and retreats (Von Engeln 1988). The most recent Wisconsinan advance, marked the last glacial maximum, and is dated to ca. 24,000 uncalibrated radiocarbon years or, Cal BP 28,200-27,200 (calibrated to calendar years before present). The Laurentide ice sheet completely covered the Onondaga Trough, with ice attaining thicknesses of hundreds to thousands of feet. As the ice sheet melted during the Late Pleistocene a series of moraines was formed along the ice front. The Valley Heads moraine offset the south of the Onondaga Basin, ultimately accounting for the northward drainage pattern represented by the present Finger Lakes. This moraine was laid down about 14,350 to 13,500 uncalibrated radiocarbon years (Cal BP 17,200-16,200); subsequently it receded northward. By 11,400 uncalibrated radiocarbon years (Cal BP 13,400) the glacial ice had retreated into its present location in Canada (Rowell 1986, Cadwell et al. 2003, Cadwell and Muller 2004). Thus, Onondaga Lake is a remnant of a proglacial lake system that formed during this time and created impounded basins between the glacier and moraines (Cadwell and Muller 2004).

Logs from previous geotechnical borings conducted during remediation projects within Wastebeds 1-8 (Crawford 2009), as well as a recent United States Geological Survey (USGS) report on paleoenvironmental studies within the Onondaga Trough (Kappel and Teece, 2007), serve as the basis for the present stratigraphic interpretations. The geotechnical descriptions, and especially the compiled geologic cross sections, helped structure our recommendations to monitor deep testing along the north shore of Wastebeds 1-8 (Aiuvalasit and Schuldenrein 2010) and produced sufficient detail to preview subsurface stratigraphy. A generalized stratigraphy for the project area consists of (from bottom to top): bedrock; tills; and fining upward glacio-lacustrine sands to clay. The latter are capped by silty marl and peats, and Solvay waste seals in the natural stratigraphy (Crawford, 2009). The former channel of Ninemile Creek is registered across the project area as a wedge of sand and gravel inset into the marl unit (Figure 4). Former natural channels of Ninemile Creek are identified in topographic maps and drawings (Crawford 2009: Figure 7). Three postcontact period channels are depicted, and all fall within the bands of mapped Ninemile Creek deposits. The oldest channel depiction (from 1898) does not extend to the modern shoreline, which may be a function of a geo-referencing error typical of geo-rectifying older maps; alternatively, the former shoreline did not extend as far out into the lake as it is today. Stratigraphic units with no archeological potential are those that antedate pre-contact settlement. Sedimentologically, these include the till and the glacio-lacustrine sequence of fining upward sand to clay.

Units deposited within pre-contact timeframes are silty marl, peats, organic soils, and paleo-shoreline sandy facies, as well as alluvial sediments of Ninemile Creek. Radiocarbon dates from the marl unit provide chronological control for the (overlying) Holocene deposits. Four radiocarbon dates from boring WB1-8SB-13BR (a nearby boring not associated with this study) are reported in Kappel and Teece (2007), while their stratigraphic sequence is documented in Crawford (2009). The dates span the complete marl unit, with sample depths ranging in elevation from approximately 315 to 355 ft (96 to 108 meters) above MSL. The base of the deposit dates to 6,050 radiocarbon years (Cal BP 6,893) while the top is 4,680 radiocarbon years (Cal BP 5,395). As discussed further, while the dates fall within the range of regional pre-contact timeframes, understanding the depositional contexts of these strata is critical to evaluating whether or not they were suitable for human habitation and site preservation.

The existing boring logs show that the lower terrace and shoreline positions preserve sequences consistent with submerged landforms and formerly higher levels of Onondaga Lake. Boring logs reviewed from the lower terrace and along the eastern margins of the project area show that the Solvay waste and fill was laid down immediately above the marl. Some cores have trace organics fragments and lenses of peat, but there is no consistent spatial pattern or lateral zonation that would suggest an intact marsh surface or living surface. The marl is described as a light olive gray wet sand and silt, with trace shell fragments, a sulfur odor, and occasional organic lenses. Along the southern and eastern shorelines and lower terrace the marl is typically encountered below approximately 6.5 ft (2 m) of fill and extends to depths of 30 ft (9 m) below ground surface.

The later prehistory of the project area attests to the dominance of the Onondaga Nation, which has occupied central New York since at least the 12th century. As extensively reviewed in the Phase I report (Hohman 2004), pre-contact sites are extensive around Onondaga Lake, including in the vicinity of Ninemile Creek. In fact, the Onondaga people still claim Onondaga Lake as part of their ancestral land (Hohman 2004). Postcontact period records also show that the Onondaga were living on the south shore of Onondaga Lake in hamlets and camps between 1600-1625 (Bruce, 1996, in Hohman 2004). This time span corresponds to the period during which Ninemile Creek flowed through the project area and sustained an active delta and swamp. Muller (1977) noted that many fluted points have been found in the regional swamps.

The project landscape was significantly different prior to postcontact period manipulations of Onondaga Lake. In 1822, the water levels of the lake were lowered to present levels to facilitate an outlet to the Seneca River (Hohman, 2004 and Crawford, 2009). Before water level depression, much of the current project area would have been marshes, swamps, salt springs, and areas immediately offshore. After the drop in water levels, more land was created and the area became known as Geddes Marsh. In addition, Ninemile Creek naturally coursed through the project area until it was channelized and diverted around the wastebeds in 1926 (Figure 4). Solvay waste was emplaced directly atop the Geddes Marsh, with perimeter berms constructed around the margins of the wastebeds. The wastebeds were in use until 1943 and the site is now currently owned by the State of New York and Onondaga County. The long history of industrial use has drastically changed water quality, biological productivity, and recreational potential of the lake (see Dean and Eggleston 1984 and Rowell 1986).

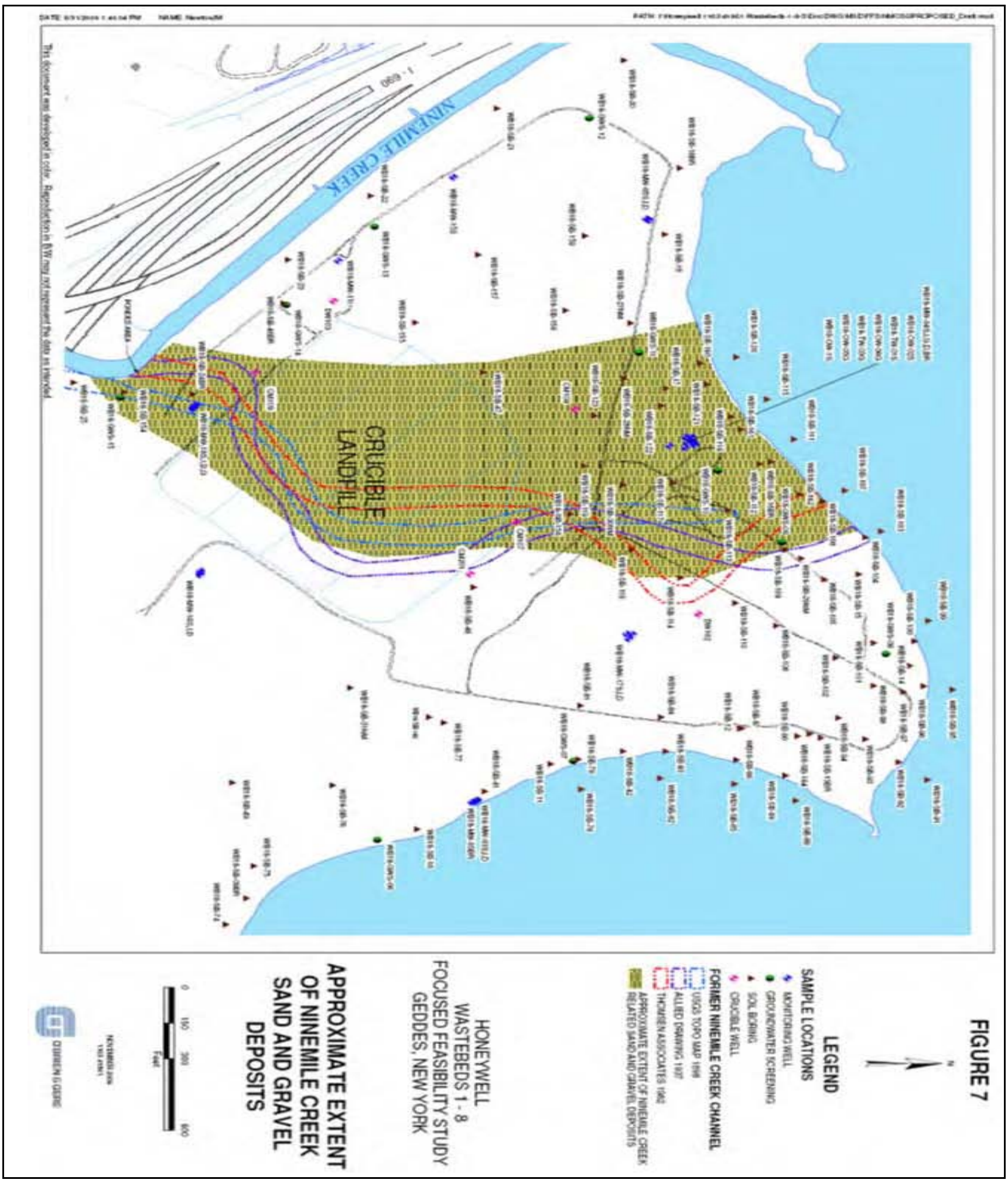

Figure 4. Reconstructed model of Ninemile Creek channel locations. The reconstruction is based on GIS integration of historical maps and sedimentological observations in borings (Crawford 2009: Figure 7).

METHODS

Seven cores were recovered from Wastebeds 1-8, which run 2.1 miles (3.4 km) along Onondaga Lake's southwestern shoreline (see Figure 1). Core extraction was powered by a CME-850 Track Rig operated by Parratt Wolff, Inc. The cores were recovered with a 2 foot long, 2 inch diameter split spoon auger mounted on the CME-850 rig (Figure 5). Each core was split open and macro-sedimentological attributes were recorded in the field. It should be noted that while core sediment recoveries were good, it was not uncommon to have less than complete yields. This can be due to compression of the sample, backfilling of the core hole by slump, or poor recovery due to saturated, unconsolidated sediments. Recorded attributes of sediments and soils included texture, Munsell color, structure, consistence, presence of organics, presence of shells, and redoximorphic features. All core descriptions are presented from the bottom of sample segment to the top, employing standards used in the soil sciences (USDA 1994) and stratigraphic sequencing (ISSC 1994).

Figure 5. Drill rig and extracted split spoon sample placed on table for sampling and description.

Due to the potentially hazardous nature of the core sediments, doubled-up Nitrile gloves were used to prevent contact between the contaminated material and skin. Tyvek suits were worn as a barrier to potential contamination with clothes. As a result of these safety precautions, a less accurate texture was achieved than would have been possible by standard touch and feel protocols. Photographs of the intact cores were also taken, as were pictures of particular sediment features. For boring locations 244 – 246, bagged samples were observed after excavations and described in the field. Samples were not collected for further analysis nor were they removed from the property.

RESULTS AND INTERPRETATIONS

Boring Descriptions

The borings recovered from Wastebeds 1-8 preserved evidence from three discrete natural depositional sources and two of anthropogenic origin. From bottom to top these include a clay and silt lacustrine deposit; a lacustrine marl, consisting of loamy silt with interbedded fluvial silty sands; and organic-rich peats (all natural). Anthropogenic sediment was represented by the Solvay waste deposit; a young surface soil developed in a capping fill and Solvay waste.

General descriptions for each unit are summarized in Table 1, with representative photographs presented in Figures 6-8. Detailed descriptions for individual soil borings follow.

Table 1. Summary descriptions of stratigraphic units.

Unit	Description
Soil	Sandy to silty loam; dark color, 10YR 6/3 to 10YR 2/1 grading from west to east; many medium to coarse roots; friable to firm; single-grained, very thin: approximately 2-4 inches
Solvay waste	Silt- and sand-sized particles; white color, 5Y 8/1; greasy texture; massive; friable to slightly firm
Marl	Sandy loam to sandy clay; 5Y 2.5/1 to 5Y 8/1; organics present; shells in matrix; significant concretions; friable to firm; massive to single-grained; contains thinner deposits of Ninemile Creek sands and gravels, as well as thin layers of peat in some places
Transmarl	Transitional zone between the marl and the glaciolacustrine silts and sands; 5Y 3/1; sediment is analogous to the marl above, but shells are either not discernible, or are very few and fine; very few organics; mostly sandy clay loam or silty clay loam;
Glaciolacustrine Silts and clays	Silty clay loam to clay; mostly 10YR 5/2; massive; firm to sticky; black Fe redox features (mottles)

Figure 6. Core photographs of surface soil a) and Solvay waste b).

Figure 7. Core photographs of marl unit a) with sands of Ninemile Creek b), and interbedded peats c).

a)

b)

Figure 8. Photographs of transmarl a) and close-up of glacio-lacustrine silts b).

WB18-SB-244

The total depth of Soil Boring (SB) 244 is 40 feet (Appendix A). It is located adjacent to Ninemile Creek (Figure 1). As stated in the methods section, this boring was not observed during extraction by O'Brien and Gere. Instead, bagged samples were set aside for descriptions. A glacio-lacustrine clay is present between 34 and 40 feet. It has a grayish brown color (10YR 5/2) and a strongly sticky consistence. Black mottles, possibly from reduced Iron, are present.

Between 26 and 34 feet, there is a transitional zone between the glacio-lacustrine clays below and the transmarl deposits above. This transitional zone is composed of clay and has a strongly sticky consistence. It contains few, fine rootlets and very few fine to medium shells.

Between 20 and 26 feet, transmarl deposits overlie the transitional clay zone. It is composed of a sandy clay and has a sticky consistence. There are no discernible organics or rock fragments. Shells were either absent or largely fragmented in the upper part of the unit. They are in evidence at the bottom of the unit and range from fine to medium in size.

Between 4 inches and 20 feet, marl deposits overlie the transmarl deposits. The unit consists exclusively of sandy clay loam with variable distributions of rock fragments and clay. From 4 inches to 12 feet, rock fragments and shells grade coarser and more abundant. Between 12 and 20 feet, clay content increases and rock fragments and shells become less abundant. Color are light gray (5Y 7/1) from 4 inches to 4 feet and light and grade to olive gray (5Y 6/2) for the rest of the unit. The unit has a friable consistence and contains few fine to medium roots, which decrease and disappear towards the bottom.

SB-244 is capped by a thin soil from 0 to 4 inches. It is a dark brown (10YR 3/3) silty clay loam with firm consistence. It is also organically enriched.

WB18-SB-245

SB-245 attained a total depth of 40 feet (Appendix A). It is located between the wastebeds and the lakeshore (Figure 1). Between 34 and 40 feet, glacio-lacustrine deposits form the base of this unit. Its upper part (36 – 38 feet) is a grayish brown (10YR 5/2) silty clay loam with slightly firm consistence. There are minimal organics, shells, and rock fragments. The lower part (38 – 40 feet) is a silty clay, similar to the overlying unit, but with sticky consistence.

Transmarl deposits overlie the glacio-lacustrine deposits between 24 and 34 feet. They are dominantly dark olive gray color (5Y 3/2) silty clay loams that grade to silty clay at 32 feet. The matrix contains common, fine rootlets, very few fine shells and shell fragments, and no rock fragments. Organic content diminishes with depth and disappears at 32 feet. The shell content slightly increases down the unit. The silty clay is as above (5Y 3/2) but with a sticky consistence. Shell sizes increase and there are no organics.

Between 6 and 24 feet, marl deposits overlie the transmarl. The unit is composed of sandy loam (upper segment: 6 – 8 feet) that grades into a sandy clay loam (8 – 24 feet). The sandy loam is gravelly, gray (5Y 5/1), and has a loose consistence. It has common shells and few fine rootlets. Besides the difference in texture, the sandy clay loam has the same attributes as the sandy loam.

Between 4 inches and 6 feet, the Solvay waste overlies the marl deposits. The waste is white (5Y 8/1), features silt- and fine sand-sized textures, and has a greasy consistence. The unit is capped by a thin soil that is 4 inches thick. It is a yellowish brown (10YR 5/6) sandy loam that is organically enhanced, has a friable consistence, and includes abundant fine to medium rock fragments.

WB18-SB-246

SB-246 attains a total depth of 42 feet (Appendix A). It is located between a wastebed and the lakeshore (Figure 1). The base of SB-246 is composed of glacio-lacustrine deposits (32 – 42 feet), typically grayish brown (10YR 5/2). The upper part of the unit (32 – 34 feet) is composed of sandy clay with very fine sand. It has slightly sticky consistence and no discernible organics, shells or rock fragments. At 34- 36 feet there is a textural transition to a silty clay loam with a slightly firm consistence, and very few, fine rootlets. The base (36 – 42 feet) is a clay, that is slightly enhanced with silts (38 to 40 feet).

Between 16 and 32 feet, transmarl deposits overlie the glaciolacustrine clays and loams. This is a very dark gray (5Y 3/1) sandy clay loam (16 – 28 feet) that grades into sandy clay (28 – 32 feet). There are few, fine rootlets and very few, fine shells.

Between 4 inches and 16 feet, olive gray (5Y 4/2) marls overlie the transmarl. The unit is composed of a sandy clay loam in the upper part (4 inches – 4 feet), grades into a greenish gray 5Y 5/1) gravelly sandy loam (4 – 8 feet), and then bottoms as a light gray (5Y 7/1) sandy clay at the base (8 – 16 feet). Organics are present in the form of a few, fine rootlets between 6 and 16 feet. Abundant fine to medium shells are present throughout, but concentrations decrease down the unit. This unit is capped by thin pale brown (10YR 6/3) sandy loam soil, 4 inches thick and organically enriched.

WB18-SB-247

The total depth of SB-247 is 42 feet (Appendix A). It is located between the base of a wastebed berm and the lakeshore (Figure 1). From about 40 to 42 feet the core is composed of a 5Y 4/1 lacustrine clay that is very firm and massive, and contains negligible shells, nodules, rock fragments, or organics.

Deposits between 30 to 40 feet represent a transitional zone between the underlying lacustrine clays and overlying transmarl, as identified by O'Brien and Gere staff while in the field. Sediments are dominated by a dark gray (5YR 4/1) sandy clay loam of massive structure. It has very firm consistence with no discernible shells, organics, or rock fragments. Clay concentrations increase towards the bottom of the unit where consistence grades to firmer and stickier.

The transmarl extends from about 14 to 30 feet. Here the unit is similar to marl, but with reduced concentrations of shell and shell fragments. The matrix is a black (5Y2.5/1) sandy clay loam to clay loam that grades to dark gray (GLEY 1- 4N towards the bottom. It has a massive structure, slightly firm to very firm consistence, and contains few fine rootlets and very few shells. There are infrequent fine, black mottles of reduced iron towards the bottom.

A marl overlays the transmarl between 2 and 14 feet. It is a gray (5Y 6/1) loamy sand to sandy clay that grades to a black (5Y 2.5 /1) towards the bottom. It has a granular to sticky consistence, granular to massive structure, and has shells and concretions that decrease in size and abundance from top to bottom. A sandy topsoil (10YR 3/2) characterizes the topmost 2 feet.

WB18-SB-248

SB-248 extended to 66 feet deep (Appendix A). The surface elevation is higher than the two soil borings on either side, and it is located between the base of a wastebed and the lakeshore, but closer to the berm. (Figure 1). Lacustrine clay forms the base between 61 and 66 feet. It is a dark grayish brown (10YR 4/2) clay loam that grades into a dark gray (10YR 4/1) clay. It has a slightly firm to very sticky consistence and massive structure.

Between 30 and 61 feet, transmarls overlie the lacustrine clays. From top to bottom the transmarl sediments are variable ranging from a very dark gray (5Y 3/1) sandy loam to dark gray (5Y 4/1) fine to medium sand to silty clay loam, and finally a very dark gray (10YR 3/1) sandy clay loam. The latter directly overlies the lacustrine clays. The sandier textured deposits are likely facies of Ninemile Creek (NMC) deposits. Few, fine to medium shells, decreasing in size and abundance towards the bottom, were observed. The matrix also contains fine fragments of rootlets and woody material which also diminish with depth. An isolated concentration of diffuse black mottles (likely reduced Iron) is present at about 52 feet.

Marl overlies the transmarl between 2 and 30 feet. The marl is a white (5Y 8/1) to olive gray (5Y 5/2) sandy clay loam that grades to black (GLEY 1-2.5N) towards the bottom. It contains common fine to medium shells, few concretions, a firm consistence, and massive structure. The dominant sandy clay loam matrix is interbedded with a series of facies likely associated with Ninemile Creek. There are beds of gray (GLEY 1-5N) to dark gray (GLEY 1-4N) fine to coarse sand with common fine to coarse shells and concretions that have a single grained structure and loose consistence. Sediments include a dark gray (10YR 3/1) sandy loam with friable to firm consistence and a dark gray (GLEY 1-4N) silt with massive structure, firm consistence and few fine rootlets.

Solvay waste overlies the marl between 4 inches and 2 feet. The waste is a white (5Y 8/1) silt to fine sand with a greasy consistence. A black (10YR 2/1) sandy soil caps this boring from 0 to 4 inches. It is organic-rich, with many fine to coarse roots and a loose to friable consistence.

WB18-SB-249

SB-249 extends to 70 feet (Appendix A). It is located between the base of a wastebed berm and the lakeshore (Figure 1). Glacio-lacustrine deposits were identified at the base of the core between 62 and 70 feet. Between 66 and 70 feet it is a black (GLEY 1-2.5N) clay to clay loam with slightly sticky to firm consistence. From 62 and 66 feet it is a grayish brown (10YR 5/2) silty clay loam with firm to very firm consistence and common black mottles of reduced Iron.

Transmarl was identified between 56 and 62 feet. It is composed of alternating sub-units of very dark gray (GLEY 1-3N) silty clay loam and dark gray (5Y 4/1) sandy clay loam. The silty clay loam has a slightly firm consistence with no discernible organics, shells, or rock fragments and only a few black mottles, possibly of reduced Iron. The sandy clay loam has a slightly firm consistence and contains very few organics, shells and shell fragments.

Between 5 inches and 56 feet, marl overlies the transmarl. The marl is composed mostly of interbedded deposits of dark gray (5Y 4/1) and very dark gray (5Y 4/2) gravelly sandy clay loam, loamy sand, and sand with some silty clay sets. Organics in the form of woody material and fine rootlets are present between 12 and 28 feet and 47 and 48 feet. Fine to medium shells are present throughout this unit. Fine gravels, possibly oncolites, were identified throughout this thick unit, with noticeable absences of gravels between 14-16, 30-42 feet, and 47-56 feet. Fine laminations of silt are present between 47 and 48 feet.

A very thin layer of white (5Y 8/1) silt- to fine sand based Solvay waste is found between 3 to 5 inches. It has a greasy consistence. Between 0 and 3 inches is a thin black (10YR 2/1) humic surface soil with common fine to coarse roots and a loose to friable consistence.

WB18-SB-250

SB-250 reached a depth of 84 feet (Appendix A). It is located on a shelf or terrace between the wastebed berm and lakeshore (Figure 1). This terrace seems to be natural in origin because no Solvay waste was identified here. Glaciolacustrine clay forms the base of this boring between 70 and 84 feet. It is dark gray (7.5YR 4/1) and features sticky consistence with black mottles, possibly of reduced Iron, towards the base.

Between 70 and 73 feet there is a transitional zone between the glacio-lacustrine and the transmarl units. It is a very dark gray (5Y 3/1) silty clay loam that grades to a black (GLEY 1-2.5N) silty clay towards the bottom. The silty clay loam has a slightly firm to slightly sticky consistence. The silty clay is finely laminated with a slightly firm to sticky consistence.

Transmarls overlie the glacio-lacustrine deposits between 66 and 70 feet. They are a dark reddish gray (10YR 4/1) fine to medium sand that grades into a sandy clay. The sands contain few fine shells and shell fragments and have a loose consistence, while the clay has a firm to sticky consistence and contains no shells. The sandy clay is very sticky, and contains few fine rootlets. There is also a thin band of fine sand at about 69 feet.

A thick marl overlies the transmarl and extends between 4 inches and 66 feet. Textural matrices are texturally consistent, ranging from silty clay loam to sandy clay loam. There are occasional deposits of fine to medium sand. Colors for the entire unit are varied and include black (5Y 2.5/1) at the top to gray (5Y 6/1) at 34 feet, and then black (5Y 2.5/2) from 34 to 50 feet. Between 50 and 66 feet the color changes from very dark gray (5Y 3/1) to olive gray (5Y 4/2). Gravels, likely a facies of Ninemile Creek, are present at about 4 feet, but by 5 feet these are completely absent. Fine to medium shells are common throughout the entire unit, but decrease in abundance below 50 feet. Organics also proliferate throughout, but are absent between 2-4, 24, and 50-54 feet, respectively.

Finally, the top of the core, between 0 and 4 inches, is capped by a thin black (10YR 2/1) humic soil. It has a high concentration of fine to coarse roots which contribute to a loose to friable consistence.

Review of Boring Logs

It is instructive to compare the detailed sequence stratigraphies from the present set of boring logs (Figure 9) with results of previous investigations, specifically Geologic Cross Section A-A' from Crawford 2009 (Figure 10). The latter is a cross-section that runs parallel and adjacent to alignment of the present borings, albeit a bit further from the lakeshore and at generally higher elevations. Both sets of subsurface tests present the same sequence and ordering of deposits, with basal glacio-lacustrine silts and clays overlain by the marl and capped by Solvay waste. Geologic Cross Section A-A' (Figure 10) extended significantly deeper beneath the glacio-lacustrine silts and clays.

Comparisons between the logs and the existing soil boring data, underscores the differences in descriptive detail for the recorded cores. For example, the borings from this investigation all have a thin soil of about 4 inches that caps the Solvay waste. This soil is absent from the Geologic Cross Section A-A' (Figure 10). This discrepancy may reflect the minimal functional significance of the soil for geotechnical purposes. Alternatively, it may simply be a consequence of elevation. The borings that compose Geologic Cross Section A-A' were taken from atop the wastebeds at a higher elevation than the GRA cores along the shoreline. Due to their heterogeneous composition and disposition, the Solvay beds may not have sustained the minimal level of pedogenesis required to form a thin A horizon.

The Solvay waste from the borings in the GRA investigation area was either thin to non-existent, as the shoreline is often removed from the wastebed surface. The relative thinness or absence of the Solvay waste in this area is likely linked to the factors accounting for soil formation. It should be noted that a soil was found at SB-19BR, a boring from the previous investigation. This isolated soil exposure may not be representative of a laterally significant pedogenic (soil forming) interval.

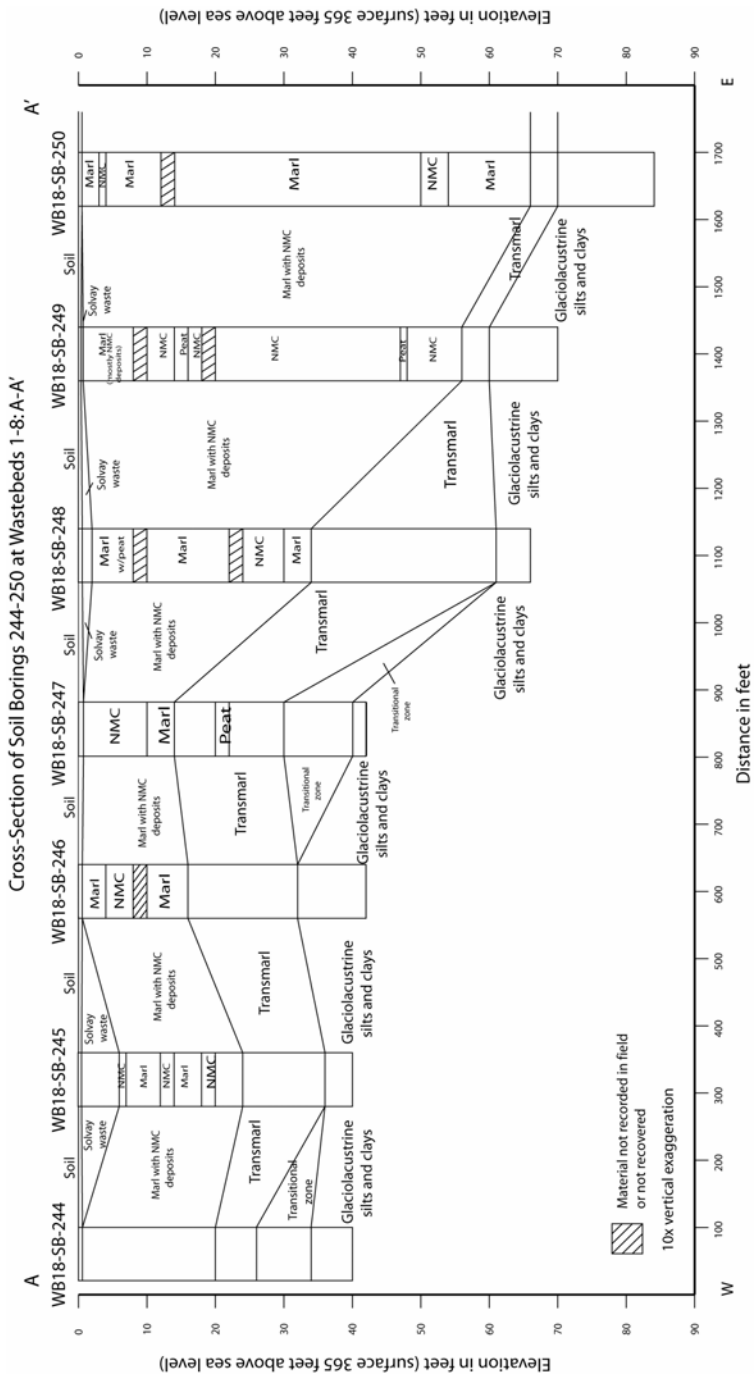

Figure 9. Stratigraphic cross section of the project area.

It should be noted that another reference boring, SB-251, outside the limits of this project area, was also investigated and recorded in the field (Figure 1). SB-251 was at a similar elevation to the borings from Geologic Cross-section A-A' (Figure10), and lies on top of one of the Solvay wastebeds. Thus the thickness of the bed at this boring is similar to those from Cross-section A-A'(Figure 10). A thin and organic-rich layer was noted at SB 251. The setting is also dotted with short trees and bushes that have taken root on the Solvay waste. This layer may be only leaf-litter, or it may be a thin soil composed solely of an O-horizon.

The other notable difference between the different sets of borings is preserved in the vicinity of the Ninemile Creek deposits. According to Crawford (2009), the Cross-Section A-A'(Figure 10) shows the Ninemile Creek deposits overlain by the marl. However he does mention that the Ninemile Creek, "… deposits (are) found within the marl" (p. 12). This investigation also finds the Ninemile Creek deposits to be within the marl, as well as in contexts including peats and capping the marl. Preliminary indications are that the Ninemile Creek sediments can be interdigitated with the marls irrespective of elevation. They may represent classic feeder stream deposits laid down variably as a consequence of inter-related lake edge movements and stream activity.

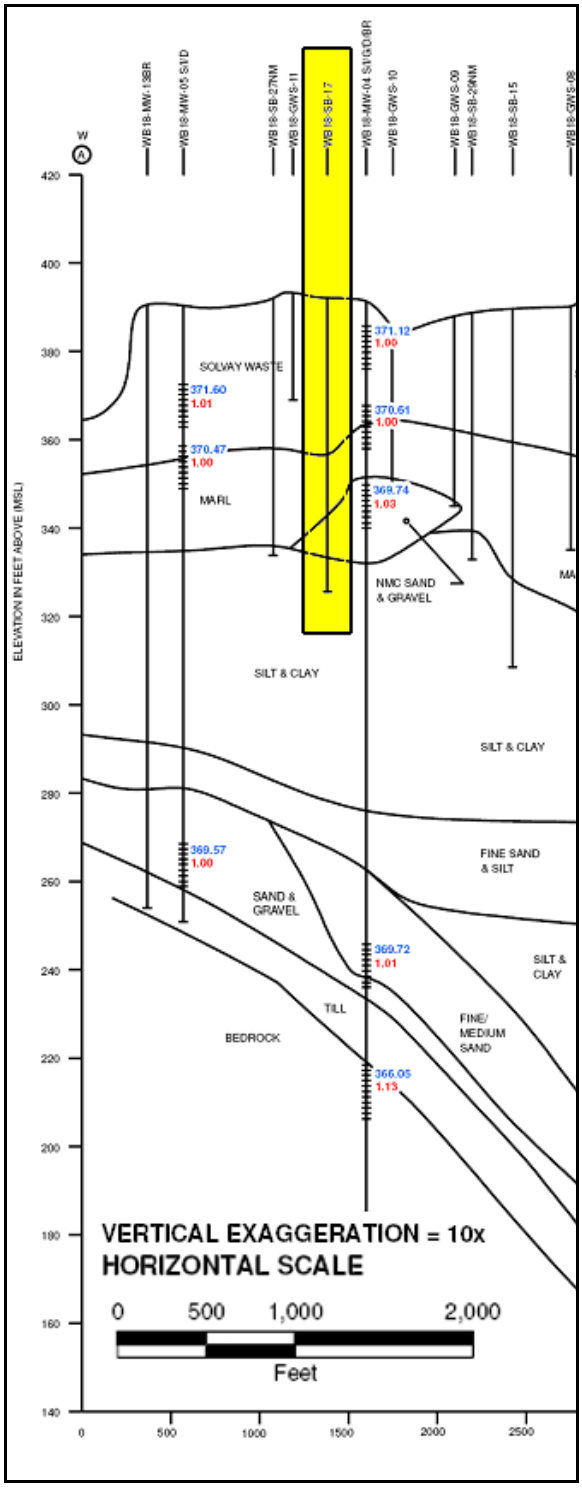

Figure 10. Selection of the Geologic Cross-section A-A' of Wastebeds 1-8. Highlighted core is most similar to our project area. (From Crawford 2009: Figure 4).

GEOARCHEOLOGICAL INTERPRETATIONS AND RECOMMENDATIONS

This project area can be split into two main areas: the eastern area which is present in the mapped delta of Ninemile Creek; and the western area which lies outside of the old Ninemile Creek delta and closest to the location of the current, channelized Ninemile Creek (see Figures 1, 9, and 10). Thus, the main difference is that borings in the eastern area would be expected to contain fluvial/deltaic deposits, while such deposits should be lacking in the western area.

The eastern borings (247-250) are all within the old Ninemile Creek delta. Expected stratigraphic sequences are as follows (bottom to top): glacio-lacustrine silts and clays, marl with interbedded fluvial sands, and a thin soil. Individual borings all preserved deposits registering these depositional suites, albeit with some variation. A singular expression of variability is the presence of peat within the marl layer. A secondary expression is the presence of Solvay waste immediately below the soil and directly above the marl.

According to the mapping presented by Crawford (2009), borings 244-246 are all outside of the old Ninemile Creek delta, and next to the current location of the channelized Ninemile Creek (Figure 4). However, borings 245 and 246 nevertheless contain fluvial deposits that may be part of the Ninemile Creek delta. Boring 244 contains no fluvial deposits, such that the margins of the old Ninemile Creek delta may fall somewhere between borings 244 and 245. Boring 244 has the same general stratigraphic sequence as the other borings save for the Ninemile Creek fluvial deposits found within the marl unit elsewhere.

The cores recovered from the Ninemile Creek site present sedimentology and stratigraphic successions that are mostly consistent with the previous work undertaken here (Crawford 2009). The glacio-lacustrine silts and clays were the earliest deposits identified, although there are earlier sediments overlying the Silurian Age Vernon Shale (refer to Crawford 2009). The glacio-lacustrine unit documents the proglacial lake that formed during the retreat of the Laurentide ice sheet and probably represents the earliest stage of Onondaga Lake. The former basin was already a topographical low, such that the disposition of the frontal moraine to the southeast and the retreat of the glacier to the northwest carved out the contours of the proglacial lake. It was during this period that the glaciolacustrine silt and sand unit was laid down in the present project area. Some of the coarser deposits may be attributed to landslides and deltas, which were probably widespread, given the large quantities of unconsolidated till left by the retreating glaciers, and the lack of vegetation to stabilize surfaces.

When the glacier receded at the end of the Pleistocene, lake levels dropped and the modern drainage pattern was established (Muller 1977; Cadwell et al. 2003, Cadwell and Muller 2004; Crawford 2009). As lake levels fell, the lake basin remained extensive, with the glacio-lacustrine sediments contained within subaqueous portion of lake. It was during this time that transmarl sediments were laid down.

Early Holocene environments were initially dynamic but were subsequently stabilized as lake levels and stream influx led to more homeostatic conditions. The succession of vegetation communities across the basin reinforced trends to stable surfaces that promoted the development of soils. While this led to an overall reduction of sediment load and depositional rates, it also resulted in an increase in detrital organic matter transported into the lake (Kappel and Teece 2007). By the Mid Holocene, marl formed within the lake basin, and Ninemile Creek represented a classic deltaic locus with seasonal sediment inputs along the lake margins. As a result, the depositional sequence of this time frame is a complex series of thicker marls prograding in near- and off-shore contexts, thinner sets of fluvial sands and gravels from the creek, and even thinner peats (possibly) removed from the lake but accumulating along swamps on the distal margins of the delta. Shoreline and water levels (and dynamics) would approximate present conditions, with fluctuations at off- and near-shore settings, and marshy shorelines. No buried soils were identified within these deposits which would confirm the presence of the subaerial (ie., exposed) shorelines and nearshore settings that could have supported pre-contact sites and potentially preserved evidence of their distributions.

The interplay between localized fluctuations in lake levels, shoreline positions, and fluvial/deltaic deposition along Ninemile Creek resulted in geomorphic configurations that largely persisted into postcontact period times. Spatial relations between these micro-environments could have been preserved well into the present, had landscaping not compromised landform relations. Thus, for example, lake levels were artificially manipulated throughout the 19th and 20th century for industrial, transport, and municipal purposes (Hohman 2004 and Hohman and Versaggi 2009). The Solvay process of the 19th century was responsible for diverting Ninemile Creek out of the project area with a resultant massive mobilization and storage operation that formed the wastebeds along the shorelines of Onondaga Lake (Hohman 2004 and Crawford 2009). Accordingly, large scale human engineering destroyed the delta in the project area, which also caused the nearshore and shoreline swamps to disappear. This disruption caused the project area to become more subaerially exposed as a shoreline along the wastebeds. This is consistent with the formation of the thin soil that caps the project area. Also, the irregular pockets of white and greasy waste-- a thin, discontinuous layer below the surface soil—is a by-product of localized erosion of the Solvay waste along the shoreline. Away from the shoreline of Wastebeds 1-8, the Solvay waste exists in beds up to 70 feet thick (Dean and Eggleston 1984; Rowell 1996; Crawford 2009).

Extensive regional records of pre-contact and post-contact occupation coupled with contemporary Onondaga territorial claims to the lake are strong foundations for high site preservation potential along present and paleo-shorelines of Onondaga Lake. The purpose of the present investigations was to test for subsurface geomorphic evidence for such landscape features below Wastebeds 1-8. Our review of Quaternary geological literature, bore logs, and observations of sediment stratigraphy within the geotechnical borings facilitated a reconstruction of natural lacustrine (lake) and post-lacustrine events that extends into the Holocene. We identified preserved and intact deposits below the Solvay waste. These reconstructions reflect the changing climatic and landscape history during intervals of human occupation of the region consistent with the archaeological record.

Our findings suggest that there are thick sediments that date to the Holocene. We interpret nearly all of them to have been deposited in subaqueous, interior portions of the lake basin. These are inclusive of the glacio-lacustrine silts and clays, and the transmarl. The marl unit, which overlies the transmarl and was dated in an unrelated study outside of the project area to the Mid-Holocene, is a dynamic deposit. It contains coarser sediments laid down along delta formed by Ninemile Creek, and interbedded peat deposits, which are reflective of nearshore and shoreline marshes and swampland. These interbedded deposits are suggestive of the fine scale lake level fluctuations attendant with settings along shoreline and immediately offshore. These areas would have likely attracted small groups of indigenous hunters to exploit aquatic resources along the swamplands.

While these nearshore and shoreline swamps along the Ninemile Creek delta could have had the potential to support pre-contact activity, preservation possibilities for the marls are minimized because the sequence of deposits lacked any evidence of buried, preserved surfaces *or paleosols*. Paleosols are former exposed surfaces that were stable long enough to sustain vegetation, as registered by at least limited soil development. The soils would have contained evidence of human occupation sufficient to have left behind an archaeological record. Rather than buried soils, the marl unit identified thin beds of peats which are accumulations of partially decayed organics more reflective of seasonally or intermittently inundated swamps, rather than stable, dry surfaces. The coarser deposits associated with Ninemile Creek would be from channel bottom or off-shore deltaic settings, which are also not conducive to occupations.

Given that investigations within the confines of the project area did not encounter buried landscape segments or surfaces with the potential to recover archaeological materials, no further work is recommended. This does not rule out the possibility of identifying paleosols with archaeological potential buried within marl units along Onondaga Lake outside of the current project area. Settings further away from the lake basin, but still close enough to have deeply buried Holocene shorelines preserved in paleosols, may have archaeological potential. Conversely, the likelihood for pre-contact site destruction further away from the basin increases significantly both because of thinner depth of soils, their compromised integrity, and the likelihood of deeper and more extensive land disturbance away from loci of inundation. In conclusion, studies such as these are necessary in complex Late Quaternary landscape contexts to assess the potential for deeply buried archaeological materials. Specialists trained in geology, soils, and archaeology have the requisite expertise to evaluate existing boring logs, and deep stratigraphic sequences in order to assess archaeological potential.

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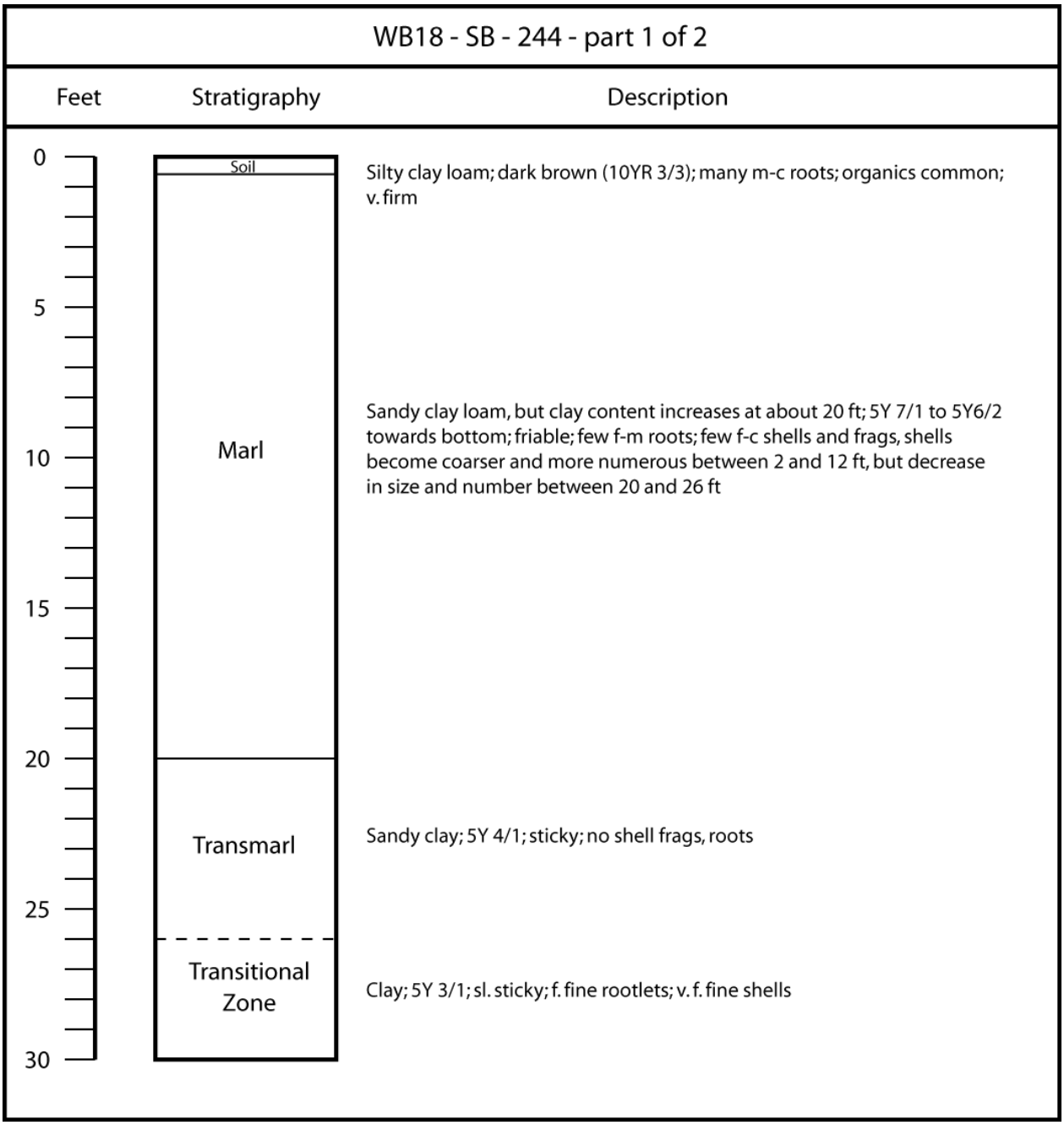
APPENDIX A: GEOTECHNICAL BORING DESCRIPTIONS

Key to Profile Descriptions

Texture:	Si = silt; L = loam; C = clay; S = sand; F = fine; V = very; G = Gravel;
Structure:	1 = weak; 2 = moderate; 3 = strong;
	gr = granular; mass = massive; strat = stratified; sbk = subangular blocky; ab = angular blocky; pr = prismatic; pl =platy; dist. = disturbed/no structure
Consistence:	fri = friable; sl = slightly; v = very; l = loose; fi = firm; st = sticky; ss = strongly sticky
Concentrations:	f =few, com. = common, m = many
Size Class:	f = fine; m = medium; c = coarse
Boundary Distinctness:	a = abrupt; c = clear; d = diffuse; g = gradual; s = sharp
Boundary Topography:	w = wavy; s = smooth; a = abrupt

E.O.B. = end of boring (upper contact is base of boring).
Shelby tube = sealed section collected by O'Brien & Gere geologists, not observed by GRA geoarchaeologists.
No recovery = no sample was recovered in 2 ft section.


WB18 - SB - 244 - part 1 of 2
Feet
Stratigraphy
Description
0
5
10
15
20
25
30
Soil
Marl
Transmarl
Transitional Zone
Silty clay loam; dark brown (10YR 3/3); many m-c roots; organics common; v. firm
Sandy clay loam, but clay content increases at about 20 ft; 5Y 7/1 to 5Y6/2 towards bottom; friable; few f-m roots; few f-c shells and frags, shells become coarser and more numerous between 2 and 12 ft, but decrease in size and number between 20 and 26 ft
Sandy clay; 5Y 4/1; sticky; no shell frags, roots
Clay; 5Y 3/1; sl. sticky; f. fine rootlets; v. f. fine shells

WB18 - SB - 244 - part 2 of 2

Feet	Stratigraphy	Description
30	Transitional Zone *continued*	
35	Glaciolacustrine deposits	Clay; 10YR 5/2; sticky; black mottles
40	E.O.B	
45		
50		
55		
60		

WB18 - SB - 245 - part 1 of 2

Feet	Stratigraphy	Description
0	Soil	Sandy loam; 10YR 5/6; common f-m roots; many f-m frags; friable
	Solvay waste	5Y 8/1; silty clay loam – like; greasy feel
5		
	NMC	
	Marl	
10		
	NMC	Sandy loam; f-m, gravelly; loose; contains shells and frags; f. fine rootlets; towards bottom – clay content increases; frags become coarser and their amount decreases
15	Marl	
	NMC	
20		
25	Transmarl	Silty clay loam and becomes a silty clay at about 32 ft; 5Y 3/2 to 5Y3/1 at about 30 ft; sl. firm; common fine rootlets; v. few fine shell and shell frags which increase in size towards bottom
30		

WB18 - SB - 245 - part 2 of 2

Feet	Stratigraphy	Description
30		
	Transmarl *continued*	
35		
	Glaciolacustrine deposits	Silty clay loam; sl. firm, that grades into a sticky silty clay at about 38 ft; 10YR 5/2; no shells, shell frags, and organics
40	E.O.B.	
45		
50		
55		
60		

WB18 - SB - 246 - part 1 of 2

Feet	Stratigraphy	Description
0	Soil	Sandy loam? (not textured); 10YR 6/3; looks singe grained, many organics
	Marl	Sandy clay loam or sandy clay? (not textured); 5Y 4/2; sticky
5	NMC	Sandy loam; f-c gravel; 5GY 5/1; many shells
		No sample collected
10	Marl	Sandy clay; 5Y 7/1; f. fine rootlets; c. f-m frags and shells
15		
20	Transmarl	Sandy clay loam; 5Y 3/1; sl. firm; f. fine rootlets, v. f. fine shells; clay content increases slightly between 18 and 20 ft; silt increases slightly between 24 and 26 ft; between 28 and 32 ft - becomes sandy clay, sticky
25		
30		

WB18 - SB - 246 - part 2 of 2

Feet	Stratigraphy	Description
30	Transmarl *continued*	*See description above.*
35	Glaciolacustrine deposits	Clay loam, silty clay, or v. f. sandy clay; 10YR 5/2; sl. sticky; between 34 and 36 ft - silty clay; sl. firm; very few, fine rootlets; between 36 and 42 ft - clay
40	E.O.B.	
45		
50		
55		
60		

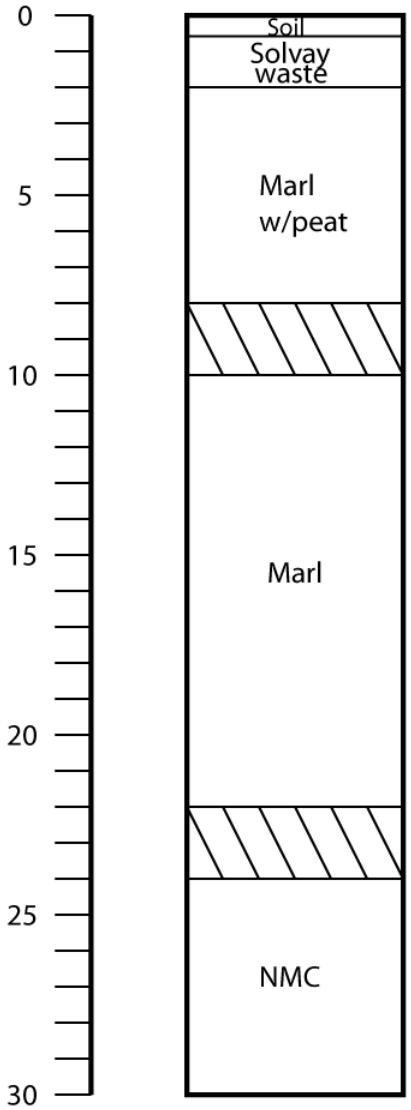
WB18 - SB - 247 - part 1 of 2

Feet	Stratigraphy	Description
0	Soil	Sandy soil; 10YR 3/2
5	NMC	Loamy sand; 5Y6/1; granular and loose to massive and friable towards bottom; very few, fine shells and concretions, and their abundance and size increase downward
10	Marl	Sandy clay; 5Y 6/2; less concretions and shells than the NMC deposits above; between 12 and 14 ft - sand decreases and clay increases to form a clay loam; 5Y 6/1; with few coarser shells
15	Transmarl	Sandy loam with decreasing sand and increasing clay forming a clay loam towards the bottom; the color goes from a black, 5Y 2.5/1, to a very dark gray, N3; some roots, which decrease down the unit; v. few shells, which decrease down the unit
20	Peat	Sandy clay loam; very dark gray (N3); common fine rootlets and v.f. med. organic fragments, possible buried marsh.wetlands; massive; firm
25	Transmarl	Sandy clay loam; N4; massive; firm to clay loam w/ black, fine mottles of reduced Fe towards the bottom
30		

WB18 - SB - 247 - part 2 of 2

Feet	Stratigraphy	Description
30		
35	Transitional zone	Sandy clay loam; 5YR 4/1; massive; v. firm; no shells or frags; clay increases towards bottom and becomes firmer and stickier
40	Glaciolacustrine deposits	Clay; 5YR 4/1; v. firm; massive; no frags or shells
	E.OB.	
45		
50		
55		
60		

WB18 - SB - 248 - part 1 of 3



Description
Sandy soil; 10YR 2/1; very dark, organic rich; many f-c roots; loose; friable
Solvay waste; 5Y 8/1; silt- and sand-sized particles w/ a greasy texture; massive; friable-sl. firm; dry
Sandy clay loam; 5Y 8/1 to 5Y5/2 towards bottom; firm; com. fine shells; com. coarse frags towards bottom; three dark (10YR 3/1 to 10YR 2/2 for two bottom-most) and organic-rich peat lenses ~1 in. thick, interbedded in the marl – sandy loam; firm; friable
Shelby tube
Alternating beds of sandy clay loam and f.-c. sand; SCL – N4; v. few frags; firm; massive; Sand – N5; V. common fine - coarse frags and shells
Shelby tube
f-m Sand; single grained; loose; very bottom of unit is silt, N4; firm; massive; few, fine rootlets, possibly channel or alluvial deposit

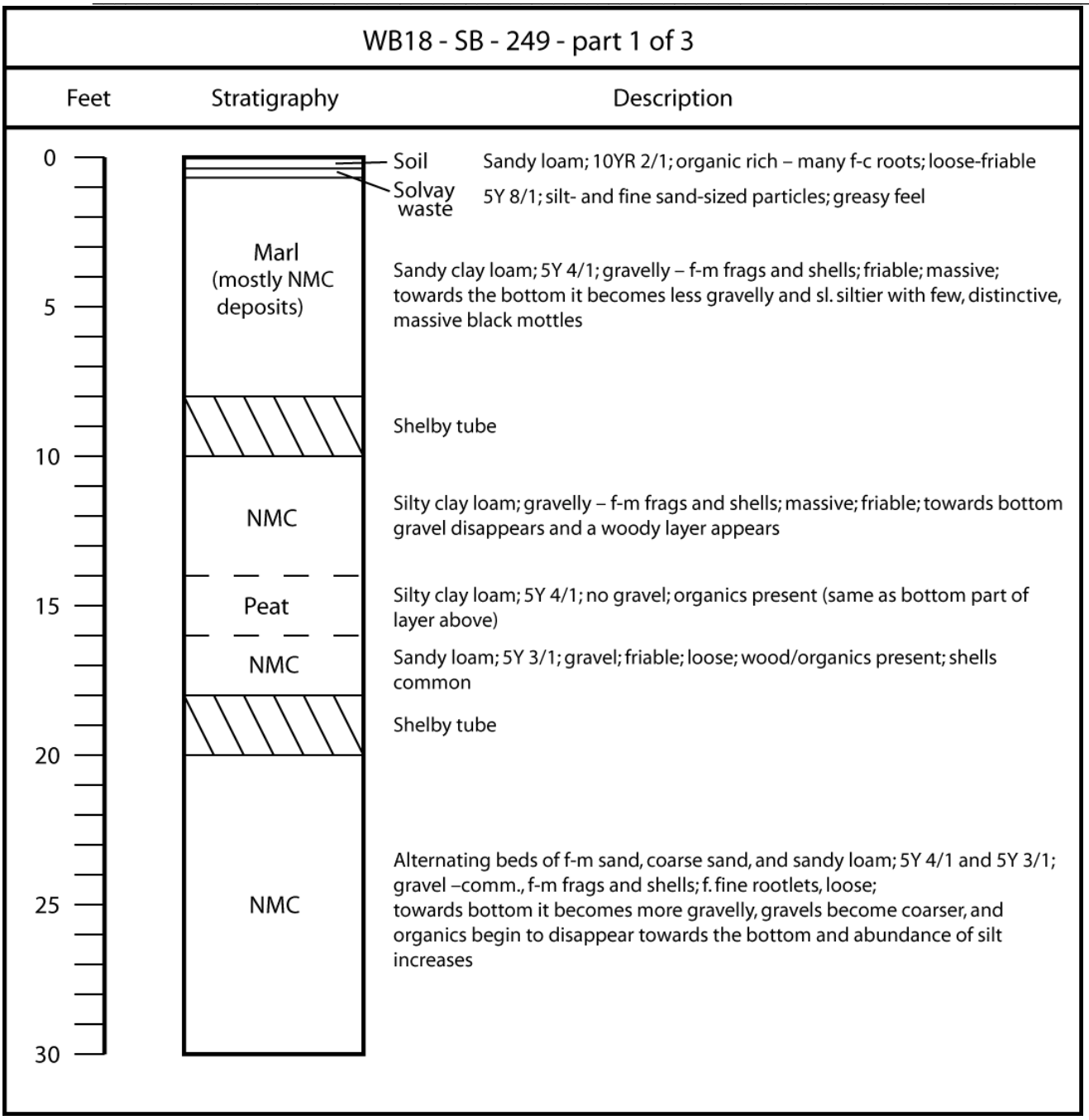
WB18 - SB - 248 - part 2 of 3

Feet	Stratigraphy	Description
30	Marl	Sandy loam (f-m sand); 5Y 3/1; massive-single grained; friable-loose; v. fine shells; coarse frags; channel deposits, but transitional because shells are still found
35		
40	Transmarl 1	f-m Sand; 5Y 3/1; single grained-massive; loose-friable; few f-m shells; few, fine rootlets; towards the bottom clay content increases and shells and rootlets decrease
45		
50	Transmarl 2	Silty clay loam; 5Y 4/1; few rootlets and wood frags; sl. firm; massive; some black mottles; possibly floodplain deposits; no soil horizons discernible
55	Transmarl 3	Sandy clay loam (f. sand); 5Y 4/1 to 10YR 3/1 towards bottom; massive; friable; f. fine shell frags present at very bottom - possibly channel deposits
60		

WB18 - SB - 248 - part 3 of 3

Feet	Stratigraphy	Description
60	Transmarl 3	*See description above.*
	Glaciolacustrine deposits	Silty clay loam/clay loam which changes to clay at 62 ft; silty clay loam/clay loam - 10YR 4/2; sl. firm; massive; no discernable frags, shells, or rootlets; clay - v. sticky; plastic
65	E.O.B.	
70		
75		
80		
85		
90		

WB18 - SB - 249 - part 1 of 3



WB18 - SB - 249 - part 2 of 3

Feet	Stratigraphy	Description
30		
35		
40	NMC *(continued)*	*See description above.*
45		
	Peat	Sandy clay loam (silt content increases) transition zone. This unit is capped by organic material that is also found throughout this deposit; laminations present towards bottom – possibly lake seds or less energy such as flood deposits
50	NMC	f-m Sand; 5Y 3/1; f-m shells and frags
55		
	Transmarl	Between 56 and 58 ft - Silty clay loam; N3; sl. firm; few black mottles; between 58 and 60 ft - Sandy clay loam; 5Y 4/1; sl. firm; v. few organics; v. few shell frags; towards bottom gets siltier
60		

WB18 - SB - 249 - part 3 of 3

Feet	Stratigraphy	Description
60		
65	Glaciolacustrine deposits	Silty clay loam to clay towards bottom; N2.5 to 10YR5/2 back to N2.5 at bottom; firm; to sticky at bottom
70	E.O.B.	
75		
80		
85		
90		

WB18 - SB - 250 - part 1 of 3

Feet	Stratigraphy	Description
0	Soil	Sandy loam; 10YR2/1; organic-rich – many fine to coarse roots; loose to friable
	Marl	Sandy clay loam; 5Y 2.5/1
	NMC	Sandy loam; gravelly; 5Y 2.5/1
5	Marl	Sandy clay loam and silty clay loam; 5Y 2.5/1; organics common; f. fine shells; towards bottom shells increase in abundance
10		
		No recovery
15		
20	Marl	Silty clay loam; 5Y 5/1; organics – towards bottom organics disappear and the color is slightly lighter (5Y 6/1); at 24 ft - f. fine shells; few organics; towards bottom organics increase and shell size increases
25		
30		

WB18 - SB - 250 - part 2 of 3

Feet	Stratigraphy	Description
30	Marl	See description above.
35		
40	Marl	Alternating bands of silt (5Y 2.5/2) and sand (5Y 2.5/1) w/ organics and f-m shells
45		
50	NMC	f-m Sand; 5Y 3/1; few f-m shell frags; loose
55	Marl	Alternating bands of silty clay loam and fine sands w/ occasional clay deposits; sand usually contains organics; color for all is 5Y3/1 – 5Y4/2 at very bottom
60		

WB18 - SB - 250 - part 3 of 3

Feet	Stratigraphy	Description
60	Marl	*See description above.*
65	Transmarl	f-m Sand; 10YR 4/1; loose, f. fine shell frags; from 67 ft – clay; 10YR 4/1; firm-sticky; few, fine rootlests towards bottom; thin band of fine sand at about 69 ft
70	Glaciolacustrine deposits	Top – silty clay loam; 5Y 3/1; sl. firm-sl. sticky; bottom – silty clay; N2.5; sl. firm-sticky; laminated
75	Glaciolacustrine deposits	Contact – top portion (1.5 ft) is like bottom part of deposit above; the rest is clay; 7.5YR 4/1; sticky; black mottles towards bottom
80		
85	E.O.B.	
90		

Appendix IV. Boring Location and Stratigraphy Maps of Wastebeds 1-8

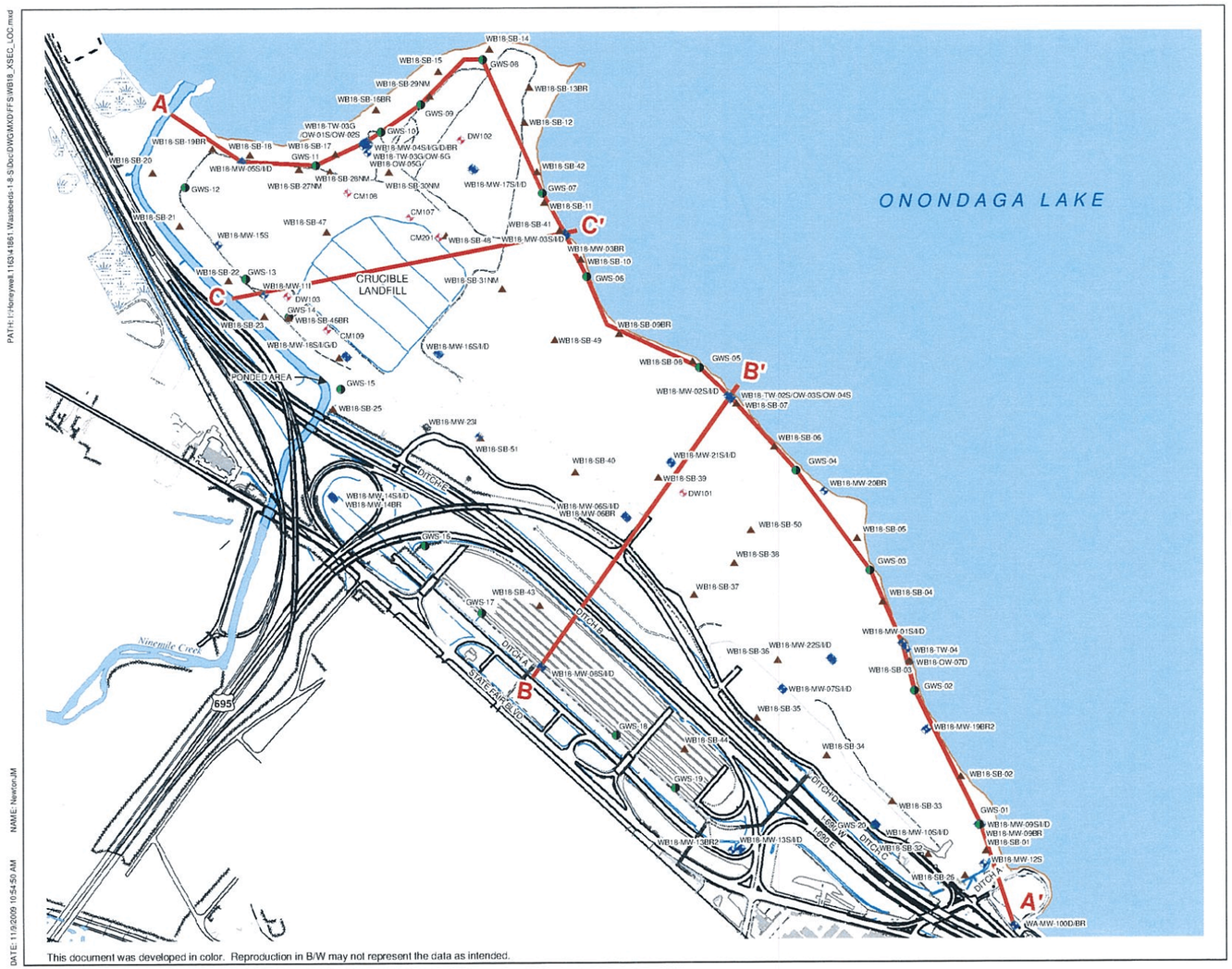


FIGURE 3

N

LEGEND

- CROSS SECTION LOCATION
- MONITORING WELL
- SOIL BORING
- GROUNDWATER SCREENING
- CRUCIBLE WELL

HONEYWELL
WASTEBEDS 1 - 8
FOCUSED FEASIBILITY STUDY
GEDDES, NEW YORK

CROSS SECTION LOCATIONS

0 350 700 1,400
Feet

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O'BRIEN & GERE

FFS Figure 3. Cross Section Locations.

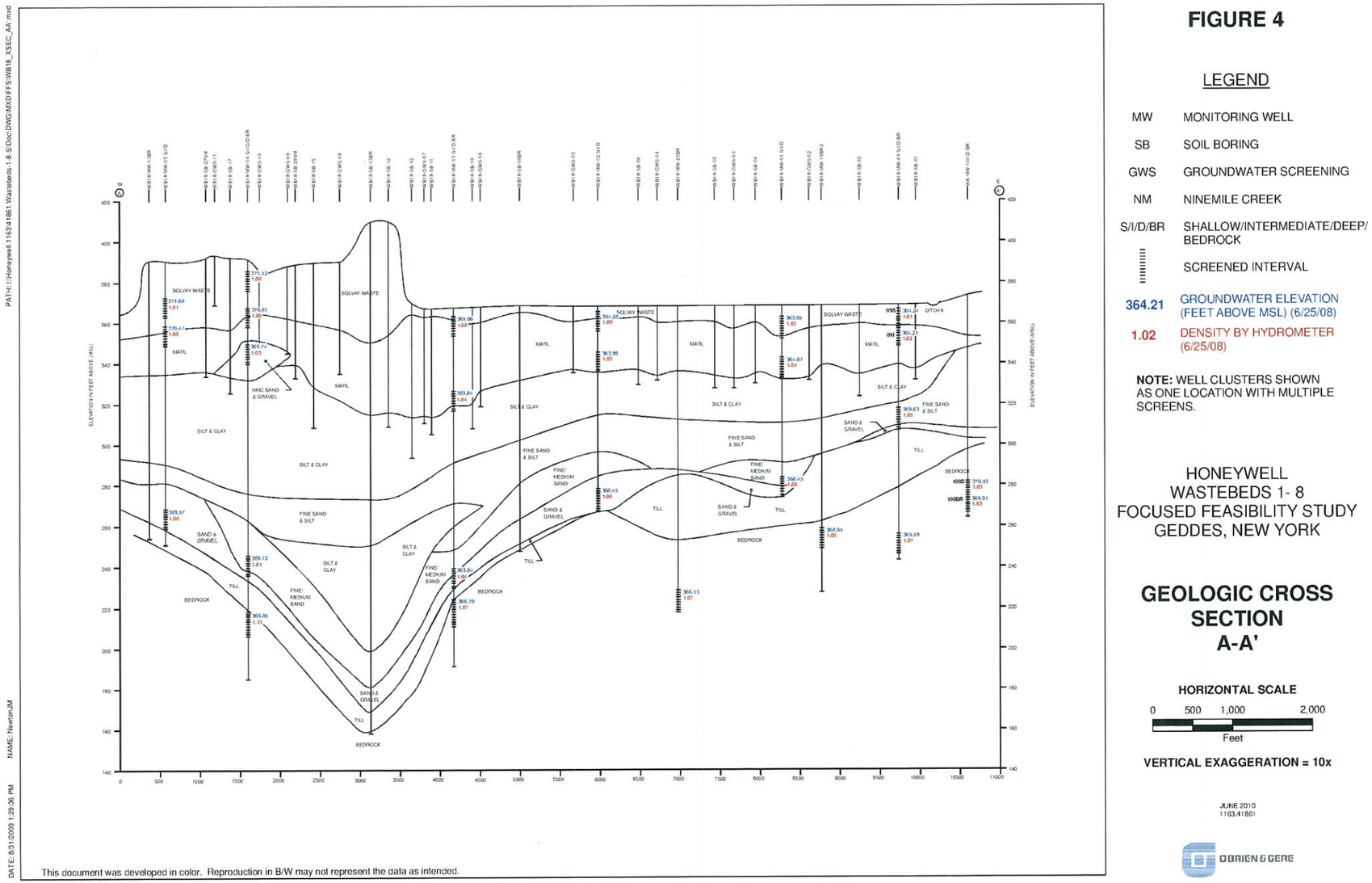

FIGURE 4

LEGEND

MW	MONITORING WELL
SB	SOIL BORING
GWS	GROUNDWATER SCREENING
NM	NINEMILE CREEK
S/I/D/BR	SHALLOW/INTERMEDIATE/DEEP/ BEDROCK
	SCREENED INTERVAL
364.21	GROUNDWATER ELEVATION (FEET ABOVE MSL) (6/25/08)
1.02	DENSITY BY HYDROMETER (6/25/08)

NOTE: WELL CLUSTERS SHOWN AS ONE LOCATION WITH MULTIPLE SCREENS.

HONEYWELL
WASTEBEDS 1- 8
FOCUSED FEASIBILITY STUDY
GEDDES, NEW YORK

GEOLOGIC CROSS SECTION A-A'

HORIZONTAL SCALE

0 500 1,000 2,000

Feet

VERTICAL EXAGGERATION = 10x

JUNE 2010
1163.41861

O'BRIEN & GERE

FFS Figure 4. Geologic Cross Section A-A'.

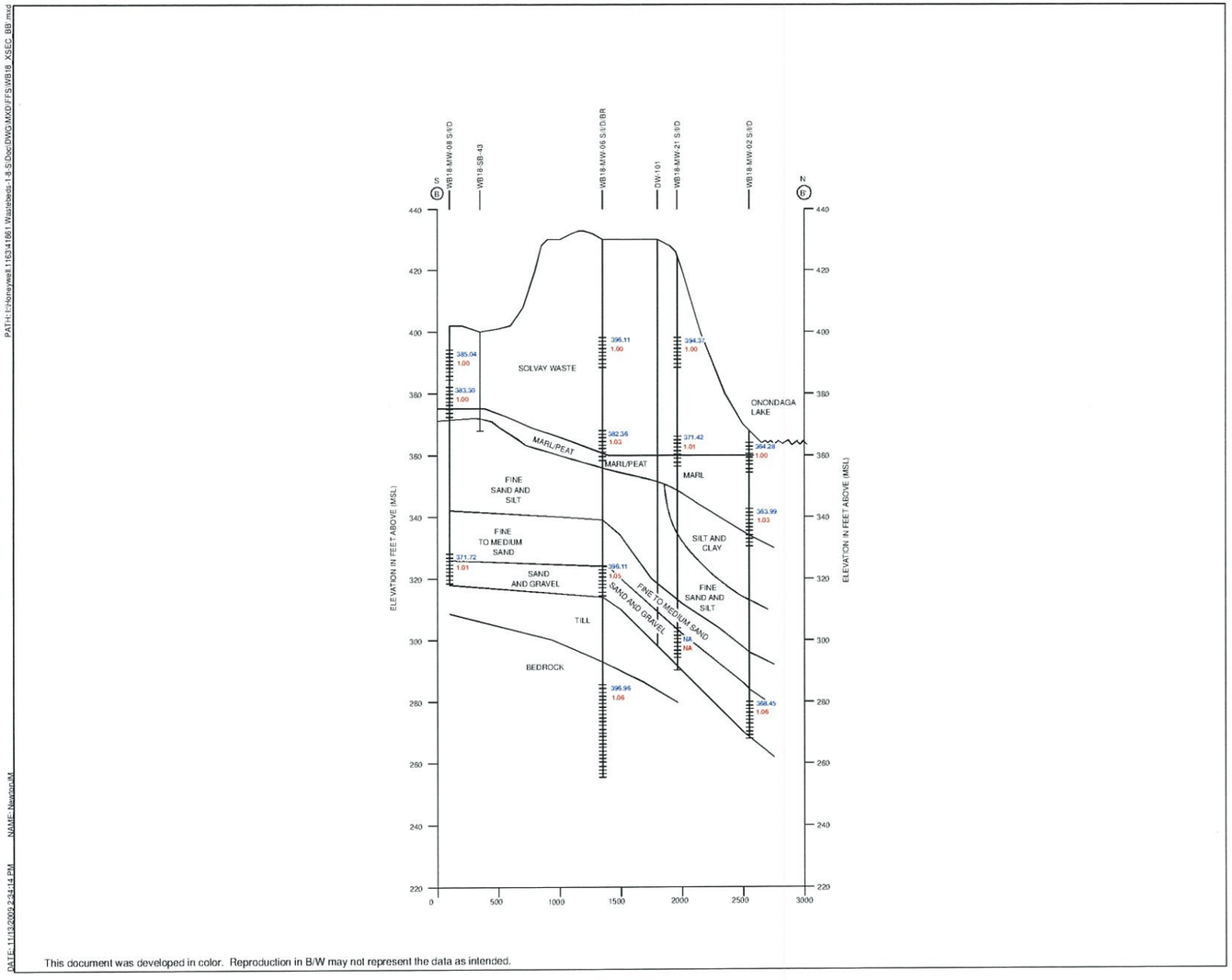

FIGURE 5

LEGEND

MW	MONITORING WELL
SB	SOIL BORING
GWS	GROUNDWATER SCREENING
NM	NINEMILE CREEK
S/I/D/BR	SHALLOW/INTERMEDIATE/DEEP/ BEDROCK
	SCREENED INTERVAL
364.21	GROUNDWATER ELEVATION (FEET ABOVE MSL) (6/25/08)
1.02	DENSITY BY HYDROMETER (6/25/08)

NOTE: WELL CLUSTERS SHOWN AS ONE LOCATION WITH MULTIPLE SCREENS.

HONEYWELL
WASTEBEDS 1 - 8
FOCUSED FEASIBILITY STUDY
GEDDES, NEW YORK

GEOLOGIC CROSS SECTION B-B'

HORIZONTAL SCALE

0 500 1,000 2,000
Feet

VERTICAL EXAGGERATION = 10x

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O'BRIEN & GERE

FFS Figure 5. Geologic Cross Section B-B'.

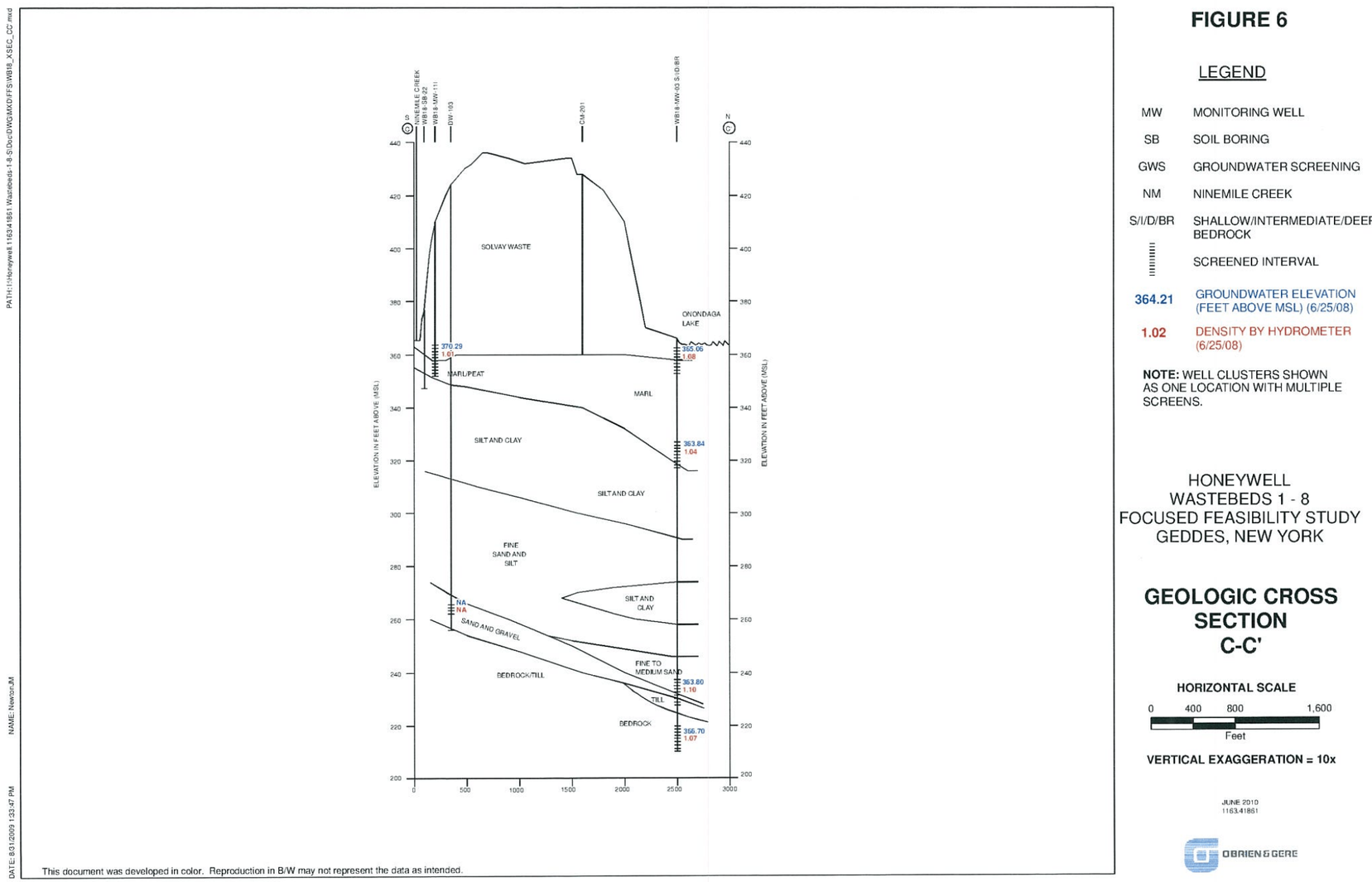

FIGURE 6

LEGEND

MW	MONITORING WELL
SB	SOIL BORING
GWS	GROUNDWATER SCREENING
NM	NINEMILE CREEK
S/I/D/BR	SHALLOW/INTERMEDIATE/DEEP/ BEDROCK
⁞⁞⁞⁞	SCREENED INTERVAL
364.21	GROUNDWATER ELEVATION (FEET ABOVE MSL) (6/25/08)
1.02	DENSITY BY HYDROMETER (6/25/08)

NOTE: WELL CLUSTERS SHOWN AS ONE LOCATION WITH MULTIPLE SCREENS.

HONEYWELL
WASTEBEDS 1 - 8
FOCUSED FEASIBILITY STUDY
GEDDES, NEW YORK

GEOLOGIC CROSS SECTION C-C'

HORIZONTAL SCALE

0 400 800 1,600
Feet

VERTICAL EXAGGERATION = 10x

JUNE 2010
1163.41861

O'BRIEN & GERE

FFS Figure 6. Geologic Cross Section C-C'.