RESULTS OF GEOARCHAEOLOGICAL SOIL BORINGS
Report #6

NEW JERSEY-NEW YORK EXPANSION PROJECT
ROUTE VARIATION 87
380 DEVELOPMENT PROPERTY
STATEN ISLAND, NEW YORK

FERC Docket No. CP11-56-000
New York SHPO No. 09PR05949

Prepared for

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INTRODUCTION

Spectra Energy Corp (Spectra Energy) is proposing to expand its pipeline systems in the New Jersey-New York region to meet the immediate and future demand for natural gas in the largest United States metropolitan area. The New Jersey-New York Expansion Project (NJ-NY Project) will create a new transportation path for 800,000 decatherms per day (Dth/d) of natural gas from multiple receipt points on the Spectra Energy systems to new delivery points in New Jersey and New York. The Project consists of approximately 19.8 miles of multi-diameter pipeline, associated pipeline support facilities, and six new metering and regulating (M&R) stations. The proposed facilities are located in New Jersey, New York, and Connecticut (Figure 1).

Previous Investigations

The Public Archaeology Laboratory, Inc. (PAL) completed Phase IA archaeological overview surveys for the New York portion of the Project in August and December 2010 (Elquist et al. 2010a and b). Since that time additional Phase IA archaeological assessments have been conducted for pipeline route variations in the New York portion of the project (Elquist and Cherau 2011a, b, and c). The Phase IA archaeological assessment recommendations for the Project alignment and route variations include a program of geoarchaeological soil borings in sensitive areas where modern fill deposits associated with heavy industrialization and urbanization land uses have occurred. A total of 52 soil borings has been proposed to date for the archaeologically sensitive areas of the Staten Island portion of the Project pipeline route where subsurface soil conditions are unknown and/or considered too deep for conventional hand testing. Of these, two soil borings were completed in December 2010 (see separate PAL report, Cherau 2011a) and 29 soil borings were completed from July to November 2011 (see separate PAL report, Cherau 2011b). The 10 soil borings along Route Variation 87 on property owned by 380 Development on Staten Island, New York were conducted in February-March 2012, and are the subject of the current report.

The ongoing goal of the soil borings program is to determine the presence and depth of ground disturbances, fill and/or marsh deposits, and of any sediments or buried landscapes containing potentially significant archaeological resources below these deposits. The Project area is dominated by industrial and commercial facilities, but the possibility remains that intact archaeological resources may be preserved within and below historically deposited fill. Additionally, large areas along the Project area of potential effect (APE) consist of former or current tidal marsh that may have been previously available for human occupation prior to marine transgression.

The following report presents the results of 10 geoarchaeological soil borings conducted along Route Variation 87 on property owned by 380 Development on Staten Island, New York. This section of pipeline route is located south of the route originally filed with FERC adjacent to the Arthur Kill shoreline, in a general area of high sensitivity for pre-contact period archaeological deposits (Figure 2). The route variation extends from approximately Station Number (STA) 197+50 just south of the Arthur Kill HDD exit point and wetlands on the west to STA 240+00 north of the Goethals Bridge HDD exit point and wetlands where it rejoins the alignment originally filed with FERC (Figures 3 through 8). The soil borings typically extended to a depth of 600 (cm) (19.7 feet [ft]), with isolated exceptions, and encountered complex stratigraphic sequences of fill, buried post-contact period surfaces, possible pre-contact period surfaces, and underlying natural unconsolidated geological deposits. The results of the geoarchaeological investigations for this portion of the Project were prepared by Geoarcheology Research

Associates (GRA), under subcontract to PAL, the cultural resources consultants to Spectra Energy. The GRA report is provided as Attachment A.

PROJECT AREA OF POTENTIAL EFFECT (APE)

The APE is the "geographic area or areas within which an undertaking may directly or indirectly cause changes in the character of or use of historical properties, if any such properties exist" (36 CFR 800.16[d]). The APE is defined based upon the *potential* for effect, which may differ for aboveground resources (historic structures and landscapes) and subsurface resources (archaeological sites). The APE includes all areas where ground disturbances are proposed, where land use (i.e., traffic patterns, drainages, etc.) may change, or any locations from which the undertaking may be visible.

For archaeological resources associated with the pipeline component of the Project, the APE consists of any areas of ground disturbance for the proposed pipeline trench and associated temporary workspace. In general, the horizontal APE for the proposed pipeline trench is anticipated to be a maximum of 4.5 m (15 ft) at the top and 3 m (10 ft) wide at the bottom; the vertical APE for the proposed pipeline trench is 2.2-2.4 m (7-8 ft) below surface, except in areas where existing utilities are present or the pipeline needs to be deeper for road and railroad crossings or other landowner concerns. The proposed Phase IB testing methodology presented in this report encompasses the horizontal and vertical APE for the pipeline trench.

SCOPE AND AUTHORITY

The Spectra Energy NJ-NY Project requires approvals and permits from federal, state, and local entities. One of the primary Project approval requirements at the federal level is a Certificate of Public Convenience and Necessity under Section 7(c) of the Natural Gas Act issued by the Federal Energy Regulatory Commission (FERC). Consequently, the Project is being reviewed under Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended. Prior to authorizing an undertaking (e.g., the issuance of a FERC approval or Certificate), Section 106 of the NHPA requires federal agencies, including the FERC, to take into account the effect of that undertaking on cultural resources listed or eligible for listing in the National Register of Historic Places (36 CFR §60). The agency must also afford the Advisory Council on Historic Preservation (ACHP) the opportunity to comment on the undertaking. The Section 106 process is coordinated at the state level by the State Historic Preservation Officer (SHPO), represented in New York by the New York State Office of Parks, Recreation, and Historic Preservation. The issuance of a federal agency certificate or approval depends, in part, on obtaining comments from the SHPO. In accordance with Section 106, FERC, as the lead federal agency for the Project, must consult with the New Jersey SHPO regarding the effects of the Project on historic properties.

The primary goals of cultural resource investigations conducted as part of the Section 106 review process are to:

- locate, document, and evaluate buildings, structures, objects, landscapes, and archaeological sites that are listed, or eligible for listing, in the National Register of Historic Places (National Register);

- assess potential impacts of the Project on those resources; and

- provide recommendations for subsequent treatment, if necessary, to assist with compliance with Section 106.

In addition to Section 106, the additional cultural resources investigation will be conducted for this portion of the Project in accordance with FERC's Office of Energy Project's *Guidelines for Reporting on Cultural Resources Investigations* (2002); the Secretary of the Interior's *Standards and Guidelines for Archaeology and Historic Preservation* (NPS, 48 Fed. Reg. 44716-42, Sept. 29, 1983); and the standards and guidelines set forth in the *Standards for Cultural Resource Investigations and the Curation of Archaeological Collections in New York State* (NYAC 1994) and *Landmarks Preservation Commission Guidelines for Archaeological Work in New York City* (NYC LPC 2002). Because of the sensitive nature of some of the material contained in this proposal, the covers and any applicable pages are labeled "CONTAINS PRIVILEGED INFORMATION – DO NOT RELEASE" in accordance with FERC guidelines and 36 CFR 800.11(c)(1).

Results and Recommendations

380 Development Property

A total of 10 geoarchaeological soil borings (the 1R-22.1-ARC series) were excavated on this single property in Staten Island, a borough of New York City. This section of pipeline route is a variation that would extend south of the of the route that was originally filed with FERC from the Arthur Kill HDD exit point in a southerly, then easterly, and then northerly direction to the Goethals Bridge HDD entry point (see Figures 3 through 8). This general area was historically marsh prior to 1900, and soils are mapped as Ipswich-Pawcatuck-Matanuck mucky peats inundated twice daily at high tide. It was assigned high sensitivity for pre-contact resources, buried beneath fill deposits, which could range from isolated finds to artifact scatters associated with campsites predating marine transgression. The pre-contact period sensitivity is derived in large part from the presence of two previously recorded sites located within one-half mile east of the Project Alternate route on the 380 Property. One of these sites is the Beulah Point or Bloomfield Watchogue Site (NYSM 7324) that included finds of clay and steatite beads, pottery, a plummet, grooved axes, and projectile points. The site was reportedly located in an area of higher ground known as Bloomfield. The area was not considered to have any sensitivity for post-contact period resources due to the presence of historically undeveloped marshlands prior to the twentieth century construction of a Gulf Oil refinery complex (Elquist et al. 2010:70-75).

The 10 soil boring are organized into three groups based on their spatial arrangement across the three major route segments. The Group 1 borings are located in a northeast-southwest line along the western edge of the 380 Development alignment alternate (see Figure 4). The group contains four cores (1R-22.1-ARC-2, 1R-22.1-ARC-3, 1R-22.1-ARC-4, and 1R-22.1-ARC-5). Boring 1R-22.1-ARC-2 contained heterogeneous fill deposits from ground surface to 493 cm below surface (cmbs) (16.2 ft), underlain by possibly dredged marsh to 511 cmbs (16.8 ft), sand fill to 514 cmbs (16.9 ft), and peat to the limit of the boring at 610 cmbs (20 ft). The presence of disturbed fill and marsh deposits in this area is supported by a stratigraphic inversion with a radiocarbon date of 1580±30 B. P. (years before present) (Beta-318413) in fill from 488-493 cmbs (16-16.2 ft) overlying a radiocarbon date of 390±30 B.P. (Beta-318413) in the fill-dredged marsh from 493-511 cmbs (16.2-16.8 ft). The inversion may be explained by redeposition of the peats either by lateral settling or historic/modern period reworking (GRA 2012:16).

Boring 1R-22.1-ARC-3 contained heterogeneous fill deposits from ground surface to 486 cmbs (15.9 ft), underlain by peat and clay layers, which could be in part dredged from 486-490 cmbs (15.9-16 ft). The bottom layer of peat from 490-610 cmbs (16-20 ft) yielded a radiocarbon date of 1290±30 B.P. (Beta-318406). Boring 1R-22.1-ARC-4 also contained a thick deposit of fill from ground surface to 457 cmbs (15 ft), underlain by fine sand and gravel with shell interpreted as the shoreface to the limit of boring at 610 cmbs (20 ft). Boring 1R-22.1-ARC-5 contained somewhat shallower fill deposits to at least 183 cmbs (6 ft) to about 335 cmbs (11 ft), underlain by silty clay and shoreline marsh setting soils to the limit of the boring at 610 cmbs (20 ft). A radiocarbon date of 2730±30 B.P. (Beta-318414) was obtained from the marsh deposits from 457-488 (15-16 ft). In summary, the Group 1 borings indicate the potential for intact pre-contact period cultural deposits below 457 cm (15 ft) at the margins of a late Holocene period marsh, although the sensitive strata could be as shallow as approximately 213 cmbs (7 ft) in the area of 1R-22.1-ARC-5 (GRA 2012:16, 23).

The Group 2 borings are located in a northwest-southeast line along the southern edge of the 380 Development alignment alternate (see Figures 4 and 5). This group contains three borings (1R-22.1-ARC-6, 1R-22.1-ARC-7, and 1R-22.1-ARC-8). Borings 1R-22.1-ARC-6 and 1R-22.1-ARC-7 are similar to 1R-22.1-ARC-2 and 1R-22.1-ARC-4 in Group 1 in that they contain nearly identical strata, with sandy fills transitioning to peat between 472-549 cmbs (15.5-18 ft). In 1R-22.1-6 radiocarbon dates of 2930±40 B.P. (Beta-318408) from 305-366 cmbs (10-12 ft) and 1950±30 B.P. from 442-472 cmbs (14.5-15.5) (Beta-318404), again inverted stratigraphically, were obtained from fill/shore deposits. This stratigraphic inversion can be explained by a dynamic geomorphic shoreline environment, which would be consistent with localized sediment displacements. Boring 1R-22.1-ARC-7 yielded a radiocarbon date of 390±30 B.P. from peat between 579-610 cmbs (19-20 ft). Boring 1R-22.1-ARC-8 contained fill deposits from ground surface to 457 cmbs (15 ft), underlain by wet sands and peats, interpreted as shoreface and estuarine deposits. In summary, the Group 2 borings indicate the potential for intact pre-contact period cultural deposits below 305 cm (10 ft) (GRA 2012:17, 24).

The Group 3 borings are located in a southwest-northeast line along the eastern edge of the 360 Development alignment alternate (see Figures 5 and 6). This group contains three borings (1R-22.1-ARC-9, 1R-22.1-ARC-10, and 1R-22.1-ARC-11). Borings 1R-22.1-ARC-9 and 1R-22.1-ARC-10 both contain deep sandy fills to a vertical depth of between 426-457 cmbs (14-15 ft), underlain by pristine, organically enriched estuarine silts above peat mat complexes to the limit of boring at 610 cmbs (20 ft). No radiocarbon dates were obtained from either of these borings. Boring 1R-22.1-ARC-11 was placed about 700 ft to the north of 1R-22.1-ARC-10 in a more interior location. The fill deposits extend to 305 cm (10 ft) at which depth there is a possible intact marsh with preserved vegetation mats to the limit of boring at 610 cmbs (20 ft). A radiocarbon date of 1840±40 (Beta-318415) was obtained from basal peats at 534 cmbs (17.5 ft). In summary the Group 3 borings indicate the potential for intact pre-contact period cultural deposits beginning at 305 cmbs (10 ft) that could extend into the early historic period (GRA 17-18,24-25).

The results of the geoarchaeological soil borings indicate the potential for intact land surfaces associated with Pleistocene-Early Holocene age shoreline and marsh environments. In the area of 1R-22.1-ARC-5 and 1R-22.1-ARC-6, along the southern portion of the alignment alternate, the sensitive strata could begin at approximately 220 cmbs (7 ft). Sensitive strata in other portions of the alignment are identified beginning at 305 cmbs (10 ft). Since the vertical pipeline APE will be constructed at a depth no greater than 220 cmbs (7 ft) along this alignment alternate, no Phase IB archaeological survey is recommended.

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Elquist, Ora, Suzanne Cherau, Nichole Gillis, and Gregory R. Dubell

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Elquist, Ora and Suzanne Cherau

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2011c *Archaeological Overview Survey, Addendum #3 to Technical Report, New Jersey-New York Expansion Project, Staten Island and Manhattan, New York.* Submitted by PAL, Inc. to Spectra Energy Transmission, LLC, Jersey City, NJ.

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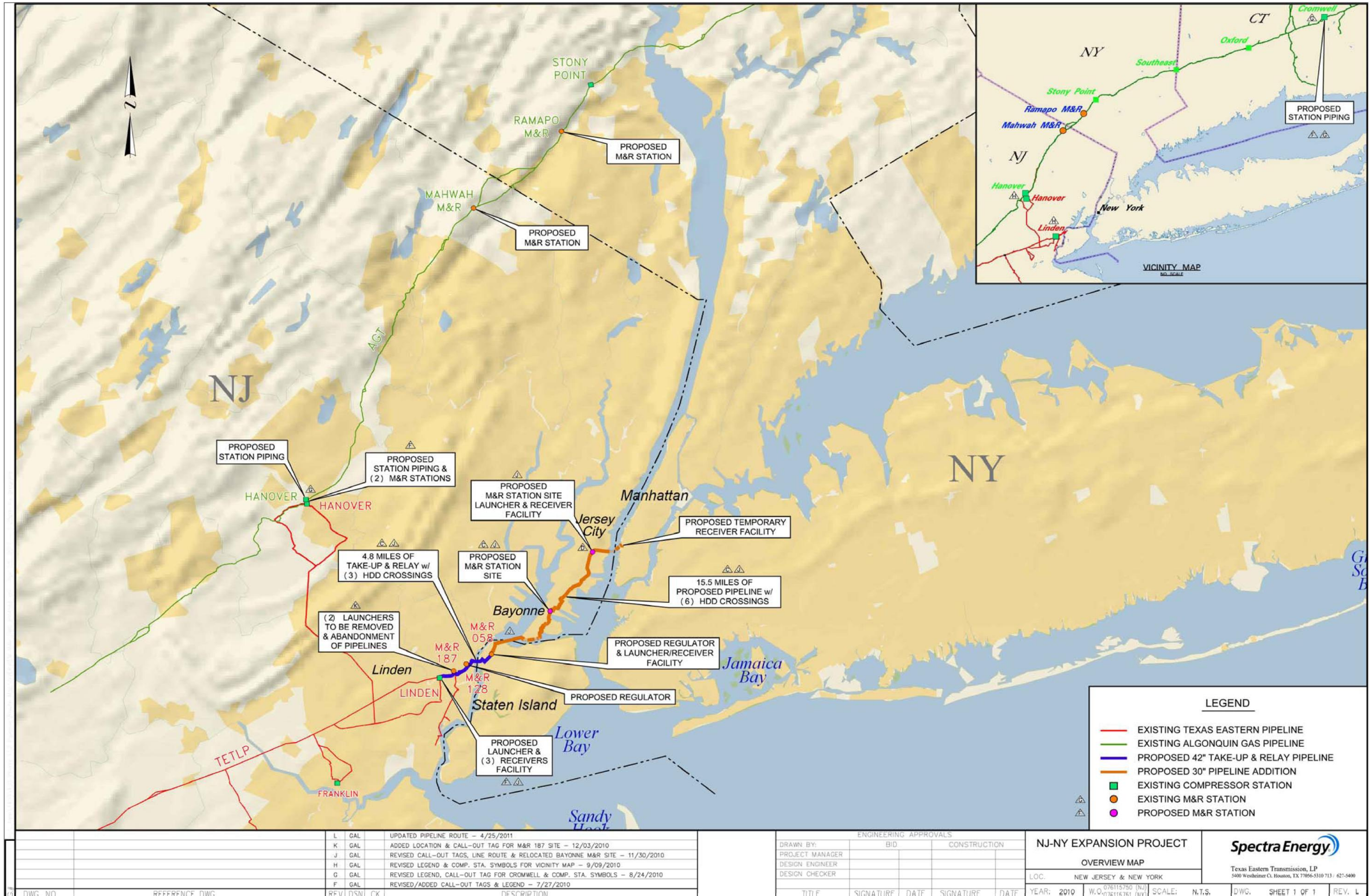

Figure 1. Overview map showing the various locations of the NJ-NY Project.

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Figure 2. NJ-NY Expansion Project, showing the locations of completed geoarchaeological soil borings within the 380 Development Property, Staten Island, NY, on the Arthur Kill NJ USGS quadrangle, 7.5 minute series .

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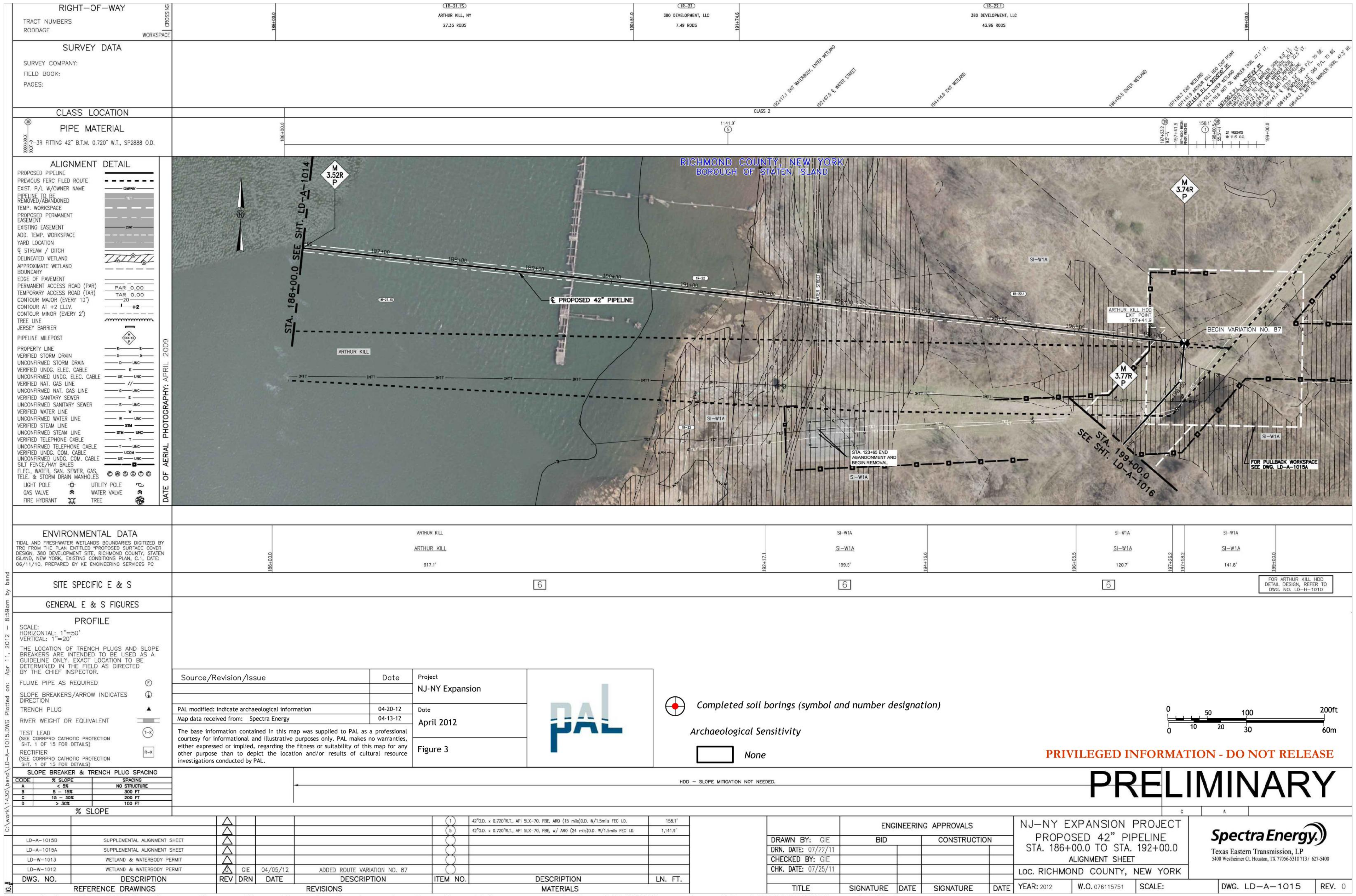

Figure 3. Location of 380 Development Property Route Alternative showing archaeological sensitivity assessment in deep drill (HDD) area, Staten Island, NY, NJ-NY Expansion Project.

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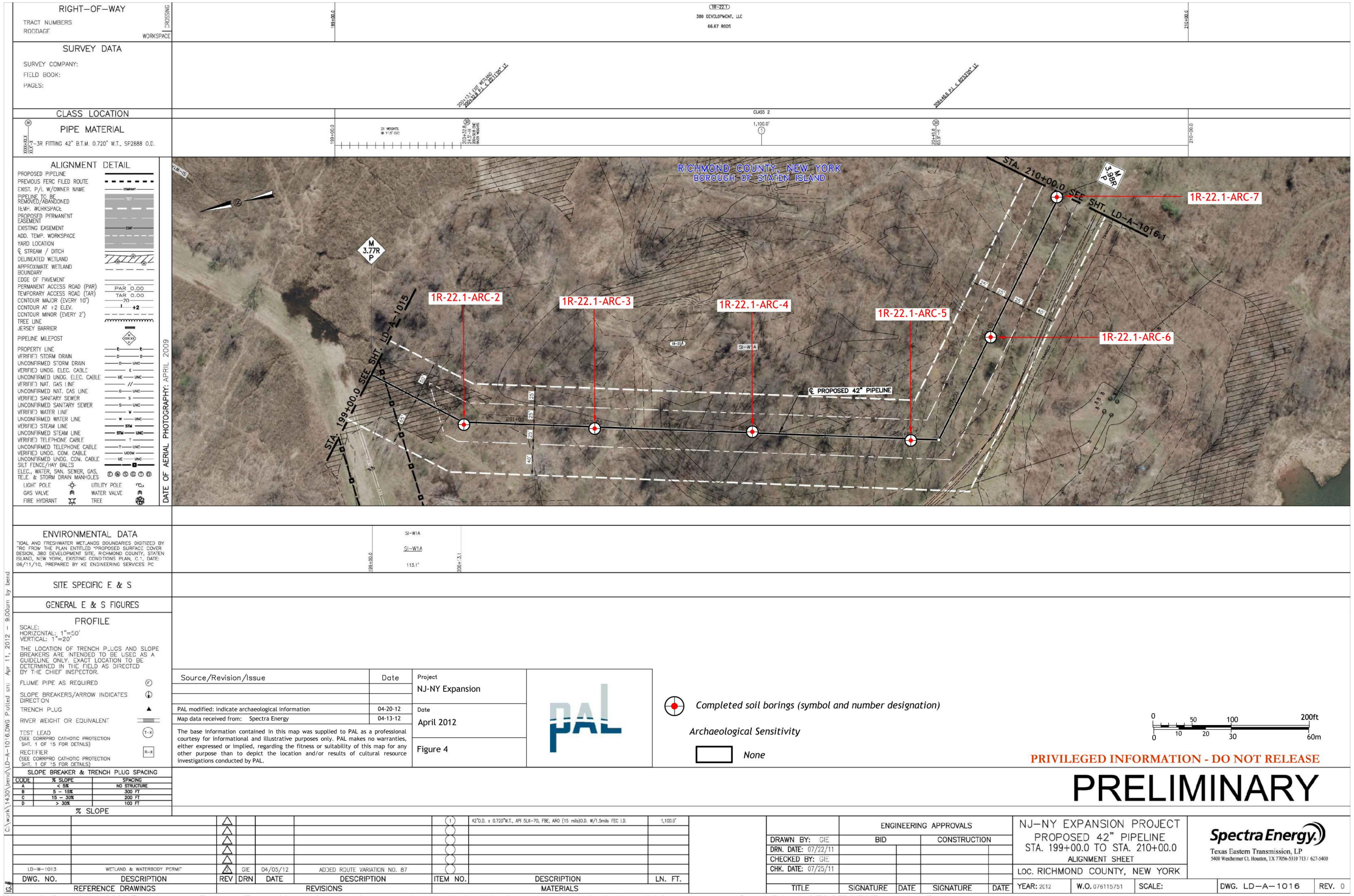

Figure 4. Location of 380 Development Property Route Alternative showing geoarchaeological soil borings and archaeological sensitivity assessment, Staten Island, NY, NJ-NY Expansion Project.

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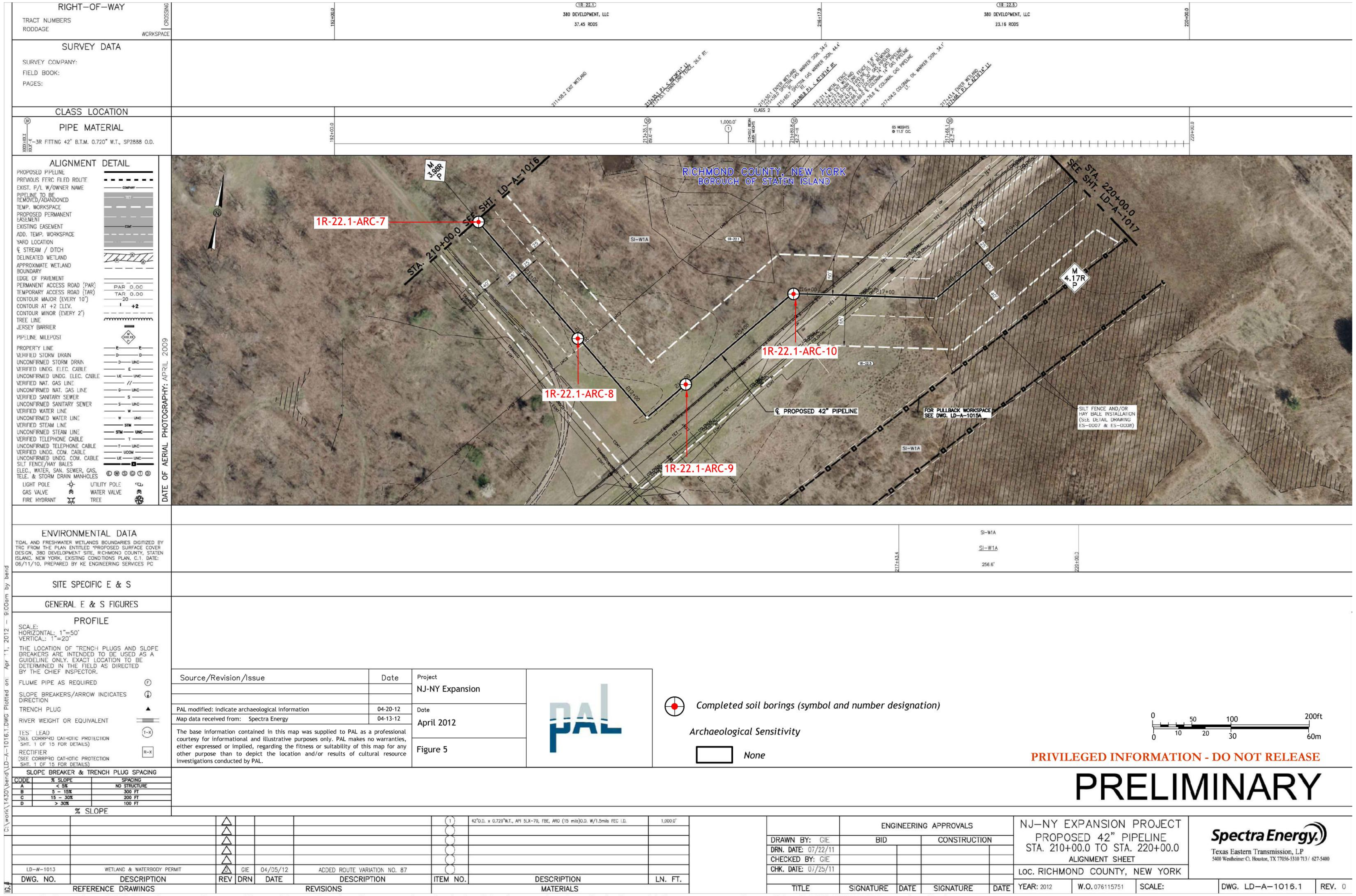

Figure 5. Location of 380 Development Property Route Alternative showing geoarchaeological soil borings and archaeological sensitivity assessment, Staten Island, NY, NJ-NY Expansion Project.

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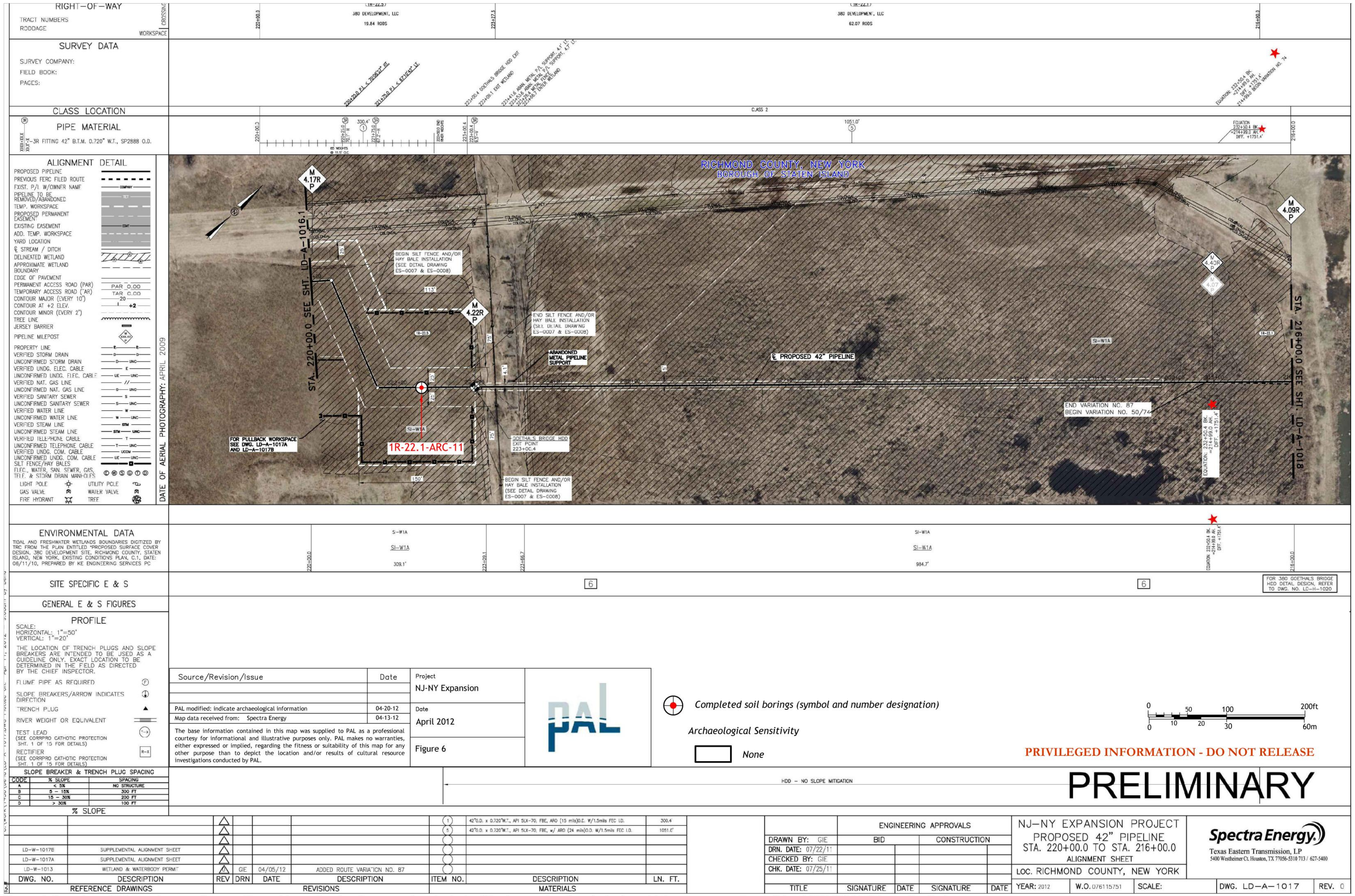

Figure 6. Location of 380 Development Property Route Alternative showing geoarchaeological soil borings and archaeological sensitivity assessment, Staten Island, NY, NJ-NY Expansion Project.

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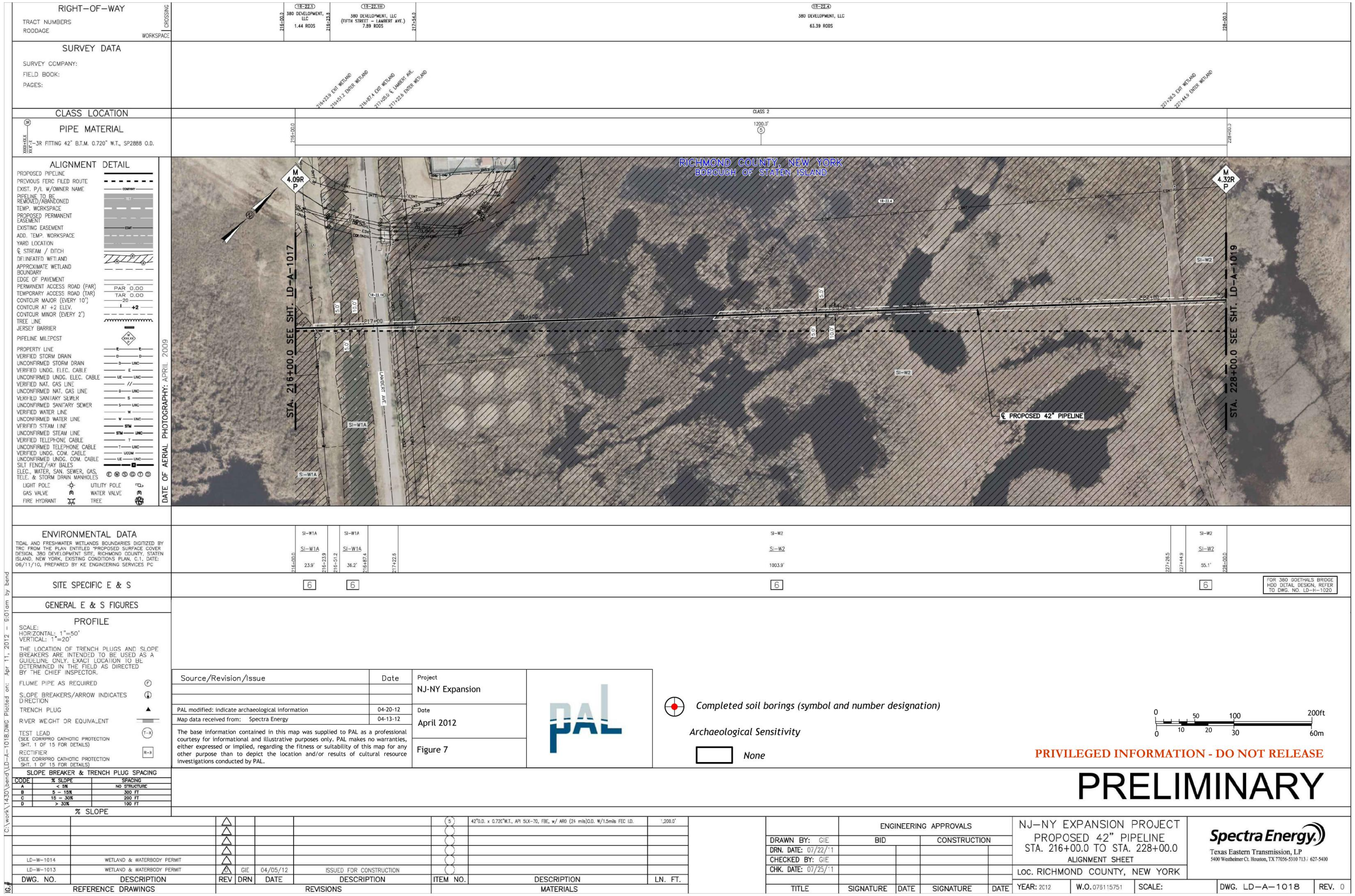

Figure 7. Location of 380 Development Property Route Alternative showing archaeological sensitivity assessment in deep drill (HDD) area, Staten Island, NY, NJ-NY Expansion Project.

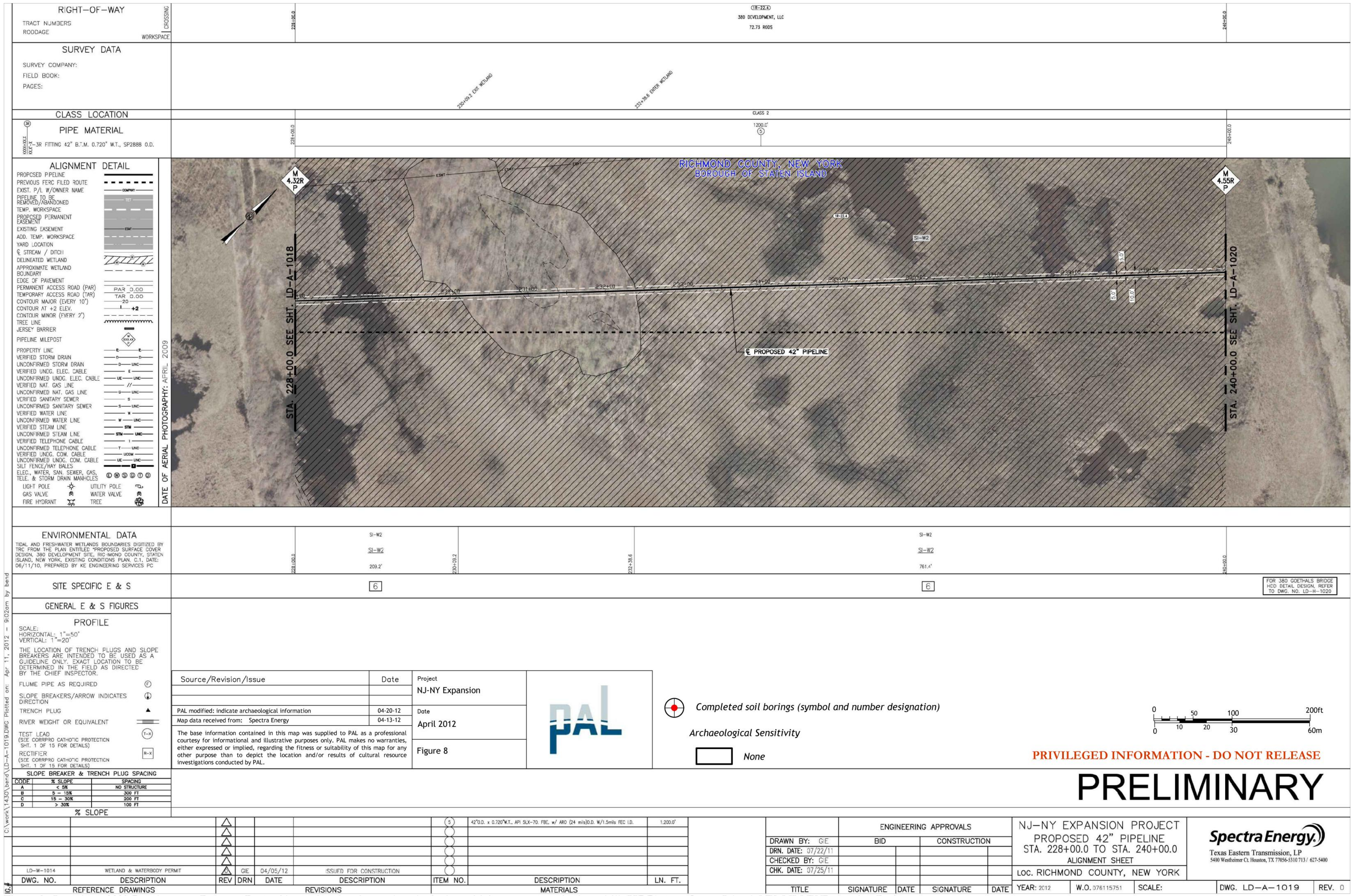

Figure 8. Location of 380 Development Property Route Alternative showing archaeological sensitivity assessment in deep drill (HDD) area, Staten Island, NY, NJ-NY Expansion Project.

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ATTACHMENT A

GEOARCHEOLOGY RESEARCH ASSOCIATES – SOIL BORING REPORT #6

PRELIMINARY REPORT:
"PRE-ANALYSIS" RESULTS OF GEOARCHAEOLOGICAL INVESTIGATIONS
PHASE 1A
NJ-NY EXPANSION PROJECT
ROUND 6
FEBRUARY-APRIL 2012

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April 4, 2012

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1. INTRODUCTION

This report presents the preliminary results of field investigations conducted over the interval February-March, 2012 for the NJ-NY Expansion Project. Geoarcheology Research Associates (GRA) of Yonkers, New York was contracted by Public Archaeology Laboratory (PAL) of Pawtucket, Rhode Island to conduct a geoarchaeological study along a proposed pipeline corridor for Spectra Energy Transmission, LLC. This study presents a summary of a sixth round of fieldwork and preliminary results for the project area. A first round produced a comprehensive report of the first thirty-two (32) cores examined for geoarchaeological purposes (GRA, 2011a). The second round documented the findings of an additional fourteen (14) cores (GRA, 2011b) and the third round examined thirty (30) cores (GRA, 2011c). The fourth round initiated reporting efforts for 2012 and provides the results of four (4) cores (GRA, 2012a) while the fifth round reported on two (2) additional cores (GRA, 2012b). The present effort documents core retrieval at ten (10) new locations. As in the case of the earlier reports, this document is a "pre-analysis" report that assembles the stratigraphy of subsurface deposits to the degree that technical field studies permit. The geoarchaeological study is being undertaken to develop a probability model for the Phase IB archaeological survey. By conducting a systematic survey involving comprehensive sub-surface exploration, GRA is providing a working schema of subsurface stratigraphic relations in this project's areas of potential effects (APE). The project impact area spans urban areas known for dense, complex, and deep archaeological and historical deposits.

The locations tested and reported herein are distributed exclusively in Staten Island (Richmond County), a borough of New York City. The pipeline route currently extends over 20.3 miles and the locales sampled in this sixth round of fieldwork were selected because they traverse terrain of potentially high archaeological sensitivity. The project alignment is segmented and irregular over this portion of the project area (see Figure 1). Accordingly, the main alignment shifts from Northeast-Southwest, then Northwest-Southeast, and finally Southwest-Northeast, over a span of approximately 0.44 miles (0.7 km), or about 2.2% of the extant length of line. These directional alignments represent discrete groupings for the series of cores. The ten (10) borings were excavated within a single (1) property in Richmond County, New York (Figure 1). The cores are identified as the "1R-22.1-ARC" series. Preliminary hand auguring typically preceded machine (Geoprobe) drilling for the uppermost six feet (180 cm). Cores typically extended to a depth of 20 feet (610 cm), with isolated exceptions, and encountered complex stratigraphic sequences of fill, buried historical surfaces, possible prehistoric surfaces, and underlying natural, unconsolidated geological deposits. A critical objective of the study was the identification of the range of Late Quaternary environments associated with the prehistoric and historic settings of potential sites along the length of line. In this connection, we report on the results of eight (8) radiocarbon dates for particularly critical locations with significant potential for recovering information on historic and prehistoric settlement and paleoenvironments.

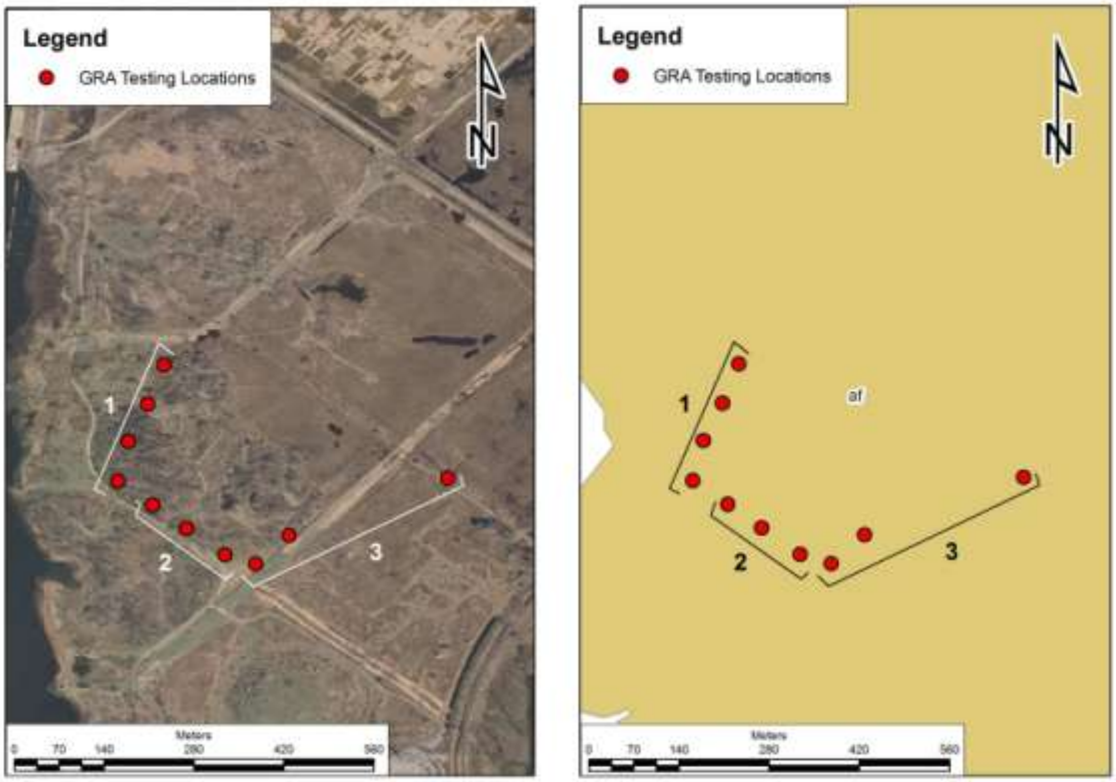

Figure 1. Aerial imagery alongside surficial geology map of project area with grouped core locations. Cores belong to the 1R-22.1-ARC series. (Source: NYS Museum / NYS Geological Survey 1999).

This preliminary report presents baseline results of this initial investigation. A thorough overview of the geological setting of the region is presented, with a particular focus on landscape history along the project corridor. A methods section follows, which details both field and laboratory techniques. Particular attention is accorded to the interpretive potential of deep coring for the development of paleolandscape reconstructions and models of archaeological probability.

Appendix A is a map of the surface geology of Staten Island. It serves as a baseline reference for geoarchaeological contexts of the sediments that were penetrated by the Geoprobe. The detailed sedimentology for each core is presented in Appendix B along with photo mosaics of the opened cores. Results of the radiocarbon assay are documented in Appendix C. More generalized descriptions of the cores are detailed in the results chapter. Preliminary recommendations of the potential for buried archaeological deposits conclude the document.

Included in the recommendations is a protocol for specialized laboratory studies that should be undertaken in support of developing a paleolandscape model that underpins a robust model of archaeological sensitivity. It should be noted that no special analyses (with the exception of the eight radiocarbon dates) have been conducted to date. As such, the interpretations presented in this preliminary report lack refinements made possible by such analyses.

Finally, it is cautioned that the recommendations presented in this study represent follow up work that would enhance the interpretive potential for reconstructing paleo-environment, site formation histories, and the development of a model of buried site preservation. For this pipeline segment in particular, the possibility of formulating a comprehensive landscape history relevant to well-documented prehistoric complexes in northwest Staten Island (see GRA 2011c) is facilitated by paleoenvironmental studies. That potential was partially confirmed in this study by the radiocarbon results (Appendix C). The results of this report and our earlier studies suggest that a comprehensive follow-up analysis design should be based on a representative sampling of the entire pipeline corridor to maximize information yield and to develop a scientifically sound and cost-effective mitigation strategy.

2. PROJECT GEOMORPHIC BACKGROUND

The entire proposed pipeline corridor, as well as the segment under consideration, is located along urbanized segments of near-shore, tidal, and offshore settings in Upper New York Bay in New Jersey and New York. The Late Quaternary landform history of the New York Bay is a function of bedrock geology and events associated with regional glacial history. The end of the Pleistocene (after 18,000 B.P.) is almost exclusively registered in the surface and subsurface deposits of the coast and near-shore settings of metropolitan New York City and adjacent New Jersey and New York. Variable accumulations of sediment record the region's history of glaciation and deglaciation and corresponding marine based submergence and emergence. Related terrestrial and marine histories reflect the dynamic balance along the glacial margins and shorelines over the course of the past million years.

Regional geological and paleoenvironmental studies are extensive. Relevant research has focused on bedrock geology (Isachsen et al. 1991; Schuberth 1968); late Pleistocene and (to a lesser degree) Holocene surficial deposits (Antevs 1925; Averill et al. 1980; Lovegreen 1974; Merguerian & Sanders 1994; Rampino & Sanders 1981; Reeds 1925, 1926; Salisbury 1902; Salisbury & Kummel, 1893; Sirkin 1986; Stanford 1997; Stanford 2010, Stanford & Harper 1991; Widmer 1964), as well as postglacial vegetation change (Peteet et al. 1990; Rue & Traverse 1997; Thieme et al. 1996) and sea level rise (Newman et al. 1969; Weiss 1974). More recently, there have been detailed studies of archeological preservation potential for the Holocene surficial deposits (GRA 1996a, 1996b; Schuldenrein 1995a, 1995b, 2000; Schuldenrein et al., 2007; Thieme & Schuldenrein 1996, 1998; Larsen et al., 2010) and estuarine sediments (GRA 1999; LaPorta et al. 1999; Wagner & Siegel 1997).

Physiography and Bedrock Geology

The Upper New York Bay is an estuary formed within a valley deepened and widened by the advance and retreat of the Laurentide continental ice sheet of the last Ice Age. Mesozoic-age Newark Group rocks underlie most of the New York Harbor region in New Jersey and extend up the west side of the Hudson River. The Palisades Sill of Triassic-age marks the western shore of the Hudson in the New York City area. The sill is an igneous intrusion into the Newark Group sedimentary rocks. These sedimentary rocks contrast with the Cambrian to Ordovician metamorphic rocks of the New York Group east of the Hudson River. Quaternary-age glacial deposits rest unconformably on the Newark Group sedimentary rocks as well as those of the New York Group.

Pleistocene Glaciation, Chronology, and Landform Development

The unique landscape configurations of the Upper New York Bay are attributable to large-scale geological processes of the last ice age. Until recently, only generic landscape chronologies served as a basis for geoarchaeologically-oriented cultural resources assessments (such as 3DI 1992). Currently, however, the combination of regional geologic mapping by the New Jersey Geological Survey (Stanford 1995, 2002 and, Stone et al. 2002), as well as older regional mapping by the New York State Geological Survey (Cadwell 1989), paleoenvironmental studies (e.g., Carbotte et al. 2004, Maenza-Gmelch, 1997), and geoarcheological investigations (e.g. Schuldenrein et al. 2007, Thieme 2003, Schuldenrein and Aiuvalasit 2011) provide a significantly more refined and chrono-stratigraphically accurate understanding of the late Quaternary geologic history and archeological potential of the Upper New York Bay.

Prior to the terminal Wisconsinan, glaciers advanced across the region at least twice during the Pleistocene (Stanford, 1997; Sirkin, 1986). Both Illinoisan, ca. 128,000-300,000 B.P. (radiocarbon years before present) and pre-Illinoisan, (> 300,000 B.P.) terminal moraines are mapped in northern New Jersey, and these ice advances may be represented by still earlier tills on Long Island (Rampino and Sanders, 1981; Merguerian and Sanders, 1994). Older tills have a "dirty" appearance and can be distinguished from late Wisconsinan deposits by the presence of unweathered mudstone, sandstone, and igneous rock clasts in the late Wisconsinan deposits (Stanford, 1997).

The Hudson-Mohawk Lobe of the latest or Wisconsinan ice sheet advanced to its Harbor Hill terminal moraine by 20,000 B.P. (Sirkin, 1986; Sirkin and Stuckenrath, 1980). The extensive and arcuate shaped Harbor Hills landform marks the final position of the ice advance, links Long Island with Staten Island, and is dated by postglacial radiocarbon dates from northwestern New Jersey of 19,340±695 B.P. in a bog on Jenny Jump Mountain (Stanford, 1997) and 18,570±250 B.P. in Francis Lake (Cotter, et al., 1986). Thieme and Schuldenrein (1998) obtained a similar date of 19,400±60 B.P. from a loamy sediment overlying glacial till along Penhorn Creek in the Hackensack Meadowlands.

During the later phases of the Pleistocene, the hydrography at the glacial margin was dynamic and resulted in a glaciolacustrine landscape that involved cyclic retreats and transgressions of linear lakes that approximated the morphologies of structural valleys. Lakes Passaic, Hackensack, Hudson, and Flushing variously occupied the terrain between Long Island and east-central New Jersey as well as the Hudson valley. In Newark Bay and the lower reaches of the Hackensack and Passaic River valleys, subsurface stratigraphy revealed uniform lake bed sequences beginning with deep, classically-varved pro-glacial sediments (Antevs, 1925; Lovegreen, 1974; Reeds, 1925, 1926; Salisbury, 1902; Salisbury and Kummel, 1893; Stanford, 1997; Stanford and Harper, 1991; Widmer, 1964). Reddish brown muds derived from Mesozoic-age Newark Group rocks form thicker winter layers, while more sandy sediment layers were deposited as the ice melted during the summer. The top of the glaciolacustrine sediment sequence is typically an unconformable contact from 12-30 feet below the present land surface in the Hackensack Meadowlands (Lovegreen, 1974). These same varved silts and clays fill the deeper parts of the incised Hudson valley and are overlain by riverine sands and gravel, which are, in turn, capped by thick marine estuarine muds.

Deglaciation of the Mohawk River lowland between 13,000 and 12,000 B.P. is a key event in the geologic history of the New York Harbor area. Proglacial Lake Iroquois, which occupied the Lake Ontario basin, subsequently drained directly to the Hudson River valley via the Mohawk lowland and added to the volume of pro-glacial Lake Hudson. Researchers disagree on the mechanism, but an outlet through the Harbor Hill moraine at the Narrows was opened at about this same time, emptying Lake Hudson and forming the present Hudson River drainage pattern. Newman and his coauthors (Newman et al., 1969) noted that marine and brackish water filled the -27 m (-89 ft)-deep channel of the Hudson River at 12,500 +/- 600 B.P. (14,830 cal yrs B.P.) as evidenced by marine and brackish marine microfossils preserved at the base of organic silts beneath peat bogs at Iona Island. It is unclear as to whether the erosion of the outlet through the Harbor Hill moraine was gradual or catastrophic as recently proposed by Uchupi et al., (2001) and Thieler et al., (2007). Nevertheless, evidence suggests that flow from the Hudson River eroded a channel and valley across the exposed continental shelf to drain and deposit a delta on the outer shelf at a lowered sea level stand. Most challenging to our understanding of the Hudson River history is the lack of a clear explanation for a direct marine connection between contemporaneous sea level at the edge of the continental shelf and the upper Hudson River valley. More generally, we consider the shelf to have been sub-aerially exposed at this time. Differential isostatic adjustment of the earth’s crust following deglaciation is the most reasonable explanation accounting for down-warping and depression of the crust beneath glacier ice in the north and commensurate uplift of the continental shelf, thereby raising sea level in line with the upper Hudson River channel. Evidence for differential uplift of the crust along the upper Hudson Valley (relative to the New York Harbor area) is based on historic tide gauge data by Fairbridge and Newman (1968), although the complete relationship remains unclear.

The present study relies on an accurate record of relative sea level rise developed for the New York Harbor area by Schuldenrein et al. (2007) for determining the submerged locations of probable prehistoric human habitation areas in the Hudson River channel. That study proposed a model for archaeological sensitivity that would help guide plans to minimize impacts on cultural resources by future marine construction. The attendant construct for sea level rise (Figure 2) is derived from existing and newly reported radiocarbon analyses from nearby submerged environmental settings acquired during baseline New York Harbor and related GRA studies. GRA (Schuldenrein et al. 2007) presented a relative sea level history consistent with “far field” eustatic sea level studies (Fleming et al., 1998). We show a rapid rise in relative sea level at a rate of approximately 9 mm/yr (0.5 inches/yr) from at least 9000 cal yrs B.P. until about 8000 cal yrs B.P. when the rate of rise diminished to a consistent 1.5 – 1.6 mm/yr (0.06 inches/yr), from 7000 cal yrs B.P. until the present. This sea level model is consistent with studies by Bloom and Stuiver (1963) for the Connecticut shore; Redfield and Rubin (1964) for Barnstable, Massachusetts; Belknap and Kraft (1977); and Nikitina et al. (2000) for Delaware Bay as reexamined by Larsen and Clark (2006). Our new model (Figure 2) differs markedly from that presented by Newman et al., (1969) and is proposed herein as a more accurate construct.

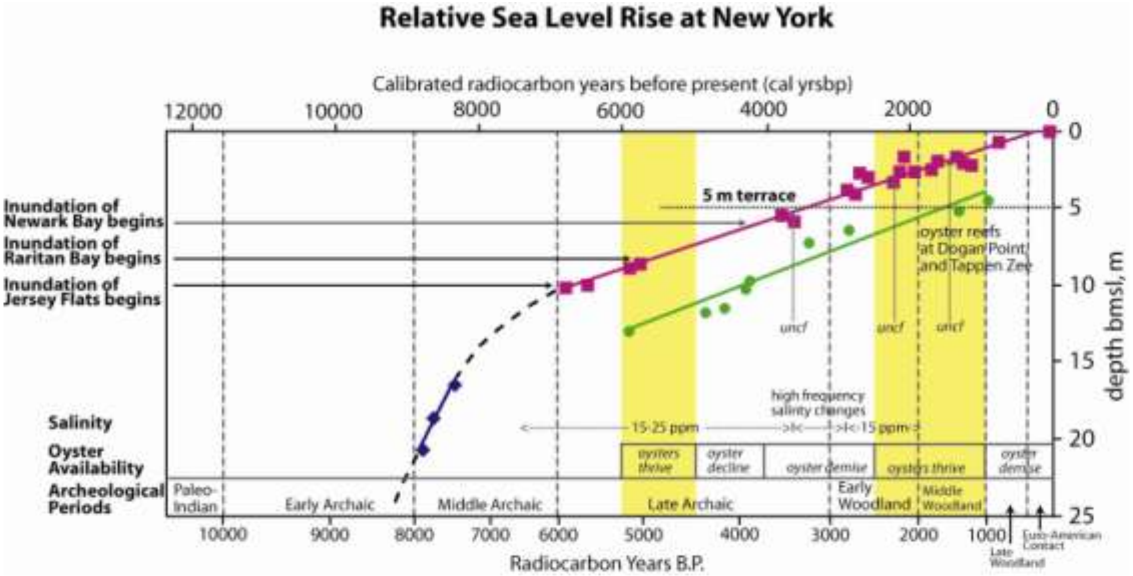

Figure 2. Sea level rise model for New York Harbor (from Schuldenrein et al. 2007).

In general terms, the new relative sea level model can be retrofitted to account for reflooding of the incised Hudson channel and Upper New York Bay as described by Thieler et al., (2007) for the Narrows at ca. 12,000 B.P. (13,875 cal yrs B.P.), as well as for the marine incursion of the upper Hudson Valley and consequent deposition of brackish estuarine sediments. It cannot, however, resolve the differential positions of the incised channel at the Narrows with the proposed delta at the edge of the continental shelf. We show progressive flooding of the main Hudson channel culminating in its present configuration. The area currently known as the New Jersey Flats was initially subject to inundation about 7,000 cal yrs B.P. Oyster reefs formed upriver at Tappan Zee at this time as well, and spread at successively shallower depths following the rising sea level (Carbotte et al., 2004). The latter record of oyster reef growth is consistent with sea level rise as demonstrated by the data points (in green) in Figure 2. The common depth range for the eastern oyster Crassostrea virginica is 8 to 24 feet (2.5-7.2 m). This explains the Tappan Zee oyster growth history which parallels but falls beneath our calculated and contemporaneous sea level curve. Marine water entered and progressively flooded Raritan Bay and Newark Bay about 6,000 cal yrs B.P. Marshes upstream from the present mouth of the Raritan River as well as the nearby Hackensack marshes became increasingly saline after 3,000 cal yrs B.P. and they subsequently evolved into salt marshes.

The estuaries and shorelines along the Upper Bay became the focus of historical Dutch settlement, and eventually blossomed into the sprawling metropolis of New York City. In general, the natural tidal zones and immediate near-shore settings through which the proposed pipeline corridor runs have been wholly reworked throughout the historic period and into the present day. The background literature review for this project conducted by PAL provides a thorough overview of the historical development of the project area with numerous archival maps that show the successive land use of the project area (Elquist et al., 2010a and 2010b).

Expected Geological Sequence within the Project Area

For the initial reports on the NJ-NY Expansion project (ie., GRA 2011a) the assessment of the age and archaeological potential within the geological sequences drew extensively from the detailed surface geology maps of New Jersey (Stone et al., 2002). The present Staten Island segment is in New York State and that state's surface geology map is structured on different mapping units (NYGS 1989; see GRA 2011c). In general, however, the units and, more significantly, the ages of the attendant surface and upper sub-surface deposits are broadly correlative between the two states. For present purposes we draw directly from the digitized New York State surface geology map (NYGS 1989). Data for the map has been generated from two traditional mapping sources: first, the state-wide surface geology map (1:250,000 scale; Cadwell, 1989) and second, a traditional Quaternary map of the Hudson Quadrangle (4° x 6°) (Fullerton et al., 1992).

There is only one surficial deposit mapped formally mapped within the project alignment corridor (Figure 1 and Appendix C). This is the *Artificial Fill* itself ("af" in Figure 1) and it is the most pervasive surface sediment actually registered in the impact zone, as detailed in our results section. Nevertheless, three pre-disturbance units are relevant to the subsurface investigations as these are likely to be encountered in immediate sub-surface contexts (Appendix C and per NYGS, 1999). The two most prominent New York-based surficial units of relevance are *Lacustrine Sands* ("ls") and *Till* ("t"), both of late Pleistocene (glacial) age and formally mapped to the east and south of the core-testing alignment (Appendix C). The third, *Peat Muck* ("pm") is a Holocene to historic age *Swamp Deposit,* effectively a salt-marsh and estuarine matrix, that underlies or interdigitates with anthropogenic fill along much of the alignment. It is stressed that these units must be considered as fundamental basal sediments that can be expected to underlie most core locations. They should not be used to infer either the age or composition of the sediments retrieved from individual cores. This is because of the pervasiveness of fill caps whose depth, composition, and lateral extent were not and could not have been mapped with requisite accuracy, despite the best efforts of the New York Geological Survey (NYGS,1999).

In general the *Till* deposits represent deposition beneath the ice, with sediment sizes ranging from boulder to silt. They are described as "variably textured…..usually poorly sorted sand-rich diamict" (NYGS, 1999). Permeability of the matrices varies with compaction thicknesses ranging from 1 to 50 meters. As in New Jersey, till complexes are non-stratified. Basins carved out by glacial ice resulted in the hummocky to variably graded topography which gave rise to the succession of lakes that emerged after the glaciers retreated.

Lacustrine Sands are most typically encountered as well-sorted quartz sand complexes, often stratified and usually laid down in pro-glacial lakes. However, the sands may also have been accreted on remnant ice as a near-shore facies, or even near a sand source. Matrices are permeable and thicknesses are highly variable (2-20 meters). Exceptions to classic lake basin sedimentation proliferated, with deltas registering on the margins of the previously described pro-glacial lakes. While the lake basins infilled with fine grained sediments, coarser deposits of sands and silts were laid down along the peripheries. Undifferentiated marine and lacustrine sand bodies have also been identified (NYGS 1999) as near shore deposits at or below the highest marine levels, where they may include fossil shells. In this connection finer grained sediments, silts and clays, may also proliferate along the margins of the pro-glacial lakes; the fines are often calcareous. Delta sediment bodies have been recognized as coarse to fine gravel and sand depositional strata, stratified and well-sorted along the ancient lake shoreline, again with variable thicknesses (3-15 m).

Finally, the *Swamp Deposits*, equivalent to the Salt-Marsh and Estuarine deposits utilized in the New Jersey reports (GRA 2011a, b; per Stone et al., 2002) are dominantly organic silts and sands in poorly drained reaches (along the coastal edge to the west). They are characteristically unoxidized, and will often overlie marl and lake silt with thickness of 2-10 m. It remains unclear as to whether or not these underlying “marl-type” complexes represent Holocene basins or, as is probably the case, they represent primary or reworked depositions of Pleistocene antiquity.

3. METHODS

Designated sampling intervals for baseline core placements were agreed upon by the State Historic Preservation Officer (SHPO) of New York. For New York the sampling interval was set at one test boring every 300 feet (90 m). An underlying hypothesis is that for any comparative study this interval should accommodate comprehensive project-wide reconstructions.

On the ground, spacing intervals had to be modified because of logistical concerns. In some cases boring locations were judgmentally re-spaced to evaluate settings and substrate associated with particular features, known locations of critical archaeological sites, and paleo-environmental settings that were both rich and varied, despite their burial beneath significant accumulations of fill. Among the primary archaeological sites in the general area, to the northeast, are the Old Place prehistoric locus, Bowman's Brook, and the Bowman's Brook North sites (see GRA 2011c). Additional considerations included questions of representative sampling and in-field circumstances such as accessibility and presence of buried contaminants. In all cases of re-spacings, resolution was obtained through negotiations with Spectra Energy and PAL. The boring locations and precise placements were mapped by a team of surveyors contracted by Spectra Energy. Most in-field adjustments to boring proveniences resulted in locational modification of no more than 5-10 feet from the originally designated placements. Remote sensing for buried utilities or obstructions was conducted at testing localities by Spectra Subsurface Imaging, LLC of Latham, NY. Their surveys augmented background subsurface map reviews by utility companies, property owners, and utility identifications by the One-Call Service. Remote sensing provided an additional control delimiting the presence and orientation of subsurface utilities and features. For this segment of line, the total of ten (10) cores emplaced along the 0.44 mile (0.7 km) traverse resulted in an average spacing of one (1) core per 230 feet (70 m), a sampling interval that exceeded minimal requirements by 23% and enhanced the effectiveness of the coring procedure substantially.

Subsurface excavation for the GRA study was performed by a Geoprobe™ boring device, operated by LAWES, Inc. of Center Moriches, NY. The Geoprobe™ is a hydraulically driven, mechanical track-mounted device that extracts cores that can be collected in stratigraphically intact sections within plastic sleeves (Figure 3). These sections are either examined in the field and/or sealed, collected, and described under controlled laboratory conditions at a later date.

For this project, cores of approximately 2 ½ inch (6 cm) diameter were collected in 5 foot sections (145 cm) to depths of up to 20 feet (6 m) below ground surface. During this round of investigations, the upper 1-6 feet (0.3-1.8 m) of each boring was extracted with the use of a hand augur and soil-sediment descriptions were made directly. This protocol was followed because of the hummocky terrain and topographic variability of the impact area, that did not allow for easy access to potentially sensitive archaeological settings. Hand auguring resulted in more precise recovery and more detailed observations. More precise inspections of the soil and sediment properties enabled the geoarchaeologists to preview the composition of potentially sensitive historic sediments. In advance of the final Geoprobe coring program two locations were hand augured to assess the geoarchaeological integrity of the substrate (Figure 1, locations A and B).

Safety gear included the use of protective eye-wear, hard-hats, steel-toed boots, neoprene gloves, and reflective safety vests. A trained environmental geologist employed by TRC, Inc. took sediment samples for characterization of contaminants, and ran a photo ion detection (PID) meter over the samples to test for volatile organic compounds. The in-field examinations of the cores were guided by health and safety procedures regarding the handling and collection of the cores.

Standard protocol calls for the core sleeves to be sealed in the field and transported to GRA's lab facilities. The 380 Property cores often contained significant levels of contaminants, such that much of the inspection of the Geoprobe cores was done in the field (Figures 4 and 5), together with photographic documentation and initial soil and sediment characterizations. Sampling for special analysis was performed under field conditions, although key specimens for dating and related analyses were identified, recorded, sampled and taken to the laboratory for detailed inspection and preparation for shipping to appropriate outside laboratory facilities. The cores were described using standardized pedo- and litho-stratigraphic terminology (ISSC 1994; USDA 1994). Samples of historical artifacts as well as soil samples for possible age determinations by radiometric analysis were collected. Upon full documentation of the cores and sample collection, the discarded sediment and soil fractions were either bulked in 55-gallon drums (when taken to the GRA facility) or transferred into the core hole. Upon completion of the project any bulked and stored specimens are sampled and characterized for contaminants; they are ultimately transported to a disposal facility.

Finally, it should be noted that full recovery from each core segment was rarely achieved. This is typical, as highly variable conditions of the substrate can result in inadvertent sediment loss upon recovery. These conditions include the presence of an elevated water table, uniquely unconsolidated sediments, and dramatic changes in sediment texture. Based on GRA's general experience working with this technique (Schuldenrein 2006, 2007), as well as regional conditions, the team has developed a method for extrapolating both the thicknesses and depths of deposits.

Figure 3. Field collection of cores.


Figure 4. Core samples prepared for in field documentation.

Figure 5. Split cores documented and sampled in the field by GRA field staff.

4. PRELIMINARY RESULTS

The ten (10) cores from this round of field investigations (February-March 2012) extend along three major segments as follows: (1) an initial Northeast-Southwest core alignment of 0.13 miles (0.2 km)(n=4); (2) a central Northwest-Southeast alignment of 0.1 miles (0.15 km) (n=3); and finally (3) a Southwest-Northeast segment of 0.2 miles (0.3 km) (n=3).

The segments may be further subdivided into landform properties and ***groups*** on the basis of the uniformity of core-spacings, terrain breaks, and universal boring tracking number. The surface geology map shows that the three alignments and groups traverse a single surface geology unit, artificial fill ("af"; NYGS 1999), such that more refined, differentiated, and accurate terrain elements are visible directly on *Google Earth* imagery. Thus the individual ***groups*** and their attendant core distributions are depicted on the landscape in Figure 6.

Across the project area topography is hummocky and landscapes are dominated by coastal meadows with tall marsh vegetation bounded by sections of unpaved roadway. NRCS (2005) mapped area soils as *Laguardia-Ebbets-Pavement and Buildings, Wet Substratum Complex* (NRCS 2005; PAL 2010). The *Laguardia-Ebbets Complex* consists of a mixture of natural soil minerals and construction debris over tidal marsh.

No archaeological sites have been found along the proposed pipeline pathway, but several pre-contact sites have been recorded in the vicinity: the Old Place site (one of the best preserved prehistoric sites in the Northeast, situated 1.5 km to the north-northwest); the Beulah Point or Bloomfield Watchogue site (NYSM 7324); and an unnamed site of indeterminate character (Elquist et al, 2001; Boesch 1994). Recent archaeological assessments of the area suggest that jasper, chert, and argillite debitage recovered in the area between Goethals Bridge Road North to the west, Gulf Avenue to the south, and Western Avenue to the east are likely related to the Old Place Site or associated prehistoric complexes (HAA 1995; Louis Berger Group 2007: 83; PAL 2010).

The basis for this geoarchaeological assessment is grounded on three sets of observations: in-field landform and topographic observations, preliminary inspection and classification of sediment properties and stratigraphy, and radiocarbon dating of plant material recovered from key organic horizons. The local conditions that factor into assessing buried site potential in the substrate are based on integrity, previously documented and field tested regional stratigraphies, and finally design plans specifying depth of the planned impact zone.

Lithostratigraphic descriptions of the individual cores with accompanying photographic documentation are presented in Appendix B. The following account details the observations for the set of borings by core alignments and groupings.

380 Development Property – *Staten Island, NY*
(Group 1: 1R-22.1-ARC-2, 1R-22.1-ARC-3, 1R-22.1-ARC-4, 1R-22.1-ARC-5)

The four (4) cores in Group 1 are located in a northeast-southwest line along the western edge of the 380 Development property. In all cases but one, 1R-22.1-5, fill composition and stratification was apparent and extended to depths on the order of 16 ft. Four (4) radiometric dates were obtained within estuarine or estuarine-derived peats at depths ranging from 16 to 20 ft. and within a range of 400-2750 B.P. In the case of 1R-22.1-ARC-2 a stratigraphic inversion was noted with a determination of ^{14}C 390±30 B.P. (Beta-318413) underlying the same matrix that produced a date of ^{14}C 1580±30 B.P. (Beta-318407). A unique and anomalous silty clay lens (2.5 YR 4/4) underlay the peat and featured an irregular consistence. The radiometric inversion coupled with the unique clay lens provided preliminary indications that the peats may have been redeposited either by lateral settling or by larger scale, possibly even historic period reworking.

More definitive contextual properties (ie. structures or inclusions) were not apparent and obviated determinations of primary late Holocene reworking or redeposition by filling. There remains the possibility that an intact natural sediment may signify an early contact or terminal prehistoric surface along the edges of this estuary. Within this core complex, 1R-22.1-ARC-5 provided the most compelling evidence for preservation of a pristine estuarine to near shore depositional transition. A radiometric determination of of 2730±30 B.P. (Beta-318414) within a 0.3 m thick dense peat is consistent with long term marsh sedimentation and the depth to fill is <7 ft. (±2 m). Additionally, the overlying and underlying matrices preserve a well stratified near-shore sand to peat complex.

1R-22.1-ARC-3 and 1R-22.1-ARC-4 are dominantly fill-based locations (fill >15 ft), with either deep fills (in the case of 1R-22.1-ARC-4) or direct interface between deep fills and the natural peat (1R-22.1-ARC-3). 1R-22.1-ARC-3 has a product saturated admixture of heterogeneously textured fills (0-15 ft.; poor recovery) immediately overlying (probable) thin peat liner; fibrous peats to base are of possible natural origins (16-20 ft). 1R-22.1-ARC-4 has upper sediments that are an admixture of fills with anthracite coal and oyster shell fragments as a classic exogenous component (0-7 ft.). Underlying peat is probable artificial liner. Massive to weakly stratified sands and silty clay loams represent older filling (to 15 ft.; note product component). Downward coarsening sands represent (probable) primary fluvial facies from 15-20 ft.

Summarily, location 1R-22.1-ARC-5 occupies a probable intact marsh setting, probably flanked by a distal, well drained, and formerly near shore location. 1R-22.1-ARC-2 may represent a similar setting, but the inverted dates may pose an interpretive problem. The settings are consistent with potentially intact prehistoric loci at the margins of the late Holocene marsh.

380 Development Property – *Staten Island, NY*
(Group 2: 1R-22.1-ARC-6, 1R-22.1-ARC-7, 1R-22.1-ARC-8)

The three (3) cores in Group 2 are oriented in a northwest-southeast line in the southwest corner of the 380 Development property. 1R-22.1-ARC-7 and 1R-22.1-ARC-8 are similar to 1R-22.1-ARC-3 and 1R-22.1-ARC-4 from Group 1: both cores consist of nearly identical strata, with sandy fills transitioning to peat below 18 ft. 1R-22.1-ARC-6 has sandy-clay fill (to 6 ft.) that passes to a complex of alternating lenses of moderately well sorted sands, loamy clays and firmer clay plugs. 1R-22.1-ARC-7 consists of a sandy loam to gravel and sandy fill cap (0-6 ft) underlain by fine (clay loam) matrices above 15ft. and then sands (15-18 ft.) that form an unconformity with a natural peat horizon (18-20 ft). 1R-22.1-ARC-8 features clast-dominant to clast-supported fill sands that become product-enriched with depth (12.5-15 ft.) and are underlain by wet sands and peats. The peat was dated at one site in this group (1R-22.1-ARC-7) to 390±30 B.P. (Beta-318405), a context that would appear to be intact since underlying marsh peats preserved an optimal vegetation mat that displayed increased disaggregation upward. Evidence of a macro-setting is not clear as there is no visible topographic gradient. Accordingly, there is no evidence of either an elevated landform or sediment complexes (ie. sands) associated with a significant topographic break in the terrain. The latter would signal the potential presence of late prehistoric or Euroamerican sites overlooking the marsh basin.

The complex of clearly stratified shoreface sands and estuarine muds would have comprised an alternately dynamic and stable setting at the location of 1R-22.1-ARC-6. Here, however, compromised core recovery impeded unequivocal interpretations of depositional contexts. A radiometric determination of ^{14}C 2930±40 B.P. (Beta-318408) occurred in sub-tidal alluvial or nearshore context (at 10 ft.) is compelling. However, here again, the sediment may be re-deposited since an underlying burnt ^{14}C sample (±15 ft.) produced a younger date of ^{14}C 1950±30 B.P. (Beta-318404). The profile exhibits stratigraphic similarities with 1R-22.1-ARC-5 such that its integrity may be equivocal. A mitigating factor here is that nearly 2 m of entraining shore-face and near-shore sands signify a dynamic geomorphic environment where stratigraphic inversions can be expected and are fully consistent with localized sediment displacements.

380 Development Property – *Staten Island, NY*
(1R-22.1-ARC-9, 1R-22.1-ARC-10, 1R-22.1-ARC-11)

The three (3) cores in Group 3 are located in the eastern part of the 380 Development property and are oriented southwest-northeast. 1R-22.1-ARC-9 and 1R-22.1-ARC-10 both contain deep sandy fills (with potential product concentrated between 10-15 ft) that extend to extend to pristine, organically enriched estuarine silts above peat mat complexes. 1R-22.1-ARC-9 consists uniquely stratified historic fills above product-enriched fines (10-13.5 ft.), that cap the estuarine matrices. At 1R-22.1-ARC-10 upper sediments represent fill intermixed with estuarine marsh fines that includes increased product component with depth (0-14 ft.); here the matrix grades conformably to probable natural marsh and peat deposit (15-20 ft.) with interdigitated sands,

> 1R-22.1-ARC-11 occupies a distinctly distal interior location. Here the upper sediments (0-10 ft.) feature shallow historic fills, probably representing localized reworking of tidal/estuarine matrices. Fill overlies possible intact historic marsh with preserved vegetation mats (10-20 ft. bgs). At 1R-22.1-ARC-11, basal peats (17.5 ft) yielded a determination of ^{14}C 1840±40 B.P. More critically this is a homogeneous peat complex that extends upward and intact for an additional 3 m (± 10 ft.) signifying uniform peat deposition, possibly into Euroamerican times. The matrix is sealed in by an alluvial cap. This setting had significant relief in the prehistoric past and offers a strong possibility for the preservation of intact deposits of Late Archaic to Euroamerican age.

Figure 6. Core locations on 380 Development Property – Staten Island, NY.

5. GEOARCHAEOLOGICAL INTERPRETATIONS AND RECOMMENDATIONS

This sixth round of GRA investigations is an assessment of the potential for locations in northwestern Staten Island to house deeply buried archaeological sites. The approach applied for this assessment is unique for two reasons. First, it examines subsurface potential for an alignment segment that spans only 0.44 miles. Second, this portion of the alignment traverses terrain that, while disturbed, is nevertheless in close proximity to some of the most sensitive archaeological terrain in New York City. The latter concern is especially true for the prehistoric component of the cultural resources, since Staten Island generally, and this (northwest) portion of the island in particular, houses intact and stratified alluvial successions that are among the oldest in the Northeast. Towards this end we have generated archaeological sensitivity assessments based both on our interpretations of subsurface geological integrity and antiquity (Tables 1 and 2) as well as proximity of core locations to the more prominent prehistoric sites in the vicinity of the alignment. For historic components, guidelines for sensitivity are based on known cultural resources (see PAL 2010) bolstered by evaluations of discrete fill components that conform to debris types that would be expected from the documented historic properties.

As in the case of earlier studies (GRA 2011a, b, c; GRA 2012 a, b) it is emphasized that these recommendations are relevant to the immediate vicinities of the coring locations, and they should not be extrapolated to adjoining properties or tracts beyond the sampling interval of the boring program. The recommendations are based on close-interval sampling schemes and it is expected that the reliability of these recommendations is high. As noted, for New York State that interval is 300 feet (90 m). Nevertheless, the recommendations are proposed largely without the benefit of additional laboratory analyses. For this study, radiocarbon dating was undertaken at eight (8) contexts but we have not established an absolute chronology for landscapes (radiocarbon dating), nor do we have unequivocal evidence for reconstructing conclusive depositional histories for the extent of the alignment. To do so would require additional analysis bearing on landform origins (sedimentology and micromorphology), and reconstructing vegetation and climate (palynology and stable isotope studies). Such analyses will be performed at locations deemed paleo-environmentally sensitive, pending protocols determined in agreements between PAL and the New York State Office of Parks and Recreation (NYSORP).

For the greater project area, as well as for individual project tracts, the formulation of a chronology of deeply buried sequences would refine our archaeological sensitivity model. In many cases, there is not enough difference in the physical characteristics of deposits—as manifest in the limited exposure furnished by cores—to differentiate between sediments with archaeological sensitivity and deposits which pre-date human arrivals. We do know, for example, that there is a significant gap between the end of Pleistocene sedimentation in the project area and the known period of human activity in this part of the world. In yet other situations, refinement of depositional environments (through paleo-ecological analysis techniques) would allow for reconstructions with sufficient data to establish the types of sites that might be expected in certain settings.

In practical terms assessments of sensitivity were determined by planned depth of impact, per project design, and specifically the depth of pipe installation. Towards that end, “historic fill” columns that extend beyond 15 ft. preclude a location from further testing. Additional considerations in sensitivity assessments include investigator familiarity with the age and type of the natural substrate. Thus, the immediate subsurface beneath the fill can be expected to be a peat or a thin veneer of alluvium. Where alluvium or weathered soil is encountered above 15 ft. there is a potential for archaeological preservation. Where peat that dates to pre-contact or contact times (i.e. date of ±400 B.P.) is encountered there is some potential for recovering prehistoric or contact area materials. Late Holocene dates may indicate archaeological potential, with the caveat that in isolated instances determinations may be demonstrably associated with fill layers. In such cases, further testing may not be warranted.

Finally, the following provisional assessments of archaeological preservation along this alignment are based on the coring program and the stratigraphies preserved at the three core groups under consideration.

Tables 1 and 2 summarize the recommendations for follow up work for each of the five groups along the alignment. These tables justify our recommendations on the strength of preliminary examinations of core sequences.

Table 1 presents general assessments of archaeological sensitivity on a core-by-core basis. Historic and prehistoric resource potentials are considered separately for each core. Rankings are assessed on a relative basis, according to “high”, “medium”, and “low” levels of sensitivity (column 3). Stratigraphic and sedimentological evidence in support of the rankings are presented in the last column.

Table 2 specifies the locations in which follow up work is recommended on the basis of formal geoarchaeological criteria. These geoarchaeological criteria are structured around baseline stratigraphies and chronologies. Accordingly, columns 3 through 8 detail the six (6) geological units that accommodate the sequences recorded in the entire population of cores. As shown, these units grade from youngest to oldest (left to right) and include: (1) Deep/Mixed Fill; (2) Discrete Fill; (3) Buried Soil; (4) Estuarine/Peats; (5) Shore facies; and (6) Till. The units have unique properties in determining archaeological potential for Historic and Prehistoric sites respectively. We consider each.

Historic Units. Units (1) and (2), the fills, represent historic deposits associated with land clearing activities and can extend from the 17^{th} through 21^{st} centuries. Most large scale clearance dates to the late 19^{th} century and subsequent. While fill is widely considered to have limited archaeological potential, we separate category (2), Discrete fill, as indicating degradation of a particular feature or episode of destruction that can be linked to a known historic structure. In that sense the Discrete Fill may represent a context favorable for yielding intact archaeological remains.

Prehistoric Units. Units (3), (4), and possibly (5) are contemporaneous with prehistoric occupations and resource environments. Thus they will invariably date to the last 10,000-12,000 (Holocene). Buried soils (3) are considered likely to contain prehistoric surfaces because they register stable environments of the Holocene. The category classed as Estuarine/Peats (4) are rich biotic settings which functioned as subsistence environments that would have attracted prehistoric peoples. Shore facies (5) are not well dated in Staten Island and may be of Pleistocene or Holocene age. Thus, they have some potential for containing prehistoric deposits. Till (6) is of late Pleistocene age and probably pre-dates prehistoric occupation.

In sum, it follows that sealed geological deposits of an age contemporaneous with human occupation are excellent indicators of buried cultural resource potential. For historic sites the optimal geological unit is (2) as it contains evidence for unique historic activities in a sealed sediment matrix. For prehistoric sites primary preservation contexts for archaeological materials include units (3) and (4).

In addition to sealed geological deposits, the archaeological sensitivity of a core location is enhanced by its proximity to known archaeological sites (column 9). Finally, the absolute dating of buried soils and sediments, through the radiocarbon method, confirms the age of a deposit and it too is an excellent measure of buried site potential (column 10).

Table 2 is a matrix that charts the set of cores by geological unit (columns 3-8) and additional measures of archaeological preservation potential—proximity to known sites (column 9) and radiocarbon dates (column 10)--to develop a measure of **archaeological potential** (column 11) that guides our recommendation for follow-up work. The key element for determining archaeological potential for each core is the age of the geological units preserved within the composite core column. A core that contains several units of prospective archaeological age, noted in Table 2 by "Yes" in the appropriate age column, would be a likely candidate for follow up testing. Proximity to archaeological sites and Radiocarbon Dates at the core location would further underscore the productivity of testing.

In general, cores for which 3 to 4 "Yes" responses are checked were considered viable candidates for prospective follow-up work. For example, if a single core preserved three geological units of archaeological age and was in proximity of a site, it would be selected for further testing. It is noted, of course, that while all the cores were in proximity of archaeological sites in this uniquely sensitive (northwestern) section of Staten Island, individual core locations would **not** be tested unless they fulfilled at least two other criteria, most typically containing at least two deposits of Holocene age. Following these guidelines a total of four (4) of the ten (10) core locations were selected for additional work.

Specific recommendations and guidelines for such work were dictated by the particular core stratigraphies. The following discussion presents the specific strategies proposed for each group of cores.

Group 1: 380 Development Property – *Staten Island, NY*

1R-22.1-ARC-2

A suspected deep fill sequence may contain intact peat and estuarine sequences above 4.8 m. The identity of the fill is not unequivocal, although that fill may contain displaced and remobilized peats from elsewhere in the site vicinity. These contexts are not clear. Radiocarbon dates of 1580±30 B.P. (Beta-318407) and 390±30 B.P. (Beta-318403) are housed in a continuous and structurally consistent peat-organic silt matrix, albeit in inverted order at depths of 4.8-5.2 m.

There are paradoxical indications of intact sedimentation with inverted dates implicating disturbance. The dates (1600-400 B.P.) are in the accepted regional range for Late Holocene marsh development in the estuary and may document the Euroamerican shoreline. Clarifying the depositional contexts will help determine if sedimentation is intact or if historic landfilling involved local displacements of intact peat deposits. Similar contexts are present throughout the area so that answering this question will alert investigators to the signature of intact vs. disturbed Late Holocene deposits.

1R-22.1-ARC-5

Relatively shallow fills (< 2m) overlie a pristine Holocene near-shore to tidal stratigraphic succession that preserves evidence for dynamic depositional suites and a broad array of late Holocene landforms. These appear to have spanned the proximal to distal ends of the local landscape. A determination of 2730±30 B.P. (Beta-318414) was obtained in a marsh pocket.

A comprehensive subsurface exploration program is proposed for this location. Somewhat pronounced paleo-relief is signified by the range of sediment types preserved in this location. There is potential for prehistoric sites flanking the setting. Paleoenvironmental data should be procured from representative horizosn and complete stratigraphic columns should be sampled. The suite of paleo-environmental tests, together with radiometric dating should be performed. This is the most diagnostic stratigraphic succession for this segment. Establishing the ages of the beach and estuary, is critical. Paleoenvironmental reconstructions should focus on sedimentology, micromorphology, pollen studies, paleobotanical identification of plant remains, and shell identifications.

Group 2: 380 Development Property – *Staten Island, NY*

1R-22.1-ARC-6

As at 1R-22.1-ARC-5 this location presents a complex stratigraphic record showing stratified shoreface sands and estuarine muds signifying an alternately dynamic and stable setting at the location. Both locations may have been part of a dynamic and subsistence rich prehistoric environment. Here, as in 1R-22.1-ARC-2, there is an inversion of radiometric determinations. A date of ^{14}C 2930±40 B.P. (Beta-318408) occurred in sub-tidal alluvial or nearshore context (at 10 ft.) but this sediment may be re-deposited since an underlying burnt ^{14}C sample (±15 ft.) produced a younger date of ^{14}C 1950±30 B.P. (Beta-318404). It is significant, however, that nearly 2 m of entraining shore-face and near-shore sands signify a dynamic geomorphic environment where stratigraphic inversions can be expected and are fully consistent with localized sediment displacements.

Clarifying the depositional contexts will resolve questions of Late Holocene sedimentation during the critical interval 3000-2000 B.P. co-incident with the Late Archaic to Early Woodland transition. Is stratigraphic inversion a product of extensive geomorphic dynamism at the shoreline edge? Here the inversion is relatively old. Sediment complexes implicate an environment that featured elevated settings conducive to prehistoric settlement, at a time when prehistoric sites dotted the local landscape. This is not an optimal locale for sampling for paleo-environmental data.

Group 3: 380 Development Property – *Staten Island, NY*

1R-22.1-ARC-11

1R-22.1-ARC-11 occupies a distinctly distal interior location. The top of the sequence (0-10 ft.) features the only evidence in the project area for earlier tidal sedimentation, perhaps associated with the colonial period. Fill overlies possible intact historic marsh with preserved vegetation mats (10-20 ft. bgs). There is a continuous 3 m thick Late Holocene estuarine sediment complex that began aggrading at ^{14}C 1840±40 B.P. and probably continued to Contact titmes. More critically this is a homogeneous peat complex that can document the transition of the vegetation cover and geomorphic environments for upwards of 3000 years.

Extensive subsurface exploration is recommended for this location. It potentially documents climatic and environmental changes bridging the transition between the later prehistoric through early historic time frames. The deposits are a unique archive of environmental change. Paleoenvironmental data should be procured from representative horizons and complete stratigraphic columns should be *sampled. Comprehensive research may answer questions about the early impact of early Euroamerican engineering projects on the prehistoric landscape.*

Table 1. Summary of Recommendations

Property	Core No.	Sensitivity Assesment	Preliminary Analysis Information			Comments
			Contamination (No Further Work)	Modem Fill = 15 ft BS (No Futher Work)	Modem Fill/ Historic Strata = 15 ft BS (Further Work)	
380 Development	1R-22.1-ARC-2	Moderate for prehistoric and historic resources.				Relatively thin, heterogeneous upper fills (0-8 ft.) overlie organic fines and dense, organic clay-silts and well-stratified, bedded sands and finer lenses of slackwater silts and clays (possible natural flood, estuarine and sub-tidal sequences; 9-20 ft.).
381 Development	1R-22.1-ARC-3	Low for prehistoric and historic resources.		Present		Product saturated mixture of heterogeneously textured fills (0-15 ft.; poor recovery) immediately overlying (probable) thin peat liner. Fibrous peats to base are of possible natural origins (16-20 ft.)
382 Development	1R-22.1-ARC-4	Low for prehistoric and historic resources		Present		Upper sediments are mixture of fills with anthracite coal and oyster shell fragments as classic exogenous component (0-7 ft.). Underlying peat is probable artificial liner. Massive to weakly stratified sands and silty clay loams represent older filling (to 15 ft.; note product component). Downward coarsening sands represent (probable) primary fluvial facies 15-20 ft.).
383 Development	1R-22.1-ARC-5	Moderate for prehistoric resources; low for historic resources.				Upper sediments (0-9 ft.) include admixtures of fills. Lower matrix is consistently moist granular sands with interdigited reddish layers (either lamellae or reworked lenses of mineralized sands) of possible fluvial origin (to 20 ft.)
384 Development	1R-22.1-ARC-6	Moderate for prehistoric and historic resources.			Present	Probable sandy-clay fill (to 6 ft.) that passes to a complex of alternating lenses of moderately well sorted sands, loamy clays and firmer clay plugs.
385 Development	1R-22.1-ARC-7	Low for prehistoric and historic resources.		Present		Probable sandy loam to gravel and sandy fill cap (0-6 ft.). Passage to fine (clay loam) matrices above 15ft. (poor recovery) and then sands (15-18 ft.) before bottoming at natural peat horizon (18-20 ft.).
386 Development	1R-22.1-ARC-8	Low for prehistoric and historic resources.		Present		Clast-dominant to clast-supported fill sands are pervasive (0-12.5 ft.) that pass to product-enriched sands (12.5-15 ft.) and are underlain by wet sands and peats (natural matrices: 15-20 ft.).
387 Development	1R-22.1-ARC-9	Low for prehistoric and historic resources.		Present		Upper sediments (0-10 ft.) include stable upper sedimentary fills that pass to product-enriched fines (10-13.5 ft.), which overlie organic clays, silts and peats above compact clays and gravels (natural matrices: 15-20 ft.).
388 Development	1R-22.1-ARC-10	Low for prehistoric and historic resources.		Present		Upper sediments represent fill intermixed with estuarine marsh fines that includes increased product component with depth (0-14 ft.); matrix grades conformably to probable natural marsh and peat deposit (15-20 ft.) with sands.
389 Development	1R-22.1-ARC-11	Moderate for prehistoric and historic resources.			Present	Upper sediments (0-10 ft.) are shallow historic fill, probably representing localized reworking of tidal/estuarine matrices. Fill overlies possible intact historic marsh with preserved vegetation mats (10-20 ft. bgs).

Table 2. Assessments of Archaeological Significance and Follow up Testing

	RELATIVE AGE YOUNGEST ⟹ OLDEST POTENTIALLY ARCHEOLOGICALLY SENSITIVE	HOLOCENE								
Core	Deep/Mixed Fill	Discrete Fill	Buried Soil	Marsh/ Peat	Shore facies	Till	Proximity to known Arc sites[1]	RC Dates	SIGNIFICANT (x/-)	COMMENTS
1R-22.1-ARC-2*	NO	NO	NO	YES	NO	NO	YES	YES	x	sandy fill over pre-contact peat; possible additional work
1R-22.1-ARC-3*	YES	NO	NO	YES	NO	NO	YES	YES	-	fill overlying peat
1R-22.1-ARC-4	YES	NO	NO	NO	YES	NO	YES	NO	-	contaminated fill overlying shorefacies
1R-22.1-ARC-5*	NO	NO	NO	YES	YES	NO	YES	YES	x	fill overlying shore/fluvial sands; possible additional work
1R-22.1-ARC-6*	NO	NO	NO	NO	YES	NO	YES	YES	x	SL fill overlying sands and clay
1R-22.1-ARC-7*	YES	NO	NO	YES	NO	NO	YES	NO	-	deep fill sands over peat
1R-22.1-ARC-8	YES	NO	NO	NO	YES	NO	YES	NO	-	sands and gravel (contaminated) over peat
1R-22.1-ARC-9	YES	NO	NO	YES	NO	NO	YES	NO	-	SCL and sand (contaminated) over marsh peat
1R-22.1-ARC-10	YES	NO	NO	YES	NO	NO	YES	NO	-	S/SiC waste over peats and estuarine sediments
1R-22.1-ARC-11*	NO	NO	NO	YES	YES	NO	YES	YES	x	S/C/SiC fill over peat and basal sand

*sampled for radiocarbon date

[1]within ~1.0 km

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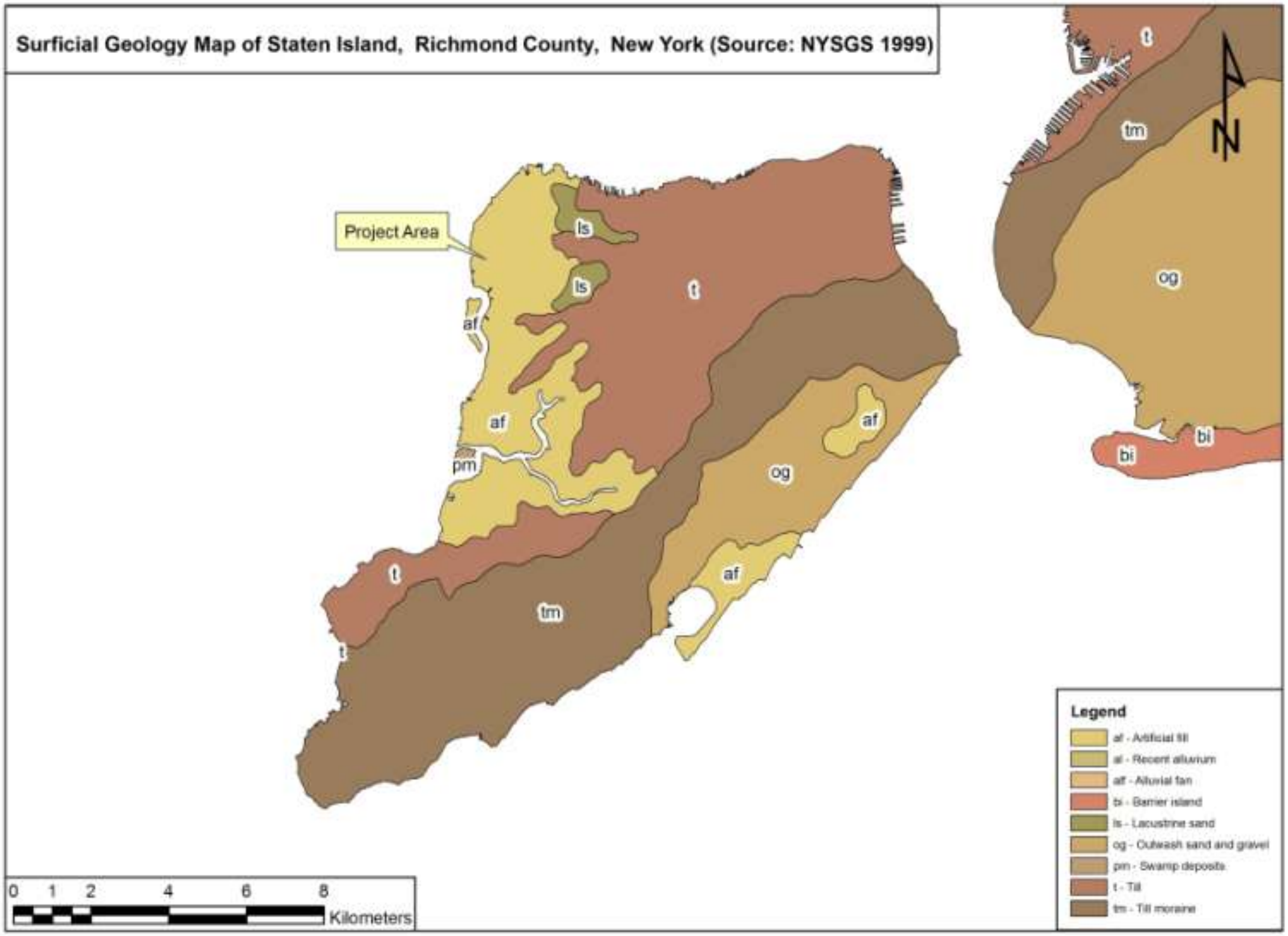
Appendix A: Surficial Geology Map



Surficial Geology Map of Staten Island, Richmond County, New York (Source: NYSGS 1999)

Appendix B: Core Photographs and Descriptions

1R-22.1-ARC-2

1R-22.1-ARC-2

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-122	122	Ap1	2.5YR 3/4	SCL	dist	l	g	<50% fine-medium gravel, shell fragments and large
FILL	122-152	30	Ap2	5YR 4/4	S-CS	1sbk	l-fri	g	sand with dark firm clay inclusions and shell
FILL	152-183	31	Ap3	5YR 2.5/1	C-S	2sbk	fi	g	mostly clay with some sand; shell and some gravel inclusions
MISSING	183-274	91	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	274-296	22	Ap4	10YR 2/1	SiC	2sbk	sl.fri	c	no inclusions
FILL	296-305	9	Ap5	10YR 2/2	SC-O	2sbk	l-sl.fri	n/a	single grain sand with plant matter and organics
MISSING	305-419	114	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	419-438	19	Ap6	10YR 2/1	S	gr	l	c	single grain sand
FILL	438-457	19	Ap7	10YR 2/1	SiC	2sbk	fi, sl.fri	n/a	common organics
MISSING	457-488	31	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	488-493	5	Ap8	10YR 4/1	S	gr	l	c	single grain sand, RC date at lower S-SiC transition 1580±30 B.P. (Beta-318407)
FILL - DREDGED MARSH?	493-511	18	Ap9	10YR 2/1	SiC-O	2sbk	fi, sl.fri	c	common organics, RC date 390±30 B.P. (Beta-318413)
FILL	511-514	3	Ap10	2.5YR 4/4	SiC	2sbk	sl.fri	a	clear color transition
PEAT	518-610	92	2C	10YR 2/1	O	2sbk	fi	n/a	contact with overlying silty clay is stained; plentiful organics

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
gr=granular; mass=massive; strat=stratified; sbk=subangular blocky; ab=angular blocky; pr=prismatic
pl=platy; dist=disturbed/no structure
Consist.: fri=friable; sl=slightly; v=very; l=loose; fi=firm; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscell.:: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-3

1R-22.1-ARC-3

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-61	61	Ap1	7.5YR 3/2 - 7.5YR 4/1	SCL	dist	l,sl.fri	g	few cobbles, highly oxidized
FILL	61-181	20	Ap2	7.5YR 4/1	SC	dist	l,sl.fri	n/a	50% medium rounded gravel; shell and organic material present
MISSING	181-350	169	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	350-457	107	Ap3	10YR 2/1	SiC	dist	fi	n/a	apparent petroleum waste material, some sand present below 427 cm
MISSING	457-480	23	n/a	n/a	n/a	n/a	n/a	n/a	n/r
MARSH/DREDGED	480-482	2	Ap4	10YR 3/1	O	2sbk	sl.fri	c	thin peaty layer with petrol smell, contamination possibly leached from above
FILL	482-486	4	Ap5	10YR 2/1	SC	2sbk	sl.fri	c	clearly distinct sediment, no visible organics
MARSH/ DREDGED	486-488	2	2C	10YR 2/1	O	2sbk	sl.fri	c	thin peaty layer with abundant organics
MARSH/ DREDGED	488-490	2	2C2	10YR 2/1	C	2sbk	fi	c	thin layer of plastic clay
PEAT	490-610	120	2C3	10YR 2/1 - 10YR 3/1	O	2sbk	sl.fri	c	thin peaty layer with abundant organics, RC date 1290±30 (Beta-318406)

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
gr=granular; mass=massive; strat=stratified; sbk=subangular blocky; ab=angular blocky; pr=prismatic
pl=platy; dist=disturbed/no structure
Consist.: fri=friable; sl=slightly; v=very; l=loose; fi=firm; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscell.: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-4

1R-22.1-ARC-4

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-152	152	Ap1	7.5YR 5/1 - 10YR 5/6	SCL	dist	fri	g	common shell and rootlets
FILL	152-183	31	Ap2	7.5YR 4/2	C	2sbk	sl.fri	c	few oxidized organics/sand inclusions
FILL	183-213	30	Ap3	10YR 3/2	SiL	1sbk	sl.fri	g	some shell fragments and organics
FILL	213-223	10	Ap4	10YR 3/2	SiL	2sbk	sl.fri	g	visible organics
FILL	223-274	51	Ap5	2.5YR 3/4	SiCL	2sbk	sl.fri	c	mottled with 10YR 4/3, <10% fine gravel
FILL	274-305	31	Ap6	10YR 2/2	S	gr	l	n/a	medium sand
MISSING	305-325	20	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	325-366	41	Ap6	2.5Y 3/1	S	gr	l	c	fine sand
FILL	366-457	91	Ap7	10YR 2/1	SiC	dist	sl.fi	c	apparent waste material (petroleum smell), some sand at 457 cm
SHOREFACE	457-610	153	2C	10YR 3/1	S-G	gr	l	n/a	poorly sorted fine gravel and sand, coarsening with depth, shell fragments present

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
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; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscellaneous: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-5

1R-22.1-ARC-5

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-91	91	Ap1	7.5YR 4/3	SCL	dist	sl.fri	g	common organics and small pebbles, clay clods present
FILL	91-122	31	Ap2	7.5YR 4/6	S-C	2sbk	sl.fri	g	clay clods, rootlets, fine-medium gravel
FILL	122-183	61	Ap3	7.5YR 4/1	S	gr	l	g	shell fragments, anthracite, rootlets present
MISSING	183-335	152	n/a	n/a	n/a	n/a	n/a	n/a	n/r
SHOREFACE	335-427	92	2C	10YR 5/1	S	gr	l	n/a	wet f-m S, <20% fine-medium gravel, homogenous, no organics
MISSING	427-457	30	n/a	n/a	n/a	n/a	n/a	n/a	n/r
MARSH	457-488	31	3C	10YR 3/1	SiC	2sbk	sl.fi	c	several distinct bands of 2.5YR 4/6 silty clay. RC date 2730±30, (Beta-318414)
SHOREFACIES/ FLUVIAL?	488-564	76	4C	10YR 4/1	S	gr	l	g	wet sand with shell and gravel (<50%)
SHOREFACIES/ FLUVIAL?	564-610	46	4C2	10YR 4/1	S	gr	l	n/a	wet sand, no inclusions

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
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; h=hard; st=sticky; ss=strongly sticky

Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp

Boundary Topography: w=wavy; s=smooth; a=abrupt

Miscellaneous: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-6

1R-22.1-ARC-6

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-122	122	Ap1	7.5YR 4/3	SL	dist	l	g	<50% gravel/cobbles, few clay inclusions, organics present, some ash at 120 cm
FILL	122-183	61	Ap2	7.5YR 4/2	S	gr	l	n/a	poorly sorted heterolithic sand with 50% gravel/cobbles
MISSING	183-213	30	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	213-244	31	Ap3	7.5YR 4/2	S	gr	l	g	poorly sorted heterolithic sand with 50% gravel/cobbles
FILL	244-274	30	Ap4	7.5YR 3/1	SCL	2sbk	fi	g	firmness increases with depth
FILL	274-305	31	Ap5	7.5YR 2.5/1	C	3sbk	fi	g	homogenous clay
FILL/SHORE?	305-366	61	Ap6	7.5YR 2.5/1	SaC	2sbk	fri	g	decrease in clay content with depth (RC date 2930±40, Beta-318408)
FILL/SHORE?	366-442	76	Ap7	7.5YR 5/1	S	gr	l	g	some small gravel, poorly sorted, some clay at 442 cm
FILL/SHORE?	442-472	30	Ap8	7.5Y 4/2	C-S	gr	l-sl.fri	g	poorly sorted sand with fractured rock and organics at 457 cm. RC date 1950±30 (Beta-318404)
SHOREFACE	472-488	16	2C	7.5YR 3/1	S	gr	l	g	poorly sorted sand and gravel, some apparent organics
SHOREFACE	488-549	61	2C2	7.5YR 3/1	S	gr	l-fri	c	medium grain sand and shattered rock, some gravel
ESTUARINE	549-610	61	3C	7.5YR 2.5/1	C	2sbk	fi	n/a	plastic clay layer

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
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; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscellaneous: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-7

1R-22.1-ARC-7

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-61	61	Ap1	2.5Y 4/2	SL	dist	l	g	<50% gravel/cobbles, few clay inclusions, organics present
FILL	61-91	30	Ap2	10YR 4/2	SL	dist	l, sl.fri	g	some blackend organic material, weakly cemented sand inclusions
FILL	91-183	92	Ap3	10YR 4/4	SL-S	gr	l	n/a	poorly sorted sand with fine gravel and few cobbles
MISSING	183-452	269	n/a	n/a	n/a	n/a	n/a	n/a	no core recovery from 183-452 cm -- likely air pockets or soft sediment
FILL	452-480	28	Ap4	10YR 2/1	SiC	2sbk	sl.fi	g	no inclusions
FILL	480-549	69	Ap5	n/r	S	gr	l	g	medium sand transitioning to single grain fine sand
MARSH	549-579	30	2C	10YR 2/1	SiC	2sbk	sl.fi	c	few organic inclusions
PEAT	579-610	31	3C	10YR 3/1	O	2sbk	fi	n/a	preserved organic material. RC date 390±30 (Beta-318405)

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
gr=granular; mass=massive; strat=stratified; sbk=subangular blocky; ab=angular blocky; pr=prismatic
pl=platy; dist=disturbed/no structure
Consist.: fri=friable; sl=slightly; v=very; l=loose; fi=firm; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscell.: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-8

1R-22.1-ARC-8

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-61	61	Ap1	7.5YR 3/2	SL	dist	l-fri	g	<50% gravel/cobbles, few clay inclusions, organics present
FILL	61-229	168	Ap2	7.5YR 4/3	S	gr	l-fri	c	sand with poorly sorted irregular gravel and cobbles
FILL	229-234	5	Ap3	7.5YR 3/1 - 7.5YR 4/2	C	1sbk	sl.fri	c	clay lens with some sand
FILL	234-274	40	Ap4	7.5YR 4/3	S	gr	l-fri	c	sand with poorly sorted irregular gravel and cobbles
FILL	274-383	109	Ap5	7.5YR 4/3	SL	gr	l	g	coarse subrounded gravel/sand in wet sandy loam matrix
FILL	383-427	44	Ap6	7.5YR 2.5/1	S-G	gr	l	c	coarse sand and fractured rock transitiong to primarily sand below 396 cm
FILL	427-457	30	Ap7	7.5yr 4/1	SiC	2sbk	fi	c	apparent waste material, organics?
SHORE FACE	457-564	107	2C	7.5yr 4/1	S	gr	l	c	fine wet sand, coarsening below 533 cm; shell fragments present
ESTUA-RINE	564-610	46	3C	7.5yr 4/1	O	2sbk	fi,sl.fri	n/a	organic rich, shell fragments present

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
gr=granular; mass=massive; strat=stratified; sbk=subangular blocky; ab=angular blocky; pr=prismatic
pl=platy; dist=disturbed/no structure
Consist: fri=friable; sl=slightly; v=very; l=loose; fi=firm; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscell: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-9

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-30	30	Ap1	7.5YR 4/6	SL	dist	fri	g	<50% gravel
FILL	30-183	153	Ap2	7.5YR 4/4	S	gr	l	n/a	common large gravel/cobbles, shell fragments present; some grayish brown to yellowish brown coloring
MISSING	183-208	25	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	208-305	97	Ap3	7.5YR 4/4	S	gr	l	n/a	common large gravel/cobbles, shell fragments present; transitioning to 10YR 4/2 sand/gravel
FILL	305-396	91	Ap4	10YR 2/1	S-G	dist	l	g	black tarry sand-sludge material, strong petrol smell
FILL	396-457	61	Ap5	10YR 2/1	SiC	dist	sl.fi	g	apparent waste material (high PID)
ESTUARINE	457-475	18	2C	10YR 4/2	SiC	1sbk	sl.fi	c	gray silty clay, few gravel inclusions
ESTUARINE	475-480	5	2C	10YR 2/1	O	2sbk	fi	c	dark organic rich layer (possibly stained)
PEAT	480-550	70	2C	10YR 2/1	O	2sbk	fi	c	very fibrous peaty material
PEAT	550-610	60	2C3	10YR 4/2	O	3sbk	v.fi	n/a	gray silty clay, few gravel inclusions; visible organics and shell present

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
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; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscellaneous: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-10

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-61	61	Ap1	7.5YR 4/4	SL	dist	l	g	shell fragments, clay clods and fine-medium sand and gravel present
FILL	61-152	61	Ap2	7.5YR 2/1	S-G	gr	l	g	<50% gravel, poorly sorted, shell fragments below 122 cm
FILL	152-188	36	Ap3	2.5YR 3/1	S	gr	l	n/a	poorly sorted sand
FILL	188-305	117	Ap4	10YR 2/1	S-SiC	dist	sl.fri	n/a	fine sand waste material transitioning to silty clay waste
MISSING	305-320	15	n/a	n/a	n/a	n/a	n/a	n/a	n/r
FILL	320-426	106	Ap5	10YR 3/1	S-SC	dist	sl.fri	a	fine sand with <10% gravel transitioning to SC waste material with no inclusions; oily sheen
ESTUARINE/MARSH	426-457	31	2C	10YR 3/1	O	2sbk	fi	n/a	organic rich
MISSING	457-498	41	n/a	n/a	n/a	n/a	n/a	n/a	n/r
ESTUARINE	498-503	5	3C	7.5YR 3/1	O-S	2sbk	sl.fri	g	sandy peat
ESTUARINE	503-610	107	3C2	7.5YR 3/1	O-SiC	2sbk	fi	n/a	organic rich estuarine deposit with partial shell material throughout

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
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; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscellaneous: n/a=not applicable, n/r=not recorded

1R-22.1-ARC-11

1R-22.1-ARC-11

Unit	Depth (cm)	Thickness (cm)	Soil Horizon	Munsell Color	Texture	Structure	Consistence	Boundary	Comments
FILL	0-61	61	Ap1	7.5YR 4/3	SL	dist	fri	g	common clay clods, some medium gravel, organics present
FILL	61-91	30	Ap2	2.5YR 4/4 - 2.5YR 4/1	S-C	2sbk	pl	g	few silty clay pockets, organics present
FILL	91-183	92	Ap3	7.5YR 3/1	C	2sbk	pl	n/a	inclusions
MISSING	183-224	41	n/a	n/a	n/a	n/a	n/a	n/a	n/r
MARSH	224-305	81	2C	7.5YR 4/1 - 7.5YR 4/2	SiC-O	2sbk	fi	n/a	well preserved organics
MISSING	305-371	66	n/a	n/a	n/a	n/a	n/a	n/a	n/r
PEAT	371-457	86	3C	7.5YR 4/1	SiC-O	2sbk	fi	n/a	very well preserved organics (reeds and grass)
MISSING	457-533		n/a	n/a	n/a	n/a	n/a	n/a	n/r
PEAT	533-594	37	3C2	7.5YR 4/1 - 7.5YR 3/4	SiC-O	2sbk	fi	n/a	very well preserved organics (reeds, grass, wood) very high PID. RC date 1840±40 (Beta-318415)
SHOREFACE	594-610	16	4C	7.5YR 4/1	SC-S	gr	l	n/a	sandy clay transitioning to single grain sand

Texture: Si=silt; L=loam; C=clay; S=sand; F=fine; V=very; G=gravel; O=organic:

Structure: 1=weak; 2= moderate; 3=strong; f=fine; m=medium; c=coarse
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; h=hard; st=sticky; ss=strongly sticky
Boundary Distinctness: a=abrupt; c=clear; d=diffuse; g=gradual; s=sharp
Boundary Topography: w=wavy; s=smooth; a=abrupt
Miscellaneous: n/a=not applicable, n/r=not recorded

Appendix C: Radiocarbon Testing Results

Sample: 1R-22.1-ARC-2(1)

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-19.3:lab. mult=1)

Laboratory number: **Beta-318407**

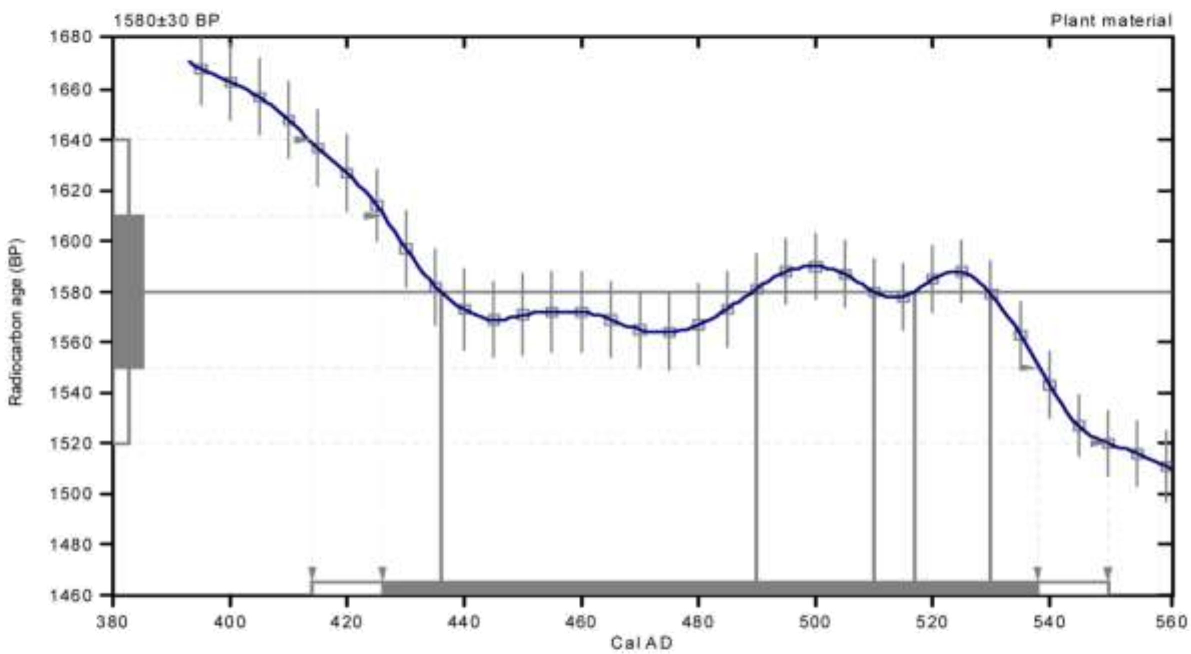
Conventional radiocarbon age: **1580±30 BP**

2 Sigma calibrated result: **Cal AD 410 to 550 (Cal BP 1540 to 1400)**
(95% probability)

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal AD 440 (Cal BP 1510) and
Cal AD 490 (Cal BP 1460) and
Cal AD 510 (Cal BP 1440) and
Cal AD 520 (Cal BP 1430) and
Cal AD 530 (Cal BP 1420)

1 Sigma calibrated result: Cal AD 430 to 540 (Cal BP 1520 to 1410)
(68% probability)



References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

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Sample: 1R-22.1-ARC-2 (2)

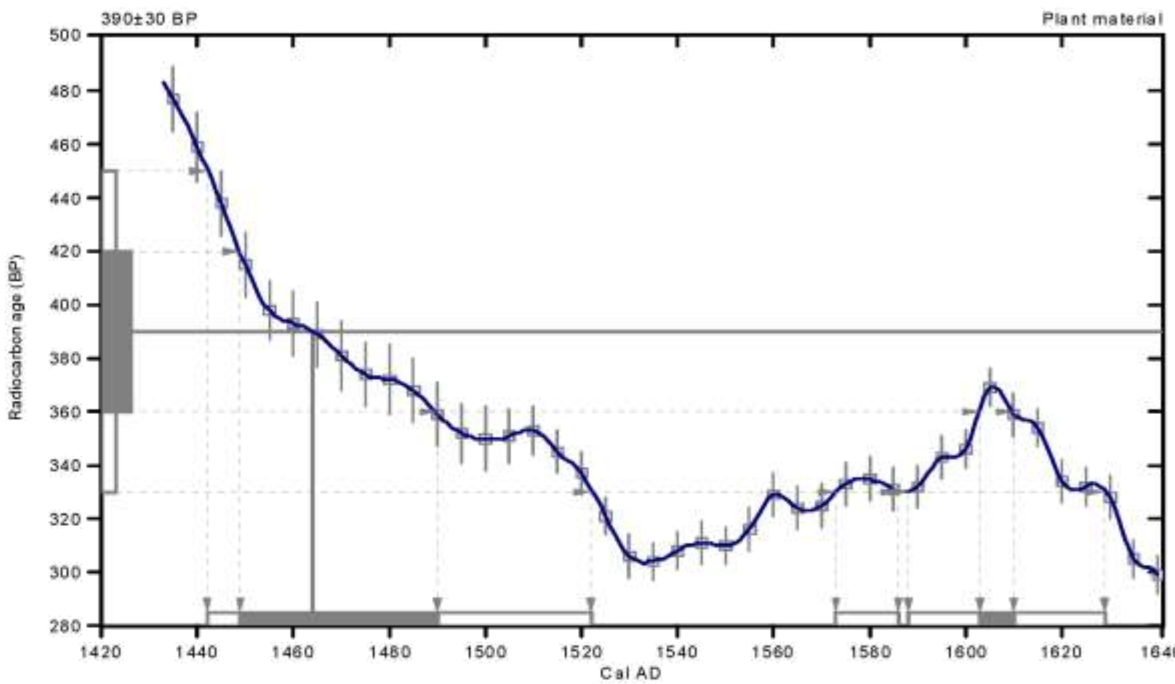
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-15.8:lab. mult=1)

Laboratory number:	**Beta-318413**
Conventional radiocarbon age:	**390±30 BP**
2 Sigma calibrated results: (95% probability)	**Cal AD 1440 to 1520 (Cal BP 510 to 430) and Cal AD 1570 to 1590 (Cal BP 380 to 360) and Cal AD 1590 to 1630 (Cal BP 360 to 320)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal AD 1460 (Cal BP 490)
1 Sigma calibrated results: (68% probability)	Cal AD 1450 to 1490 (Cal BP 500 to 460) and Cal AD 1600 to 1610 (Cal BP 350 to 340)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

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Sample: 1R-22.1-ARC-3(1)

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-11:lab. mult=1)

Laboratory number: **Beta-318406**

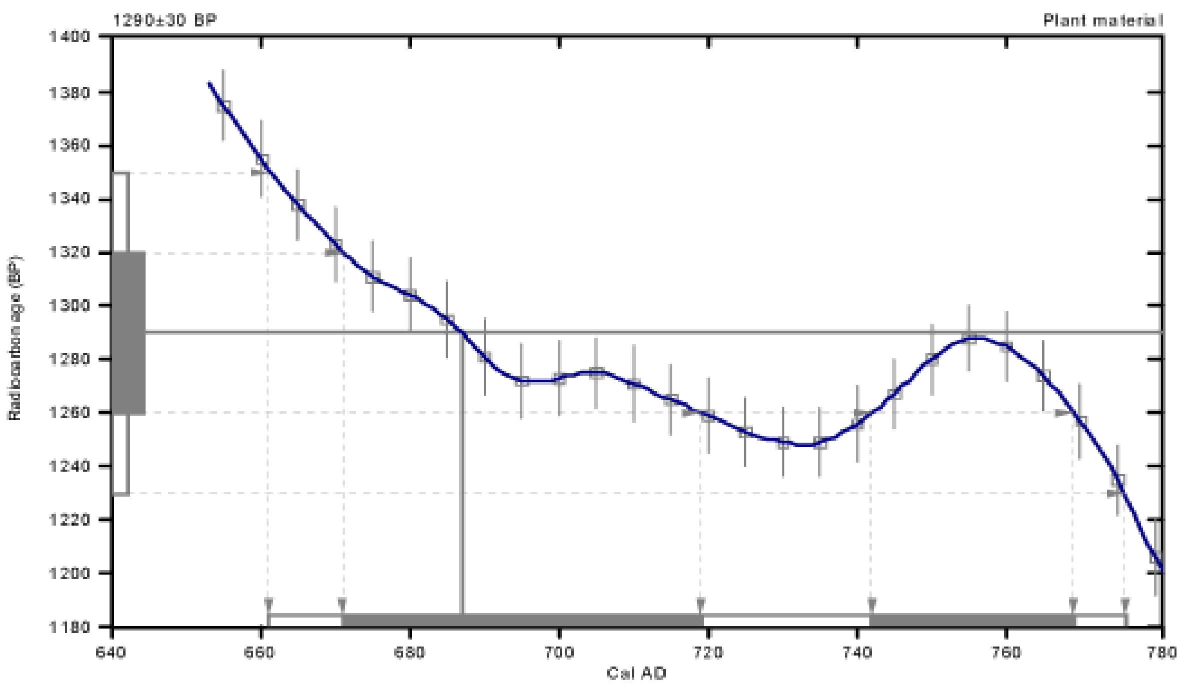
Conventional radiocarbon age: **1290±30 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 660 to 780 (Cal BP 1290 to 1170)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 690 (Cal BP 1260)

1 Sigma calibrated results: (68% probability) Cal AD 670 to 720 (Cal BP 1280 to 1230) and Cal AD 740 to 770 (Cal BP 1210 to 1180)



References:

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Mathematics used for calibration scenario

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Sample: 1R-22.1-ARC-5(1)

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-14.6:lab. mult=1)

Laboratory number: **Beta-318414**

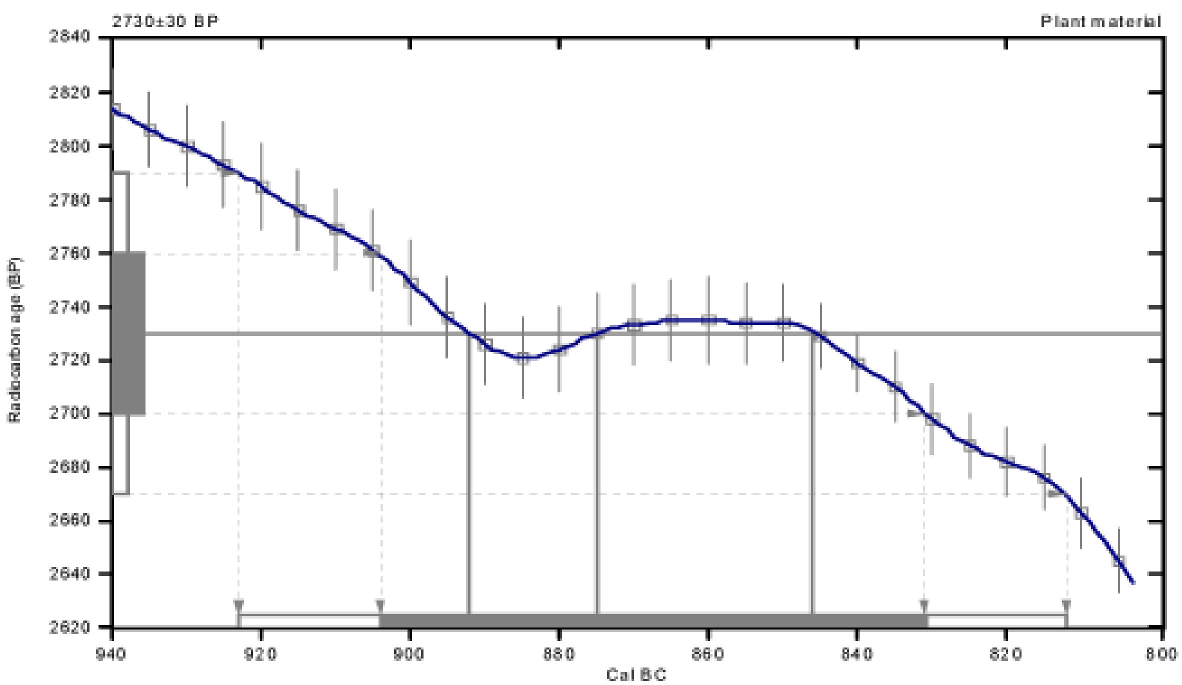
Conventional radiocarbon age: **2730±30 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 920 to 810 (Cal BP 2870 to 2760)**

Intercept data

Intercepts of radiocarbon age with calibration curve: Cal BC 890 (Cal BP 2840) and
Cal BC 880 (Cal BP 2820) and
Cal BC 850 (Cal BP 2800)

1 Sigma calibrated result: (68% probability) Cal BC 900 to 830 (Cal BP 2850 to 2780)



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Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

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Sample: 1R-22.1-ARC-6 (1)

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.2:lab. mult=1)

Laboratory number: **Beta-318408**

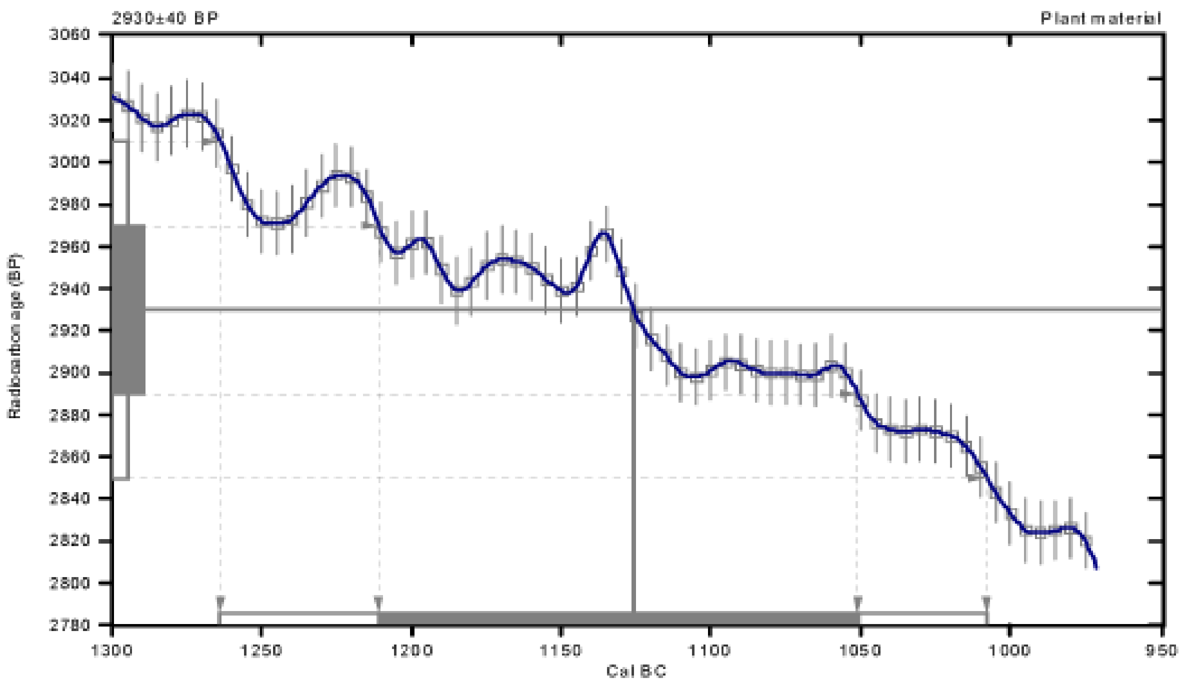
Conventional radiocarbon age: **2930±40 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 1260 to 1010 (Cal BP 3210 to 2960)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 1130 (Cal BP 3080)

1 Sigma calibrated result: (68% probability) Cal BC 1210 to 1050 (Cal BP 3160 to 3000)



References:

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Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

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Sample: 1R-22.1-ARC-6(3)

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-15.3:lab. mult=1)

Laboratory number: **Beta-318404**

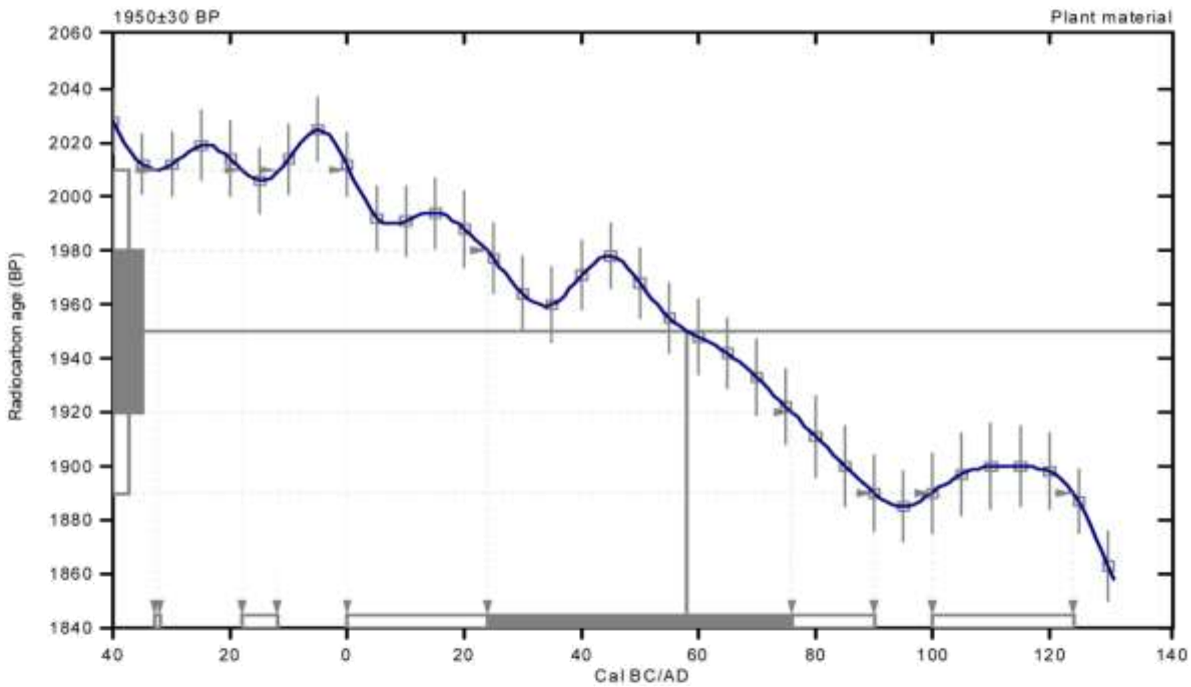
Conventional radiocarbon age: **1950±30 BP**

2 Sigma calibrated results: (95% probability) **Cal BC 30 to 30 (Cal BP 1980 to 1980) and Cal BC 20 to 10 (Cal BP 1970 to 1960) and Cal AD 0 to 90 (Cal BP 1950 to 1860) and Cal AD 100 to 120 (Cal BP 1850 to 1830)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 60 (Cal BP 1890)

1 Sigma calibrated result: (68% probability) Cal AD 20 to 80 (Cal BP 1930 to 1870)



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Sample: 1R-22.1-ARC-7 (1)

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-22.7:lab. mult=1)

Laboratory number: **Beta-318405**

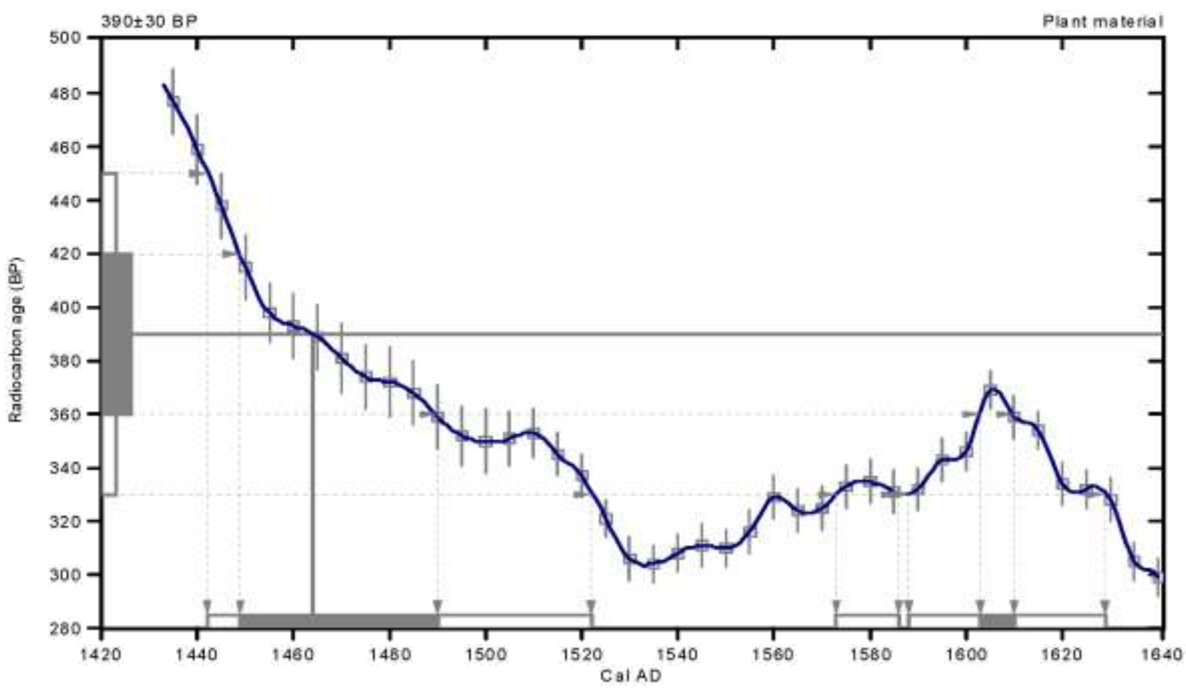
Conventional radiocarbon age: **390±30 BP**

2 Sigma calibrated results: **Cal AD 1440 to 1520 (Cal BP 510 to 430) and**
(95% probability) **Cal AD 1570 to 1590 (Cal BP 380 to 360) and**
Cal AD 1590 to 1630 (Cal BP 360 to 320)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 1460 (Cal BP 490)

1 Sigma calibrated results: Cal AD 1450 to 1490 (Cal BP 500 to 460) and
(68% probability) Cal AD 1600 to 1610 (Cal BP 350 to 340)



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Sample: 1R-22.1-ARC-11(2)

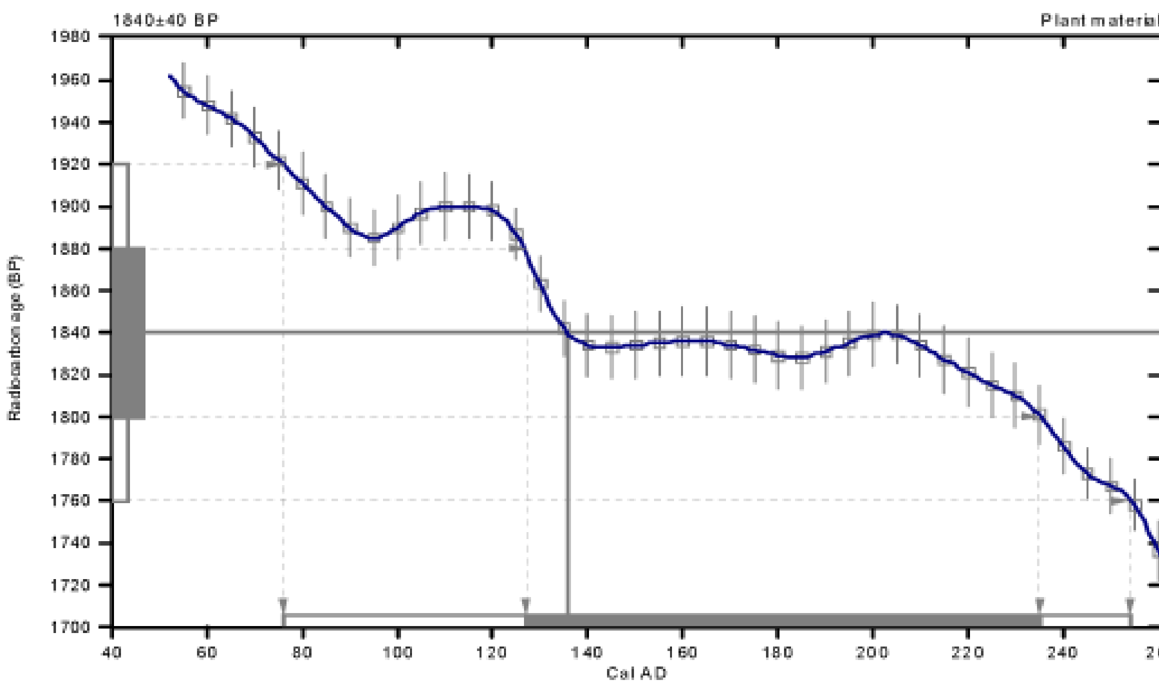
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-21.6:lab. mult=1)

Laboratory number:	**Beta-318415**
Conventional radiocarbon age:	**1840±40 BP**
2 Sigma calibrated result: (95% probability)	**Cal AD 80 to 250 (Cal BP 1870 to 1700)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal AD 140 (Cal BP 1810)
1 Sigma calibrated result: (68% probability)	Cal AD 130 to 240 (Cal BP 1820 to 1720)



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