Appendix A
Joint Permit Application

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National Aeronautics and Space Administration

Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337

March 24, 2026

Claire Gorman
Environmental Engineer, Habitat Management Division
Virginia Marine Resources Commission
2600 Washington Avenue,
Newport News, VA 23607

Re: NASA Wallops Flight Facility Shoreline Protection Program Joint Permit Application

Dear Ms. Gorman,

Attached please find the Joint Permit Application for the above referenced project. The following supporting material is available electronically via NASA Box at: https://nasagov.box.com/s/6y6y5ggudempd6szgu87plowmwkj8grv.

1. Joint Permit Application Engineering Form
2. Purpose and Need, Alternatives Considered, and Description of Project
3. Periodic Surveying Evaluation Spring 2021
4. Periodic Surveying Evaluation Fall 2024
5. Beach Permit Plan Set
6. Breakwaters Permit Plan Set
7. Wallops Island Shoreline Protection Project Design Analysis and Appendices
8. Pre-Application Meeting Presentation

Please contact Ms. Lori Levine, Wallops Flight Facility Natural Resources Manager, at Lori.M.Levine@nasa.gov with any questions or comments.

Sincerely,

Paul Bull Digitally signed by Paul Bull
Date: 2026.03.24 13:56:09
-04'00'

Paul Bull, PE

cc:
228/Mr. M. Ballance
228/Mr. J. Saecker
250/Mr. B. Deyo
250/Ms. L. Levine
250/Ms. I. Romero
250/Ms. S. Miller
BOEM/Ms. L. Brandt
BOEM/Ms. J. Bucatari
USACE/Ms. A. Crawford
USACE/Ms. S. Reinheimer
USACE/Ms. S. Williams
USACE/Ms. M. Wood
Stantec/Mr. J. Lowenthal
Stantec/Ms. E. Pruitt

FOR AGENCY USE ONLY	
	Notes:
JPA#	

APPLICANTS

PLEASE PRINT OR TYPE ALL ANSWERS. If a question does not apply to your project, please print N/A (not applicable) in the space provided. ***If additional space is needed, attach extra 8 ½ x 11 inch sheets of paper.***

Check all that apply			
Pre-Construction Notification (PCN) ☐ NWP # _____ (*For Nationwide Permits ONLY - No DEQ-VWP permit writer will be assigned*)	SPGP ☐	DEQ Reapplication ☐ Existing permit number: _____	Receiving federal funds ☐ Agency providing funding: _____

PREVIOUS ACTIONS RELATED TO THE PROPOSED WORK (Include all federal, state, and local pre-application coordination, site visits, previous permits, or applications whether issued, withdrawn, or denied)

Historical information for past permit submittals can be found online with VMRC - https://webapps.mrc.virginia.gov/public/habitat/ - or VIMS - http://ccrm.vims.edu/perms/newpermits.html

Agency	Action / Activity	Permit/Project number, including any non-reporting Nationwide permits previously used (e.g., NWP 13)	Date of Action	If denied, give reason for denial
Corps/DEQ/V	Pre-Application Meeting	USACE Project 1196	4/28/25	
Corps/DEQ/V	Pro-Application Meeting	NAO 1992-1455/18-1050	July 2010	

1. APPLICANT, AGENT, PROPERTY OWNER, AND CONTRACTOR INFORMATION
The applicant(s) is/are the legal entity to which the permit may be issued (see How to Apply at beginning of form). The applicant(s) can either be the property owner(s) or the person/people/company(ies) that intend(s) to undertake the activity. The agent is the person or company that is representing the applicant(s). If a company, please also provide the company name that is registered with the State Corporation Commission (SCC), or indicate no registration with the SCC.

Legal Name(s) of Applicant(s) NASA Wallops Flight Facility			Agent (if applicable)		
Mailing address Wallops Island/Accomack County			Mailing address		
City Wallops Island	State VA	ZIP Code 23337	City	State	ZIP Code
Phone number w/area code	Fax		Phone number w/area code	Fax	
Mobile	E-mail		Mobile	E-mail	
State Corporation Commission Name and ID number (if applicable)			State Corporation Commission Name and ID number (if applicable)		

Certain permits or permit authorizations may be provided via electronic mail. If the applicant wishes to receive their permit via electronic mail, please provide an e-mail address here: _____

1. APPLICANT, AGENT, PROPERTY OWNER, AND CONTRACTOR INFORMATION (Continued)

Property owner(s) legal name, if different from applicant			Contractor, if known		
Paul Bull, PE					
Mailing address			Mailing address		
NASA Wallops Flight Facility, Building N-161, Code 228					
City	State	ZIP code	City	State	ZIP code
Wallops Island	VA	23337			
Phone number w/area code	Fax		Phone number w/area code	Fax	
757-824-1168	757-824-1831				
Mobile	E-mail		Mobile	E-mail	
	paul.c.bull@nasa.gov				
State Corporation Commission Name and ID number (if applicable)			State Corporation Commission Name ID number (if applicable)		

2. PROJECT LOCATION INFORMATION

(Attach a copy of a detailed map, such as a USGS topographic map or street map showing the site location and project boundary, so that it may be located for inspection. Include an arrow indicating the north direction. Include the drainage area if the SPGP box is checked on Page 7.)

Street Address (911 address if available)	City/County/ZIP Code
Wallops Island	Accomack County
Subdivision	Lot/Block/Parcel #

Name of water body(ies) within project boundaries and drainage area (acres or square miles).
Atlantic Ocean

Tributary(ies) to: NA
Basin: _____ Sub-basin: _____
(*Example: Basin: James River Sub-basin: Middle James River*)

Special Standards (based on DEQ Water Quality Standards 9VAC25-260 et seq.): NA

Project type (check one)

- ☐ Single user (private, non-commercial, residential)
- ☑ Multi-user (community, commercial, industrial, government)
- ☐ Surface water withdrawal

Latitude and longitude at center of project site (decimal degrees): 37-50-45 / -75-28-29
(Example: 37.33164/-77.68200)

USGS topographic map name: Wallops Island

8-digit USGS Hydrologic Unit Code (HUC) for your project site (See http://cfpub.epa.gov/surf/locate/index.cfm): 02040303
If known, indicate the 10-digit and 12-digit USGS HUCs (see *http://dswcapps.dcr.virginia.gov/htdocs/maps/HUExplorer.htm* :
_____ _____

Name of your project (*Example: Water Creek driveway crossing*) Shoreline Enhancement Restoration Project

Is there an access road to the project? ☑ Yes ☐ No. If yes, check all that apply: ☐ public ☑ private ☐ improved ☐ unimproved

Total size of the project area (in acres): 180.5 acres (beach,breakwaters, staging)

2. PROJECT LOCATION INFORMATION (Continued)

Provide driving directions to your site, giving distances from the best and nearest visible landmarks or major intersections:

Access to project site will require NASA security badging. The NASA security office/badging facility directions are as follows: From Route 13 North, turn right on Chincoteague Road/Rt. 175. Travel east for 3.5 miles toward Town of Chincoteague. At Wallops Island stoplight, turn left (north) on Atlantic Road/Rt. 798. Travel north for one mile: veer off to the right (east) to parking area for NASA badging facility. NASA project personnel shall provide escort to the site.

Does your project site cross boundaries of two or more localities (i.e., cities/counties/towns)? ☐ Yes ☑ No
If so, name those localities:

3. DESCRIPTION OF THE PROJECT, PROJECT PRIMARY AND SECONDARY *PURPOSES*, PROJECT *NEED*, INTENDED USE(S), AND ALTERNATIVES CONSIDERED (Attach additional sheets if necessary)

- The purpose and need must include any new development or expansion of an existing land use and/or proposed future use of residual land.
- Describe the physical alteration of surface waters, including the use of pilings (#, materials), vibratory hammers, explosives, and hydraulic dredging, when applicable, and *whether or not tree clearing will occur* (include the area in square feet and time of year).
- Include a description of alternatives considered and measures taken to avoid or minimize impacts to surface waters, including wetlands, to the maximum extent practicable. Include factors such as, but not limited to, alternative construction technologies, alternative project layout and design, alternative locations, local land use regulations, and existing infrastructure
- For utility crossings, include both alternative routes and alternative construction methodologies considered
- For surface water withdrawals, public surface water supply withdrawals, or projects that will alter in-stream flows, include the water supply issues that form the basis of the proposed project.

See Attachment 1

Date of proposed commencement of work (MM/DD/YYYY)	Date of proposed completion of work (MM/DD/YYYY)
10/1/26	10/1/32
Are you submitting this application at the direction of any state, local, or federal agency? ☐ Yes ☑ No	Has any work commenced or has any portion of the project for which you are seeking a permit been completed? ☐ Yes ☑ No

If you answered "yes" to either question above, give details stating when the work was completed and/or when it commenced, who performed the work, and which agency (if any) directed you to submit this application. In addition, you will need to clearly differentiate between completed work and proposed work on your project drawings.

Are you aware of any unresolved violations of environmental law or litigation involving the property? ☐ Yes ☑ No
(If yes, please explain)

4. PROJECT COSTS

Approximate cost of the entire project, including materials and labor: $ 40,000,000
Approximate cost of only the portion of the project affecting state waters (channelward of mean low water in tidal areas and below ordinary high water mark in nontidal areas): $ 20,000,000

5. PUBLIC NOTIFICATION (Attach additional sheets if necessary)

Complete information for all property owners adjacent to the project site and across the waterway, if the waterway is less than 500 feet in width. If your project is located within a cove, you will need to provide names and mailing addresses for all property owners within the cove. If you own the adjacent lot, provide the requested information for the first adjacent parcel beyond your property line.

Failure to provide this information may result in a delay in the processing of your application by VMRC.

Property owner's name	Mailing address	City	State	ZIP code
USFWS Chincoteague NWR, (Mr. Robert Leffel,acting refuge manager)	PO Box 62, 8231 Beach Road	Chincoteague	VA	23336

Name of newspaper having general circulation in the area of the project: Shore Daily Newspaper
Address and phone number (including area code) of newspaper PO Box 460 Only, VA 23418, 757-787-3919

Have adjacent property owners been notified with forms in Appendix A? ☐ Yes ☑ No (attach copies of distributed forms)

6. THREATENED AND ENDANGERED SPECIES INFORMATION

Please provide any information concerning the potential for your project to impact state and/or federally threatened and endangered species (listed or proposed). Attach correspondence from agencies and/or reference materials that address potential impacts, such as database search results or confirmed waters and wetlands delineation/jurisdictional determination. Include information when applicable regarding the location of the project in Endangered Species Act-designated or -critical habitats. Contact information for the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, Virginia Dept. of Game and Inland Fisheries, and the Virginia Dept. of Conservation and Recreation-Division of Natural Heritage can be found on page 4 of this package.

7. HISTORIC RESOURCES INFORMATION

Note: Historic properties include but are not limited to archeological sites, battlefields, Civil War earthworks, graveyards, buildings, bridges, canals, etc. Prospective permittees should be aware that section 110k of the NHPA (16 U.S.C. 470h-2(k)) prevents the USACE from granting a permit or other assistance to an applicant who, with intent to avoid the requirements of Section 106 of the NHPA, has intentionally significantly adversely affected a historic property to which the permit would relate, or having legal power to prevent it, allowed such significant adverse effect to occur, unless the USACE, after consultation with the Advisory Council on Historic Preservation (ACHP), determines that circumstances justify granting such assistance despite the adverse effect created or permitted by the applicant.

Are any historic properties located within or adjacent to the project site? ☐ Yes ☑ No ☐ Uncertain
If Yes, please provide a map showing the location of the historic property within or adjacent to the project site.

Are there any buildings or structures 50 years old or older located on the project site? ☐ Yes ☑ No ☐ Uncertain
If Yes, please provide a map showing the location of these buildings or structures on the project site.

Is your project located within a historic district? ☐ Yes ☑ No ☐ Uncertain

If Yes, please indicate which district: _____

7. HISTORIC RESOURCES INFORMATION (Continued)

Has a survey to locate archeological sites and/or historic structures been carried out on the property?
☑ Yes ☐ No ☐ Uncertain

If Yes, please provide the following information: Date of Survey: November 2003 and June/July 2010

Name of firm: URSD Group and EG&G Technical Services

Is there a report on file with the Virginia Department of Historic Resources? ☑ Yes ☐ No ☐ Uncertain

Title of Cultural Resources Management (CRM) report: Cultural Resources Assessment of Wallops Flight Facility

Was any historic property located? ☐ Yes ☑ No ☐ Uncertain

8. WETLANDS, WATERS, AND DUNES/BEACHES IMPACT INFORMATION

Report each impact site in a separate column. If needed, attach additional sheets using a similar table format. Please ensure that the associated project drawings clearly depict the location and footprint of each numbered impact site. For dredging, mining, and excavating projects, use Section 17.

	Impact site number 1	Impact site number 2	Impact site number 3	Impact site number 4	Impact site number 5
Impact description (use all that apply): F=fill EX=excavation S=Structure T=tidal NT=non-tidal TE=temporary PE=permanent PR=perennial IN=intermittent SB=subaqueous bottom DB=dune/beach IS=hydrologically isolated V=vegetated NV=non-vegetated MC=Mechanized Clearing of PFO (*Example: F, NT, PE, V)*	F, T, PE, SB, DB, NV				
Latitude / Longitude (in decimal degrees)	37-50-45/75-28-29				
Wetland/waters impact area (square feet / acres)	See attached narrat				
Dune/beach impact area (square feet)	See attached narrat				
Stream dimensions at impact site (length and average width in linear feet, and area in square feet)	NA				
Volume of fill below Mean High Water or Ordinary High Water (cubic yards)	See attached narrative				

8. WETLANDS/WATERS IMPACT INFORMATION (Continued)

Cowardin classification of impacted wetland/water or geomorphological classification of stream *Example wetland: PFO; Example stream: 'C' channel and if tidal, whether vegetated or non-vegetated wetlands per Section 28.2-1300 of the Code of Virginia*	Marine, Intertidal/ Subtidal,Rock				
Average stream flow at site (flow rate under normal rainfall conditions in cubic feet per second) and method of deriving it (gage, estimate, etc.)	NA	NA			
Contributing drainage area in acres or square miles (*VMRC cannot complete review without this information*)	NA	NA			
DEQ classification of impacted resource(s): Estuarine Class II Non-tidal waters Class III Mountainous zone waters Class IV Stockable trout waters Class V Natural trout waters Class VI Wetlands Class VII http://leg1.state.va.us/cgi-bin/legp504.exe?000+reg+9VAC25-260-50	Class I Open Ocean	Class I Open Ocean			

For DEQ permitting purposes, also submit as part of this section a wetland and waters boundary delineation map – see (3) in the Footnotes section in the form instructions.

For DEQ permitting purposes, also submit as part of this section a written disclosure of all wetlands, open water, or streams that are located within the proposed project or compensation areas that are also under a deed restriction, conservation easement, restrictive covenant, or other land-use protective instrument.

9. APPLICANT, AGENT, PROPERTY OWNER, AND CONTRACTOR CERTIFICATIONS

READ ALL OF THE FOLLOWING CAREFULLY BEFORE SIGNING

PRIVACY ACT STATEMENT: The Department of the Army permit program is authorized by Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act, and Section 103 of the Marine Protection Research and Sanctuaries Act of 1972. These laws require that individuals obtain permits that authorize structures and work in or affecting navigable waters of the United States, the discharge of dredged or fill material into waters of the United States, and the transportation of dredged material for the purpose of dumping it into ocean waters prior to undertaking the activity. Information provided in the Joint Permit Application will be used in the permit review process and is a matter of public record once the application is filed. Disclosure of the requested information is voluntary, but it may not be possible to evaluate the permit application or to issue a permit if the information requested is not provided.

CERTIFICATION: I am hereby applying for permits typically issued by the DEQ, VMRC, USACE, and/or Local Wetlands Boards for the activities I have described herein. I agree to allow the duly authorized representatives of any regulatory or advisory agency to enter upon the premises of the project site at reasonable times to inspect and photograph site conditions, both in reviewing a proposal to issue a permit and after permit issuance to determine compliance with the permit.

In addition, I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

9. APPLICANT, AGENT, PROPERTY OWNER, AND CONTRACTOR CERTIFICATIONS (Continued)

Is/Are the Applicant(s) and Owner(s) the same? ☑ *Yes* ☐ *No*

Legal name & title of Applicant Paul Bull, PE NASA Project Manager	Second applicant's legal name & title, if applicable
Applicant's signature	Second applicant's signature
Date 4/8/26	Date
Property owner's legal name, if different from Applicant	Second property owner's legal name, if applicable
Property owner's signature, if different from Applicant	Second property owner's signature
Date	Date

CERTIFICATION OF AUTHORIZATION TO ALLOW AGENT(S) TO ACT ON APPLICANT'S(S') BEHALF (IF APPLICABLE)

I (we), NA _____ (and) _____ ,
APPLICANT'S LEGAL NAME(S) – *complete the second blank if more than one Applicant*

hereby certify that I (we) have authorized _____ (and) _____
AGENT'S NAME(S) – *complete the second blank if more than one Agent*
to act on my (our) behalf and take all actions necessary to the processing, issuance, and acceptance of this permit and any and all standard and special conditions attached. I (we) hereby certify that the information submitted in this application is true and accurate to the best of my (our) knowledge.

Applicant's signature	Second applicant's signature, if applicable
Date	Date
Agent's signature and title	Second agent's signature and title, if applicable
Date	Date

CONTRACTOR ACKNOWLEDGEMENT (IF APPLICABLE)

I (we), _____ (and) _____ ,
APPLICANT'S LEGAL NAME(S) – *complete the second blank if more than one Applicant*

have contracted _____ (and) _____
CONTRACTOR'S NAME(S) – *complete the second blank if more than one Contractor*

to perform the work described in this Joint Permit Application, signed and dated _____.

I (we) will read and abide by all conditions as set forth in all federal, state, and local permits as required for this project. I (we) understand that failure to follow the conditions of the permits may constitute a violation of applicable federal, state, and local statutes and that we will be liable for any civil and/or criminal penalties imposed by these statutes.
In addition, I (we) agree to make available a copy of any permit to any regulatory representative visiting the project site to ensure permit compliance. If I (we) fail to provide the applicable permit upon request, I (we) understand that the representative will have the option of stopping our operation until it has been determined that we have a properly signed and executed permit and are in full compliance with all of the terms and conditions.

Contractor's name or name of firm (printed/typed)	Contractor's or firm's mailing address	
Contractor's signature and title	Contractor's license number	Date
Applicant's signature	Second applicant's signature, if applicable	
Date	Date	

U.S. Army Corps
Of Engineers
Norfolk District

Regional Permit 17 Certificate of Compliance Form

Please obtain and read a copy of the 13-RP-17 prior to completion of this form. Copies can be obtained by contacting the U.S. Army Corps of Engineers Regulatory Branch (Corps) at (757) 201-7652 or on our website at: http://www.nao.usace.army.mil/Missions/Regulatory/RBregional.aspx .

YES ☐ NO ☐ Is the proposed pier for private use ONLY?

YES ☐ NO ☐ Does the proposed pier extend LESS than ¼ the width of the waterway as measured from MHW to MHW or OHW to OHW (including channelward wetlands) based on the narrowest distance across the waterway regardless of the orientation of the proposed pier (MHW = mean high water line; OHW = ordinary high water line)?

YES ☐ NO ☐ Does the proposed pier and/or mooring structure(s) extend LESS than 300 feet from the mean high water line or ordinary high water line?

YES ☐ NO ☐ N/A ☐ If the proposed structure crosses wetland vegetation, is it of an open-pile design that has a maximum width of five (5) feet and a minimum height of four (4) feet between the decking and the wetland substrate?

YES ☐ NO ☐ N/A ☐ If the proposed pier is to include an attached open-sided roof designed to provide shelter, is the cumulative roof square footage less than 700 square feet?

YES ☐ NO ☐ N/A ☐ Is the total number of boat slips on the property less than or equal to two boat slips?

YES ☐ NO ☐ Have you confirmed that the proposed construction will not take place in one of the reaches which serve as habitat for federally threatened and endangered species, Federal Navigation Channels, and/or does not meet any of the requirements listed in the "V. NOTIFICATION REQUIREMENTS #1-7" section of this permit?

YES ☐ NO ☐ N/A ☐ If the proposed work is in portions of any waterways listed in Special Condition 6, have you obtained an easement to cross government property from the Army Corps of Engineers Real Estate Office?

IF YOU HAVE ANSWERED "NO" TO ANY OF THE QUESTIONS ABOVE, THE REGIONAL PERMIT 17 WILL NOT APPLY AND YOU WILL NEED TO SUBMIT A JOINT PERMIT APPLICATION AND OBTAIN A SEPARATE PERMIT FROM THE CORPS BEFORE COMMENCING CONSTRUCTION.

IF YOU HAVE ANSWERED "YES" (OR "N/A", WHERE APPLICABLE) TO ALL OF THE QUESTIONS ABOVE, YOU ARE IN COMPLIANCE WITH THE REGIONAL PERMIT 17. PLEASE SIGN BELOW, ATTACH, AND SUBMIT WITH YOUR COMPLETED JOINT PERMIT APPLICATION. THIS SIGNED CERTIFICATE SERVES AS YOUR LETTER OF AUTHORIZATION FROM THE CORPS. YOU WILL NOT RECEIVE ANY OTHER WRITTEN AUTHORIZATION FROM THE CORPS. HOWEVER, YOU MAY NOT PROCEED WITH CONSTRUCTION UNTIL YOU HAVE OBTAINED ALL OTHER NECESSARY STATE AND LOCAL PERMITS.

I CERTIFY THAT I HAVE READ AND UNDERSTAND ALL CONDITIONS OF THE REGIONAL PERMIT 17 (13-RP-17), DATED AUGUST 14 2013, ISSUED BY THE US ARMY CORPS OF ENGINEERS, NORFOLK DISTRICT REGULATORY BRANCH (CENAO-WR-R), NORFOLK, VIRGINIA.

_____
Signature of Property Owner(s) or Agent

Date _____

Proposed work to be located at:

_____

_____

_____

Revision Date: August 2013

APPENDIX C

Chesapeake Bay Preservation Act Information

Please answer the following questions to determine if your project is subject to the requirements of the Bay Act Regulations:

1. Is your project located within Tidewater Virginia? ☐ Yes ☐ No (See map on page 31) - If the answer is "no", the Bay Act requirements do not apply; if "yes", then please continue to question #2.

2. Please indicate if the project proposes to impact any of the following Resource Protection Area (RPA) features:

   ☐ Tidal wetlands,

   ☐ Nontidal wetlands connected by surface flow and contiguous to tidal wetlands or water bodies with perennial flow,

   ☐ Tidal shores,

   ☐ Other lands considered by the local government to meet the provisions of subsection A of 9VAC25-830-80 and to be necessary to protect the quality of state waters (contact the local government for specific information),

   ☐ A buffer area not less than 100 feet in width located adjacent to and landward of the components listed above, and along both sides of any water body with perennial flow.

If the answer to question #1 was "yes" and any of the features listed under question #2 will be impacted, compliance with the Chesapeake Bay Preservation Area Designation and Management Regulations is required. **The Chesapeake Bay Preservation Area Designation and Management Regulations** are enforced through locally adopted ordinances based on the Chesapeake Bay Preservation Act (CBPA) program. Compliance with state and local CBPA requirements mandates the submission of a ***Water Quality Impact Assessment (WQIA)*** for the review and approval of the local government. Contact the appropriate local government office to determine if a WQIA is required for the proposed activity(ies).

The individual localities, not the DEQ, USACE, or the Local Wetlands Boards, are responsible for enforcing the CBPA requirements and, therefore, local permits for land disturbance are not issued through this JPA process. **Approval of this wetlands permit does not constitute compliance with the CBPA regulations nor does it guarantee that the local government will grant approval for encroachments into the RPA that may result from this project.**

Notes for all projects in RPAs

Development, redevelopment, construction, land disturbance, or placement of fill within the RPA features listed above requires the approval of the locality and may require an exception or variance from the local Bay Act ordinance. Please contact the appropriate local government to determine the types of development or land uses that are permitted within RPAs.

Pursuant to 9VAC25-830-110, *on-site delineation of the RPA is required for all projects in CBPAs*. Because USGS maps are not always indicative of actual "in-field" conditions, they may not be used to determine the site-specific boundaries of the RPA.

Notes for shoreline erosion control projects in RPAs

Re-establishment of woody vegetation in the buffer will be required by the locality to mitigate for the removal or disturbance of buffer vegetation associated with your proposed project. Please contact the local government to determine the mitigation requirements for impacts to the 100-foot RPA buffer.

Pursuant to 9VAC25-830-140 5 a (4) of the Virginia Administrative Code, shoreline erosion projects are a permitted modification to RPAs provided that the project is based on the "best technical advice" and complies with applicable permit conditions. In accordance with 9VAC25-830-140 1 of the Virginia Administrative Code, the locality will use the information provided in this Appendix, in the project drawings, in this permit application, and as required by the locality, to make a determination that:

1. Any proposed shoreline erosion control measure is necessary and consistent with the nature of the erosion occurring on the site, and the measures have employed the "best available technical advice"
2. Indigenous vegetation will be preserved to the maximum extent practicable
3. Proposed land disturbance has been minimized
4. Appropriate mitigation plantings will provide the required water quality functions of the buffer (9VAC25-830-140 3)
5. The project is consistent with the locality's comprehensive plan
6. Access to the project will be provided with the minimum disturbance necessary.

TIDEWATER VIRGINIA



APPENDIX D

Sample Drawings

On the following pages, you will find lists of information required on drawings, as well as sample drawings in plan and cross-sectional views. While the lists attempt to capture all required information for drawings, please verify your submittal with the applicable agency regulations. For DEQ drawing definitions and requirements, see Sections 10 and 80 of 9VAC25-210; and in Section 60 of the general permit regulations 9VAC25-660, 9VAC25-670, 9VAC25-680, and 9VAC25-690. Please be advised that some Local Wetlands Boards (LWB) require you to have a licensed engineer certify the drawings. You should contact your LWB to determine their specific requirements. Failure to include all necessary information on your drawings may mean that your application is not considered complete by one or more agencies.

All projects will require the submittal of plan view and cross-sectional view drawings. Drawings should be drawn to a scale no smaller than 1 inch = 200 feet. The number of sets of drawings to be submitted is detailed in the HOW TO APPLY section starting on page 2 of this package. Drawings can be computer-generated or hand-drawn. The sample drawings demonstrate the **general** format necessary, *but for ease of viewing, not all of the required information is shown in the sample drawings***.**

Plan view *drawings should contain the following general informational items:*

- Name of project
- North arrow
- Scale
- Waterway name, if designated
- Existing topographic or bathymetric contours
- Proposed topographic or bathymetric contours
- Width of waterway from the mean high water level to the mean high water level (tidal areas), or the ordinary high water mark to the ordinary high water mark (nontidal areas)
- Direction of flood and ebb (tidal areas), and/or direction of flow in nontidal areas (if applicable)
- Mean low water level and mean high water level (tidal areas), or ordinary high water mark (nontidal areas)
- Landward limit of the dune or beach at the site
- Limits of proposed impacts to surface waters, such as fill areas, riprap scour protection placement, and dredged areas; the amount of such impacts in square feet and acres; and the latitude/longitude (decimal degrees) at each impact site
- All delineated wetlands and all surface waters on the site, including the Cowardin classification (i.e., emergent, scrub-shrub, or forested) for those surface waters and waterway name, if designated

AND Plan view *drawings should also contain the following specific informational items* ***if they apply to the project****:*

Resource Impact/Protection-Specific Items:

- Limits of: existing*, non-delineated* wetlands, open water, or streams, including submerged aquatic vegetation (SAV), riffle/pool complexes, or bars; Chesapeake Bay Preservation Act Resource Protection Area(s) (RPA), including the 100-foot buffer; proposed clearing within the RPA buffer; and any areas that are under a deed restriction, conservation easement, restrictive covenant, or other land use protective instrument (i.e., protected areas)
- Location and type of existing vegetation within the 100-foot RPA buffer and location of proposed wetland planting areas (as restoration for temporary impacts or mitigation for permanent impacts)
- Historic/cultural resources
- Threatened/Endangered resources

Structure/Project-Specific Items:

- Existing and proposed structures, labeled as ‘existing’ and ‘proposed’, and their dimensions. These items may include pier(s), including L-heads, T-heads, platforms, and/or decks; roof(s) on roofed structures located over waterways, including boathouses; gasoline storage tanks and/or structures for collecting and handling hazardous material, including settling tanks for travel lift washdown water, paint chips, etc.; return walls; tie-ins to existing bulkhead(s) or riprap; utility line easement(s); utility line/road right(s)-of-way; aerial transmission line structure(s), including towers, poles, platforms, etc.; onsite or offsite dredged material disposal areas, including location of all berms, spillways, erosion and sediment control measures, outfall pipes, and aprons; temporary stockpiles of excavated material; temporary construction access facilities; risers and/or emergency spillways, labeled with their proposed invert elevations; design pool/normal pool for stormwater management ponds/impoundments/reservoirs; intakes and/or outfalls, including splash aprons, relative to mean high water, mean low water, or ordinary high water mark(s); anchoring devices and weights (mooring buoys), including the total swing radius
- Channelward encroachment of proposed structure(s) from mean high water and mean low water, or from ordinary high water mark
- For piers that cover ¼ or more of the waterway width: depth soundings, taken at the mean low water level (tidal areas) or the ordinary high water mark (nontidal areas)
- Distance(s) between structure(s) (piers, boathouses, catwalks, etc.) and mooring pile(s)
- Minimum distance between dredge cut and vegetated wetlands
- Latitude and longitude of all mooring structures, in degrees, minutes, and seconds
- End points and turning points along proposed bulkhead(s), labeled as such

- For bulkheads, measurements from each end point and each turning point along proposed bulkhead(s) to two fixed points of reference (labeled as such)
- Structure or method used to contain fill (hay bales, silt fences, etc.)
- Dimensions of impoundment, dam, or stormwater management facility and area of any vegetative management areas

Cross-sectional view drawings, and when required profile view* drawings, *should contain the following General Informational items:*

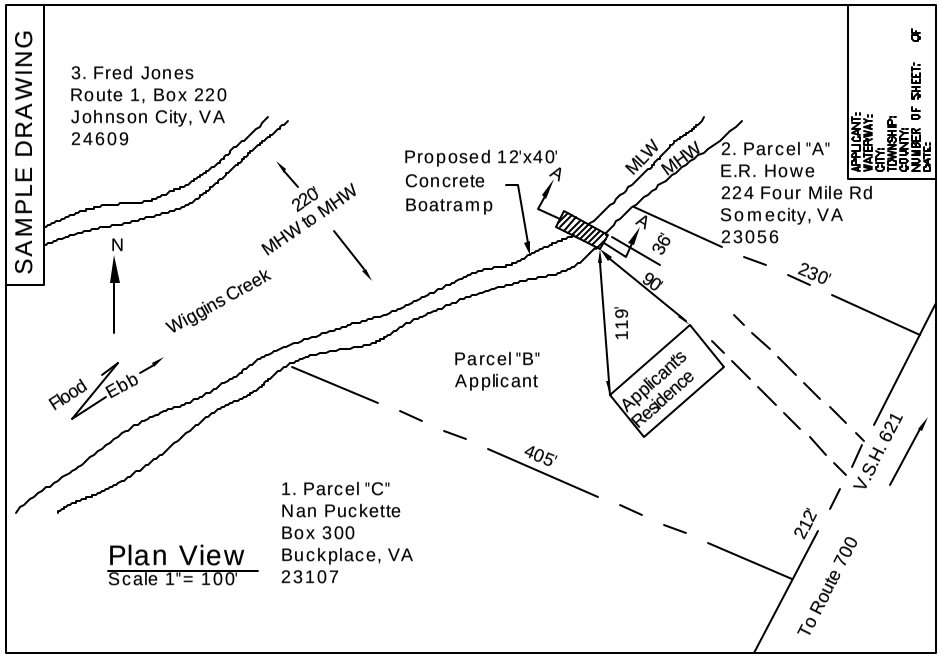
- Name of project
- North arrow
- Scale
- Waterway name
- Mean low water and mean high water lines (tidal areas), and/or ordinary high water mark (nontidal areas)
- Direction of flood and ebb (tidal areas), and/or direction of flow in nontidal areas (if applicable)
- Existing contours of the bottom (depths relative to mean low water or ordinary high water mark) and the bank itself
- Existing contours of the dune or beach
- Existing and proposed elevations
- Location of all existing and proposed structures
- Limits of proposed impacts to surface waters, such as fill areas, riprap scour protection placement, and dredged areas; the amount of such impacts in square feet and acres; and the latitude/longitude (decimal degrees) at each impact site

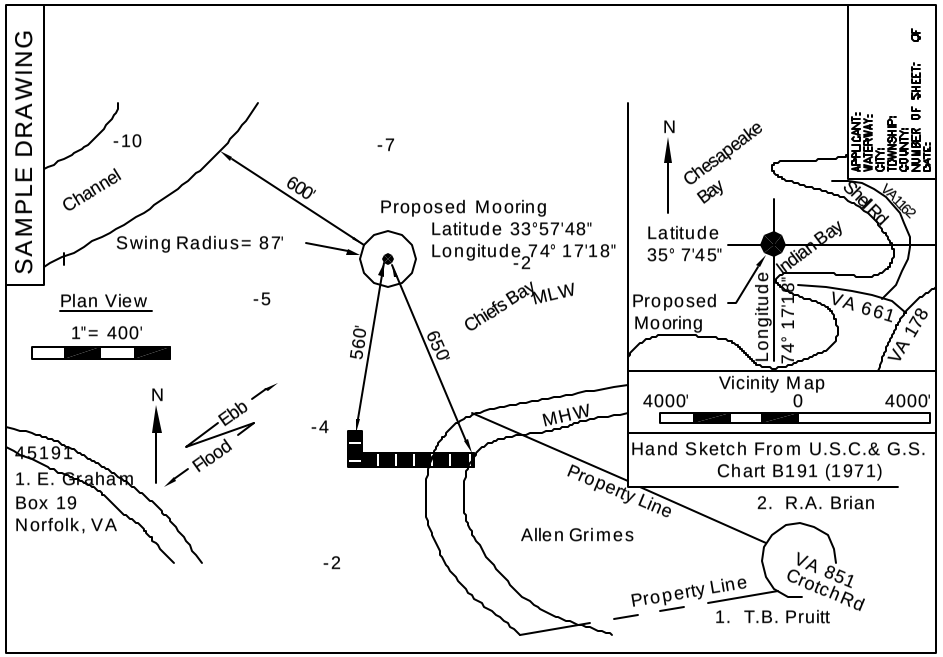
AND Cross-sectional view drawings, and when required profile view* drawings, *should also contain the following specific informational items* ***if they apply to the project****:*

Resource impact/protection-specific Items:
- Limits of: existing*, non-delineated* wetlands, open water, or streams, including submerged aquatic vegetation (SAV), riffle/pool complexes, or bars; Chesapeake Bay Preservation Act Resource Protection Area(s) (RPA), including the 100-foot buffer; and proposed clearing within the RPA buffer
- Riprap scour protection
- Proposed wetland planting areas, relative to mean high water and mean low water (tidal areas), or ordinary high water mark (nontidal areas)
- Depth of buried toe of riprap or marsh toe stabilization
- Base width, top width, and slope of stone/concrete stabilization structures

Structure/Project-Specific Items:
- Existing and proposed structures, labeled as 'existing' and 'proposed', and their dimensions. These items may include fill areas, labeled with square footage(s) or acreage(s) over vegetated wetlands and subaqueous bottom; berms, spillways, erosion and sediment control measures, outfall pipes, and aprons at onsite or offsite dredged material disposal area(s); bank grades; deadmen, sheeting, knee braces, etc., as used in the construction of bulkheads; filter cloth; weep holes; intakes and/or outfalls, including splash aprons, relative to mean high water, mean low water, or ordinary high water mark; risers and/or emergency spillways; low-flow channels; culverts, including their proposed invert elevations and diameters; anchoring systems for aquaculture structures; type of chain used to secure mooring buoys to subaqueous bottom
- For dredge projects, proposed contours of the bottom (depth relative to mean low water or ordinary water level)
- Bottom width of proposed dredge cut, projected side slope of cut, and estimated top width of cut
- Ponding depth of onsite or offsite dredged material disposal area
- Minimum distance between pier decking and vegetated wetland substrate (a.k.a. the "mud line")
- Water depth below mean low water at the end of proposed boat ramps
- Depth of penetration of pilings and/or sheeting (bulkheads)
- Elevation of any proposed fill (including backfill)
- Structure or method used to contain fill (hay bales, silt fences, etc.)
- Design pool/normal pool elevation for stormwater management facilities/impoundments/reservoirs
- Vertical distance from the water surface (relative to mean high water or ordinary high water mark) for all aerial crossings (bridges or overhead utility lines) over navigable water bodies
- Depth below bottom of water body for submarine utility crossings
- Dimensions of impoundment, dam, or stormwater management facility through a cross-section of the structure(s); bottom elevation(s) of basin created; depth of pool; and depth(s) to structure(s) on the bottom.

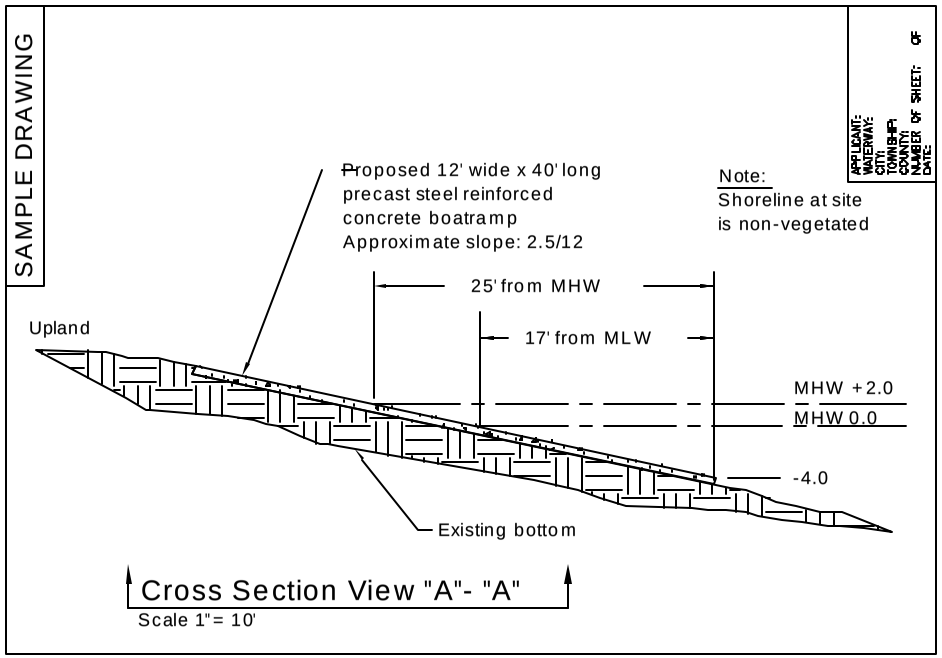
** Profile drawing or drawings with the information noted in Appendix D may be required by DEQ on a case-by-case basis to demonstrate minimization of impacts. When required, any application that proposes piping or culverting stream flows shall provide a longitudinal profile of the pipe or culvert position and stream bed thalweg, or shall provide spot elevations of the stream thalweg at the beginning and end of the pipe or culvert, extending to a minimum of 10 feet beyond the limits of proposed impact.*

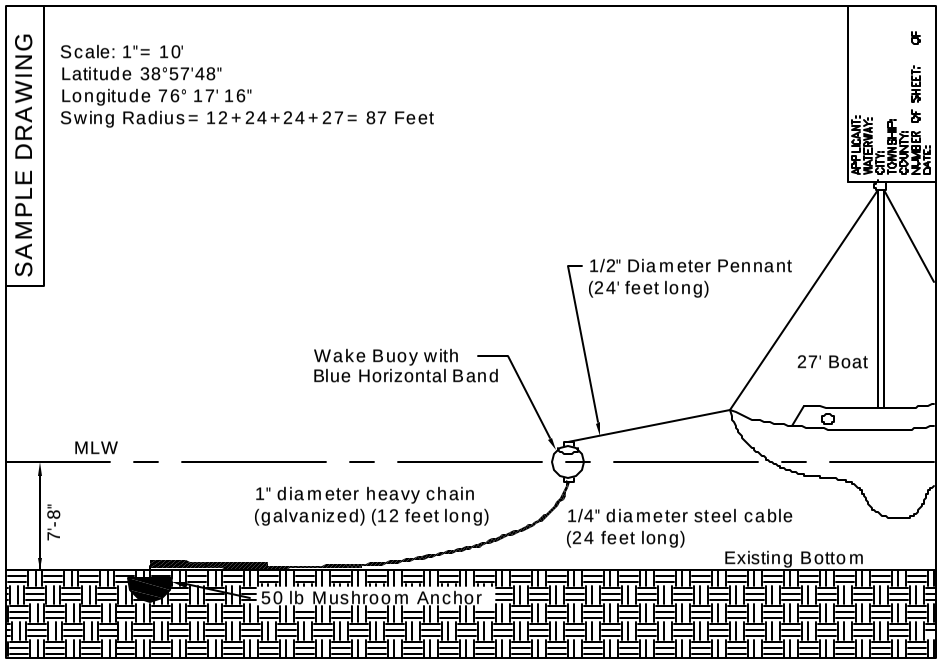


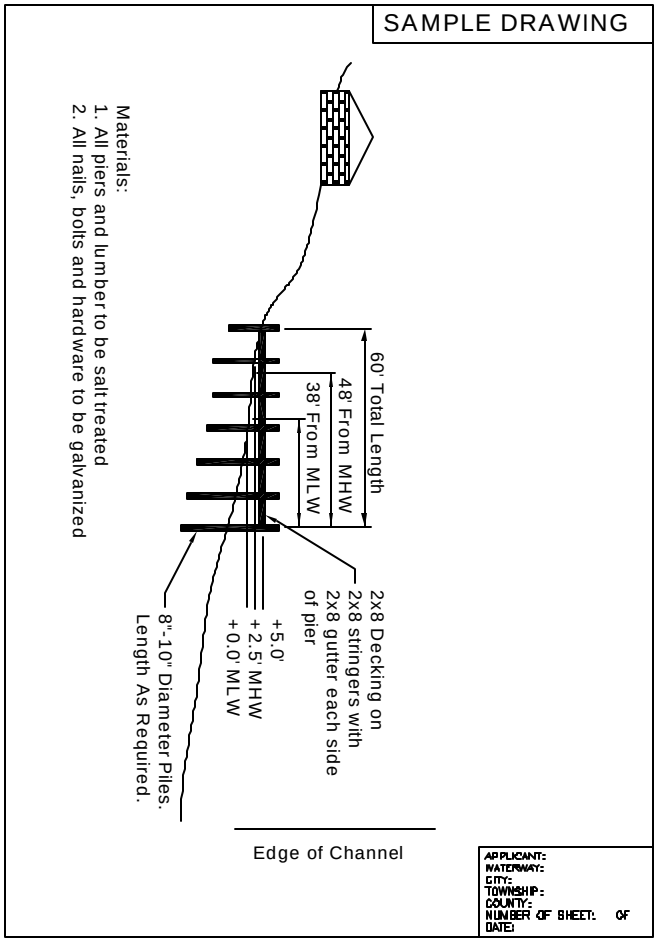


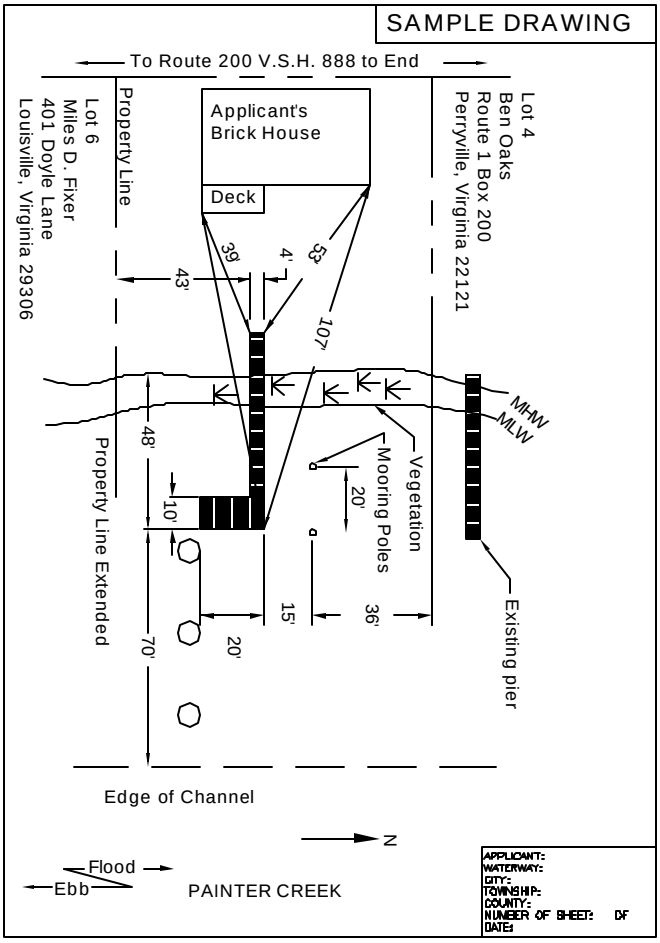
Boat Ramps

Dolphins or Moorings

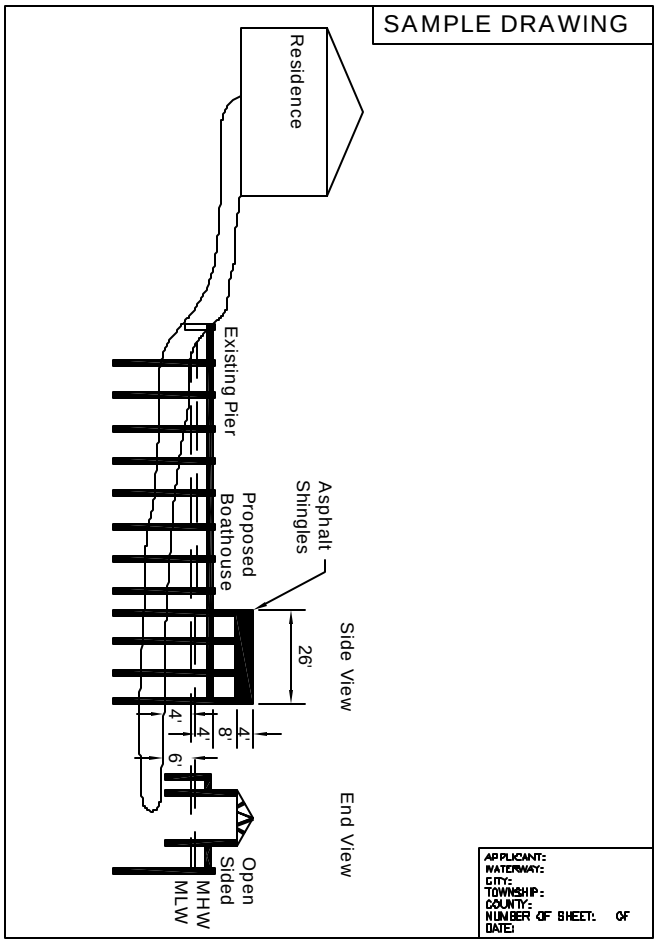


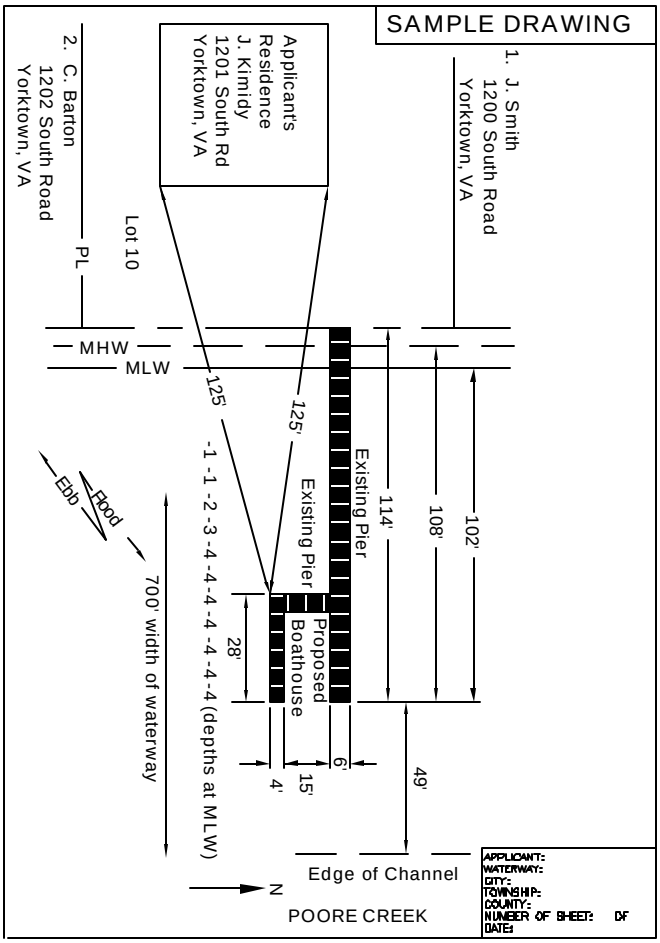




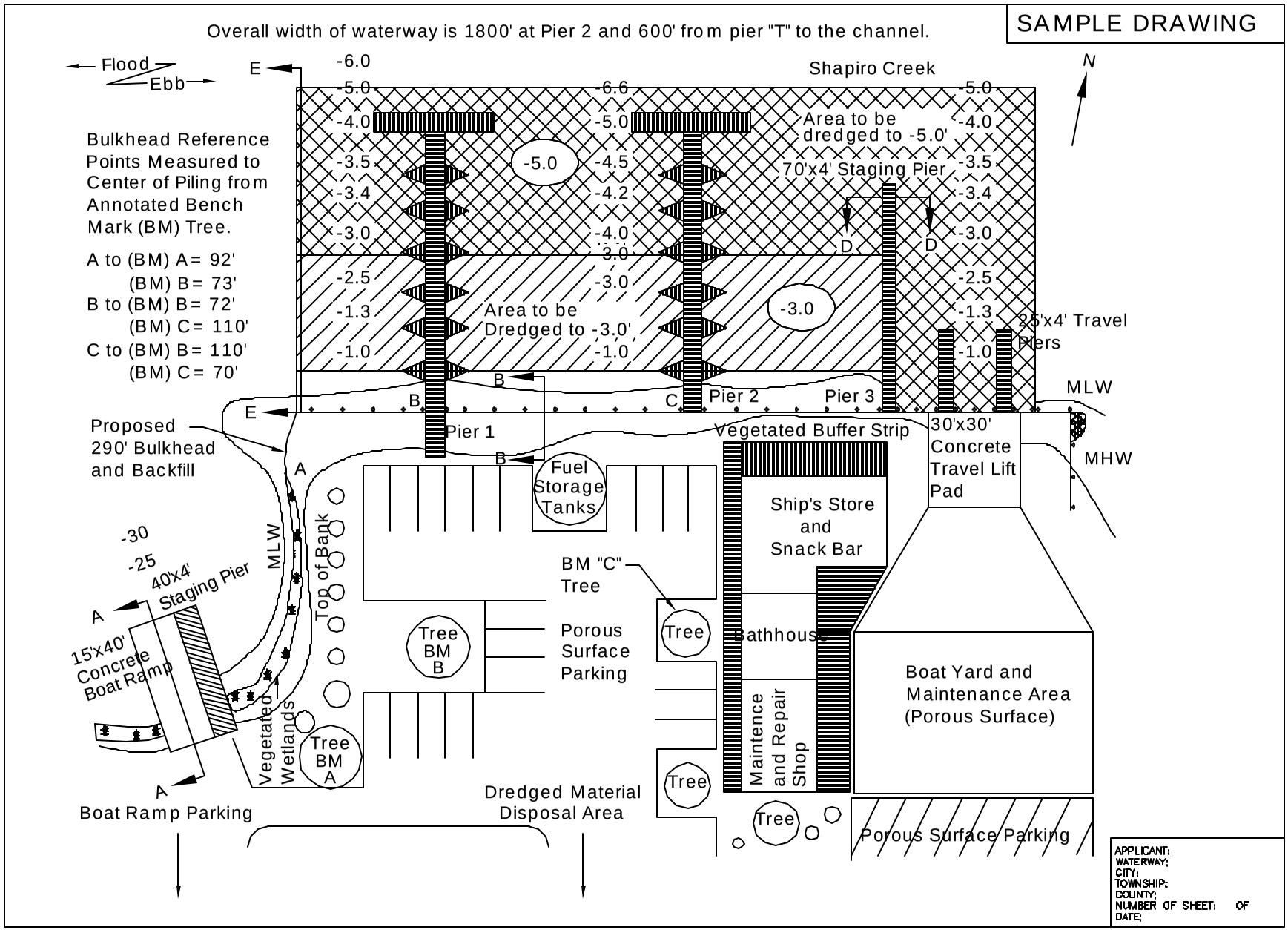


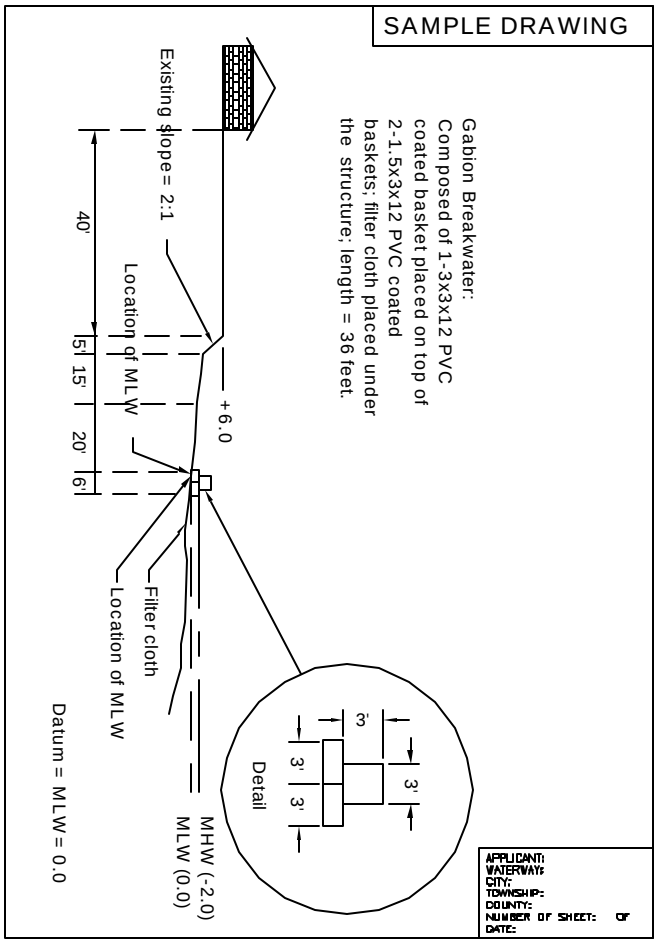
Private Piers & Marginal Wharves

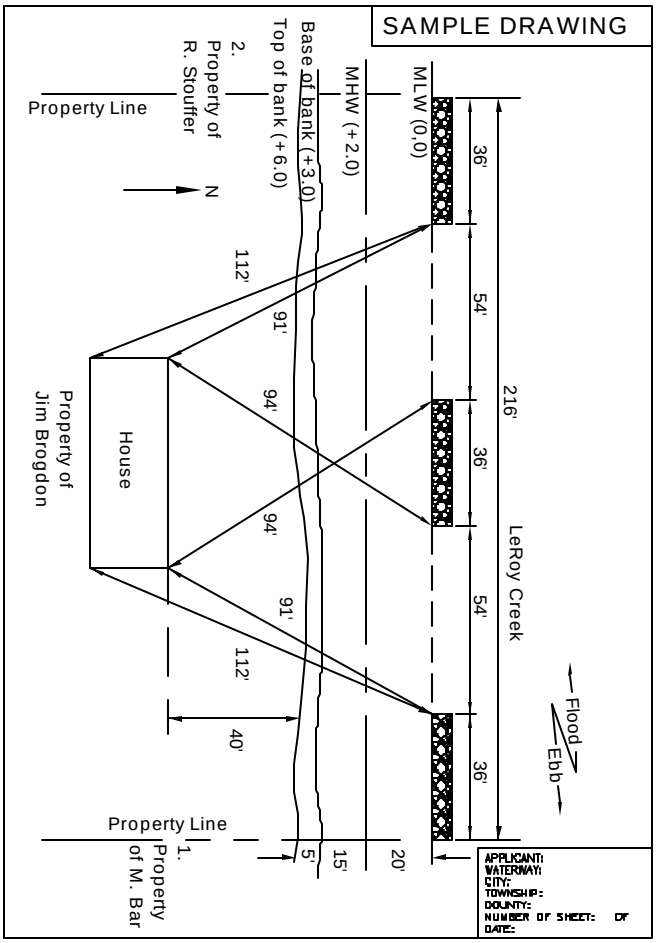




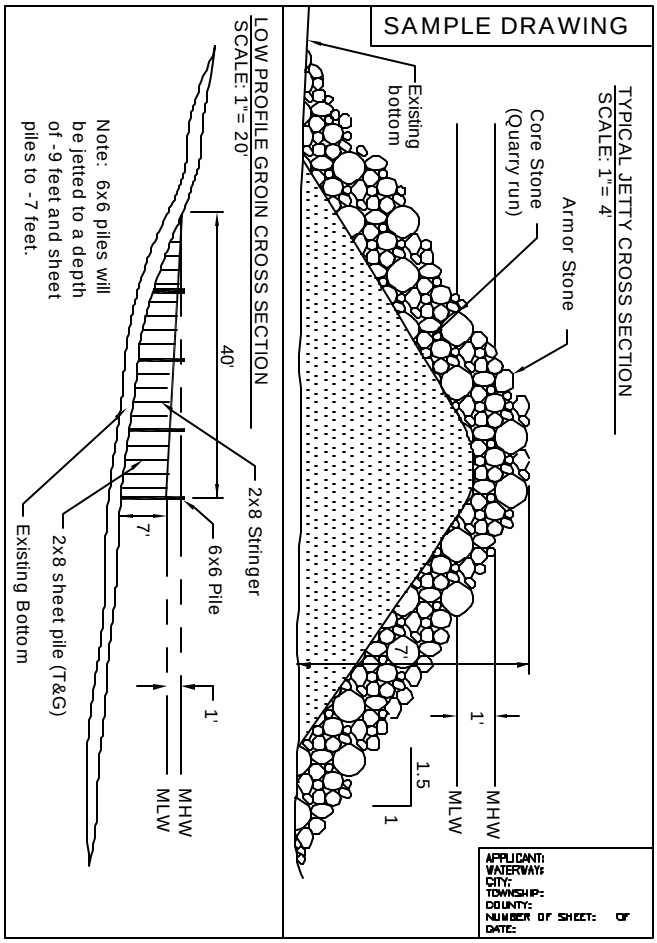
Boathouses

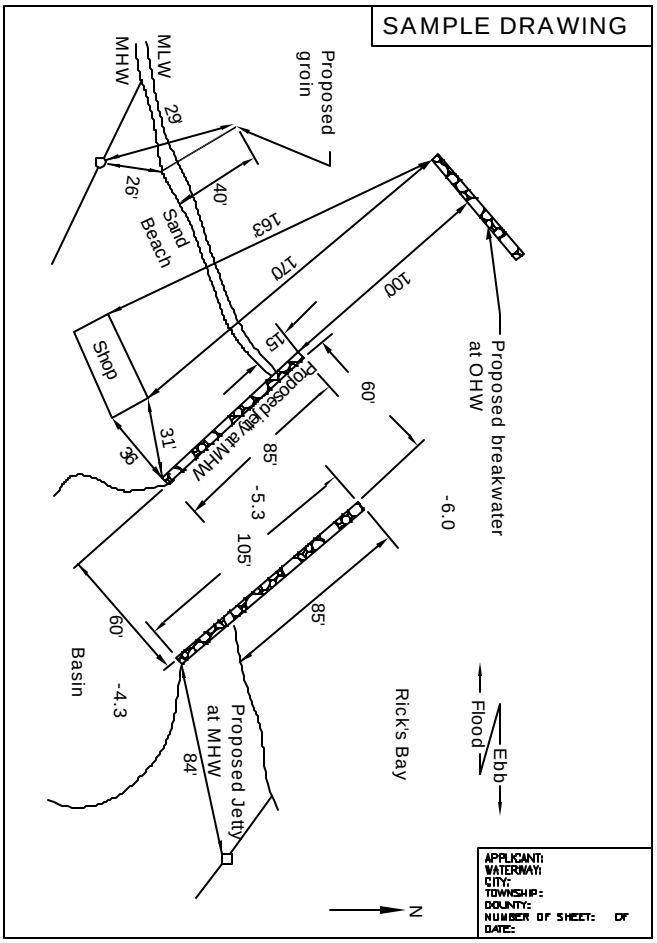

SAMPLE DRAWING
Overall width of waterway is 1800' at Pier 2 and 600' from pier "T" to the channel.
Flood
Ebb
Shapiro Creek
N
Bulkhead Reference Points Measured to Center of Piling from Annotated Bench Mark (BM) Tree.
A to (BM) A= 92'
(BM) B= 73'
B to (BM) B= 72'
(BM) C= 110'
C to (BM) B= 110'
(BM) C= 70'
Area to be dredged to -5.0'
70'x4' Staging Pier
Area to be Dredged to -3.0'
25'x4' Travel Piers
Pier 1
Pier 2
Pier 3
MLW
MHW
Proposed 290' Bulkhead and Backfill
Vegetated Buffer Strip
30'x30' Concrete Travel Lift Pad
Fuel Storage Tanks
Ship's Store and Snack Bar
Top of Bank
MLW
-30
-25
40'x4' Staging Pier
BM "C" Tree
Tree BM B
Porous Surface Parking
Bathhouse
Boat Yard and Maintenance Area (Porous Surface)
15'x40' Concrete Boat Ramp
Vegetated Wetlands
Tree BM A
Maintence and Repair Shop
Boat Ramp Parking
Dredged Material Disposal Area
Porous Surface Parking
APPLICANT:
WATERWAY:
CITY:
TOWNSHIP:
COUNTY:
NUMBER OF SHEET: OF
DATE:





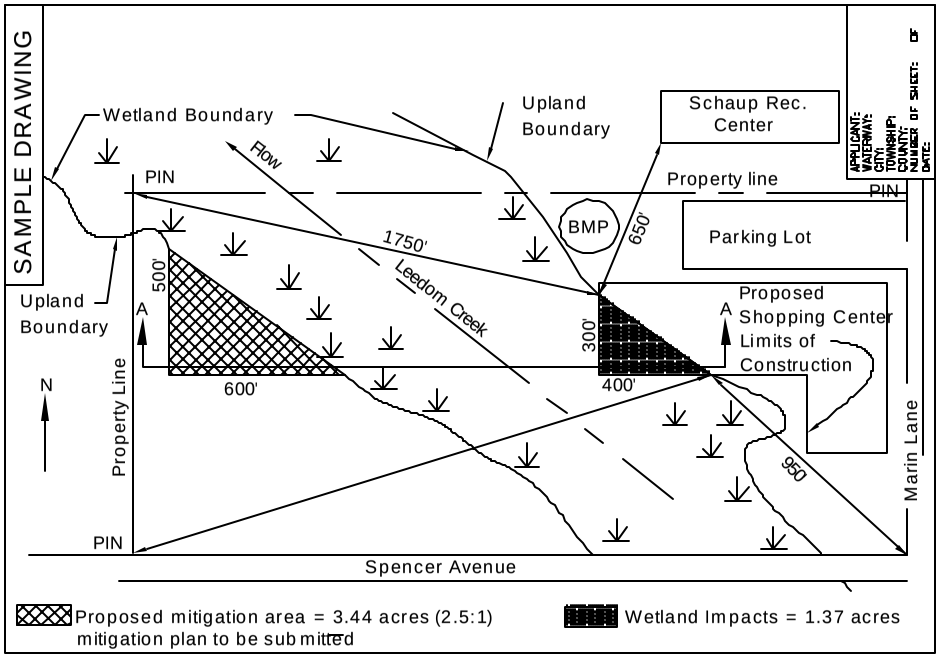
Breakwaters

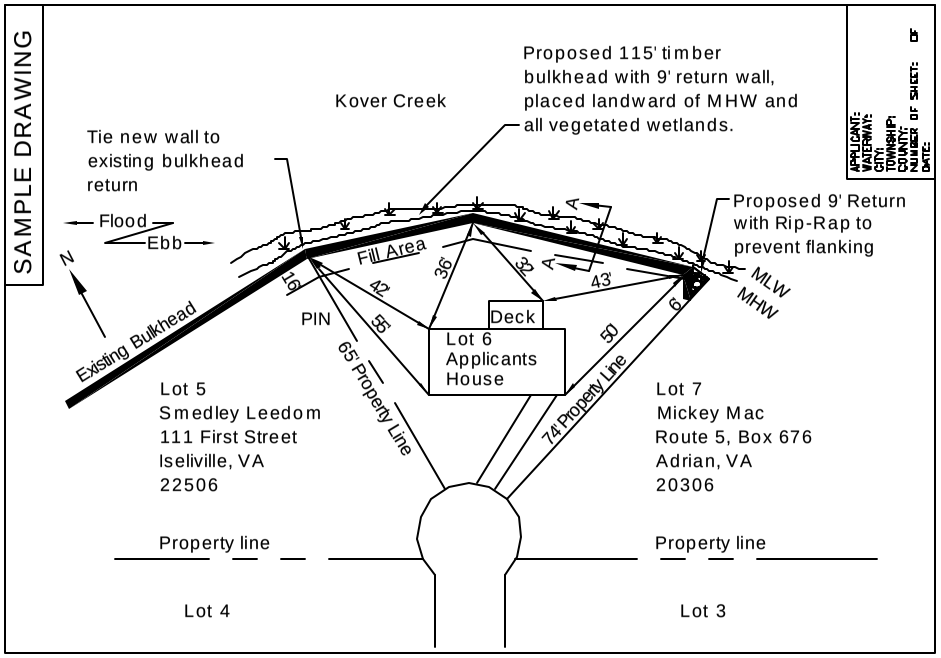




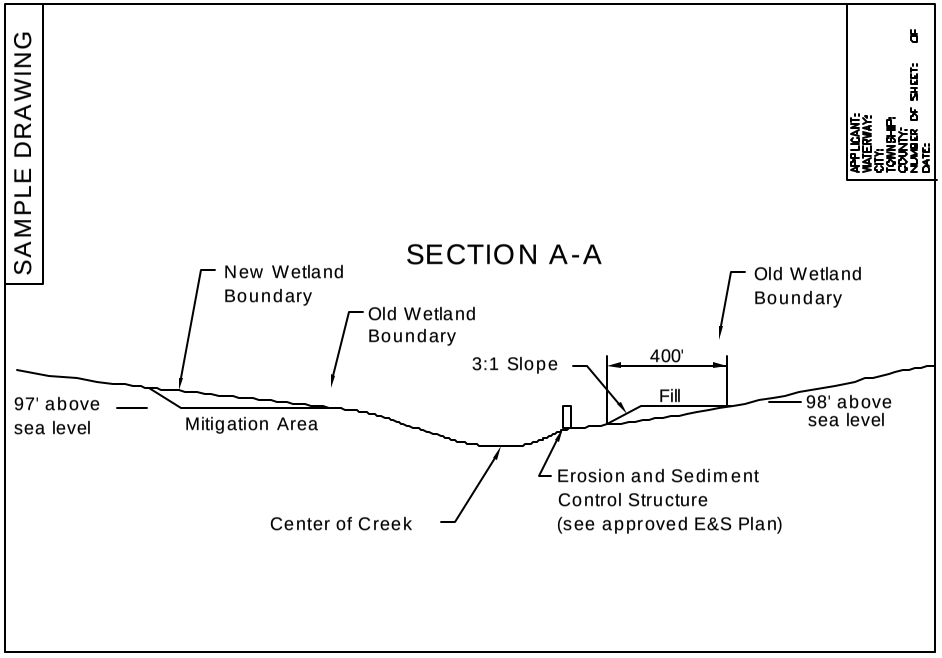
Groins & Jetties

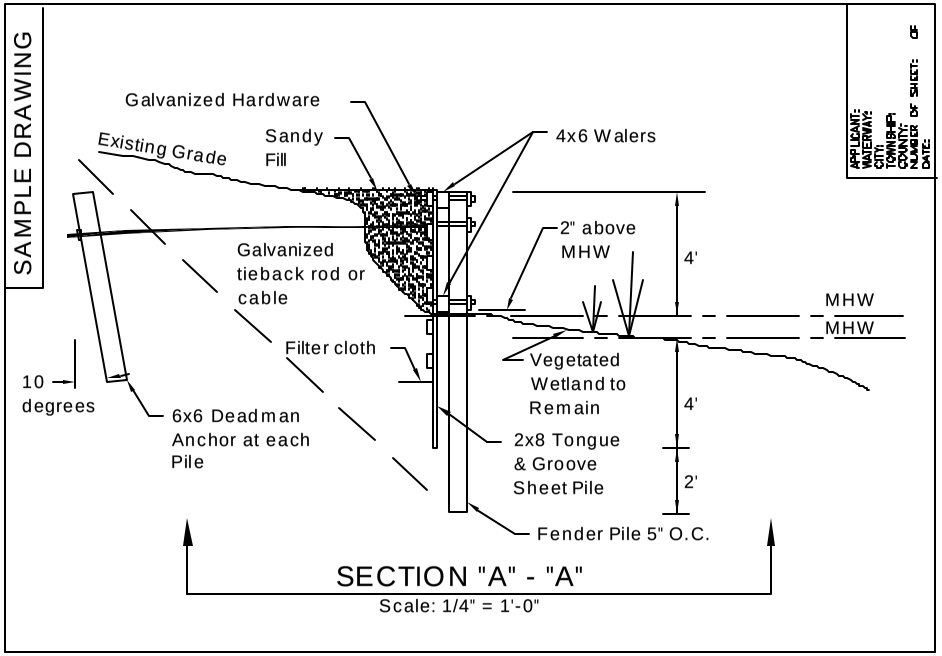
Filling Waters/Wetlands

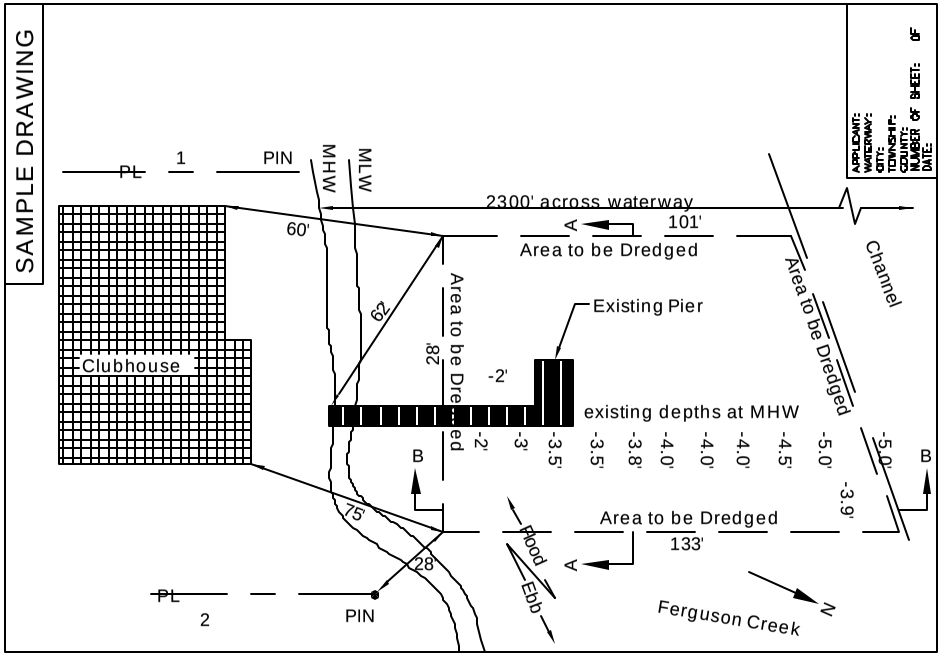


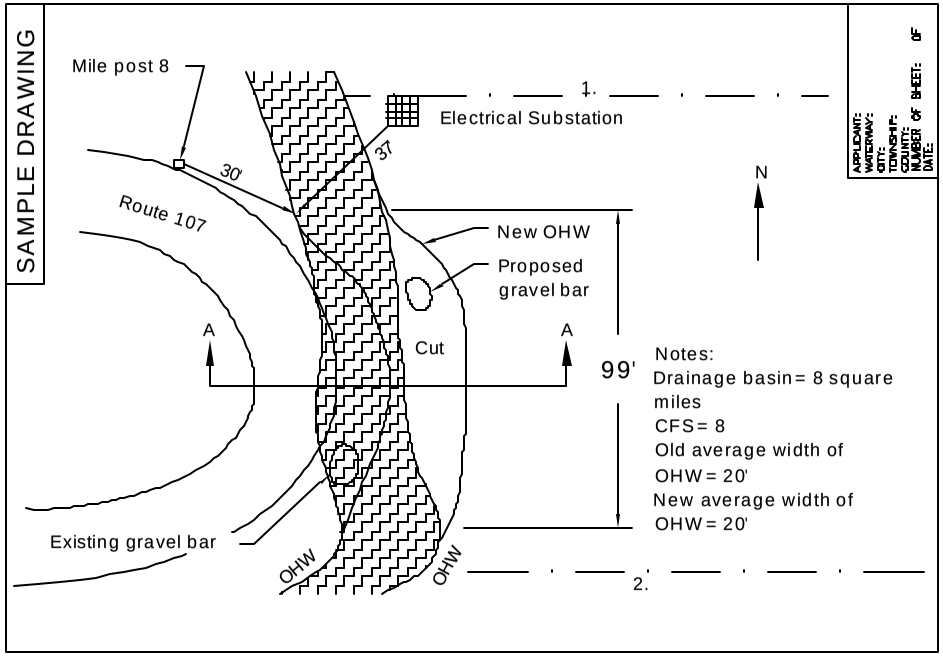


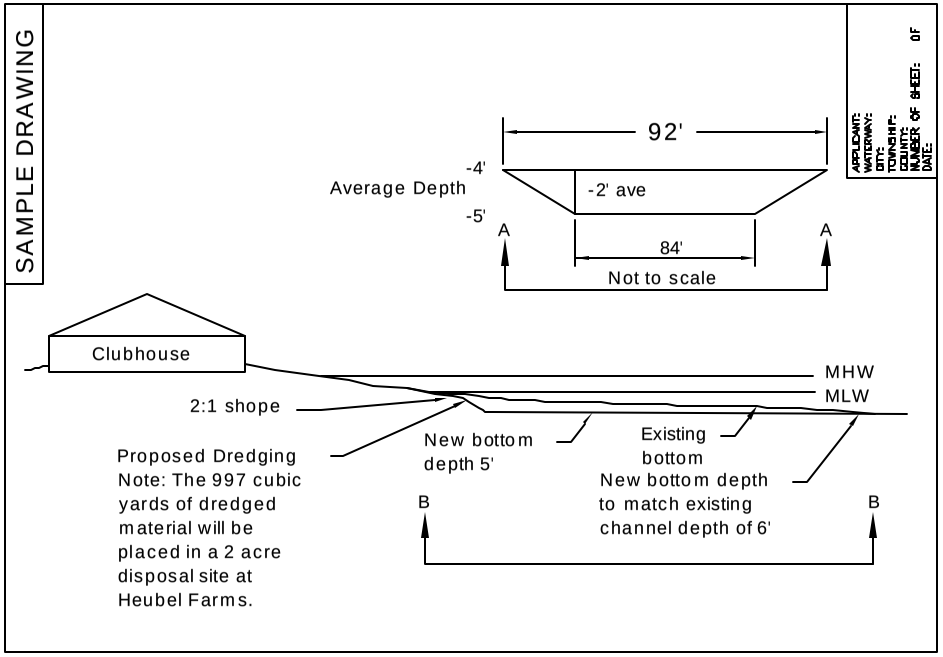
Bulkheads and Associated Backfill

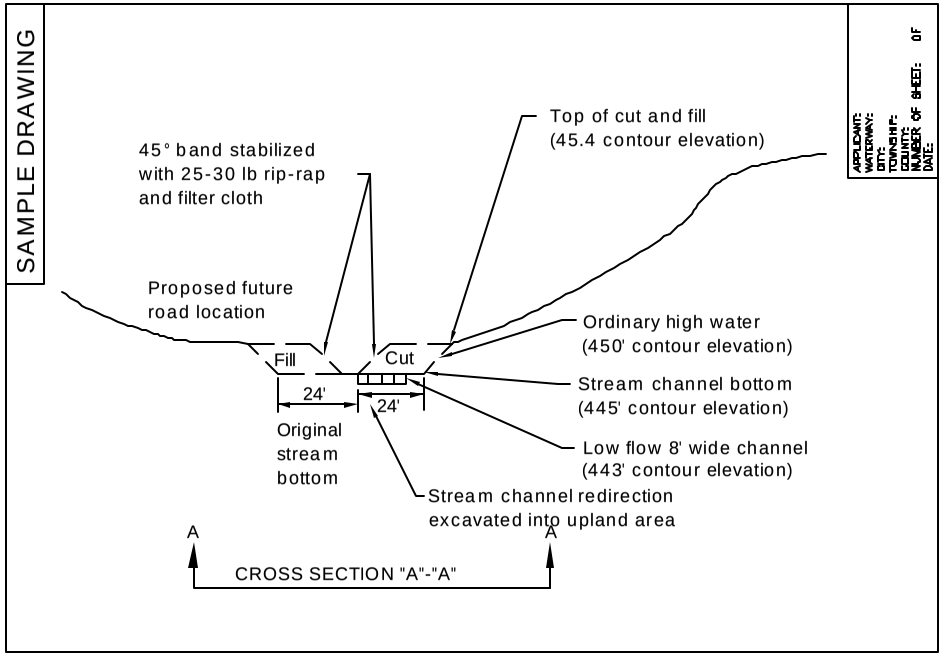





SAMPLE DRAWING
APPLICANT:
WATERWAY:
DIT:
TOWNSHIP:
COUNTY:
NUMBER OF SHEET: OF
DATE:
PL 1
PIN
MHW
MLW
2300' across waterway
60'
A
101'
Area to be Dredged
Channel
Area to be Dredged
62'
Existing Pier
Clubhouse
82'
-2'
existing depths at MHW
-2'
-3'
-3.5'
-3.5'
-3.8'
-4.0'
-4.0'
-4.0'
-4.5'
-5.0'
-5.0'
-3.9'
B
B
Area to be Dredged
133'
75'
28'
Flood
Ebb
A
PL 2
PIN
Ferguson Creek
N

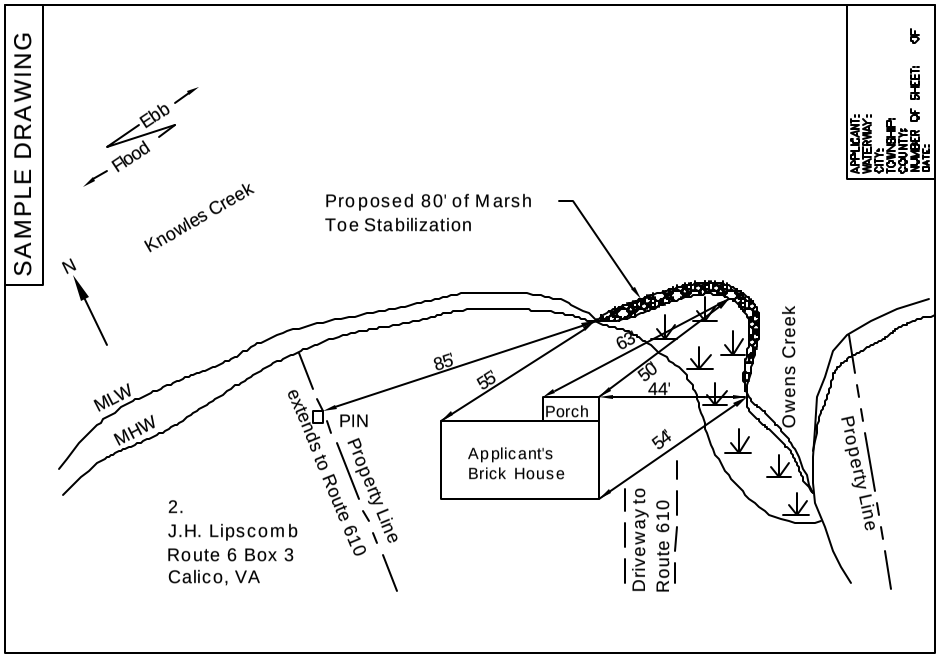

SAMPLE DRAWING
APPLICANT:
WATERWAY:
DIT:
TOWNSHIP:
COUNTY:
NUMBER OF SHEET: OF
DATE:
Mile post 8
1.
Electrical Substation
30'
37'
Route 107
N
New OHW
Proposed gravel bar
A
A
Cut
99'
Notes:
Drainage basin= 8 square miles
CFS= 8
Old average width of OHW= 20'
New average width of OHW= 20'
Existing gravel bar
OHW
OHW
2.

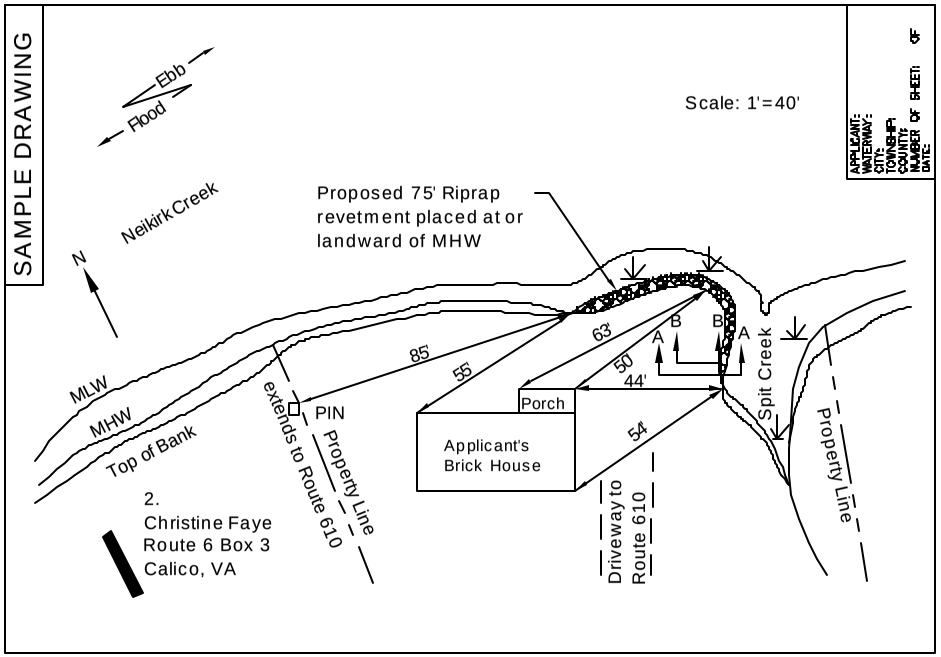

SAMPLE DRAWING
APPLICANT:
WATERWAY:
DIT:
TOWNSHIP:
COUNTY:
NUMBER OF SHEET: OF
DATE:
92'
-4'
Average Depth
-2' ave
-5'
A
A
84'
Not to scale
Clubhouse
MHW
MLW
2:1 shope
Proposed Dredging
Note: The 997 cubic yards of dredged material will be placed in a 2 acre disposal site at Heubel Farms.
New bottom depth 5'
Existing bottom
New bottom depth to match existing channel depth of 6'
B
B


SAMPLE DRAWING
APPLICANT:
WATERWAY:
DIT:
TOWNSHIP:
COUNTY:
NUMBER OF SHEET: OF
DATE:
45° band stabilized with 25-30 lb rip-rap and filter cloth
Top of cut and fill (45.4 contour elevation)
Proposed future road location
Ordinary high water (450' contour elevation)
Fill
Cut
Stream channel bottom (445' contour elevation)
24'
24'
Original stream bottom
Low flow 8' wide channel (443' contour elevation)
Stream channel redirection excavated into upland area
A
A
CROSS SECTION "A"-"A"

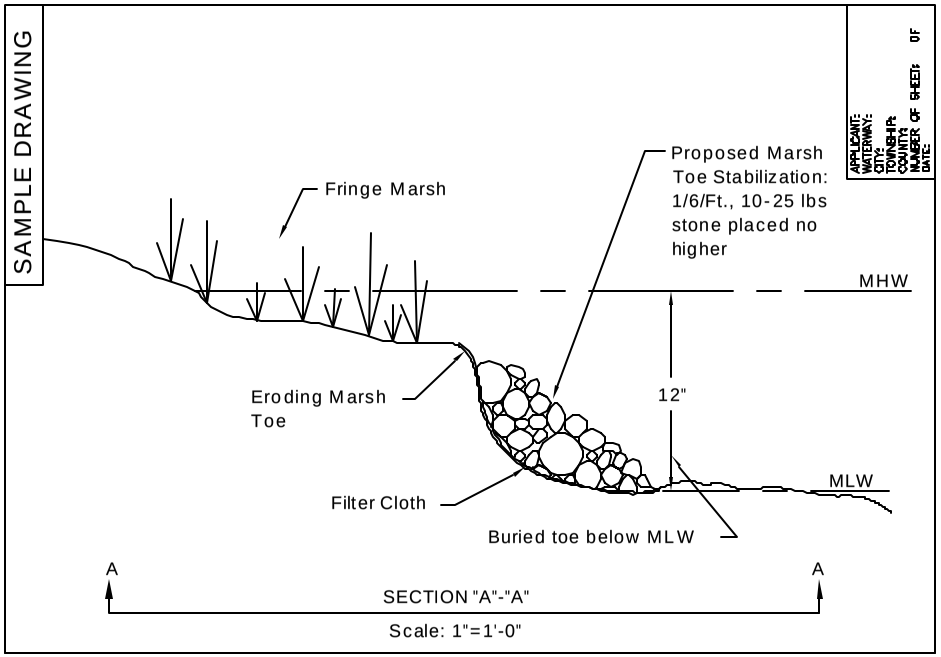
Intake/Outfall Structures

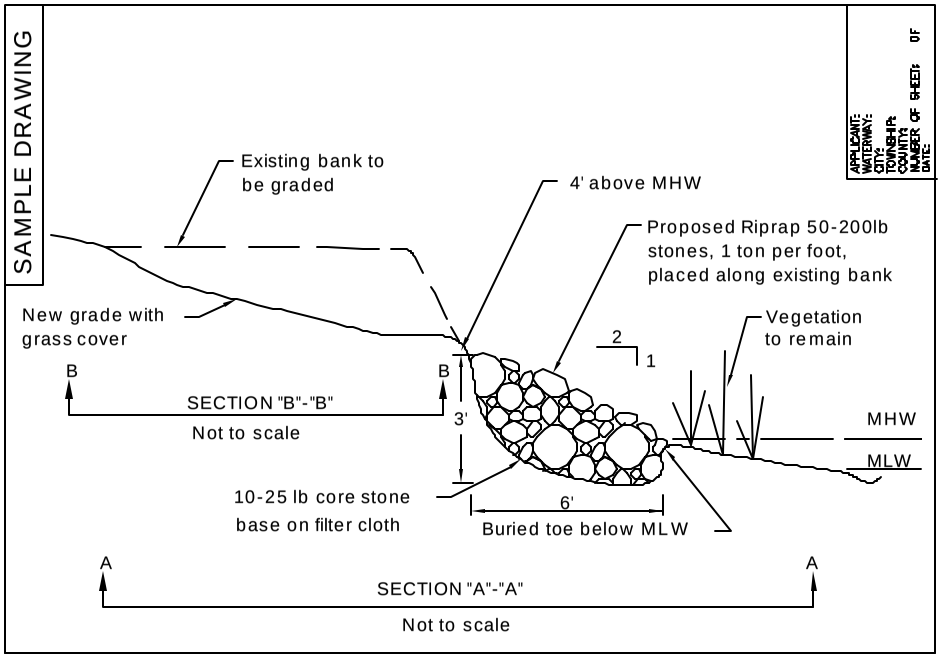
Beach Nourishment



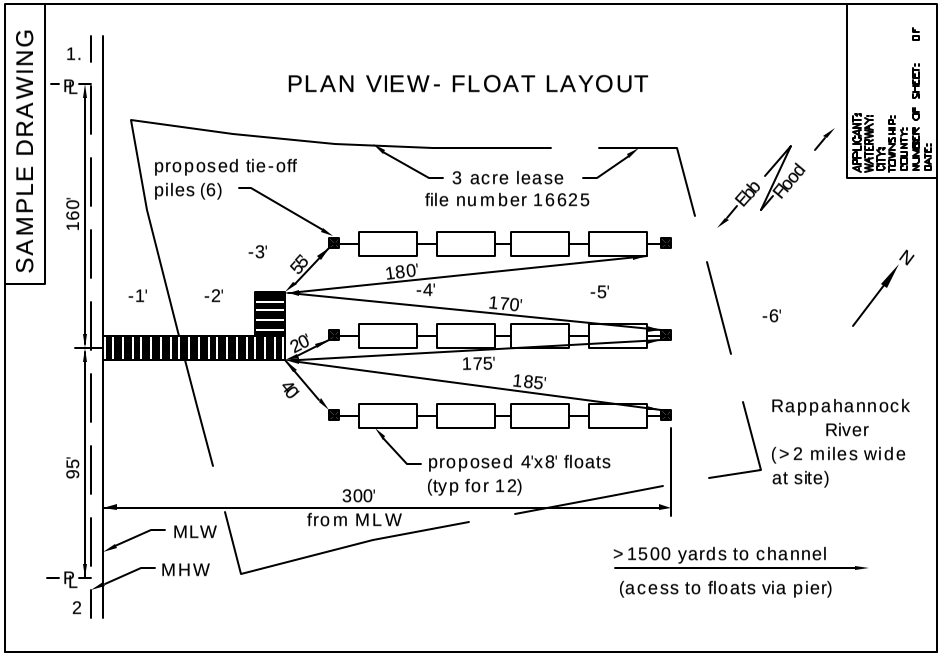


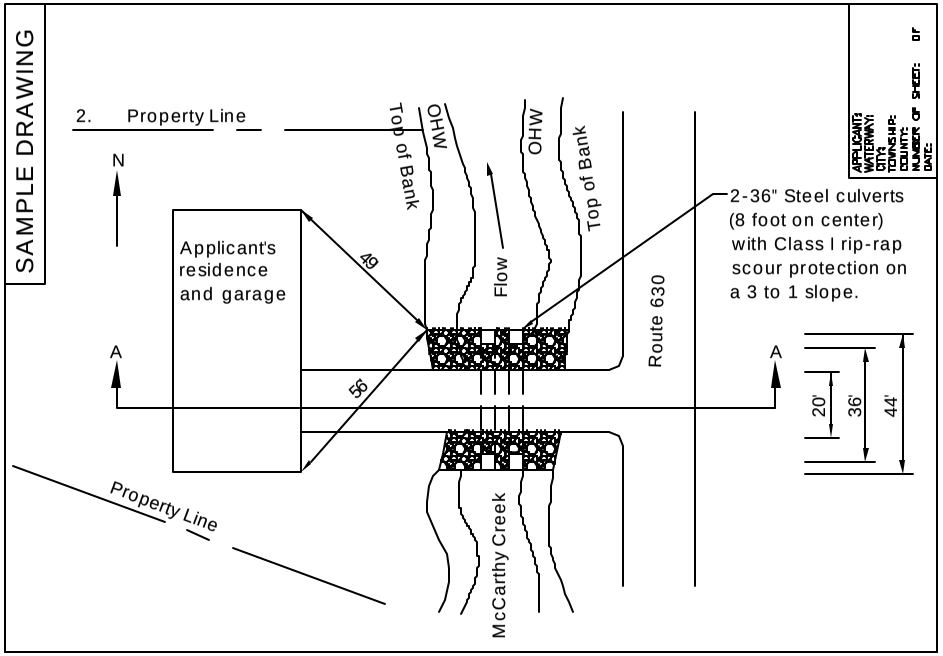
Marsh Toe Stabilization



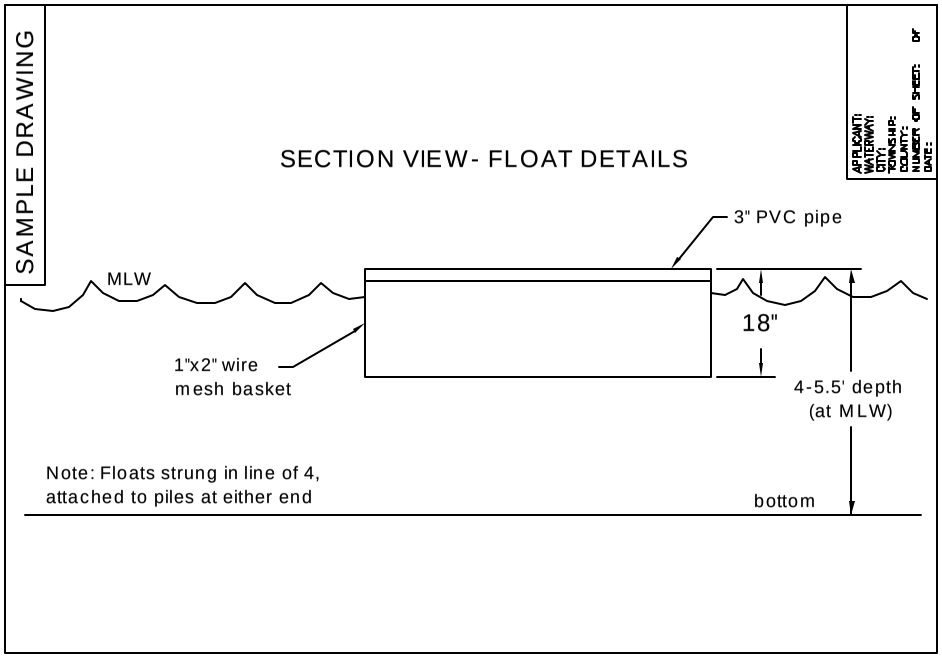


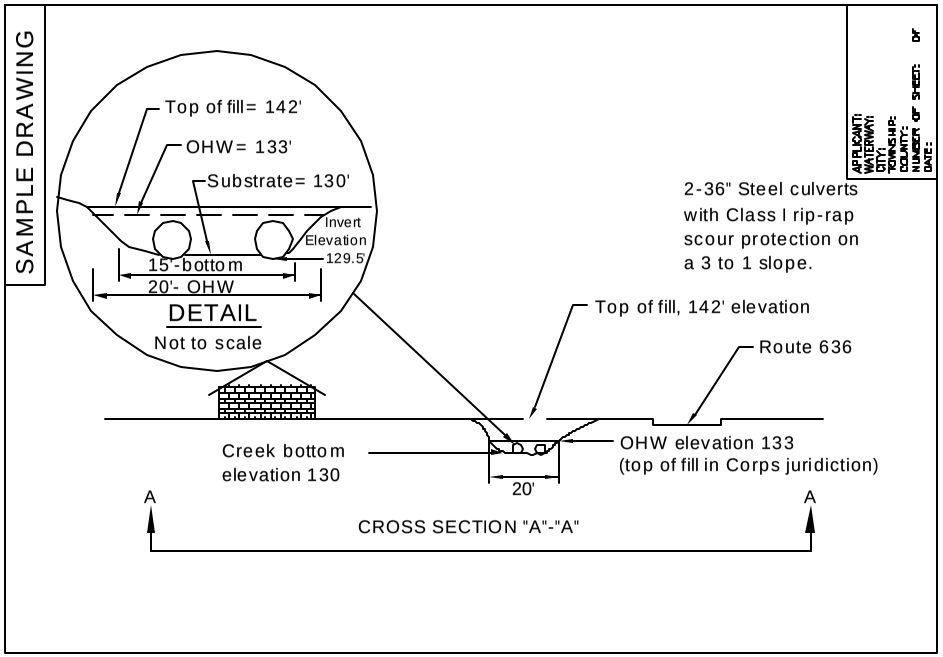
Riprap Revetment & Associated Backfill



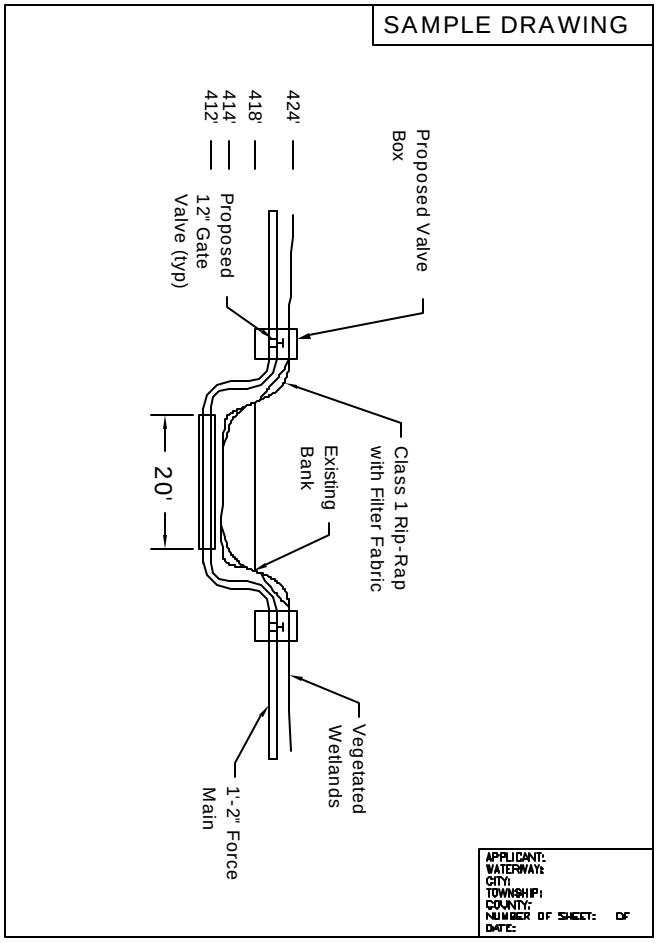


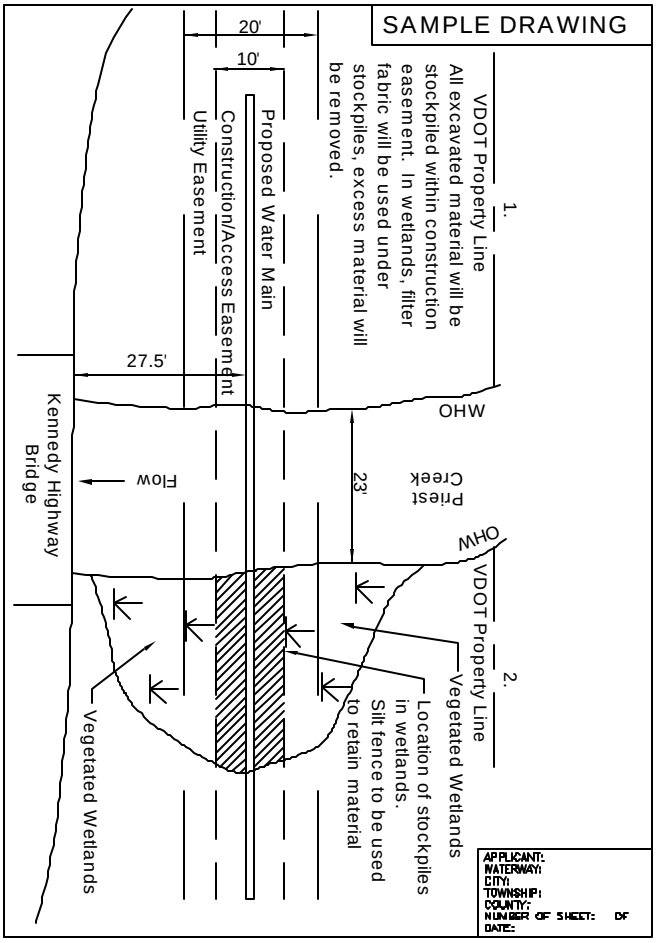
Private & Commercial Aquaculture Activities



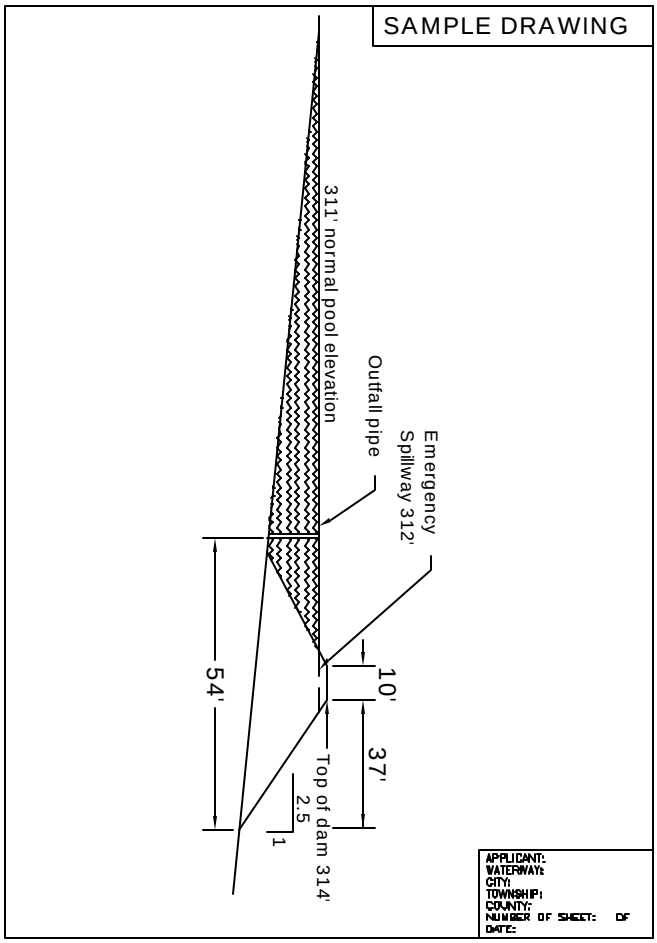


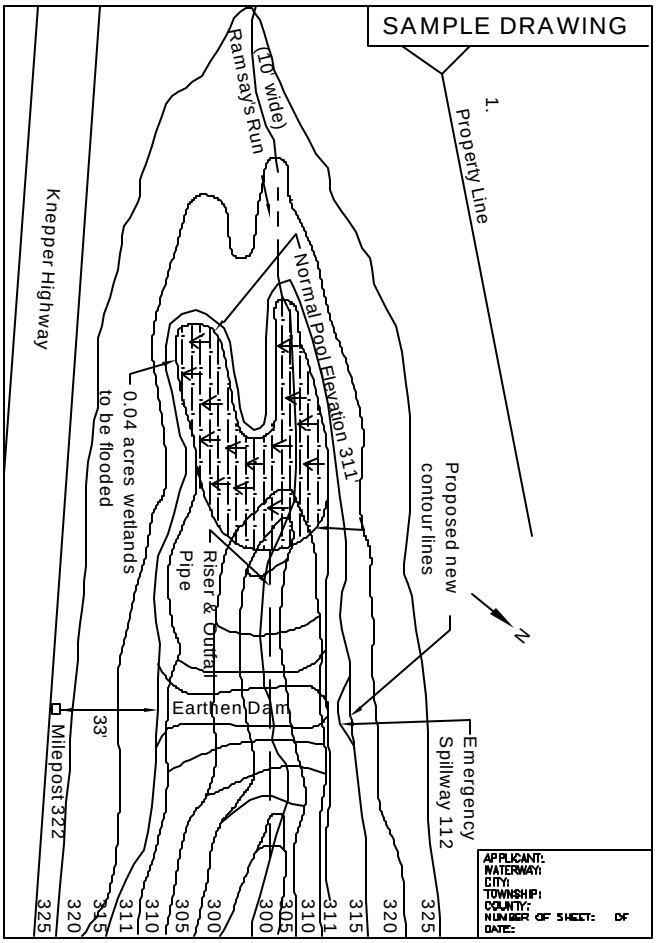
Road Crossings





Utility Crossings





Impoundment/Dams

PURPOSE AND NEED, ALTERNATIVES CONSIDERED, AND DESCRIPTION OF PROJECT

The National Aeronautics and Space Administration (NASA) is proposing to enhance and restore the shoreline on Wallops Island. The Shoreline Protection Project would reduce the potential for damage to or loss of NASA, United States (U.S.) Navy (Navy), U.S. Air Force (Air Force), and Virginia Spaceport Authority (VSA) Mid-Atlantic Regional Spaceport (MARS) assets on Wallops Island from effects associated with storm events and erosion. Below is a summary of the purpose of and need for the project. The alternatives considered for permitting of the project are discussed in the Programmatic Environmental Assessment (EA) for the Wallops Island Shoreline Protection Program. The Draft EA was made available for review and comment. The Final EA would be provided when available.

1.0 PURPOSE AND NEED FOR THE PROJECT

The purpose of NASA's Proposed Project is to protect the Wallops Island shoreline through beach renourishment, and construction of additional breakwaters, in order to reduce the potential for damage to, or loss of assets on Wallops Island.

NASA needs the Proposed Project because the beach berm and dune system that was established to protect NASA's Wallops Island launch range infrastructure in 2012 has been subject to erosion through storm wind and wave damage. The originally designed and constructed beach system served its intended purpose of reducing damage to the range assets; however, a notable portion of sub-aerial (i.e., on land surface) sand is often relocated by storm winds and waves, with a majority of this sand volume transported to the north end of Wallops Island. The effects of storms are most apparent within the southern half of the Wallops Island beach, where the majority of the critical launch assets are located. Within this area, the seaward half of the beach berm and dune system must be maintained to ensure the level of functionality it was originally intended through periodic beach renourishment and shoreline protection.

2.0 BACKGROUND

On December 13, 2010, NASA issued a Record of Decision (ROD) for the Wallops Flight Facility (WFF) *2010 Final Shoreline Restoration and Infrastructure Placement Program (SRIPP) Programmatic Environmental Impact Statement (PEIS)*. The U.S. Department of the

Interior's Bureau of Ocean Energy Management (BOEM)[1] and the U.S. Army Corps of Engineers (USACE) Norfolk District were Cooperating Agencies. The primary goal of the SRIPP is to reduce direct damage to Wallops Island's infrastructure; however, its primary benefit is the continued use of the island to support the aerospace programs that are at the core of WFF's mission (NASA 2010). The *2010 Final SRIPP PEIS* analyzed three Project Alternatives including structural and non-structural options, varying beach berm widths, and multiple sources of fill material. In its ROD, NASA selected *Alternative 1: Full Beach Fill, Seawall Extension* and adopted a suite of mitigation and monitoring protocols to both reduce potential environmental effects and track project performance. Implementing the initial phase of Alternative 1 entailed: (1) the placement along the Wallops Island shoreline of approximately 3.2 million cubic yards of sand material dredged from Unnamed Shoal A, an offshore sand ridge located approximately 11 miles northeast of Wallops Island on the Outer Continental Shelf (OCS) in the Atlantic Ocean under BOEM jurisdiction; and (2) an initial 1,430-foot southerly extension of the Wallops Island rock seawall with future extensions to be completed as funds are available to a maximum length of 4,600 feet.

The *2010 Final SRIPP PEIS* ROD stated that fill material for future renourishment cycles could be taken from either OCS Unnamed Shoal A, OCS Unnamed Shoal B (another offshore sand ridge located approximately 13 miles northeast of Wallops Island), or north Wallops Island beach and left the specifics of how and when the fill material was obtained to be addressed in future project-specific National Environmental Policy Act (NEPA) documentation.

The initial beach renourishment (3.2 million cubic yards) was completed in August 2012. A second renourishment was required shortly thereafter when, in October 2012, Hurricane Sandy made landfall. Monitoring surveys following the storm event identified the need to repair a section of the seawall and the southern two-thirds of the recently nourished beach. NASA signed a Finding of No Significant Impact (FONSI) on June 6, 2013, for the *Wallops Island Post-Hurricane Sandy Shoreline Repair Final EA* (NASA 2013). Repairs to the seawall and second beach renourishment of 650,000 cubic yards of sand were completed in September 2014[2]. Subsequent storms in 2015 (Hurricane Joaquin), in 2016 (Winter Storm Jonas), and in 2018 (Winter Storm Riley) resulted in a reduction of over a million cubic yards of sand in the southern portion of the island as compared to volumes present after the 2014 shoreline repair (USACE 2018a).

[1] BOEM adopted the 2010 Final SRIPP PEIS ROD and signed its own ROD on March 2, 2011. The BOEM ROD authorized the use of OCS sand for the initial beach fill and stated each subsequent beach fill proposal would require a new negotiated contract and an updated environmental analysis.
[2] BOEM, as a cooperating agency, signed a FONSI on July 5, 2013, supporting the decision to issue a negotiated agreement for use of OCS sand supporting nourishment in 2014.

In 2018, NASA requested the USACE Norfolk District Hydraulics and Hydrology Section to evaluate the effectiveness of constructing a breakwater or series of breakwaters along the Wallops Island shoreline to reduce the intensity of wave impacts and the rate of sediment transport since previous renourishments provided only temporary protection. The USACE modeled seven alternative configurations with varying placement, size, and number of breakwaters and calculated how each alternative affected shoreline stabilization and sediment transport. The analysis employed numerical modeling to determine the size and placement of breakwater(s) that would address the erosion issues. Modeling indicated the placement of detached parallel breakwater structures approximately 200 feet offshore from the mean high water (MHW) line would be most effective (USACE 2018b).

On July 16, 2019, NASA signed a FONSI for the *Final Shoreline Enhancement and Restoration Project EA* (NASA 2019) to implement a third renourishment[3]. The project placed approximately 1.1 million cubic yards of sand sourced from the north Wallops Island beach. Prior to renourishment, a total of five breakwaters were constructed approximately 200 feet offshore from the MHW line of the Wallops Island shoreline infrastructure protection area. Two breakwaters were constructed in front of the Horizontal Integration Facility (HIF; Building X-079) and three breakwaters were constructed in front of Launch Pad 0-B.

The following figures provide a visualization of the shoreline infrastructure protection area prior to renourishment in 2019 (**Figure 1**), post-renourishment in 2021 with the initial breakwaters in place (**Figure 2**), and in May 2023 (**Figure 3**). The recent image indicates a noticeable retention in sand material in front of the HIF and Launch Pad 0-B north of where breakwater structures were placed in 2020/2021, and along the remaining shoreline area.

[3] BOEM, as a cooperating agency, signed a FONSI on February 6, 2019, supporting the decision to issue a negotiated agreement for use of OCS sand supporting nourishment in 2020. However, sand was transferred from North Wallops Island Beach and OCS sand was never required.



Figure 1 Shoreline Infrastructure Protection Area in 2019 Before Breakwater Construction and Renourishment (Photo courtesy of Patrick J. Hendrickson)



Figure 2 Shoreline Infrastructure Protection Area in 2021 After Breakwater Construction and Renourishment (Photo courtesy of Patrick J. Hendrickson)



Figure 3 Shoreline Infrastructure Protection Area in 2023
(Photo courtesy of Patrick J. Hendrickson)

3.0 PROJECT DESCRIPTION AND CONSTRUCTION METHODOLOGY

Consistent with the Project Alternatives described in detail in the *2010 Final SRIPP PEIS* (NASA 2010), re-examined in the *2013 Final Post-Hurricane Sandy EA* (NASA 2013), and implemented following completion of the *2019 Final Shoreline Enhancement and Restoration Project EA* (NASA 2019), NASA is currently preparing the Shoreline Protection Program EA. The Proposed Action analyzed in this EA would implement measures to protect the beach along the Wallops Island shoreline infrastructure protection area. Over the next 7 years, the proposed project could involve the following (**Figure 4**):

- sand renourishment within an approximate 15,000-foot section of shoreline from the south property line on Wallops Island north to the location of the fire station;
- construction of up to six breakwaters in the nearshore area between the existing breakwaters; and
- repairs and extension of the existing seawall.

Shoreline stabilization activities would occur in phases depending on a number of factors, including infrastructure prioritized for protection, the pace and location of erosion, and the availability of funding. For example, a section of beach that experiences rapid erosion in a storm event could be renourished followed by construction of breakwaters in 1 year, and in another year additional renourishment, breakwaters construction, or both, could occur in another area. Current funding only allows Phase 1 (Project) of the Program and is discussed in the following sections.



Figure 4 Project Area and Components

3.1 Renourishment Processes

NASA has procured a set amount of funding for this federal project. Actual bid costs may affect the amount of sand that can be dredged and placed for renourishment. Therefore, NASA and USACE have separated this project into a base bid with two options, one north end and one south end options. The base bid would renourish approximately 950,000 cubic yards of sand over 6,400 linear feet. The south end bid option would add approximately 380,000 cubic yards of sand over 4,000 linear feet and the north end bid option would add approximately 200,000 cubic yards of sand over 4,600 linear feet. This analysis is for the totality of approximately 1,530,000 cubic yards of sand placed over 15,000 linear feet (see the attached Beach Permit Drawing Set Sheets CH-101 – CH-102).

3.1.1 Beach Fill Mobilization

The renourishment process would begin with the dredge contractor transporting equipment and materials to the project site. Offshore equipment would include several miles of discharge pipe,

pumpout buoys, and multiple barges, tugboats, derricks, and smaller crew transportation vessels. It is expected that the discharge lines would be assembled inside the protected waters of Chincoteague Inlet, rafted together, and then positioned by mechanical means at their ultimate placement site, as weather conditions allow. Onshore, it is expected that sections of the discharge lines would be trucked in, staged, and placed using a front-end loader or crane. Other onshore support equipment would be trucked in and may include multiple bulldozers, several all-terrain vehicles, an office trailer, mobile generators, construction site lighting, and mobile fuel tanks. The mobilization is expected to take 30 to 45 days. Laydown areas would be located on previously cleared areas and would not involve additional disturbance.

Once the dredge hopper is filled, the dredge would transport the material to a pump-out station that would be placed at a water depth of approximately 30 feet, approximately 2 miles offshore of the placement area. The pathway from Unnamed Shoal A to the pump-out buoy is not a straight line, but a dogleg shape with a turning point, for the purpose of avoiding Chincoteague Shoal and Blackfish Bank. The distance from the turning point to the pump-out buoy is approximately 8 miles. The one-way distance from Unnamed Shoal A to the pump-out buoy is approximately 14 miles. It is estimated that the pump-out station would be moved up to 10 times to accommodate transit by the dredge. Booster pumps may be needed to aid the offloading of sand from the pump-out buoy to the shoreline.

3.1.2 Dredging and Sand Placement

Upon receipt of all necessary authorizations, the USACE (on NASA's behalf) would contract for the dredging and placement of sand. Munitions and explosives of concern (MEC) screens would be used on the dragheads of trailing hopper dredges. The dredging process would be cyclical in nature, with the vessel transiting to the borrow site, lowering its drag arms, filling its hopper, and returning to a discharge site. The dredge would connect to the floating end of the submerged pipeline offshore of the beach renourishment area. The sand/water slurry would be pumped from the dredge site through this pipeline to the beach. Up to several miles of submerged steel pipeline would be temporarily placed on the seafloor in areas previously cleared for cultural resources and/or on hardbottom. All dredging and equipment placement would take place in areas previously surveyed. Dredging would occur in Section A1 of Unnamed Offshore Shoal A. Elevations of dredging material is below -30' NAVD88. All material would be below mean low water (MLW). The area of material to be dredged is approximately 20,647,440 square feet (474 acres). Table 1 summarizes dredge volumes necessary for three areas: the base project site, south end, and north end. It is anticipated that up to 50% of the volume of sand dredged would be lost during transit to the renourishment site; therefore, a larger volume would be harvested than would ultimately be placed on the beach.

Table 1 Dredging Sand Volumes (cubic yards)

	Design Volume	50% Losses	Total Volume Dredged
Project Site Base Bid (STA 40+00 to STA 104+00)	949,370	474,690	1,424,060
South End Bid Option (STA 0+00 to STA 40+00)	381,920	190,960	572,890
North End Bid Option (STA 104+00 to STA 150+00)	199,060	99,530	298,590
TOTAL	1,530,350	765,180	2,295,540

Nearshore, it is expected that the contractor would employ one or more anchored pump-out stations. As the sand slurry is discharged onto the shoreline, bulldozers would grade the material to the desired design template.

Dredging would be conducted in a manner consistent with the recommendations of two publications examining the effects of dredging of offshore shoals in the mid-Atlantic as presented in the *2010 Final SRIPP PEIS* (CSA International Inc. et al. 2009; Dibajnia and Nairn 2010). More specifically, NASA would at a minimum:

- dredge offshore sand from Unnamed Shoal A sub-area A-1 (an accretional area);
- dredge over a large area and not create deep pits;
- require that dredge cut depth not be excessive;
- require that dredging not occur over the entire length of the shoal;
- require MEC screening at the drag head;
- require a lookout bridge watch always be present on the dredge from April 1–November 30; and
- if a listed whale is spotted within 1 kilometer (km) (0.62 mile) of the dredge, stop dredging until the whale is farther than 1 km from the dredge.

Including both bid options, sand would be placed onshore along the beach extending from just north of the southern property line to the north near the fire station. **Table 2** summarizes the sand placement volumes and areas. The tidal cycle would influence the location on the beach within which the equipment would work for a given dredge load. During low tide, the equipment would likely concentrate on the intertidal and subtidal zones, whereas, during high tide, work would be focused on the upper beach berm and dune. After each section of beach is confirmed to meet design criteria, the process would continue in the longshore direction, with sections of discharge pipe added as it progressed. At the conclusion of dredging and beach fill, the construction contractor would begin the demobilization phase of the project, the largest task of which would be the disassembly, staging, and loading of discharge piping for transport off-site.

Table 2 Sand Placement Volumes and Areas

Sand Placement	Project Site Base Bid (STA 40+00 to STA 104+00)	South End Bid Option (STA 0+00 to STA 40+00)	North End Bid Option (STA 104+00 to STA 150+00)
Vegetated Wetland Impacts	0.0	0.0	0.0
Non-Vegetated Wetland Impacts	0.0	0.0	0.0
Sand Placement – Volume MHHW to MLW (CY)	118,796	54,367	39,638
Sand Placement – Area MHHW to MLW (SF)	497,254	290,875	246,950
Sand Placement – Volume MHW to MLW (CY)	110,547	50,350	36,982
Sand Placement – Area MHW to MLW (SF)	469,446	274,240	232,820
Sand Placement – Volume < MLW (CY)	105,718	29,437	11,698
Sand Placement – Area < MLW (SF)	1,037,533	413,655	189,390
Sand Placement – Area > MHHW (SF)	724,855	298,119	147,722
Sand Placement - Volume > MHHW (CY)	2,048,552	1,283,150	1,401,715

Legend: CY = cubic yard; MHHW = Mean Higher High Water; MHW = Mean High Water; MLW = Mean Low Water; SF = square foot/feet

3.2 Breakwater Construction

Two to four breakwaters would be constructed nearshore between the two existing sets of breakwaters, approximately 200 feet offshore (see attached Breakwaters Permit Drawing Set). Breakwaters would vary in height and width depending on the elevation of the sea bottom. Each breakwater covers between 16,000 and 18,000 square feet of bottom. Construction materials for breakwaters would include a 9-foot layer of Type II Armor Stone, a center core of Virginia Department of Transportation Class III stone. Breakwaters may be placed on underlying 12-inch marine filter mattresses and/or a layer of geotextile fabric (see the attached Breakwaters Permit Drawing Set Sheets C-501–502). The locations and dimensions of the breakwaters are illustrated in the attached 100% design plans (see Breakwaters Permit Drawing Set Sheet C-101).

Breakwater construction may include the use of barges and/or temporary causeways. Construction of each breakwater is estimated to take approximately 2 months. The materials and equipment would be transported by truck to and from the island via State Road 803 to South Bypass Road to a staging area. The staging area locations and sizes would be the same as was established in 2021 and used during construction of the temporary causeways. Laydown areas would be located on previously cleared areas and would not involve additional disturbance and

are included in the attached 100% design plans (see Breakwaters Permit Drawing Set Sheet G-004).

To construct breakwaters from shore, a temporary causeway would be constructed to accommodate heavy equipment. These would be approximately 30 feet wide and the causeway from mean higher high water (MHHW) to the breakwaters would have a temporary footprint of up to approximately 120,000 square feet. Temporary sheet piles would be filled with up to approximately 80,000 cubic yards of sand material from renourishment sand material or from an offsite source (matching characteristics of existing beach sand in terms of grain size and color, as approved by the USACE Contracting Officer's Representative [COR]). Causeways would be constructed up to the same height as the proposed breakwaters. Based on the existing topography, the height of the temporary causeway would range from the existing grade up to 10.5 feet. The process to build each breakwater would include the following steps or similar:

- place equipment (e.g., crawler crane, hydraulic excavator, and vibratory hammer) and material (e.g., steel sheet piles, timber mats, high density polyethylene mats, marine mattresses, armor stone, and core stone) in the staging area;
- fill a sand template;
- install steel pilings using vibratory hammer and crane to create wall (i.e., bulkhead) at each breakwater location;
- place mats and marine mattress;
- transfer armor stone and core stone from staging area to placement site per design plan; and
- extract steel pilings using vibratory hammer and crane, smooth out sand and move to the next breakwater location, and repeat the construction process.

Temporary causeways would only be in place for the duration of breakwater construction. Accounting for the time needed to install the causeway, construct the breakwater, and remove the causeway, it is expected that the causeway would be in place for 1 to 2 months. Removing the temporary causeways would include removal of the sheet piles and the sand would be redistributed along the beach using heavy equipment. The voids of the sheet piles are expected to be filled in with the surrounding sand as soon as they are removed from the ground. The steel sheet piles would then be transported off-site.

4.0 CONSTRUCTION MONITORING

The Contractor's own Quality Control Manager would perform construction monitoring to independently verify the construction meets all project design requirements and specifications. USACE would have at least one dedicated Construction Control Representative on site during dredging, beach construction, and breakwater construction for quality assurance. USACE would

also have the COR on site to work through any contracting concerns and address all project concerns. The USACE COR would work closely with the USACE Program Manager and also the USACE Design Team for responses to Requests for Information (RFIs) and to review construction submittals.

5.0 FEDERAL AND STATE CONSULTATIONS

Concurrent with the development of the Shoreline Protection Program EA, required regulatory consultations are underway. NASA:

- sent letters to the Virginia State Historic Preservation Office and the following tribes to initiate National Historic Preservation Act Section 106 Consultation: Catawba Indian Nation, Chickahominy Indian Tribe, Nansemond Indian Tribal Association, Pamunkey Indian Nation, Rappahannock Tribe of Virginia, Chickahominy Indians Eastern Division, and Pocomoke Indian Nation;
- submitted Biological Evaluations to the U.S. Fish and Wildlife Service (USFWS) and National Oceanographic and Atmospheric Administration (NOAA) Fisheries and requested concurrence with their effects determinations;
- submitted an Essential Fish Habitat Assessment to NOAA Fisheries Greater Atlantic Regional Fisheries Office; and
- provided a Federal Consistency Determination to the Virginia Department of Environmental Quality.

Results of these consultations would be provided to USACE when available.

6.0 MITIGATION

Well before NASA's presence on Wallops Island in the mid-1940s, the project site has been in a state of constant change. Accordingly, much of the project site is now open ocean with the normal tidal range falling along the existing seawall. Construction of the project would restore the Wallops Island beach to pre-Hurricane Sandy condition.

6.1 Dredging and Sand Placement

Consistent with the overall Shoreline Erosion Restoration Program, it is expected that the mitigation plan would be adjusted based on monitoring results and effectiveness of the measures. A summary of mitigation measures is provided below.

To minimize these effects, the following mitigations have been incorporated into the Proposed Action:

- dredge offshore sand from Unnamed Shoal A sub-area A-1 (an accretional area);

- dredge over a large area and not create deep pits;
- dredge cut depth would not be excessive;
- dredging would not occur over the entire length of the shoal;
- MEC screening at the drag head;
- ensure dredged materials brought to the beach are comparable sediment type (a similar percentage of sand, silt, and clay), grain size, and color as the existing beach material; and
- implement erosion and sediment control and spill prevention Best Management Practices (BMPs).

6.2 Water Quality

Onshore, NASA would implement erosion and sediment control BMPs to minimize adverse effects on adjacent water bodies. All BMPs would be designed and installed in accordance with the latest version of the Virginia Erosion and Sediment Control Handbook.

For both onshore and offshore operations, spill prevention BMPs would be implemented to reduce potential impacts on soils and sediments during seawall construction, and all work would be performed in accordance with the most current version of WFF's Integrated Contingency Plan. Prior to starting work, the contractor would be required to submit an Environmental Protection Plan which would outline all measures that would be employed during onshore and offshore construction activities to minimize adverse environmental impacts.

As funding allows, NASA would continue a shoreline monitoring program to evaluate the performance of the breakwaters and beach fill and identify the need for future beach renourishment. The monitoring program would consist of subaerial beach cross-section surveys, subaqueous beach profile surveys, aerial photographs, and storm data summaries, beginning before construction. The program would compare the post-construction data with the pre-construction data and evaluate the performance of the project.

6.3 Munitions and Explosives of Concern

As with the previous sand harvest from Unnamed Offshore Shoal A, MEC screen would be used on the dredge draghead. Construction personnel would be provided MEC awareness briefing prior to beginning work. Additionally, informational signs would be posted conspicuously in areas of the jobsite most frequently visited by workers. If any MEC is identified along the Wallops shoreline, it would be reported to the WFF Security Office and managed in accordance with WFF's established program. Any MEC discovered offshore would be immediately reported to the U.S. Coast Guard and WFF personnel.

6.4 Protected Species

6.4.1 Onshore

NASA's existing USFWS Programmatic Biological Opinion (BO) requires the following mitigation measures, which would be implemented for this project:

- Preparation and distribution of a fact sheet containing this information to all project personnel.
- Minimization of foot traffic during construction.
- Inspection of all vehicles for leaks immediately prior to work in beach habitat.
- Notification to the USFWS regarding the projected and actual start dates, progress, and completion of the project and confirmation that all conservation measures were followed.
- Submission of an annual report summarizing the survey and monitoring efforts, location and status of all occurrences of listed species recorded, and any additional relevant information to the USFWS by December 31 of each year.
- Should renourishment activities be scheduled between March 15 and August 31, NASA would ensure that a qualified biological monitor conducts daily surveys of the project site and adjacent areas to detect nesting piping plovers and sea turtles, in accordance with established and approved monitoring protocols.
- In accordance with WFF's Protected Species Monitoring Plan, if piping plover or sea turtle nests are identified, the nests would be clearly marked using exclosures or signage and rope barriers encircling each site. A qualified biological monitor would conduct daily nest inspections. All on-site personnel would be informed of the nesting status, and all project activities within 1,000 feet of a nest would be suspended or relocated until hatching is complete.

6.4.2 Offshore

NASA's existing NOAA Fisheries BO requires the following mitigation measures, which would be implemented for this project:

- A lookout/bridge watch, knowledgeable in listed species identification, would always be present on board the hopper dredge to inspect the draghead each time it is removed from the water.
- If a listed whale is spotted within 1 kilometer (0.62 mile) of the dredge, stop dredging until the whale is farther than 1 kilometer from the dredge.

- Dredge operators would monitor the right whale sighting reports (i.e., sighting advisory system, dynamic management areas, seasonal management areas) to remain informed on the whereabouts of right whales within the vicinity of the action area.
- Dredge operators would conform to the regulations prohibiting the approach of right whales closer than 500 yards. Any vessel finding itself within the 500-yard buffer zone around a right whale must depart the area immediately at a safe, slow speed, unless one of the exceptions applies (see 50 Code of Federal Regulations 224. l 03 (c)).

6.5 Essential Fish Habitat

NASA has prepared an Essential Fish Habitat Assessment and is consulting with NOAA's Fisheries Habitat Conservation Division to identify any necessary mitigation measures. Any measures identified would be added as soon as the coordination with the agencies is concluded.

6.6 Cultural Resources

NASA is consulting with the Virginia State Historic Preservation Office and potentially affected tribes with ties to Wallops Island. The inadvertent discovery of any previously unidentified archaeological resources would result in immediate cessation of work and notification of the WFF Cultural Resources Manager.

7.0 LIST OF ADDITIONAL ATTACHMENTS

1. Breakwater Design and Analysis Report
2. Periodic Surveying Evaluation Spring 2021
3. Periodic Surveying Evaluation Fall 2024
4. Beach and Dredging Permit Plan Set

References

CSA International, Inc., Applied Coastal Research and Engineering, Inc., Barry A. Vittor & Associates, Inc., C.F. Bean, L.L.C., and Florida Institute of Technology. 2009. Analysis of Potential Biological and Physical Impacts of Dredging on Offshore Ridge and Shoal Features. Prepared by CSA International, Inc. in cooperation with Applied Coastal Research and Engineering, Inc., Barry A. Vittor & Associates, Inc., C.F. Bean, L.L.C., and the Florida Institute of Technology for the U.S. Department of the Interior, Minerals Management Service, Leasing Division, Marine Minerals Branch, Herndon, VA. OCS Study MMS 2010-010. 160 pp. + apps.

Dibajnia, M. and R.B, Nairn. 2010. Investigation of Dredging Guidelines to Maintain and Protect the Geomorphic Integrity of Offshore Ridge and Shoal Regimes, U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, Herndon, VA., OCS Study MMS 2011-025. 150 pp. + appendices.

NASA. 2010. Final Programmatic Environmental Impact Statement for Wallops Flight Facility Shoreline Restoration and Infrastructure Protection Programs. October. Available at: https://www.nasa.gov/goddard/memd/nepa/shoreline/#documents.

NASA. 2013. Final Environmental Assessment Wallops Island Post-Hurricane Sandy Shoreline Repair. June. Available at: https://www.nasa.gov/goddard/memd/nepa/shoreline/#documents.

NASA. 2018a. 2018 Wallops Island Protected Species Monitoring Report. National Aeronautics and Space Administration Wallops Flight Facility Wallops Island, Virginia

NASA. 2019. Final Environmental Assessment. NASA Wallops Flight Facility Shoreline Enhancement and Restoration Project. June. Available at: https://www.nasa.gov/goddard/memd/nepa/shoreline/#documents https://code200-11 external.gsfc.nasa.gov/250-WFF/serp-ea

USACE. 2018a. Wallops Island, VA. Fall 2017 Shoreline Mapping Program Beach Profile Monitoring Survey Evaluation, Final Report. January.

USACE. 2018b. Breakwater(s) Analysis, Design, and Modeling Report for National Aeronautics and Space Administration Goddard Space Flight Center Wallops Flight Facility. May.

SAND EXCAVATION FROM BORROW AREA

After Excavation Survey

Station 00+00 to 90+91

Section 35 20 22

Transmittal # 35 20 22-3

BREAKWATER(S) AND BEACH RENOURISHMENT PROJECT

NASA WALLOPS ISLAND, VIRGINIA

CONTRACT NO. W912-36-20-C-0002

U.S. Army Corps of Engineers®

USACE Langley Resident Office

402 Helms Ave, Bldg. 801

Langley AFB, VA. 23665

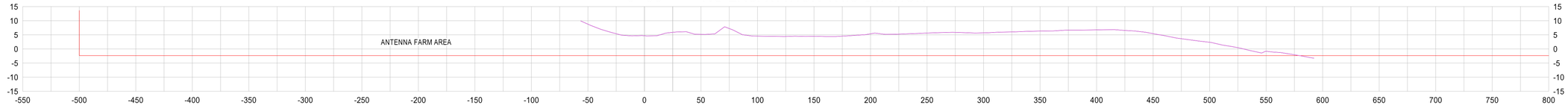
Prepared by:

Continental Heavy Civil Corp
13131 SW 132nd Street, Suite 102
Miami, Florida 33186

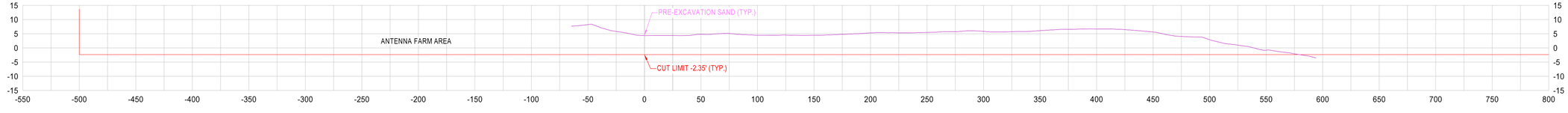
CONTINENTAL HEAVY CIVIL

July 23, 2020

0+00 NO EXCAVATION THIS STATION



1+00 NO EXCAVATION THIS STATION



VERTICAL SCALE: 1" = 20'

NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
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LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:
DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SIZE: ANSI D
ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/23/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

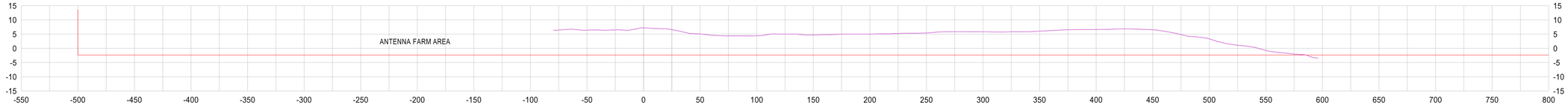
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NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

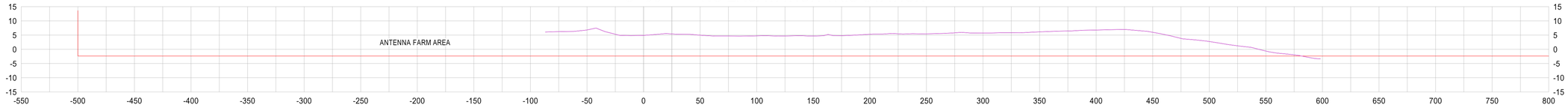
BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 0+00 TO 1+00

SHEET ID
1 OF 16

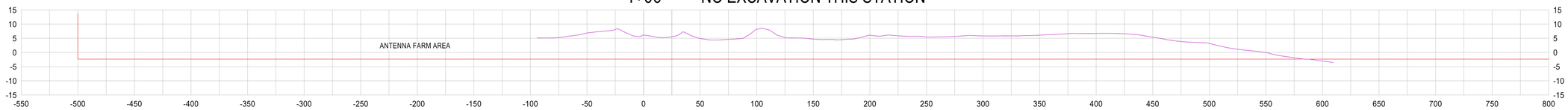
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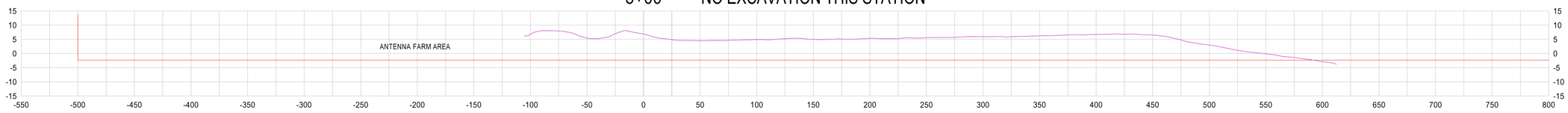
3+00 NO EXCAVATION THIS STATION



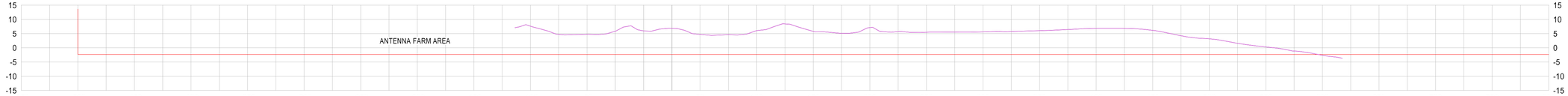
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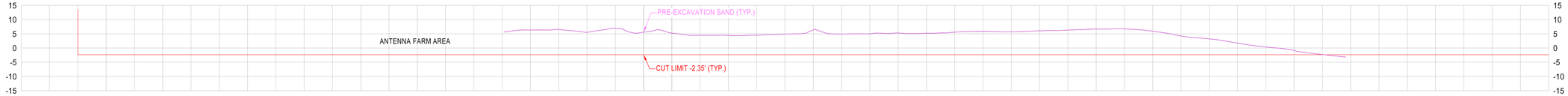
5+00 NO EXCAVATION THIS STATION



6+00 NO EXCAVATION THIS STATION



7+00 NO EXCAVATION THIS STATION





NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
Land Surveyors
333 KELLAM ROAD, SUITE 200
VIRGINIA BEACH, VA. 23462
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Email: hfrye@haydenfrye.com

COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
No. 2532
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:
DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SCALE: AS NOTED
ANSI D
ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7-23-21
FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 2+00 TO 7+00

SHEET ID
2 OF 16

80 FEET
40
20
0
VERTICAL SCALE: 1" = 20'

NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
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3. UNITS: US SURVEY FEET
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5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
PRE-EXCAVATION GRADE
CUT LIMIT GRADE
POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
No. 2532
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:
DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SIZE: ANSI D
ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/23/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

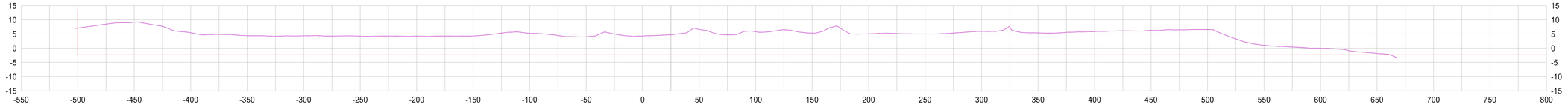
U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

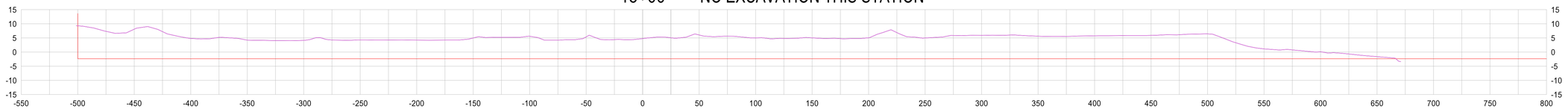
BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 8+00 TO 13+00

SHEET ID
3 OF 16

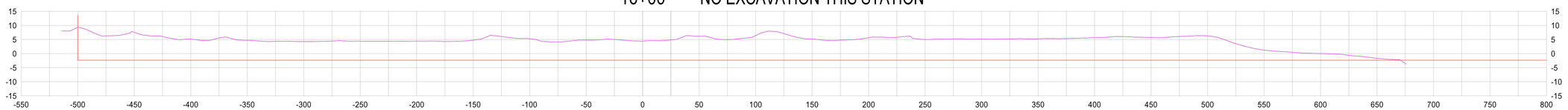
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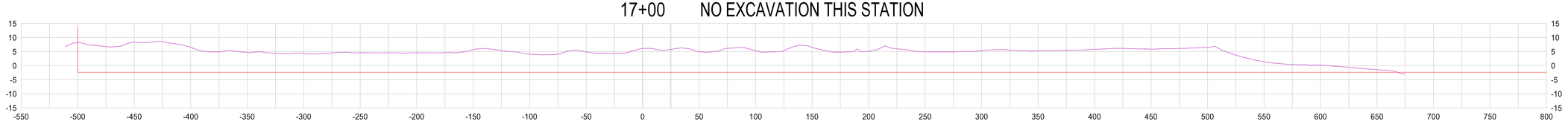
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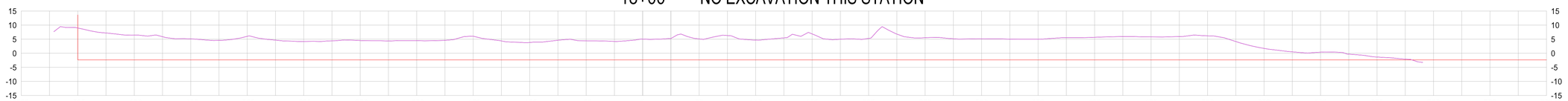
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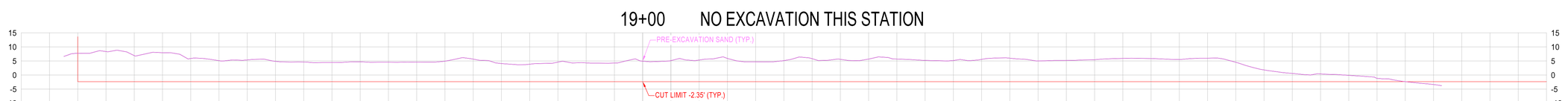
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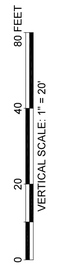


18+00 NO EXCAVATION THIS STATION



19+00 NO EXCAVATION THIS STATION





NOTES:

1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND

- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET

HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
Land Surveyors
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
No. 2532
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:
DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SCALE: AS NOTED
ANSI D

ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/23/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

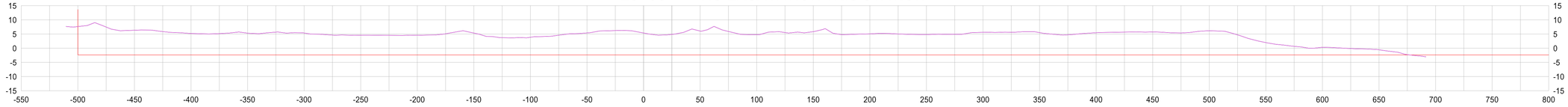
NASA-WALLOPS ISLAND BREAKWATERS AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 14+00 TO 19+00

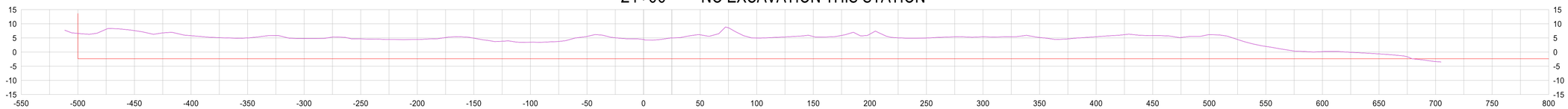
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4 OF 16

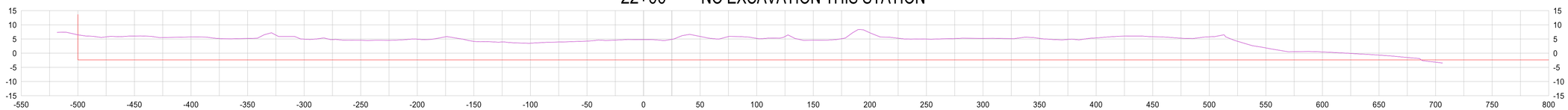
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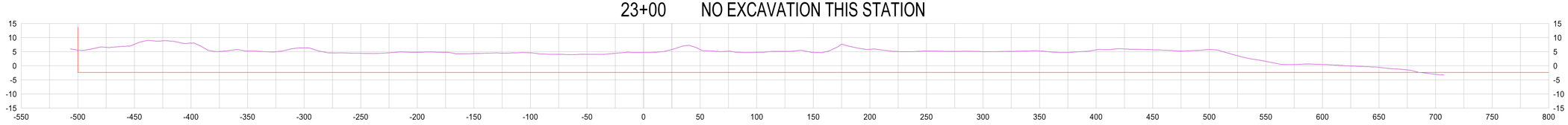
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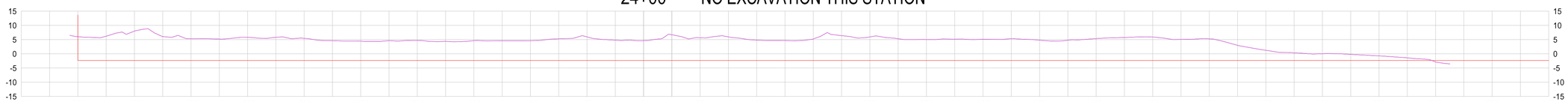
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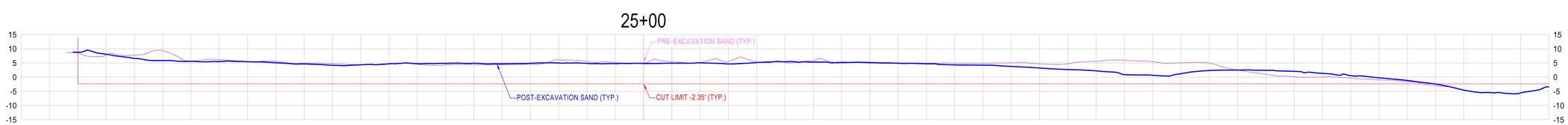
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24+00 NO EXCAVATION THIS STATION



25+00





NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
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5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc. Land Surveyors
333 KELLAM ROAD, SUITE 200
VIRGINIA BEACH, VA. 23462
PH: (757) 491-7228 FX:(757) 491-7229
Email: hfrye@haydenfrye.com

COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
LAND SURVEYOR
No. 2532

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

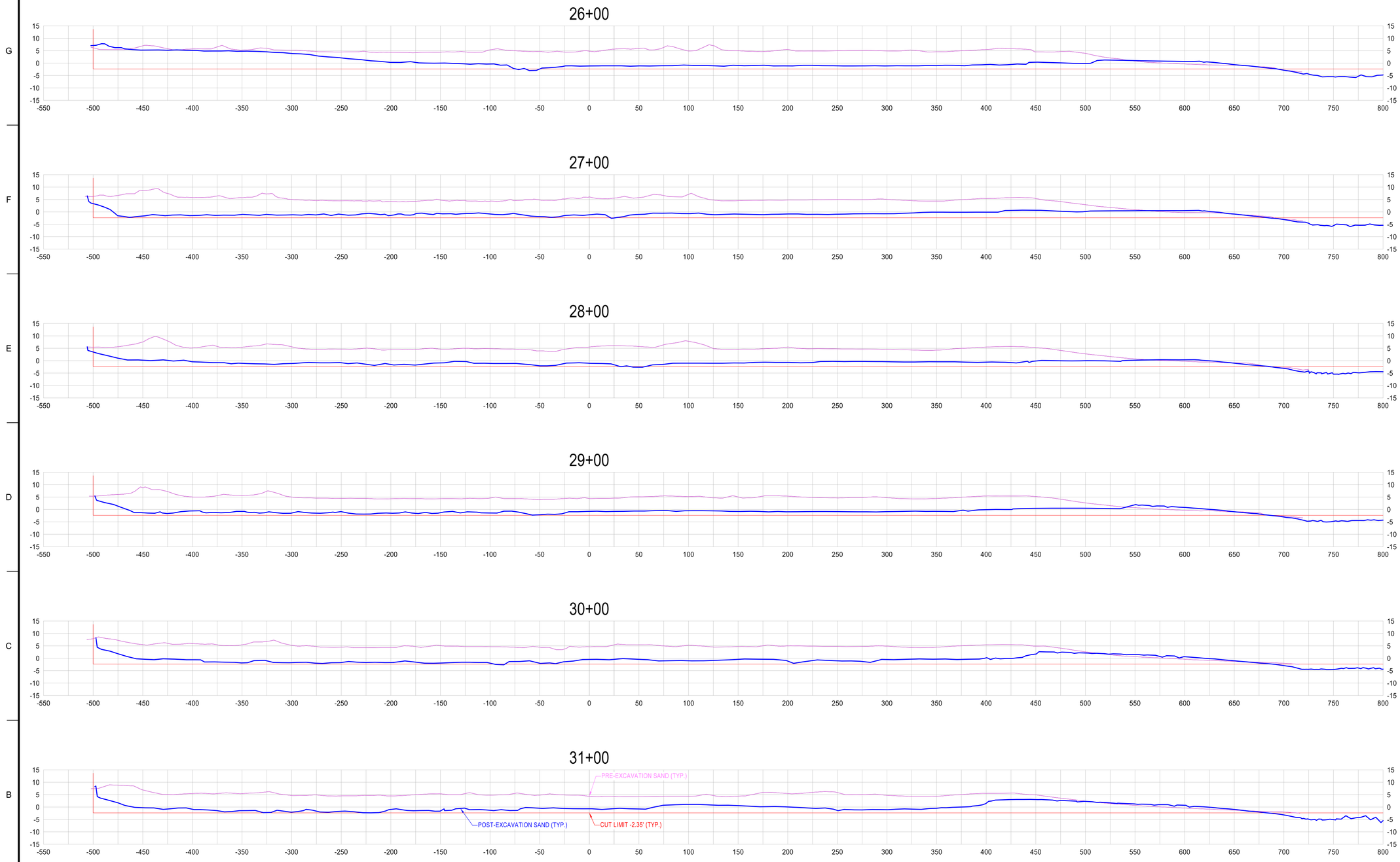
DESIGNED BY:
DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SIZE: ANSI D
ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/23/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 20+00 TO 25+00

SHEET ID
5 OF 16



NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
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5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

80 FEET 40 20 0
VERTICAL SCALE: 1" = 20'

Hayden Frye and Associates, Inc.
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
LAND SURVEYOR
No. 2532

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

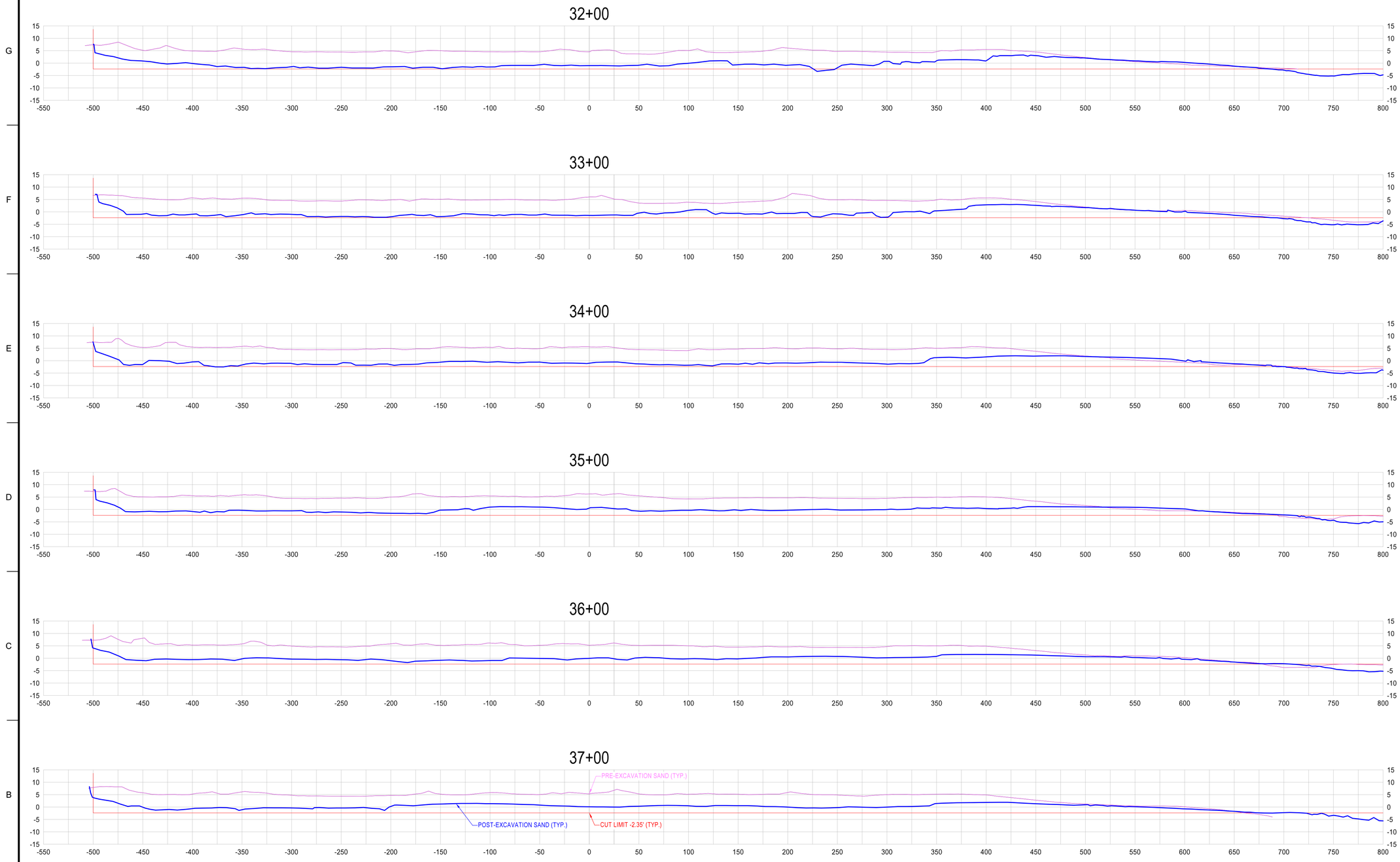
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DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SCALE: ANSI D
ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/23/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATION 26+00 TO 31+00

SHEET ID
6 OF 16



NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
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5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

VERTICAL SCALE: 1" = 20'
0 20 40 80 FEET

Hayden Frye and Associates, Inc.
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
LIC. No. 2532
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US Army Corps of Engineers®

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DRAWN BY: MTW	SOLICITATION NO.:
CHECKED BY: HF	CONTRACT NO.:
SUBMITTED BY: HFRA	PLOT DATE: 7/23/2021
SCALE: ANSI D	FILE NAME: WALLOPS BORROW SITE POST.dwg

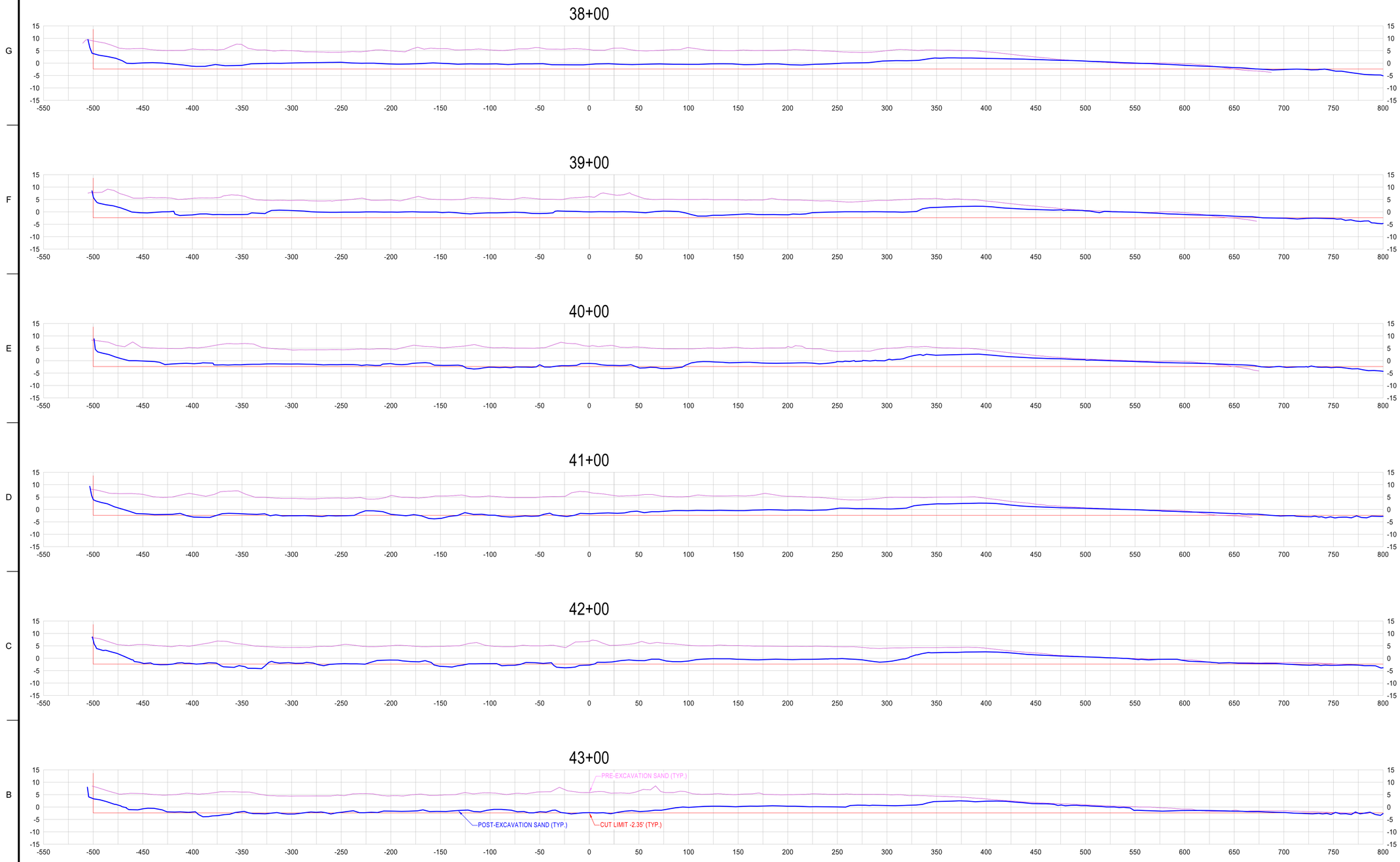
U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS
AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 32+00 TO 37+00

SHEET ID

7 OF 16



VERTICAL SCALE: 1" = 20'

NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
No. 2532
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

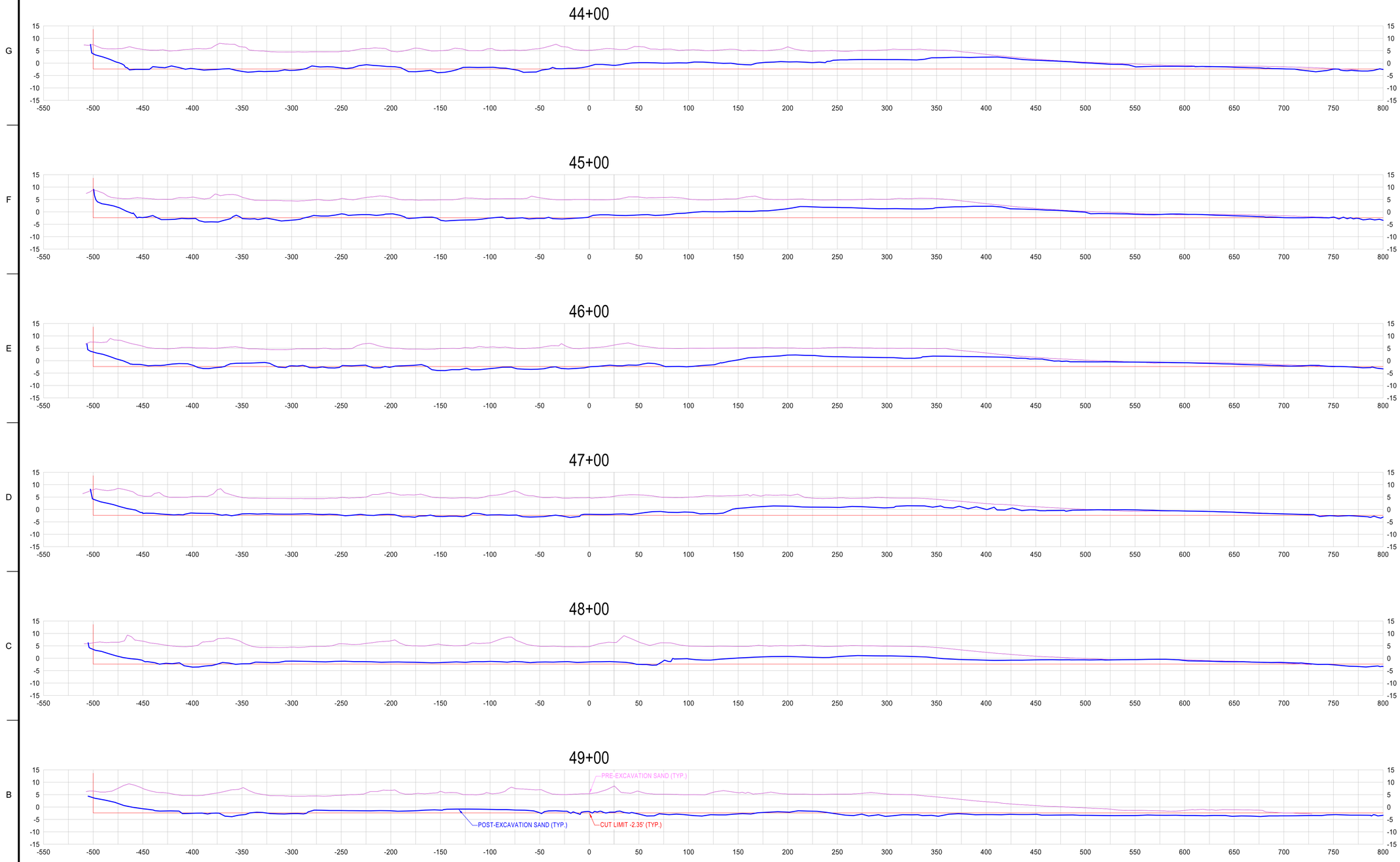
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DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SCALE: ANSI D
ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/23/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 38+00 TO 43+00

SHEET ID
8 OF 16



80 FEET
40
20
0
VERTICAL SCALE: 1" = 20'

NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
LAND SURVEYOR
No. 2532

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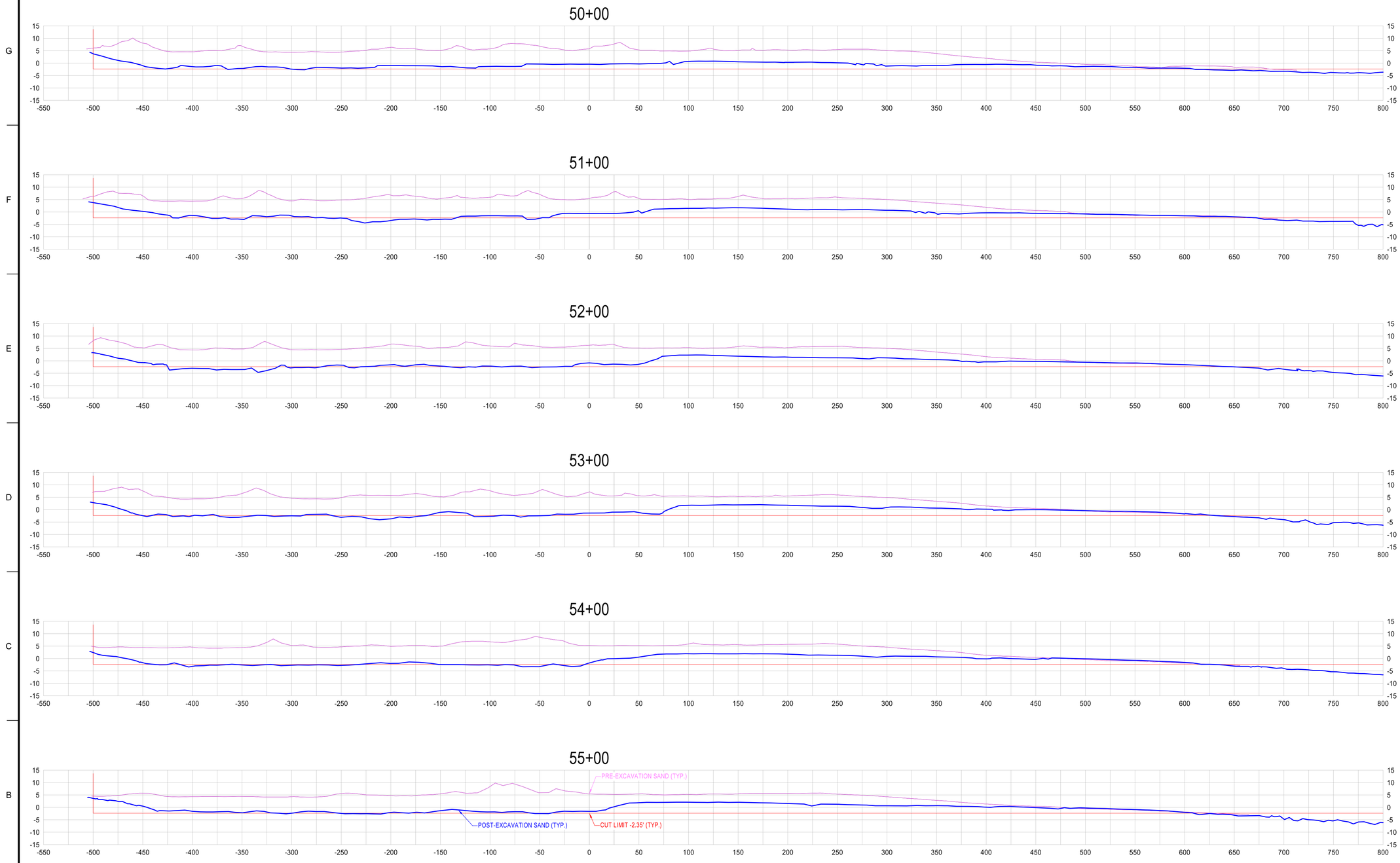
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DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
SCALE: ANSI D
ISSUE DATE:
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FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHDFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 44+00 TO 49+00

SHEET ID
9 OF 16



NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

80 FEET 40 20 0
VERTICAL SCALE: 1" = 20'

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COMMONWEALTH OF VIRGINIA
07-25-21
HAYDEN R. FRYE
No. 2732
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

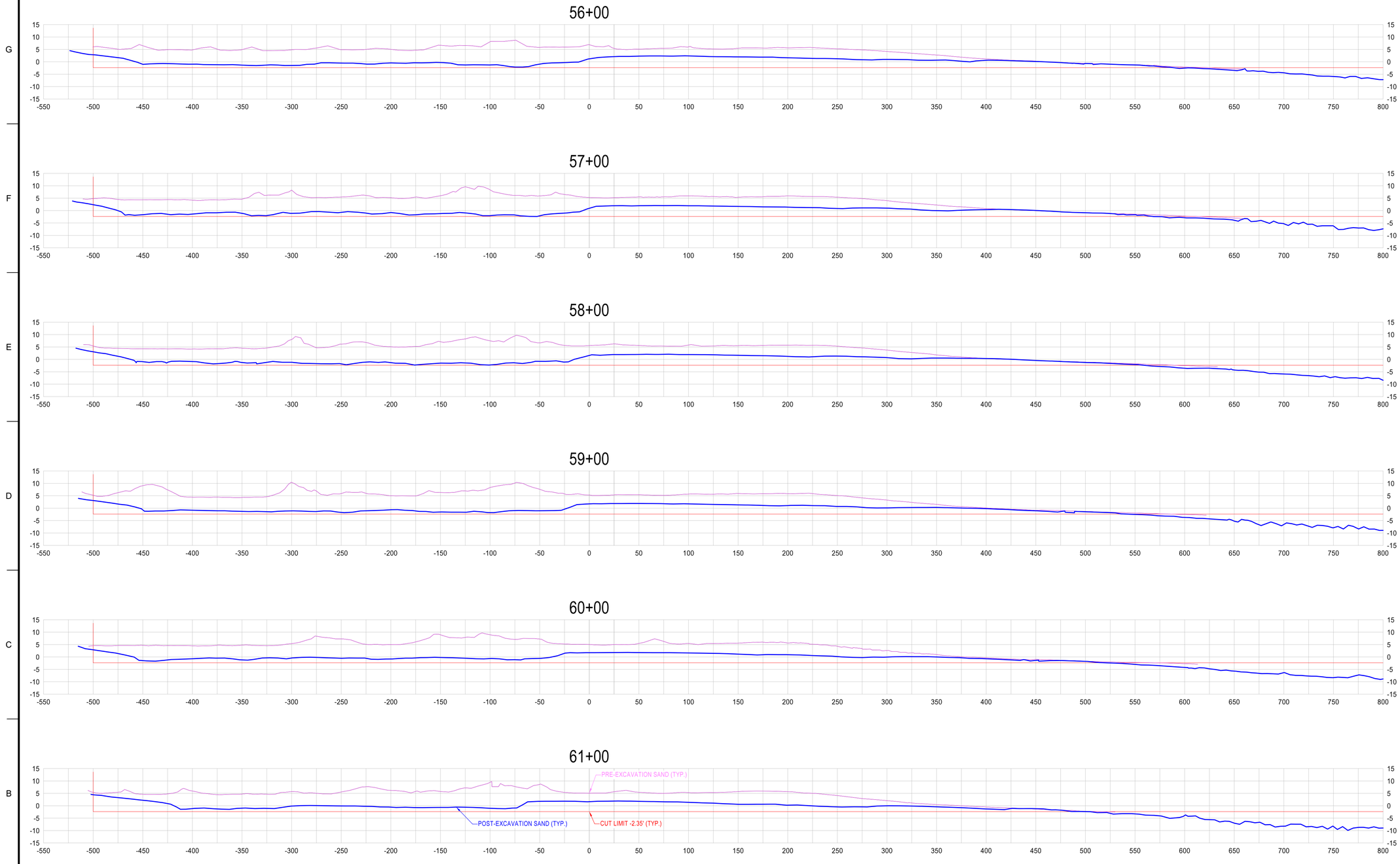
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DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY: HF&A
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ISSUE DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/25/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 50+00 TO 55+00

SHEET ID
10 OF 16



VERTICAL SCALE: 1" = 20'

NOTES:
1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND
- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
Lic. No. 2932
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

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DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY:
SCALE: AS NOTED
SIZE: ANSI D
FILE NAME: WALLOPS BORROW SITE POST.dwg

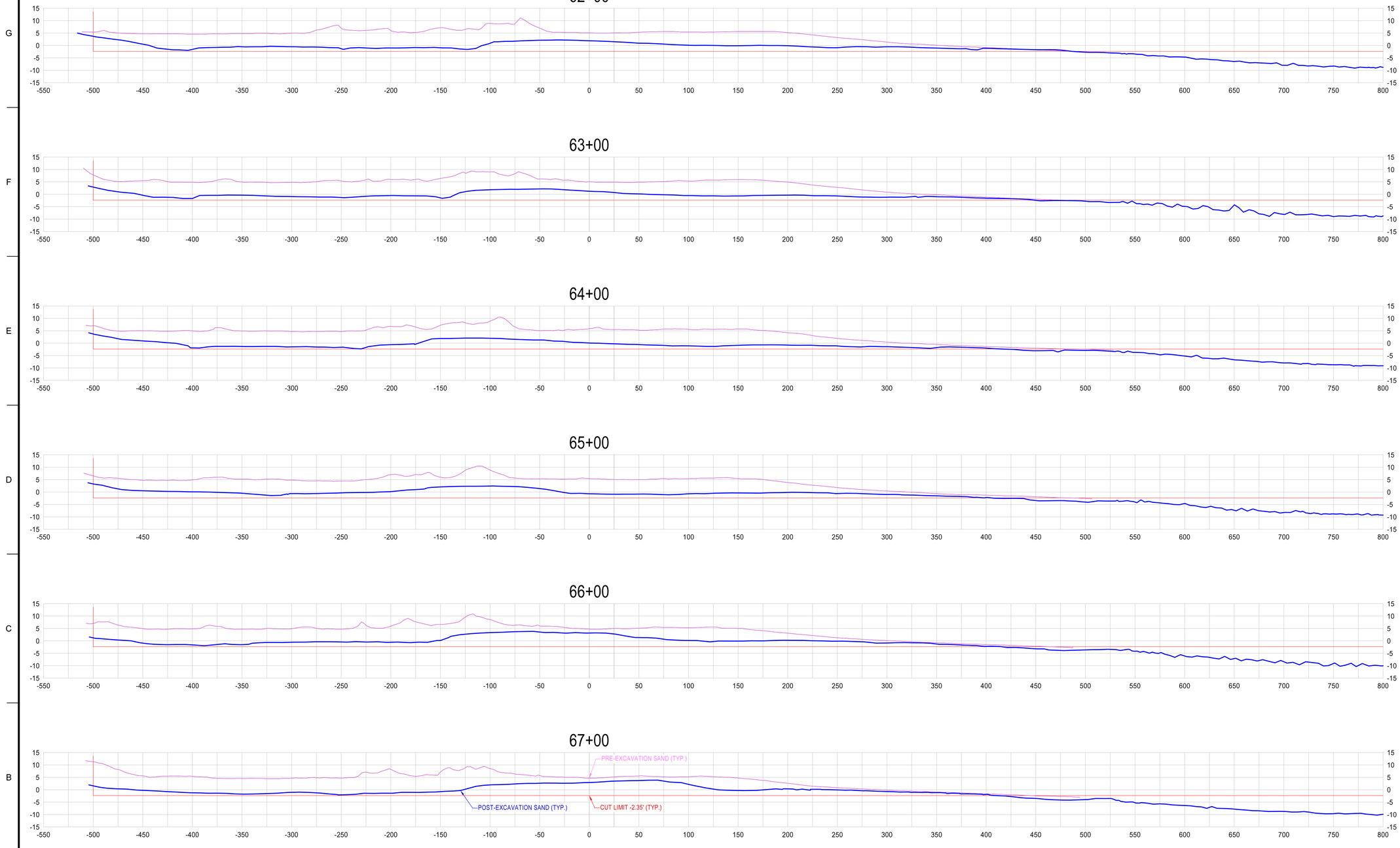
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SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 7/23/2021
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NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS
AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 56+00 TO 61+00

SHEET ID
11 OF 16





NOTES:

1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND

- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET

HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
Land Surveyors
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
Lic. No. 2352
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

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CHECKED BY: HF
SUBMITTED BY:
SCALE AS NOTED
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FILE NAME:

ISSUE DATE:
SOLICITATION NO.:
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PLOT DATE: 7/23/2021
FILE NAME: WALLOPS BORROW SITE POST.dwg

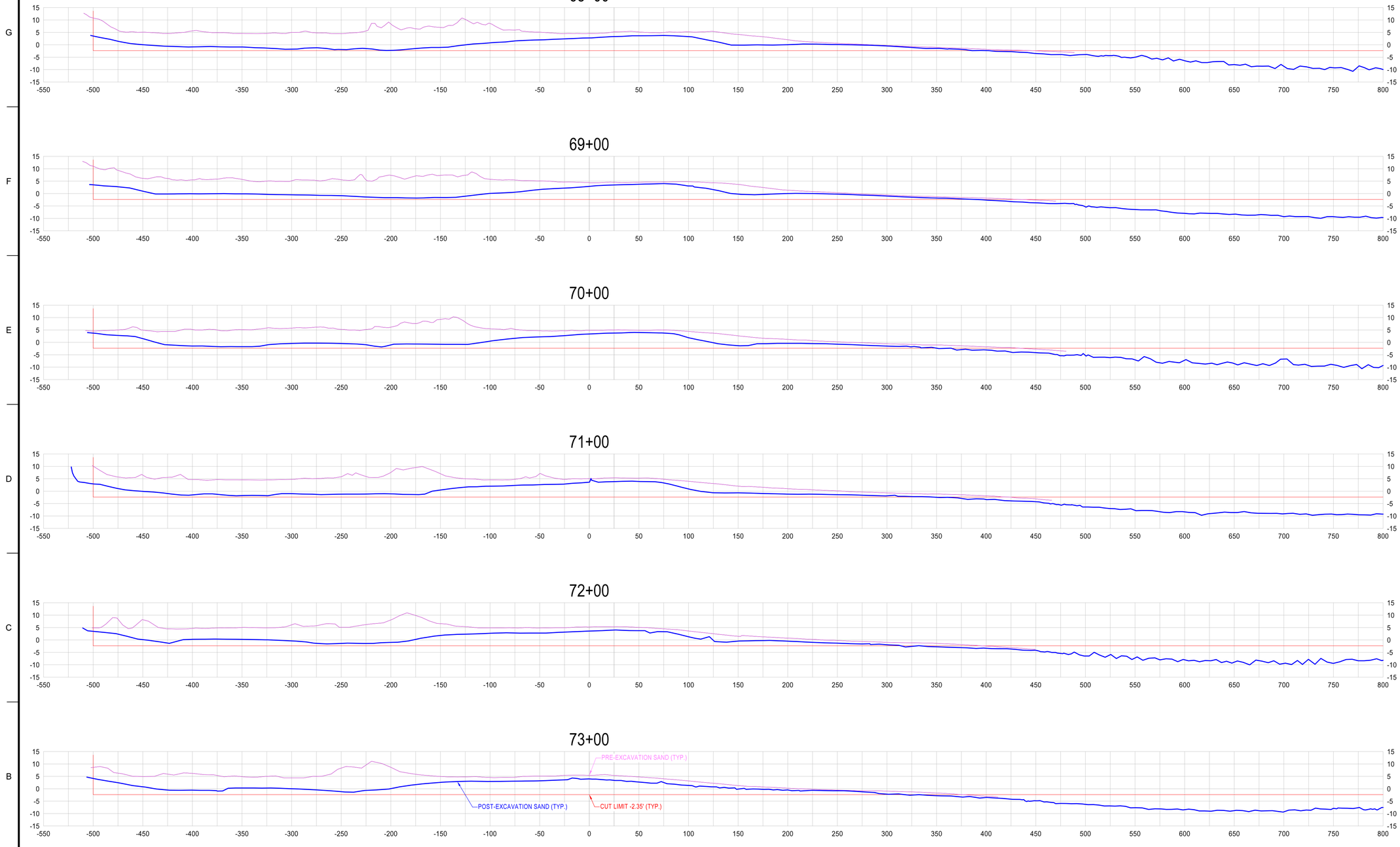
U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS
AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 62+00 TO 67+00

SHEET ID

12 OF 16



80 FEET
40
20
0
VERTICAL SCALE: 1" = 20'

NOTES:

1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
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3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND

- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
Lic. No. 2932
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:
DRAWN BY: MTW
CHECKED BY: HF
SUBMITTED BY:
SCALE: AS NOTED
SIZE: ANSI D
FILE NAME:

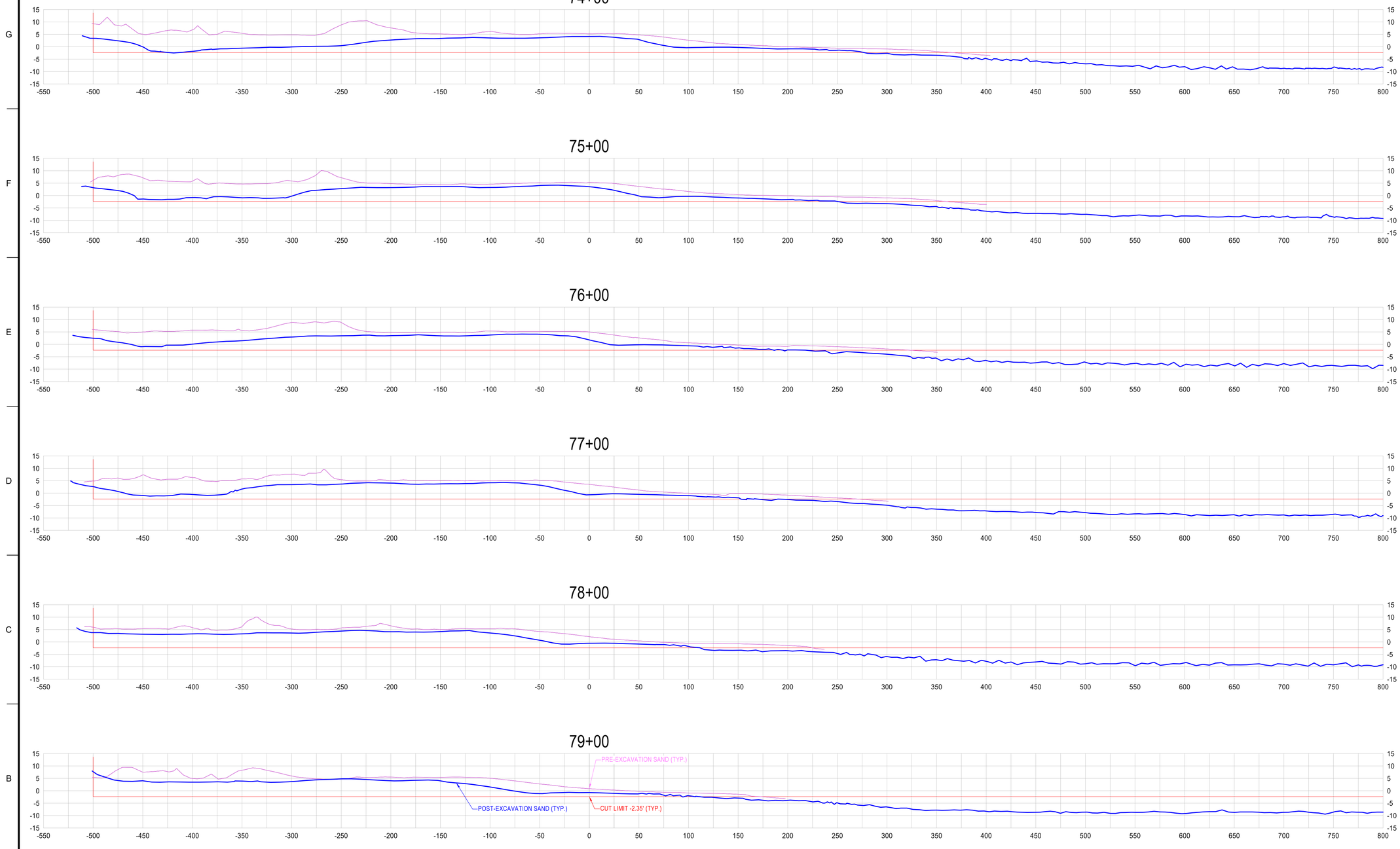
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FILE NAME: WALLOPS BORROW SITE POST.dwg

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS
AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 68+00 TO 73+00

SHEET ID
13 OF 16



NOTES:

1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
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3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND

- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET

HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
Lic. No. 2352
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:
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SCALE: AS NOTED
FILE NAME: BORROW POST.dwg

ISSUE DATE:
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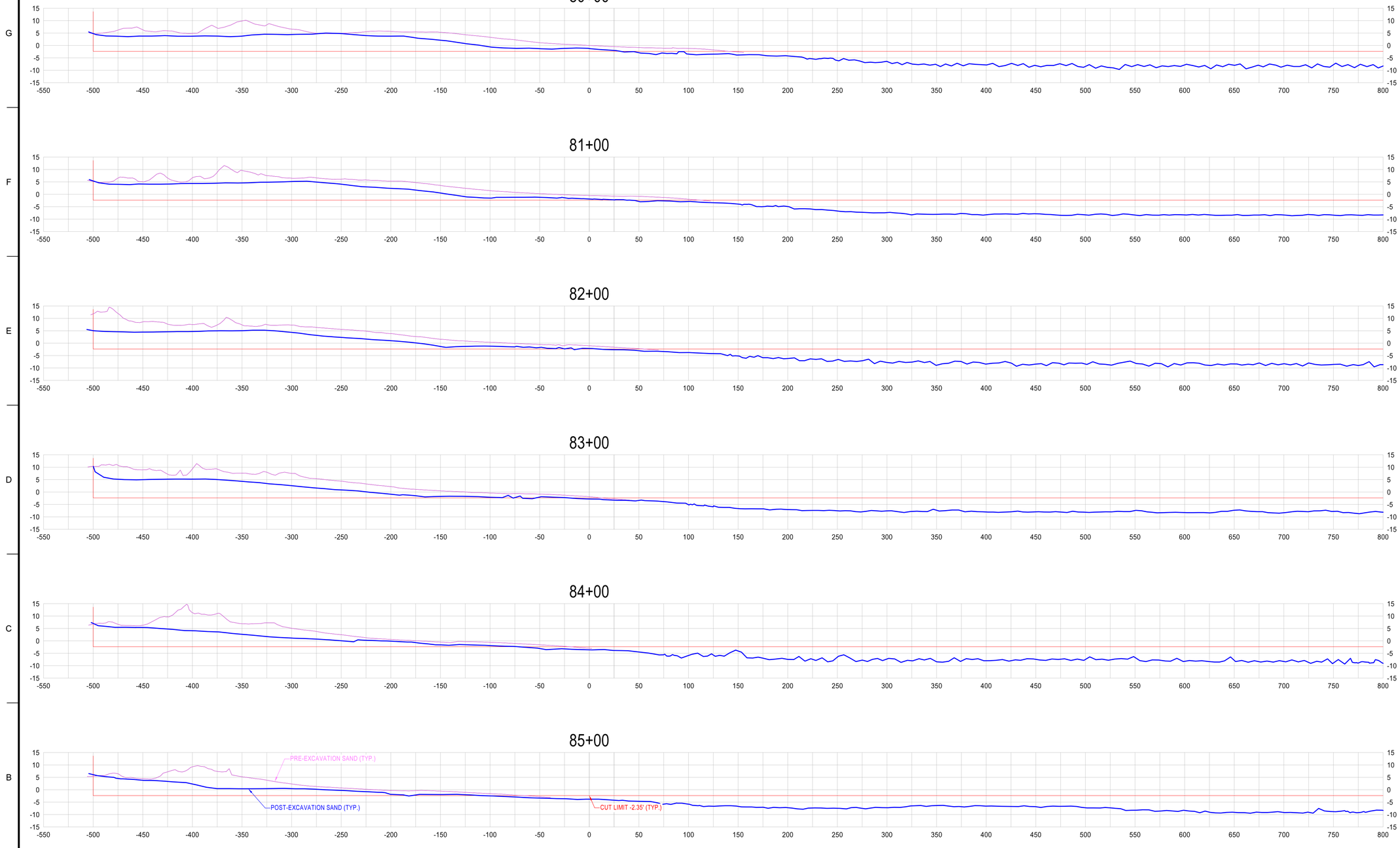
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NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 74+00 TO 79+00

SHEET ID

14 OF 16



80 FEET
40
20
0
VERTICAL SCALE: 1" = 20'

NOTES:

1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
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5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
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LEGEND

- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET
HORIZONTAL SCALE: 1" = 50'

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07-23-21
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MARK	DESCRIPTION	DATE

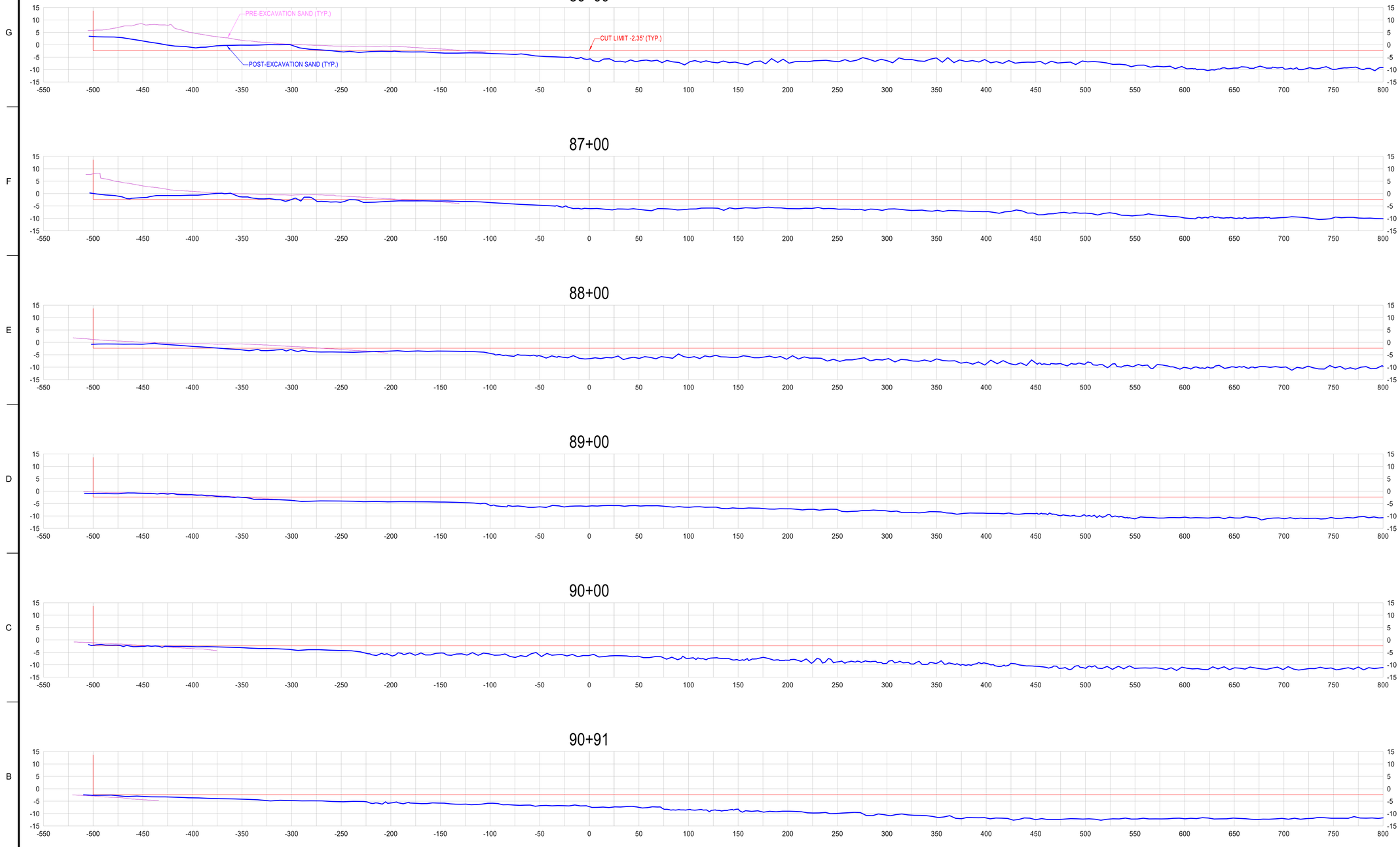
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U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
NORFOLK, VIRGINIA

NASA-WALLOPS ISLAND BREAKWATERS
AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 80+00 TO 85+00

SHEET ID
15 OF 16





NOTES:

1. HORIZONTAL DATUM: VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83) (SEE NOTE 6 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
2. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88) (SEE NOTE 7 ON PAGE 3 OF "NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT")
3. UNITS: US SURVEY FEET
4. DATES OF PRE-EXCAVATION FIELD SURVEY: 03-28-20; 03-30-20; 03-31-20; 04-01-20; 04-02-20; 04-03-20; 04-06-20; 04-07-20; 04-08-20; 04-09-20; REFERENCE DATA FILE: BORROW PRE.csv
5. DATES OF POST-EXCAVATION FIELD SURVEY: 05-03-21; 05-04-21; 05-05-21; 05-06-21; 05-07-21; 05-11-21; 05-13-21; 05-14-21; 05-17-21; 05-18-21; 05-19-21; 05-20-21; 05-21-21; 05-24-21; 05-25-21; 05-26-21; 05-27-21; 05-28-21; 06-01-21; 06-02-21; 06-07-21; 06-08-21; 06-09-21; 06-10-21; 06-16-21; 06-17-21 REFERENCE DATA FILE: BORROW POST.csv
6. THIS DOCUMENT IS PREPARED FOR CONTINENTAL HEAVY CIVIL, CORP; CONTRACT W91236-20-C-0002

LEGEND

- PRE-EXCAVATION GRADE
- CUT LIMIT GRADE
- POST-EXCAVATION GRADE

0 50 100 150 FEET

HORIZONTAL SCALE: 1" = 50'

Hayden Frye and Associates, Inc.
Land Surveyors
333 KELLAM ROAD, SUITE 200
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COMMONWEALTH OF VIRGINIA
07-23-21
HAYDEN R. FRYE
Lic. No. 2932
LAND SURVEYOR

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

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U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
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NASA-WALLOPS ISLAND BREAKWATERS AND BEACHFILL PROJECT
NASA-WALLOPS ISLAND
ACCOMACK, VIRGINIA

BORROW SITE AREA
POST EXCAVATION TOPOGRAPHIC SURVEY
STATIONS 86+00 TO 90+91

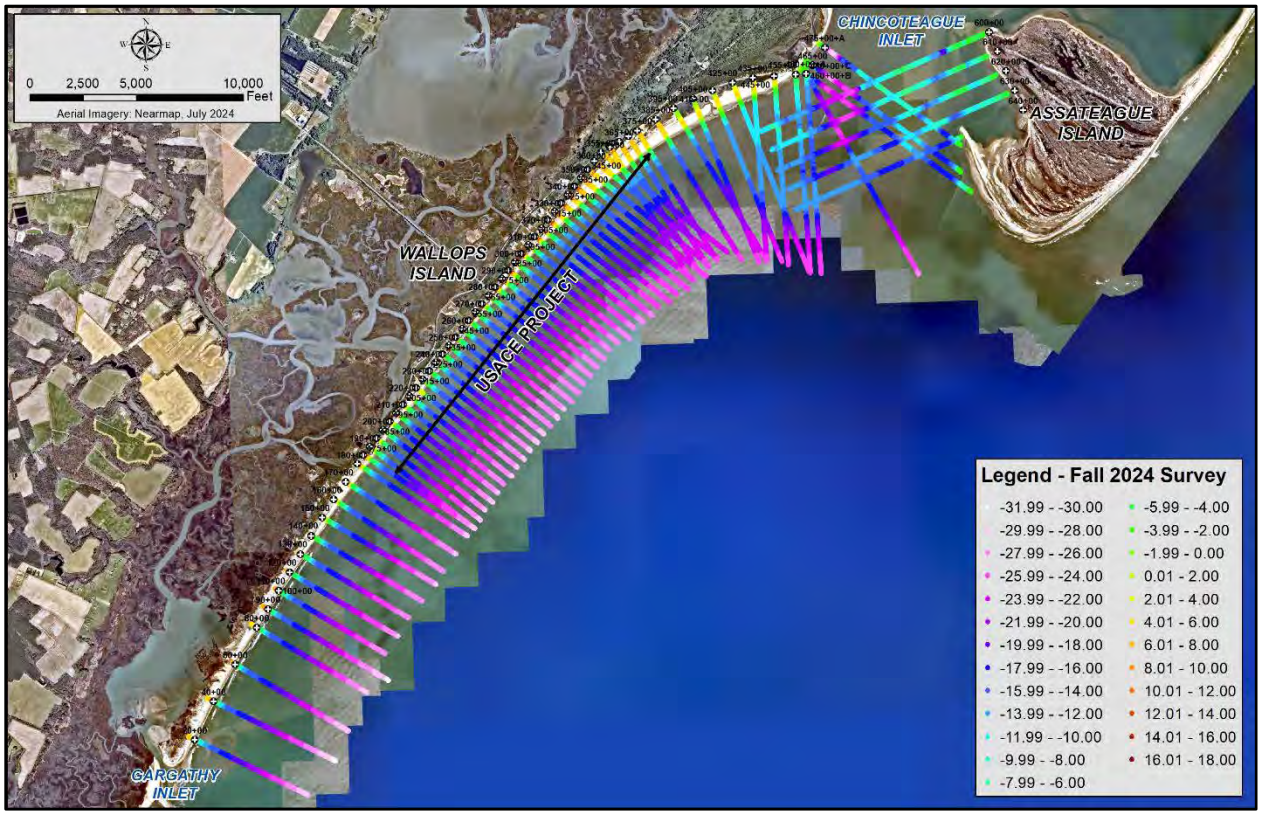
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16 OF 16

WALLOPS ISLAND, VA
Fall 2024
MONITORING REPORT

DRAFT REPORT

Submitted November 2024



Prepared By: Moffatt & Nichol and Geodynamics

moffatt & nichol

geodynamics AN NV5 COMPANY

Prepared For: USACE and NASA

US Army Corps of Engineers®

NASA

Executive Summary

The US Army Corps of Engineers (USACE) Norfolk District constructed an engineered beach project placing 3.2 Mcy of sand along approximately 19,000 ft of shoreline on Wallops Island during Summer 2012. The project serves to protect a stretch of shoreline along which critical NASA infrastructure is located. Immediately after completion of the 2012 project, Hurricane Sandy impacted the area and significant loss to a portion of the project was experienced. Therefore, approximately 11,500 ft of shoreline was renourished during Summer 2014 with 682,000 cy of sand. As a requirement of the EIS associated with the engineered beach project, semi-annual (fall and spring) beach monitoring surveys and analyses commenced in Fall 2015 along Wallops Island extending to the north as far as Toms Cove / Assateague Island and to the south as far as Gargathy Inlet. Monitoring was completed in Spring 2019 after which the USACE Norfolk District designed a renourishment project based on the findings and recommendations. The renourishment project took place in 2020, placing roughly 1.3 Mcy of sand, which was excavated from a highly accretional area on the northern end of Wallops Island, along approximately 14,000 ft of shoreline and included construction of 5 offshore breakwaters to further protect critical infrastructure. In Fall 2024, the USACE requested an updated survey and analysis of the Wallops Island shoreline in order to assess performance of the 2020 renourishment project and breakwater construction and also to guide the timing and design of the next renourishment project.

Figure ES-1 presents the Fall 2024 monitoring transects that were surveyed along Wallops Island and Assateague Island in relation to the full USACE project area. In total, 67 transects were surveyed on Wallops Island and 5 transects were surveyed offshore of Assateague Island. The same transects were surveyed during the Spring 2019 survey referenced in this report. In general, transects were stationed 2000 ft apart along the southernmost portion of Wallops Island, transitioning to 1000 ft spacing approaching the southern end of the USACE project. The transect spacing throughout the USACE project was 500 ft, transitioning back to 1000 ft spacing north of the project to Chincoteague Inlet.

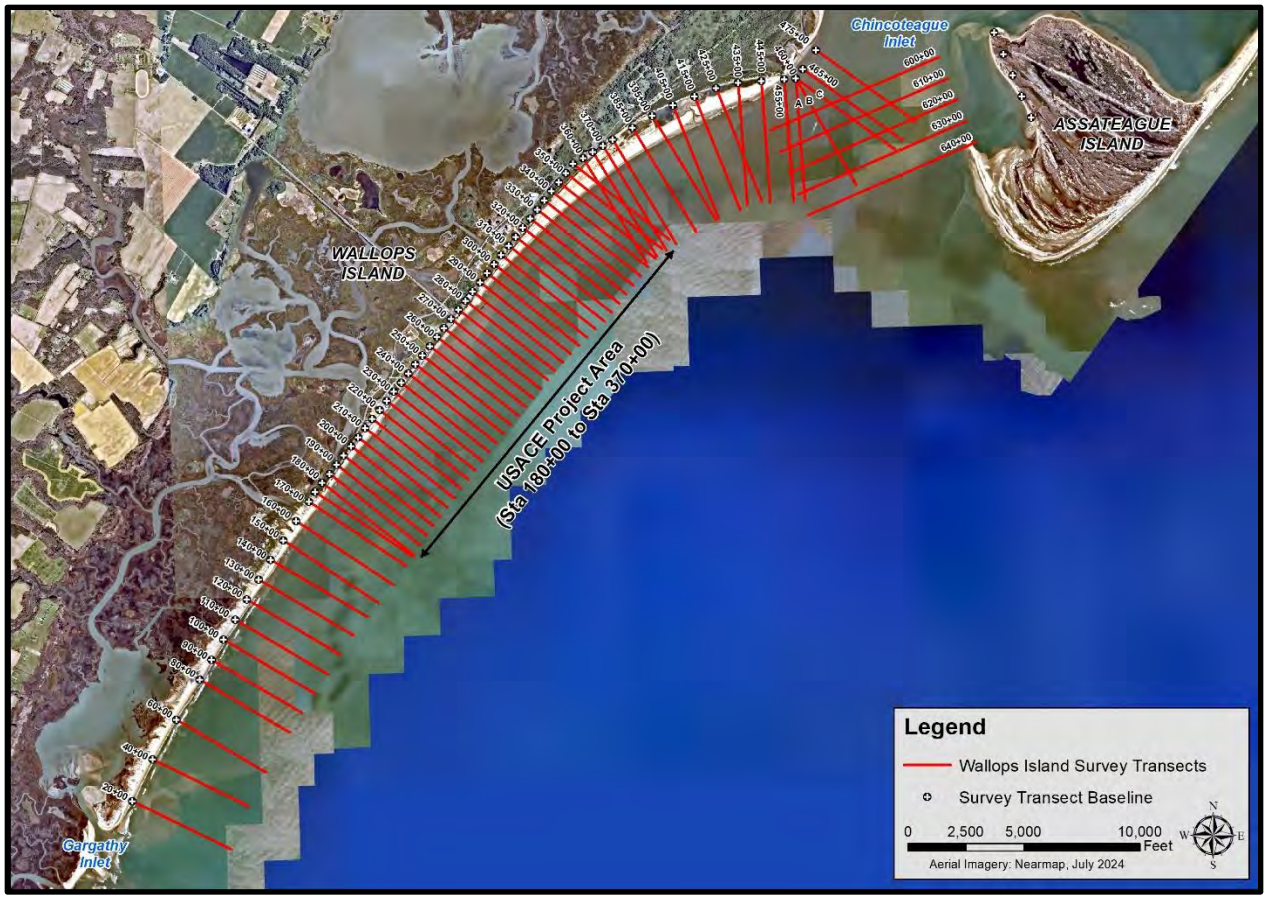


Figure ES-1. Plate Illustrating 2024 Wallops Island Monitoring Survey Design

This Fall 2024 monitoring report documents the data sources, methods and results of the shoreline monitoring evaluation performed to compare the September 2024 survey data with similar information collected by Geodynamics in February 2019 to assess the current condition of the beach as compared to the condition of the beach prior to the previous renourishment project. Specifically, this report utilizes survey data collected in February 2019 and September 2024 to compute the shoreline location change at +1.5 ft NAVD88, which is designated as the Mean High Water (MHW) elevation, and +6.0 ft NAVD88 (for the USACE project area only), which is designated as the design berm elevation. Volume changes were also calculated above +1.5 ft NAVD88 (MHW), -5 ft NAVD88 (wading depth), -10 ft NAVD88 (outer bar), -15 ft NAVD88, and -20 ft NAVD88 from the foredune out to the specified elevation. The elevations of -15 ft NAVD88 and -20 ft NAVD88 are believed to bracket the expected depth of closure (DOC). Figure ES-2 presents a graphical display of the various elevations for which volume change calculations were made along with an example showing which portion of the profile is included in the volume calculations.

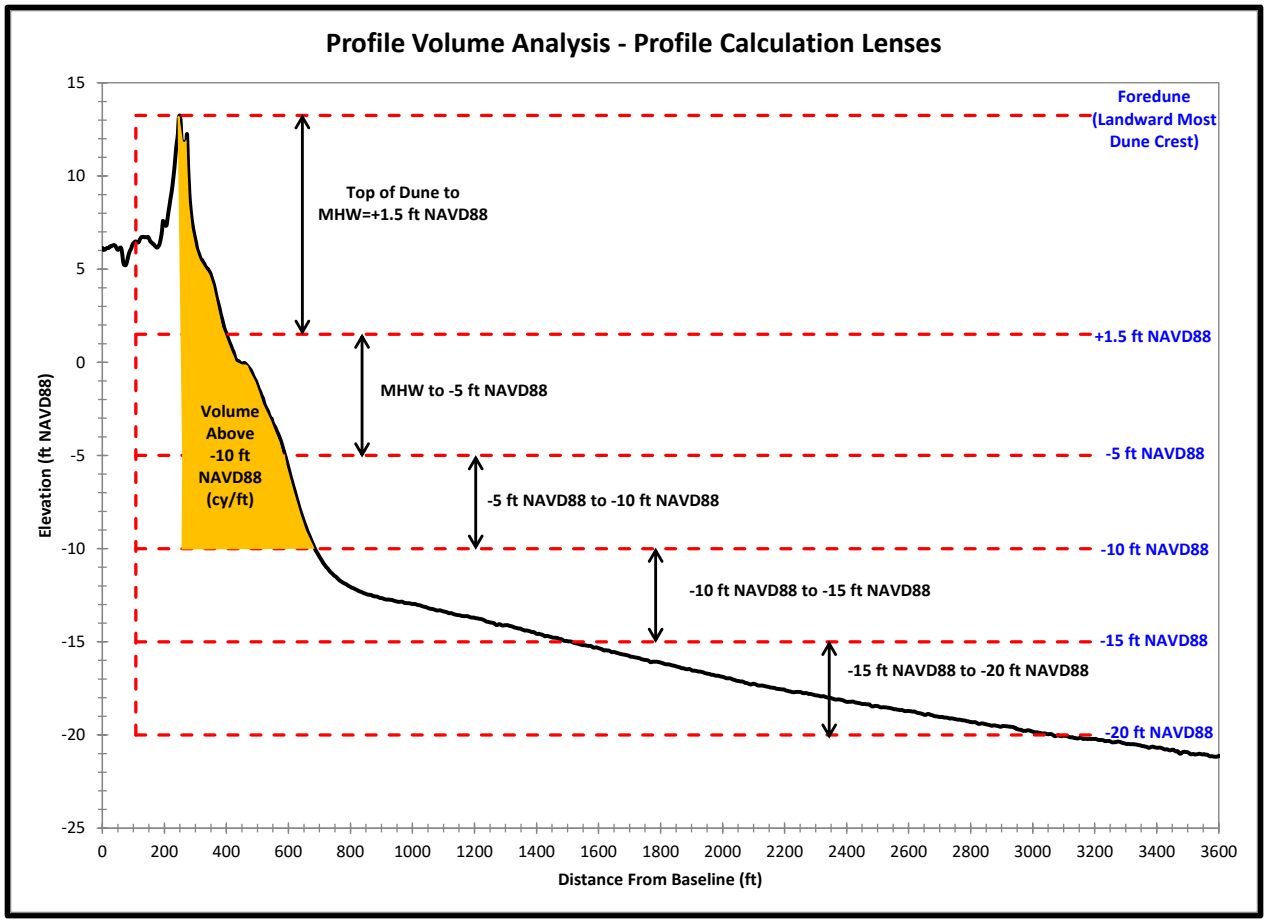


Figure ES-2. Profile Volume Calculation Lenses

In addition, the September 2024 survey was compared to the design and construction templates for the 2020 USACE project and analysis was performed to provide an indication of the 2020 project performance and help in planning of the next renourishment project. The difference in shoreline position at MHW (+1.5 ft NAVD88) and the design berm elevation (+6.0 ft NAVD88) as well as volume difference above MHW (+1.5 ft NAVD88), -5 ft NAVD88, -10 ft NAVD88, and -12 ft NAVD88 were calculated. Volume difference above -12 ft NAVD88 was added to the analysis because this is the approximate elevation of the toe of the fill, allowing for the most accurate estimates of volume surpluses and deficits as compared to the templates.

Table ES-1 presents the average summary statistics calculated between February 2019 and September 2024 for each reach of shoreline in the study area along Wallops Island. Reaches and subreaches developed during the initial Fall 2015 monitoring period based upon profiles with similar characteristics (dune height, berm width, offshore slope, etc.), nourishment extents, and alignment of the shoreline were modified slightly for this report to better reflect more recent morphological changes to the beach resulting from the 2020 renourishment project, construction of offshore breakwaters, and excavation of sand from the northern portion of Wallops Island. Stationing for the monitoring events is consistent with stationing previously determined by the USACE and generally runs south to north. Sta 20+00 is located at the southern end of Assawoman Island adjacent to Gargathy Inlet, while Sta 475+00 is located 45,500 ft to the north, along

Wallops Island, adjacent to Chincoteague Inlet (Figure ES-1). It should be noted that the stations act as midpoints for volume calculations. Therefore, the volume change calculated at each transect is multiplied by a length calculated from halfway between that station and the previous station to halfway between that station and the next station. Consequently, a reach extending from Sta 180+00 to Sta 205+00 (i.e. Wallops Island – USACE Project Subreach 1) also includes the 250 ft on either side of Sta 180+00 and Sta 205+00 making it a total of 3,000 ft in length.

Table ES-1. Shoreline and Volume Change Statistics by Reach for Wallops Island (February 2019 – September 2024)

	Reach Length	Average Shoreline Change @ MHW (+1.5 ft NAVD88)	Average Volume Change Above +1.5 ft NAVD88	Cumulative Volume Change Above +1.5 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -10 ft NAVD88	Cumulative Volume Change Above -10 ft NAVD88	Average Volume Change Above -15 ft NAVD88	Cumulative Volume Change Above -15 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88
Reach (Stations)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	-47.5	-0.5	-7,911	-12.2	-191,454	-16.6	-262,053	-22.5	-354,171	-41.8	-658,565
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	-43.5	-20.0	-59,877	-27.7	-83,026	-30.9	-92,661	-35.5	-106,628	-60.2	-180,610
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	28.6	3.2	27,135	16.3	138,865	27.9	237,046	35.6	302,803	28.6	243,201
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	11.2	-0.7	-2,063	9.4	28,344	19.6	58,926	19.0	57,066	11.8	35,292
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	117.8	17.2	86,119	53.5	267,677	86.6	433,126	111.6	557,760	103.4	517,176
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	181.7	37.3	65,321	83.7	146,480	126.1	220,714	166.0	290,436	188.5	329,872
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	149.4	-52.3	-313,620	-40.9	-245,543	-14.8	-88,555	24.1	144,849	107.9	647,692
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	-213.8	-23.7	-59,288	-69.8	-174,520	-117.6	-293,993	-181.3	-453,242	-211.6	-529,089
TOTAL - Wallops Island (Sta 20+00 to Sta 475+00 A)	*45,500*	*14.7*	*-5.8*	*-264,183*	*-2.5*	*-113,178*	*4.7*	*212,550*	*9.6*	*438,872*	*8.9*	*404,969*

The Wallops Island – South analysis reach experienced landward recession of the shoreline at MHW as well as moderate volume losses above all the elevations analyzed. Volume losses increased above each elevation moving offshore, indicating that the sand has been removed from the system within the monitoring reach, likely being transported south towards Gargathy Inlet. It should be noted that the average annual erosion rate throughout the monitoring period was slightly smaller than the background erosion rate (see Table ES-4) determined using all monitoring surveys.

The statistics indicate an overall volume gain in the Wallops Island - USACE Project analysis reach above all elevations since 2019, indicating that a significant amount of the material placed during the 2020 renourishment project is still within the overall USACE project extents. However, a majority of the remaining material appears to have been transported north to Subreach 4 which had the largest volume gains but did not receive any placement in 2020. Despite placement during the 2020 renourishment project, Subreach 1, which has a historically high erosion rates, experienced significant volume erosion as compared to 2019, indicating that material placed in this reach during the 2020 project has likely already eroded. Conversely, Subreach 2, which also has historically high erosion rates, actually experienced a gain in volume since 2019, indicating that some of the material placed during the 2020 project is still in place, most likely the result of the two sets of breakwaters constructed in this area in conjunction with the 2020 renourishment. Subreach 3 also experienced volume gains as compared to 2019, indicating some of the nourishment material is still present. This area of the USACE project has much lower historical erosion rates and encompasses the portion of shoreline along the Wallops Island USACE project where erosional trends to the south transition to accretional trends to the north.

Several different morphological trends were present within the Wallops Island – North analysis reach. Wallops Island - North Subreach 1 experienced significant volume gains above all elevations from February 2019 to September 2024 which is typical behavior given the longshore transport from the immediately adjacent USACE project. Wallops Island – North Subreach 2 indicates volume losses above MHW, -5 ft NAVD88, and -10 ft NAVD88 but volume gains offshore above -15 ft NAVD88 and -20 ft NAVD88. This is due to the excavation of material for the 2020 renourishment project being combined with typical accretional profile behavior in this area. The profiles continued to show significant accretion seaward of the excavation limits due to sediment transport from the USACE project. However, the volume losses from the excavation itself outweigh the volume gains along the upper elevations of the profile, leading to net losses. Moving further offshore, the volume gains begin to outweigh the losses from excavation, leading to net volume gains. Wallops Island – North Subreach 3 experienced overall losses above all elevations analyzed which is typical for the shoreline adjacent to Chincoteague Inlet.

In order to take a closer look at the performance of the USACE project and begin developing concepts for future nourishment placement and quantities, the September 2024 profiles located in the project area (Sta 180+00 to Sta 370+00) were also compared to the USACE design and construction templates. The design template consists of a 25 ft wide dune at +14 ft NAVD88 with a 30 ft wide berm at +6.0 ft NAVD88 while the construction template consists of a 25 ft wide dune at +14 ft NAVD88 with a 130 ft wide berm at +6.0 ft NAVD88, essentially offset 100 ft seaward from the design template. Therefore, differences calculated between the September 2024 survey data and each of the templates may be very large. For example, in places where the profile has eroded only slightly landward of the design template, it has eroded significantly (an extra 100 ft) landward of the construction template. On the contrary, in places where the profile has accreted just seaward of the construction template, it has accreted significantly seaward (an extra 100 ft) of the design template. Figure ES-3 shows an example profile in the USACE project area along with the design and construction templates for comparison of volume gains and losses with each of the templates.

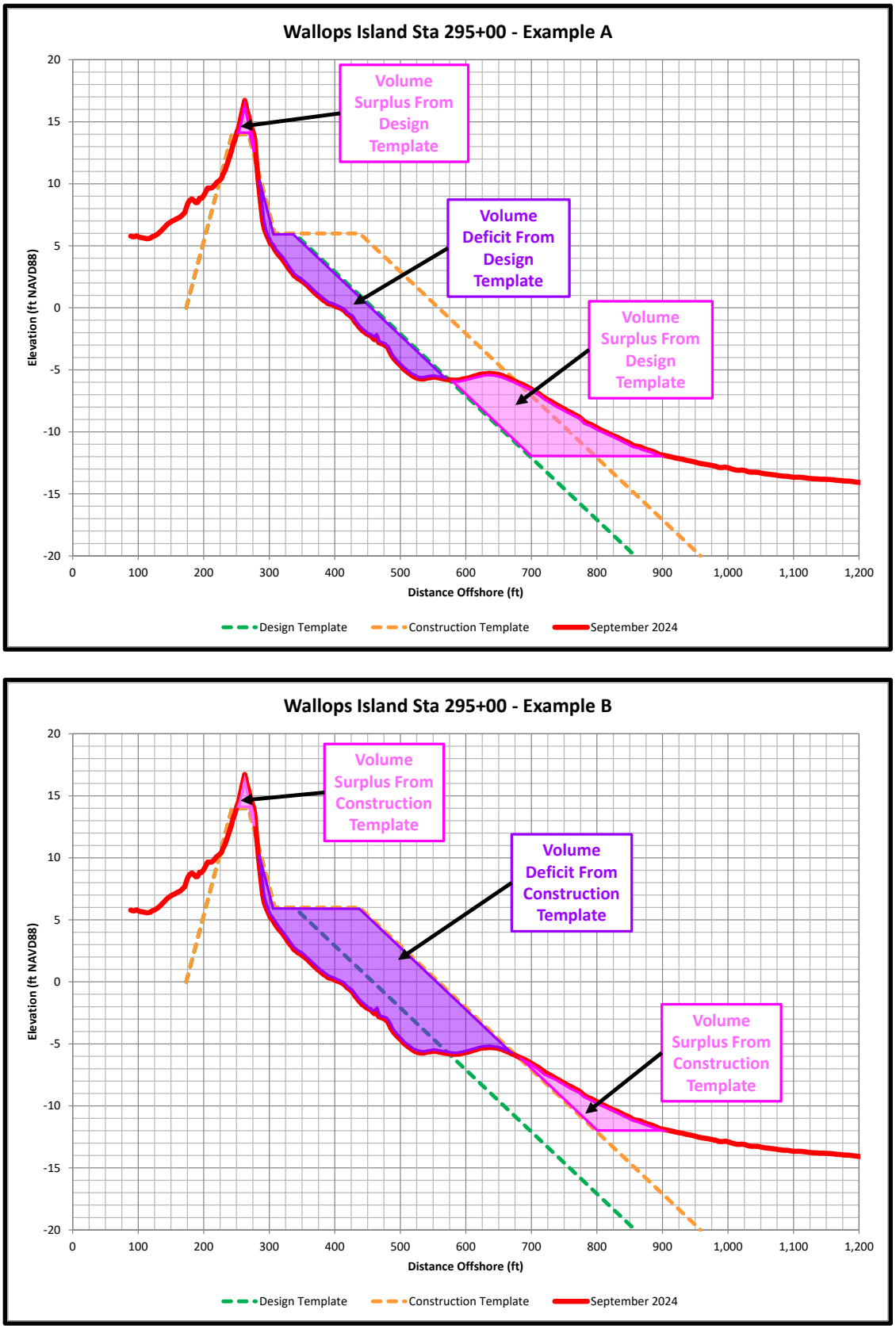


Figure ES-3. Example Profile Surpluses and Deficits From USACE Project Templates

Table ES-2 presents the shoreline position and volume difference between the September 2024 survey and the USACE design template above several elevations. Overall, the total project currently contains more material than the design template, with a net volume surplus of approximately 2.17 million cy above -12 ft NAVD88 (typical extent of fill placement), mostly located in Subreach 4. However, there are areas of the project in Subreaches 1, 2, and 3 which have receded landward of the design template. Due to profile behavior where material eroded from the upper portions of the profile has been captured at lower elevations of the design template in many locations, the largest net volume deficit to the design template actually occurs above -5 ft NAVD88 totaling -139,264 cy in Subreach 1 and -389,360 cy in Subreach 2 for a total of -528,624 cy. Furthermore, there are some transects in Subreach 1, Subreach 2, and Subreach 3 that contain a surplus of material and some that contain a deficit. Therefore, if only the transects containing a deficit of material in Subreach 1, Subreach 2, and Subreach 3 are considered, there is a total deficit of approximately -591,301 cy of material above -5 ft NAVD88 between the September 2024 survey and the design template.

Table ES-2. Design Template Comparison

	Reach Length	Average Shoreline Difference @ +6.0 ft NAVD88	Average Shoreline Difference @ MHW (+1.5 ft NAVD88)	Average Volume Difference Above +1.5 ft NAVD88	Cumulative Volume Difference Above +1.5 ft NAVD88	Average Volume Difference Above -5 ft NAVD88	Cumulative Volume Difference Above -5 ft NAVD88	Average Volume Difference Above -10 ft NAVD88	Cumulative Volume Difference Above -10 ft NAVD88	Average Volume Difference Above -12 ft NAVD88	Cumulative Volume Difference Above -12 ft NAVD88
Reach (Profiles)	ft	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 210+00)	3,000	-63.4	-79.5	-25.6	-76,783	-46.4	-139,264	-32.3	-97,003	-19.9	-59,555
Wallops Island - USACE Project Subreach 2 (Sta 215+00 to Sta 295+00)	8,500	-62.9	-95.5	-23.8	-202,171	-45.8	-389,360	-33.2	-281,835	-22.0	-186,953
Wallops Island - USACE Project Subreach 3 (Sta 300+00 to Sta 320+00)	3,000	53.5	56.3	16.1	48,349	32.7	97,960	76.4	229,326	100.1	300,194
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	437.4	537.6	90.9	454,559	223.4	1,117,167	361.3	1,806,586	424.3	2,121,299
TOTAL - Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)	***19,500***	***83.2***	***92.6***	***11.5***	***223,954***	***35.2***	***686,502***	***85.0***	***1,657,075***	***111.5***	***2,174,985***

Table ES-3 presents the shoreline position and volume difference between the September 2024 survey and the USACE construction template. Overall, the total project currently contains slightly more material than the construction template, with a net volume surplus of approximately 878,691 cy above -12 ft NAVD88 (typical extent of fill placement), mostly located in Subreach 4. However, there are some large portions of the project which have eroded significantly from the construction template. Due to profile behavior where material eroded from the upper portions of the profile has been captured at lower elevations of the construction template in many locations, the largest net volume deficit to the construction template actually occurs above -10 ft NAVD88 totaling -274,781 cy in Subreach 1 and -785,538 cy in Subreach 2 for a total of -1,060,318 cy. Furthermore, there are some transects in Subreach 1, Subreach 2, and Subreach 3 that contain a surplus of material and some that contain a deficit. Therefore, if only the transects containing a deficit of material in Subreach 1, Subreach 2, and Subreach 3 are considered, there is a total deficit of approximately -1,140,764 cy of material above -10 ft NAVD88 between the September 2024 survey and the construction template.

Table ES-3. Construction Template Comparison

	Reach Length	Average Shoreline Difference @ +6.0 ft NAVD88	Average Shoreline Difference @ MHW (+1.5 ft NAVD88)	Average Volume Difference Above +1.5 ft NAVD88	Cumulative Volume Difference Above +1.5 ft NAVD88	Average Volume Difference Above -5 ft NAVD88	Cumulative Volume Difference Above -5 ft NAVD88	Average Volume Difference Above -10 ft NAVD88	Cumulative Volume Difference Above -10 ft NAVD88	Average Volume Difference Above -12 ft NAVD88	Cumulative Volume Difference Above -12 ft NAVD88
Reach (Profiles)	ft	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 210+00)	3,000	-163.4	-179.5	-42.3	-126,783	-87.2	-261,486	-91.6	-274,781	-86.5	-259,556
Wallops Island - USACE Project Subreach 2 (Sta 215+00 to Sta 295+00)	8,500	-162.9	-195.5	-40.5	-343,837	-87.6	-744,917	-92.4	-785,538	-88.2	-749,914
Wallops Island - USACE Project Subreach 3 (Sta 300+00 to Sta 320+00)	3,000	-46.5	-43.8	-0.6	-1,652	-8.1	-24,263	17.2	51,549	33.4	100,194
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	337.4	437.6	74.2	371,225	182.7	913,463	302.1	1,510,290	357.6	1,787,967
TOTAL - Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)	***19,500***	***-16.8***	***-7.4***	***-5.2***	***-101,046***	***-6.0***	***-117,203***	***25.7***	***501,521***	***45.1***	***878,691***

It is evident that considerable erosion has occurred since the 2020 renourishment project a majority of the area which received material during the 2020 renourishment project (Subreaches 1, 2, and 3) has shown considerable erosion, significantly increasing vulnerability to the next storm event. While the breakwaters appear to be performing well and are holding sand in the immediate area of construction, protecting the valuable infrastructure on land, the beneficial impacts are highly localized, allowing for the continued high loss rates of material along a majority of Subreaches 1 and 2.

To establish the long-term erosion and accretion patterns in the Wallops Island study area which will help to optimize future shoreline stabilization and restoration efforts, a background erosion rate was calculated for each subreach. The calculated background erosion rates remove the effects of the 2012, 2014, and 2020 nourishment events, thus enabling the determination of volumetric change that would occur without the projects, assisting in determining future nourishment quantities and timing. This report updates the erosion rates from February 2019 to include volume changes from February 2019 to September 2024. To accomplish this process, the volume changes above -15 ft NAVD88 for the February 2019 through September 2024 time period were added to the volume changes calculated for the previous monitoring reports spanning from 2011 through February 2019. The elevation of -15 ft NAVD88 represents the seaward limits of all of the sand placement occurring during the maintenance events. Nourishment volumes were then subtracted from total volume changes above -15 ft NAVD88. From this, the average annual background erosion rate was calculated. Table ES-4 shows the documented placement volumes and volume change as well as the calculated background erosion rates for the defined reaches and subreaches.

Table ES-4. Average Annual Background Erosion Rates

Reach	Length (ft)	Total Nourishment Volume (cy) (Oct 2011 - Sept 2024)	Total Volume Change Above -15 ft NAVD88 (cy) (Oct 2011 - Sept 2024)	Cumulative Background Erosion (cy)	Annualized Cumulative Background Erosion Rate (cy/yr)	Average Annual Background Erosion Rate (cy/ft/yr)
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	0	-1,150,188	-1,150,188	-88,888	-5.64
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	942,633	238,201	-704,432	-54,439	-18.15
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	2,670,793	816,018	-1,854,775	-143,340	-16.86
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	764,617	607,374	-157,243	-12,152	-4.05
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	826,085	2,221,113	1,395,028	107,810	21.56
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	0	953,566	953,566	73,693	42.11
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	-1,300,000	2,041,355	3,341,355	258,225	43.04
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	0	-1,351,594	-1,351,594	-104,453	-41.78
TOTAL - WALLOPS ISLAND (Sta 20+00 to Sta 475+00)	***45,500***	***3,904,128***	***4,375,845***	***471,717***	***36,455***	***0.80***

Subreaches 1 and 2 of the Wallops Island – USACE Project analysis reach experience the highest background erosion rates in the project area. Based on the computed background erosion rates of -18.15 cy/ft/yr in Subreach 1, -16.86 cy/ft/yr in Subreach 2, and -4.05 cy/ft/yr in Subreach 3 it is possible that approximately 210,000 cy of material could be lost from these two reaches each year if the erosional trend continues.

In order to gain knowledge on the morphology of Chincoteague Inlet, a possible future source of nourishment material, the hydrographic portion of profiles along Assateague Island adjacent to the inlet were surveyed for future monitoring. Volume calculations were not performed but rather the profiles were qualitatively examined for changes in inlet channel location and possible shoaling. Results indicate that while there was a small amount of shoaling at the mouth of the inlet (Sta 600+00), the channel position and depth remained fairly stable between February 2019 and September 2024.

In conclusion, this Fall 2024 monitoring survey is the first monitoring survey performed since the semi-annual monitoring program from Fall 2015 to Spring 2019 was completed. During the 5.5 year time period since the last survey, the USACE placed approximately 1.3 Mcy along 14,000 ft of shoreline within the USACE project area and constructed five offshore breakwaters. Survey results indicate that in many locations along Subreach 1, Subreach 2, and the southern half of Subreach 3, beach profiles have receded landward of the 2019 survey (see Figure ES-4), the design template, and the construction template (see Figure ES-5) despite the 2020 nourishment efforts, significantly increasing vulnerability to the next storm event. As of the Fall 2024 survey, it is estimated that the volume deficit to the construction template is approximately -1,140,764 cy, equivalent to 88% of the 2020 project volume. It should be noted that the two breakwater fields appear to be holding sand well in the immediate vicinity, but positive impacts do not extend very far alongshore. In addition, the area north of the USACE project which was excavated as a

borrow source for the 2020 project appears to be continuing to accrete seaward of the excavation limits.

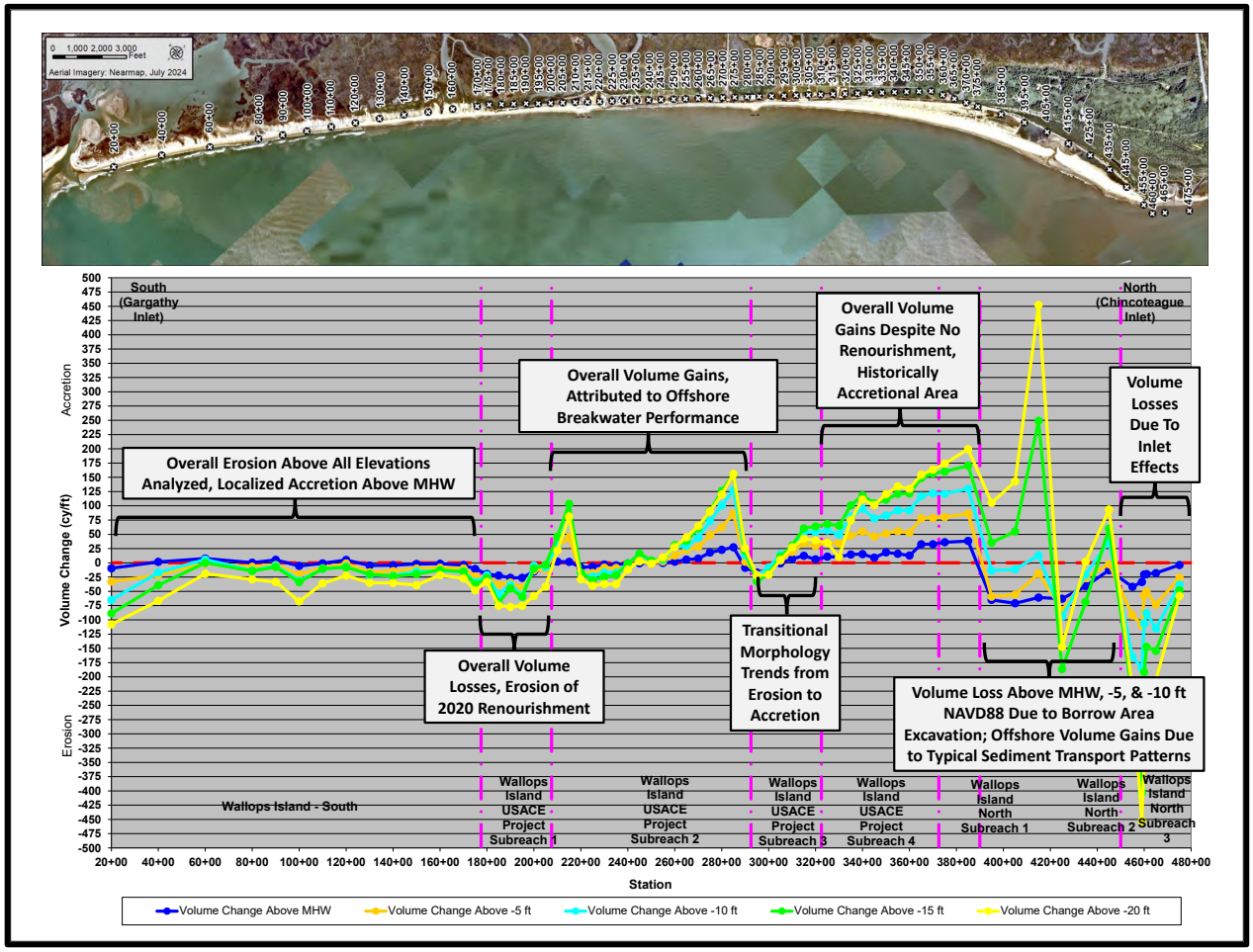


Figure ES-4. Wallops Island Volume Change (February 2019 – September 2024)

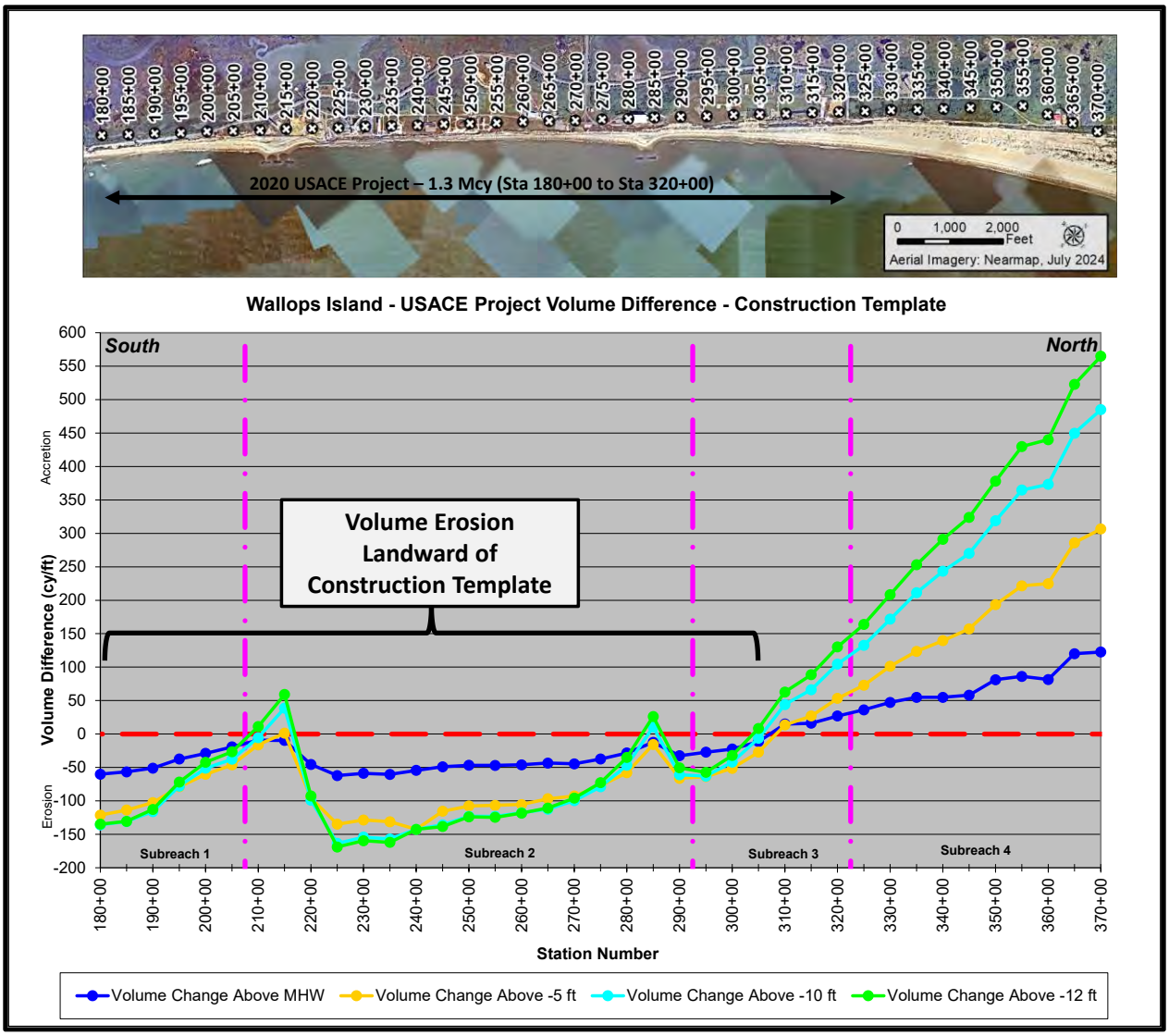


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1.0 Objective

The US Army Corps of Engineers (USACE) Norfolk District constructed an engineered beach project placing 3.2 Mcy of sand along approximately 19,000 ft of shoreline on Wallops Island during Summer 2012. The project serves to protect a stretch of shoreline along which critical NASA infrastructure is located. Immediately after completion of the 2012 project, Hurricane Sandy impacted the area and significant loss to a portion of the project was experienced. Therefore, approximately 11,500 ft of shoreline was renourished during Summer 2014 with 682,000 cy of sand. As a requirement of the EIS associated with the engineered beach project, semi-annual (fall and spring) beach monitoring surveys and analyses commenced in Fall 2015 along Wallops Island extending to the north as far as Toms Cove / Assateague Island and to the south as far as Gargathy Inlet. Monitoring was completed in Spring 2019 after which the USACE Norfolk District designed a renourishment project based on the findings and recommendations. The renourishment project took place in 2020, placing roughly 1.3 Mcy of sand along approximately 14,000 ft of shoreline and included construction of 5 offshore breakwaters to further protect critical infrastructure at two locations along the project extents. In Fall 2024, the USACE requested an updated survey and analysis of the Wallops Island shoreline in order to assess performance of the 2020 renourishment project and breakwater construction and also to guide the timing and design of the next renourishment project.

Therefore, the most recent survey event was performed in September 2024 by Geodynamics, an NV5 company (Geodynamics). This Fall 2024 monitoring report documents the data sources, methods, and results of the shoreline monitoring evaluation performed to compare the September 2024 survey data with similar information collected by Geodynamics in February 2019 to assess the current condition of the beach as compared to the condition of the beach prior to the previous renourishment project. In addition, the September 2024 survey will also be compared to the design and construction templates for the 2020 USACE project and analysis will be performed to provide an indication of the 2020 project performance, assess the current state of the beach as compared to the templates, and help in planning of the next renourishment project.

Figure 1-1 presents the Fall 2024 monitoring transects that were surveyed along Wallops Island and Assateague Island in relation to the full USACE project area. In total, 67 transects were surveyed on Wallops Island from Gargathy Inlet to Chincoteague Inlet and 5 transects were surveyed offshore of Assateague Island, immediately adjacent to Chincoteague Inlet. The same transects were surveyed during the Spring 2019 survey referenced in this report. In general, transects were stationed 2000 ft apart along the southernmost portion of Wallops Island, transitioning to 1000 ft spacing approaching the southern end of the USACE project. The transect spacing throughout the USACE project was further reduced to 500 ft, transitioning back to 1000 ft spacing north of the project to Chincoteague Inlet and along Assateague Island.

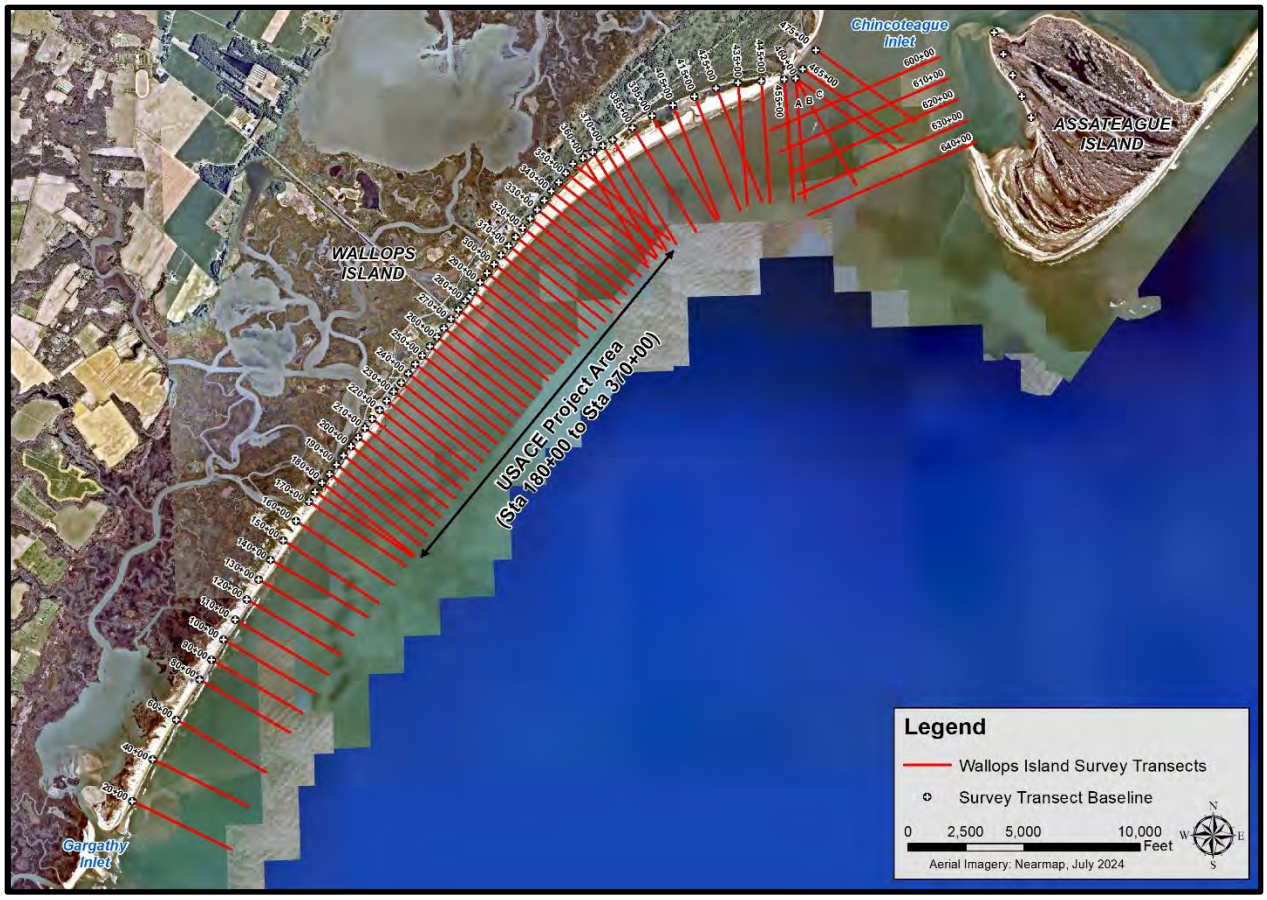


Figure 1-1. 2024 Monitoring Transects and Extents

2.0 Survey Methods and Data Sources

2.1 Survey Transects and Reaches

In September 2024, Geodynamics conducted a survey of Wallops Island using selected profile lines and origins established by the USACE for the project to collect elevation and positioning data for the entire study area. For analysis purposes, the study area was divided into reaches and subreaches to provide the most representative statistics regarding the behavior of the beach. Formulation of reaches and subreaches for the Fall 2024 monitoring was based upon profiles with similar characteristics (dune height, berm width, offshore slope, etc.), USACE project extents and structure locations, and historical beach morphology trends (i.e. erosion, accretion). It should be noted that the reaches and subreaches developed for the Fall 2024 monitoring differ slightly from those formulated for the monitoring which took place from 2015 to 2019 due to altered morphological trends from the incorporation of offshore breakwaters into the USACE project design and location of the borrow area along the northern extents of Wallops Island. Table 2-1 presents the division of the study area into reaches and subreaches.

Table 2-1. Wallops Island Study Area Analysis Reaches and Subreaches

Reach	Stations	Subreach	Stations
Wallops Island - South	Sta 20+00 to Sta 175+00	N/A	Sta 20+00 to Sta 175+00
Wallops Island - USACE Project	Sta 180+00 to Sta 370+00	Subreach 1	Sta 180+00 to Sta 205+00
		Subreach 2	Sta 210+00 to Sta 290+00
		Subreach 3	Sta 295+00 to Sta 320+00
		Subreach 4	Sta 325+00 to Sta 370+00
Wallops Island - North	Sta 375+00 to Sta 475+00	Subreach 1	Sta 375+00 to Sta 385+00
		Subreach 2	Sta 395+00 to Sta 445+00
		Subreach 3	Sta 455+00 to Sta 475+00
Assateague Island - Hydro Only	Sta 600+00 to Sta 640+00	N/A	Sta 600+00 to Sta 640+00

It should also be noted that the stations act as midpoints for volume calculations. Therefore, the volume change calculated at each transect is multiplied by a length calculated from halfway between that station and the previous station to halfway between that station and the next station. Consequently, a reach extending from Sta 180+00 to Sta 205+00 (i.e. Wallops Island – USACE Project Subreach 1) also includes the 250 ft on either side of Sta 180+00 and Sta 205+00 making it a total of 3,000 ft in length.

Figure 2-1 details how the survey area has been divided into reaches and subreaches for the purpose of calculating meaningful shoreline and volume change statistics. The location of the transects and stationing applied by Geodynamics for the monitoring events is consistent with stationing previously determined by the USACE and generally runs south to north. Sta 20+00 is located at the southern end of Assawoman Island adjacent to Gargathy Inlet while Sta 475+00 is located 45,500 ft to the north, along Wallops Island, adjacent to Chincoteague Inlet. Select hydrographic transects offshore of Assateague Island start at Sta 600+00 adjacent to Chincoteague Inlet and run southeast toward the oceanfront to Sta 640+00, covering 4,000 ft of shoreline.



Figure 2-1. Wallops Island Study Area Analysis Reaches and Subreaches

2.2 Survey Data Acquisition

Several steps were taken by Geodynamics to ensure the most accurate survey data. All surveys conducted by Geodynamics meet the requirements specified in the criteria for Navigation and Dredging Support Hydrographic Surveys as outlined in the U.S. Army Corps of Engineers Hydrographic Surveying Manual, EM 1110-2-1003 (EM 1110-2-1003 November 2013).

The processed survey data was provided to Moffatt & Nichol in ASCII (xyz), Excel (xyz), Shapefile (GIS), and Free Format (BMAP) formats allowing for compatibility with multiple programs. The data referenced the North American Datum 1983 (NAD83) State Plane Virginia South (feet), and the vertical datum used was the North American Vertical Datum of 1988 (NAVD88). A copy of the survey data files is included on the attached USB also containing an electronic copy of the report.

Appendix A contains the Geodynamics Field Report which discusses in detail the singlebeam (bathymetric) and topographic data acquisition. The Field Report also provides the associated equipment and quality control procedures (QA/QC) utilized in the data collection and processing tasks.

2.3 Survey Data Acquisition Timeline

As mentioned previously, the most recent survey was completed in September 2024 and will be compared to the applicable profiles from the previous survey completed in February 2019. The survey dates and extents referenced in this report are presented below.

<u>Spring 2019 Survey Event</u>

- February 19-21, 2019 (Sta 20+00 to Sta 640+00)

<u>Fall 2024 Survey Event</u>

- September 9-12, 2024 (Sta 20+00 to Sta 640+00)

3.0 Survey Evaluation Methods

Survey comparisons and respective analysis were performed using Beach Morphology Analysis Package (BMAP). BMAP is a program developed by the USACE to analyze morphologic and dynamic properties of beach profiles.

All survey data was imported into ArcGIS in xyz format and displayed to compare the coverage of each data set. Design and construction templates for the USACE project were also overlaid in GIS for comparison. Free format files containing the February 2019 and September 2024 beach profiles being used for the comparison were imported into BMAP. The USACE templates were converted from plan view in GIS and imported into BMAP. Using BMAP, shoreline change was calculated for each transect. Volume change was also calculated, within BMAP, above different elevations to track sand movement across the entire profile.

3.1 Shoreline Change (February 2019 – September 2024)

Shoreline change is analyzed using a tidal datum derived shoreline that is extracted from the topographic portion of the beach profile data. The Mean High Water (MHW) contour is used to define the intersection of the land and water and is the primary marker to analyze both short- and long-term shoreline change trends. A MHW contour of +1.5 ft NAVD88 was derived for the project through the official NOAA / NGS VDatum model and the position change calculated between the February 2019 and September 2024 surveys. Change in contour position at the design berm elevation of +6.0 NAVD88 was also calculated for just the USACE Project area (Sta 180+00 to Sta 370+00) to track the movement of this important design feature over time. For reference, Appendix B presents the pre-project (2011), December 2015, February 2016 (where applicable), October 2016, April 2017, October 2017, February 2018, August 2018, February 2019, and September 2024 MHW shorelines overlain on 2024 aerial photography by Nearmap.

3.2 Volume Change (February 2019 – September 2024)

Representative volume changes were calculated at each transect between the February 2019 and September 2024 profiles. Volume changes were calculated above five different elevations in order to better understand the processes occurring onshore and offshore of the Wallops Island shoreline. Calculations included volume change above +1.5 ft NAVD88 (MHW), above -5 ft NAVD88, above -10 ft NAVD88, above -15 ft NAVD88 and above -20 ft NAVD88 from the foredune out to the specified elevation. These elevations were picked based on profile shape and morphology. Upon inspection of recent survey data, it appears the depth of closure is somewhere between -15 ft NAVD88 and -20 ft NAVD88.

Figure 3-1 presents a graphical display of the various elevations for which volume change calculations were made along with an example showing which portion of the profile is included in the volume calculations. The profile volume calculation lenses were strategically chosen to help understand and track the movement of sand onshore and offshore. Volume changes calculated for portions of the profiles above MHW are representative of changes in the amount of material in the dune system and on the subaerial beach. This area is highly influenced by the impact of storm activity. Volume comparisons for portions of the profiles above -5 ft NAVD88 are representative of changes in a very dynamic portion of the beach profile where waves break before running onshore, often causing significant sand movement. Volume comparisons above -10 ft NAVD88 help to track sand movement to and from the outer sand bar, encompassing a majority of the sand placement activities. Material above this elevation also provides most of the protection for the beach by absorbing the wave energy. Volume comparisons above -15 ft NAVD88 provide general estimates of the total volumetric change along the respective profile out to the depth of closure. Significant changes in the profile shape should not occur seaward of the depth of closure, currently estimated between -15 ft NAVD88 and -20 ft NAVD88. Therefore, volumetric change measurements above -15 ft NAVD88 and -20 ft NAVD88 should provide relatively similar results. Large discrepancies between the -15 ft NAVD88 and -20 ft NAVD88 calculations should be reviewed to verify the vertical accuracy of the survey has not influenced the results. Often, discrepancies can be attributed to the range of accuracy (±0.11 ft) in the hydrographic survey measurements. Thus, this method of volume calculation fully assesses the impact of storm activity on the subaerial beach and dune system. The calculations also provide

a means to track the movement of sand offshore and quantify total gains and losses in the entire beach system.

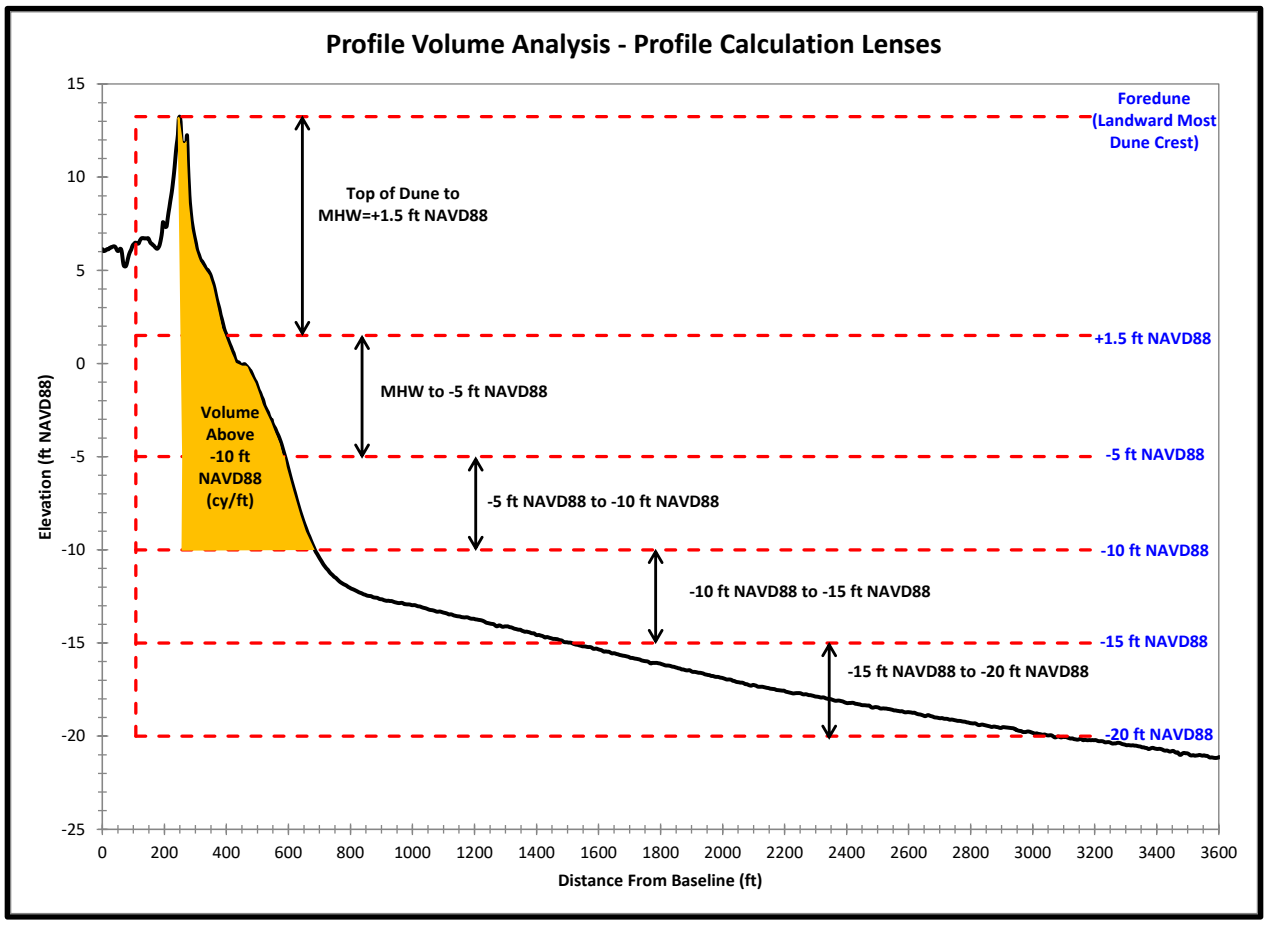


Figure 3-1. Profile Volume Calculation Lenses

Similar to shoreline change, the resulting values represent volume change (cy/ft) over the period of time between surveys. In addition, the volume changes were converted to cumulative changes (cy) over the entire reach/subreach. This was done by applying the average end area method to the unit volume changes (cy/ft) computed at each transect and summing the total volume changes over the entire reach/subreach. The resulting value indicates the total loss or gain of material (cy) between survey periods based on the applicable profile extents. It should be noted that the stations act as midpoints for volume calculations. Therefore, the volume change calculated at each transect is multiplied by a length calculated from halfway between that station and the previous station to halfway between that station and the next station. Consequently, a reach extending from Sta 180+00 to Sta 205+00 (i.e. Wallops Island – USACE Project Subreach 1) also includes the 250 ft on either side of Sta 180+00 and Sta 205+00 making it a total of 3,000 ft in length. The survey measurement accuracy in the hydrographic portions of the survey is approximately ±0.11 ft. This level of accuracy is important to remember when looking at volume change results over long distances offshore as well as alongshore.

3.3 USACE Project Comparison (September 2024)

A similar shoreline and volume change comparison was performed between the September 2024 survey and the design and construction templates for the USACE project. Volume difference was calculated above +1.5 ft NAVD88 (MHW), above -5 ft NAVD88 (wading depth/recreational beach), above -10 ft NAVD88 (outer bar), and above -12 ft NAVD88 (approximate toe of nourishment). Volume difference above -12 ft NAVD88 was added to the analysis because this is the approximate elevation of the toe of the fill, allowing for the most accurate estimates of volume surpluses and deficits as compared to the templates. Differences above -15 ft NAVD88 and -20 ft NAVD88 were excluded from these calculations due to the fact that these elevations are beyond the limits of sand placement. The resulting values indicate the deficit or surplus of material as compared to the templates, showing how the project has performed thus far and which areas may be in need of renourishment.

4.0 Discussion of Periodic Surveying Evaluation

This section will discuss recent events (i.e. nourishment projects, storms, etc.) within the reporting time period from February 2019 to September 2024, update of background erosion rates to include the September 2024 survey, and the shoreline and volume change analysis performed between the February 2019 and September 2024 monitoring events. Profile comparison plots for individual transects, which include the February 2019 and September 2024 survey profiles as well as the design and construction templates, where applicable, are presented in Appendix C. The computed shoreline changes and volume changes at each individual transect for the time periods being covered are tabulated, for reference, in Appendix D.

4.1 Key Events During the Reporting Period

Beach changes are greatly influenced by natural (i.e. storms) and engineering processes (i.e. sand placements). This section describes key events that occurred during the February 2019 to September 2024 reporting period that likely had an impact on shoreline change as well as profile volume gains and losses.

4.1.1 Storm Events

To ascertain the extent of storm activity which may have impacted the Wallops Island study area, wave data for the region was analyzed from February 2019 to September 2024. In late June 2016, a new buoy was brought online approximately 10 miles offshore of the project area by the ERDC-CHL Field Research Facility (FRF) as part of the long-term monitoring effort at Wallops Island (Station 44089-Wallops Island). This buoy was chosen from the National Data Buoy Center for analysis of the presence of storm events which may have impacted the study area from February 2019 to September 2024. The location of the buoy is shown in Figure 4-1.



Figure 4-1. Buoy Location for Wallops Island Study Area

Figure 4-2 shows the significant wave heights measured at the Wallops Island buoy for the time period from February 2019 to September 2024. It should be noted that the buoy was offline from January 13 – July 16, 2020. As can be seen, there were multiple storm events with elevated wave heights throughout the 5.5 year time period between surveys. Most of the events occurred during the winter time period with the largest events occurring during the most recent 2023/2024 winter season. In this region of the country, winter storms are typically more plentiful and have larger erosional impact on the beach while the beach usually undergoes some sort of recovery during the summer season. Therefore, due to the consistent active winter weather throughout the monitoring time period, it is expected that erosion may have been significant.

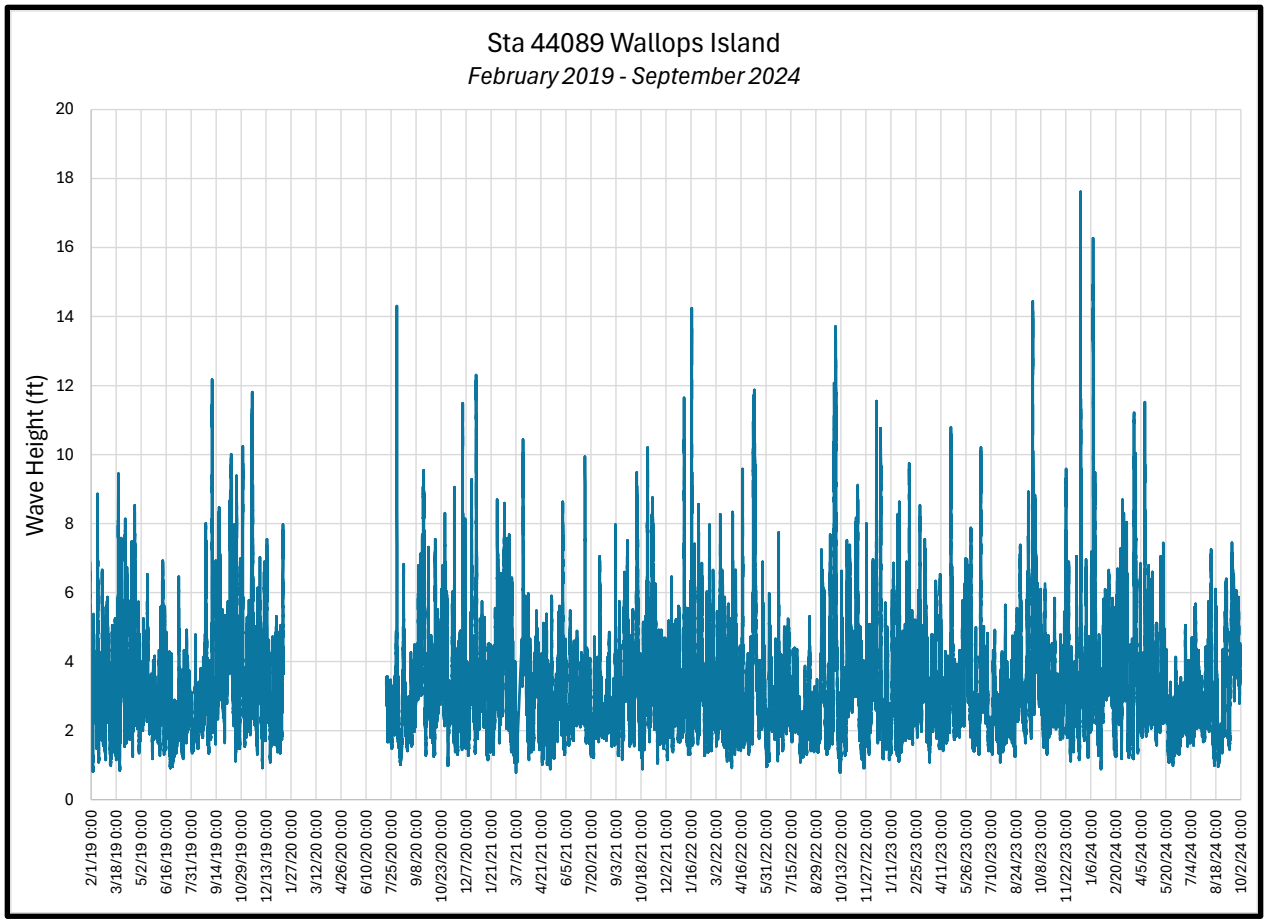


Figure 4-2. Sta 44089 Wallops Island Significant Wave Height (February 2019 – September 2024)

4.1.2 Sand Placement Events

The USACE constructed a renourishment project during the Spring 2019 to Fall 2024 monitoring period. In 2020, the USACE placed approximately 1.3 Mcy of material along roughly 14,000 ft from Sta 180+00 to Sta 320+00. The project consisted of a 25 ft wide dune at elevation +14.0 ft NAVD88 and a 130 ft wide berm at elevation +6.0 ft NAVD88. The borrow area for the project consisted of excavation and truck haul from a highly accretional area on the northern end of Wallops Island located from Sta 395+00 to Sta 445+00. The project also included construction of five offshore breakwaters at two separate locations. Three breakwaters are located near the southern end of the project around Sta 215+00. The other two are located further north around Sta 285+00. Figure 4-3 shows the approximate placement extents of the 2020 project in relation to the overall USACE project extents as well as the newly constructed breakwater locations and the borrow area location.

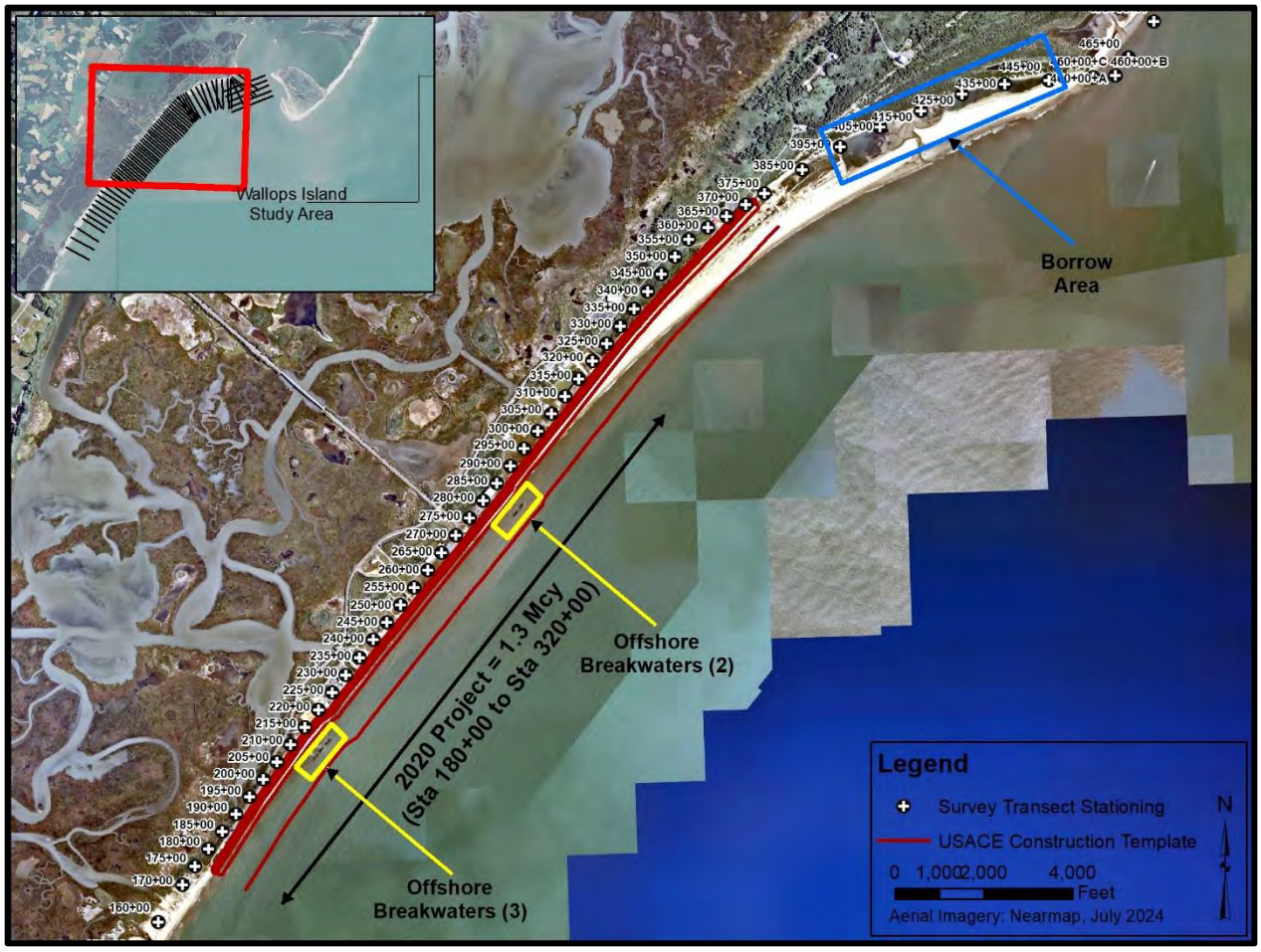


Figure 4-3. 2020 Wallops Island USACE Projects

Figure 4-4 shows an example profile in the USACE project area along with the design and construction templates for comparison. As can be seen, the Fall 2024 profile has receded landward of the design and construction templates, especially above -5 ft NAVD88. Some material has been captured further offshore between -5 ft NAVD88 and the toe of the fill. This was a common occurrence throughout the project area. In the most extremely eroded areas, the material captured near the toe of fill was still landward of the design and construction templates, creating volume deficits along the entire profile from both templates. Figure 4-5 shows an example profile in the immediate vicinity of the southern set of breakwaters. As can be seen, the profile maintained the construction template fairly well in this location, indicating successful protection of the infrastructure immediately landward of the breakwaters.

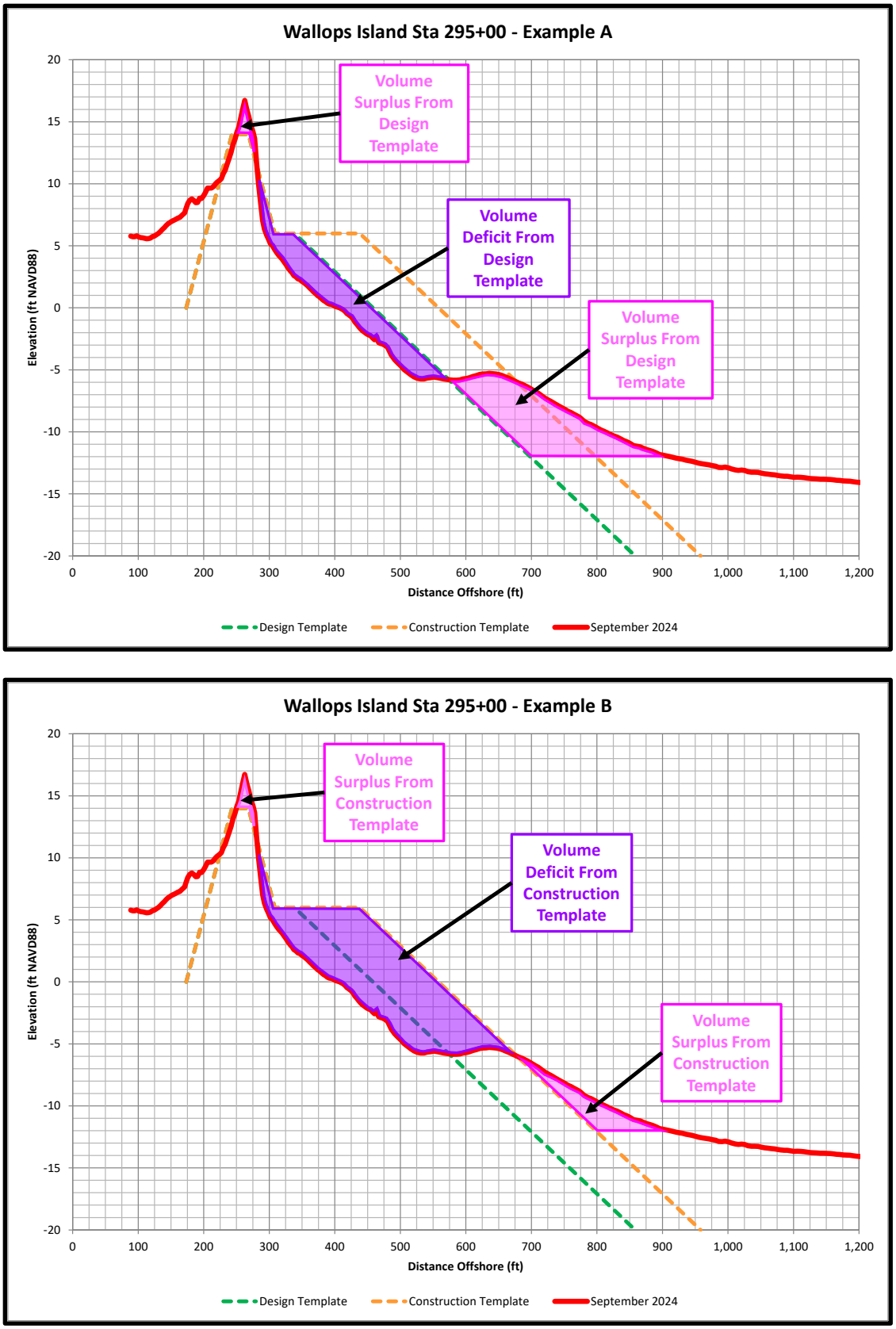


Figure 4-4. Example Profiles from USACE Project – Typical Erosion

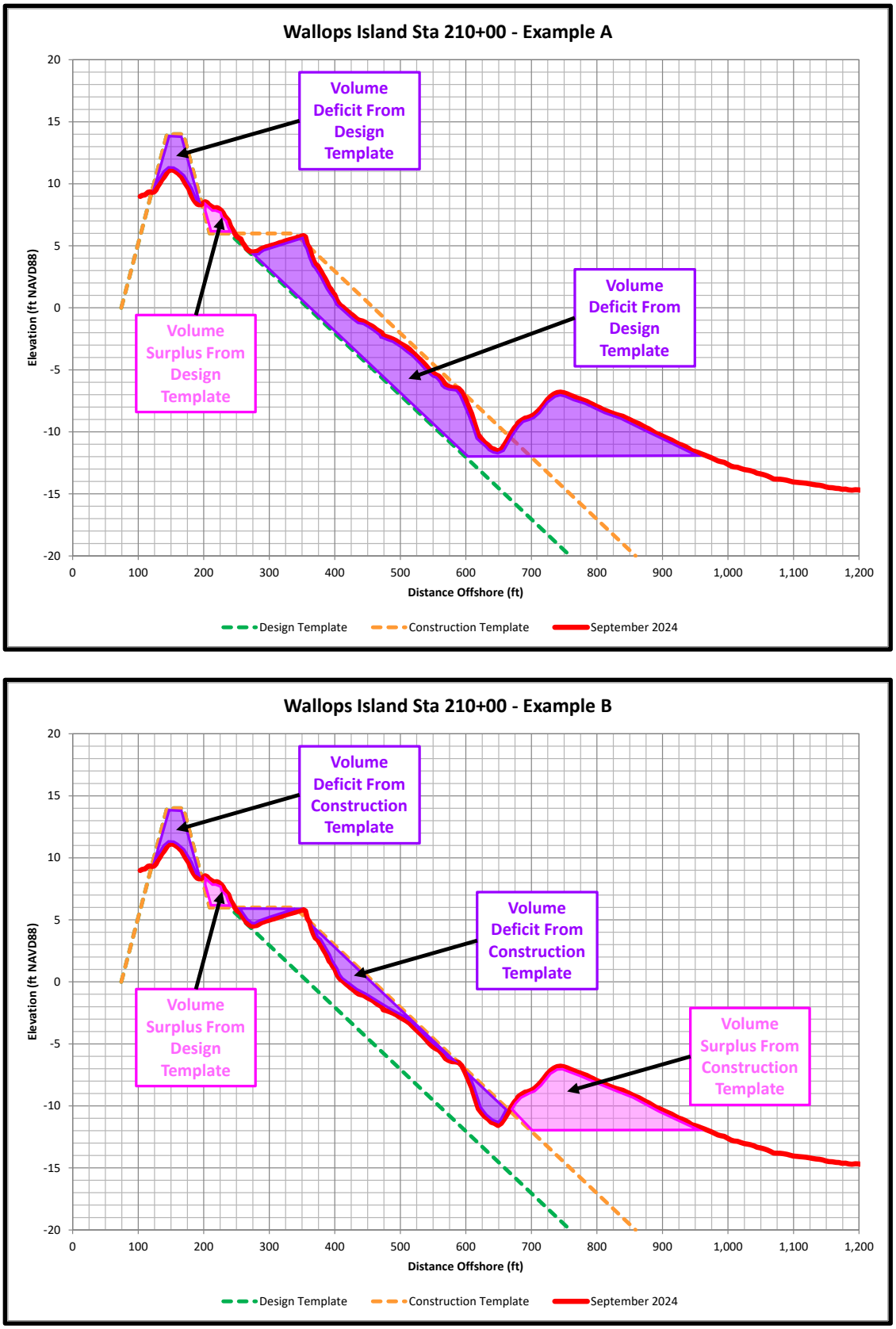


Figure 4-5. Example Profiles From USACE Project – Breakwater Area

4.2 Determination of Background Erosion Rates

It is important to determine a background erosion rate, which removes the effects of sand placement, from which to develop long-term trends in volume losses/gains that may be expected without nourishment projects. Background erosion rates aid in focusing on areas of concern, helping to predict which portions of the shoreline will likely require the most nourishment. This report updates the background erosion rates calculated for the Spring 2019 monitoring report to include the September 2024 survey.

First, the sand placement volumes for the 2012, 2014, and 2020 projects were documented and proportioned into each of the subreaches included in the USACE Project area based on length of shoreline. Table 4-1 summarizes the volumes placed in the study area during these projects. In addition, it was noted that 1.3 Mcy of material was removed from the northern portion of Wallops Island (Wallops Island – North Subreach 2) in order to construct the 2020 project.

Table 4-1. Placement Volumes by Subreach

Sub-Reach	Length (ft)	2012 Project (cy)	2014 Project (cy)	2020 Project (cy)	Total (cy)
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	495,651	178,016	268,966	942,633
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	1,404,345	504,380	762,069	2,670,793
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	495,651	0	268,966	764,617
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	826,085	0	0	826,085
TOTAL	***19,500***	***3,221,732***	***682,396***	***1,300,000***	***5,204,128***

Second, the historical volume changes above -15 ft NAVD88 were calculated for the February 2019 through September 2024 time period and added to the volume changes calculated for the previous monitoring reports spanning from October 2011 through February 2019 (see Section 4.3 for detailed discussion of volume change calculations). The elevation of -15 ft NAVD88 was selected since all of the sand placed during nourishment events was placed above this elevation, close to the approximate depth of closure. Table 4-2 presents the volume changes calculated from the previous and current monitoring reports along with the total volume change from October 2011 to September 2024 which will be used in determination of the background erosion rate.

Table 4-2. Historical and Current Volume Changes

Reach	Length (ft)	Volume Change Above -15 ft NAVD88 (cy) (Oct 2011 - Dec 2015)	Volume Change Above -15 ft NAVD88 (cy) (Dec 2015 - Oct 2016)	Volume Change Above -15 ft NAVD88 (cy) (Oct 2016 - April 2017)	Volume Change Above -15 ft NAVD88 (cy) (April 2017 - Oct 2017)	Volume Change Above -15 ft NAVD88 (cy) (Oct 2017 - Feb 2018)	Volume Change Above -15 ft NAVD88 (cy) (Feb 2018 - Aug 2018)	Volume Change Above -15 ft NAVD88 (cy) (Aug 2018 - Feb 2019)	Volume Change Above -15 ft NAVD88 (cy) (Feb 2019 - Sept 2024)	Total Volume Change Above -15 ft NAVD88 (cy) (Oct 2011 - Sept 2024)
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	-206,887	-281,008	-76,961	-71,821	17,839	-16,190	-160,989	-354,171	-1,150,188
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	497,777	-78,626	-14,783	-8,416	-3,359	-11,658	-36,108	-106,628	238,201
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	1,160,746	-339,052	-82,059	-63,266	-32,534	-84,181	-46,439	302,803	816,018
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	518,469	-15,281	-2,580	9,674	4,877	3,951	31,198	57,066	607,374
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	1,143,813	140,681	74,497	147,936	19,951	84,010	52,467	557,760	2,221,113
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	431,531	67,519	21,046	40,115	9,273	56,457	37190.75	290,436	953,566
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	1,290,297	164,464	154,951	-20,887	83,099	162,308	62,274	144,849	2,041,355
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	-527,889	-81,500	-78,679	-44,764	-5,890	-90,536	-69,095	-453,242	-1,351,594
TOTAL - WALLOPS ISLAND (Sta 20+00 to Sta 475+00 A)	***45,500***	***4,307,857***	***-422,803***	***-4,567***	***-11,430***	***93,255***	***104,161***	***-129,501***	***438,872***	***4,375,845***

To calculate the background erosion rate, sand placement (and removal) volumes were subtracted from total volume changes above -15 ft NAVD88. From this, the average annual background erosion rate was calculated for each subreach. Table 4-3 shows the documented placement volumes and total volume changes as well as the calculated background erosion rates for the defined subreaches.

Table 4-3. Average Annual Background Erosion Rates (2011 - 2024)

Reach	Length (ft)	Total Nourishment Volume (cy) (Oct 2011 - Sept 2024)	Total Volume Change Above -15 ft NAVD88 (cy) (Oct 2011 - Sept 2024)	Cumulative Background Erosion (cy)	Annualized Cumulative Background Erosion Rate (cy/yr)	Average Annual Background Erosion Rate (cy/ft/yr)
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	0	-1,150,188	-1,150,188	-88,888	-5.64
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	942,633	238,201	-704,432	-54,439	-18.15
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	2,670,793	816,018	-1,854,775	-143,340	-16.86
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	764,617	607,374	-157,243	-12,152	-4.05
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	826,085	2,221,113	1,395,028	107,810	21.56
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	0	953,566	953,566	73,693	42.11
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	-1,300,000	2,041,355	3,341,355	258,225	43.04
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	0	-1,351,594	-1,351,594	-104,453	-41.78
TOTAL - WALLOPS ISLAND (Sta 20+00 to Sta 475+00)	***45,500***	***3,904,128***	***4,375,845***	***471,717***	***36,455***	***0.80***

As can be seen, the Wallops Island shoreline experiences a wide range of background erosion and accretion rates. Of major importance are the Wallops Island - USACE Project subreaches which show a significant erosional trend in Subreaches 1 and 2 while Subreach 3 appears to be more stable, albeit slightly erosional, and Subreach 4 is accretional. Based on the preliminary background erosion rates of -18.15 cy/ft/yr in Subreach 1, -16.86 cy/ft/yr in Subreach 2, and -4.05 cy/ft/yr in Subreach 3, it is possible that approximately 210,000 cy of material could be lost from these three reaches each year if the erosional trend continues. The Wallops Island – South

analysis reach has experienced some moderate erosion while the Wallops Island – North analysis reach has experienced a large amount of accretion, except immediately adjacent to the inlet, which is expected. It is likely that a majority of material eroding from Subreach 1 and Subreach 2 of the USACE project is being transported north to Subreaches 3 and 4 as well as beyond the project area itself to Subreaches 1 and 2 of the Wallops Island – North analysis reach. It should be noted that a smaller portion of the project material likely gets transported south to the Wallops Island – South analysis reach, helping to abate erosion and causing the background erosion rate to be much smaller than the adjacent project subreaches.

4.3 Profile Analysis - Shoreline and Volume Change

Key statistics were calculated to quantify average shoreline and volume changes for each individual analysis reach, and any associated subreaches, within the Wallops Island study area. Please refer back to Table 2-1 and Figure 2-1 for a visual representation of the location of each analysis reach and subreach.

The computed statistics for the February 2019 to September 2024 analysis include average shoreline change, average volume change and cumulative volume change (i.e. total volume of material lost or gained along a section of shoreline). Evaluation of the computed statistics will take into account shoreline position changes at +1.5 ft NAVD88 (MHW) and +6.0 ft NAVD88 (USACE project area only) as well as volume changes computed for portions of the profile above +1.5 ft NAVD88 (MHW), above -5 ft NAVD88, above -10 ft NAVD88, above -15 ft NAVD88 and above -20 ft NAVD88 in order to better understand onshore and offshore processes. Since transects are not always evenly spaced and reaches differ in length, a weighted average for unit shoreline change (ft) and unit volume change (cy/ft) was calculated for each analysis reach and subreach based on the length of beach that each transect covers.

In addition, the volume difference between the September 2024 survey and the design and construction templates was calculated for the Wallops Island - USACE Project analysis reach and subreaches to assess performance of the project to date, determine which areas may be in critical need of renourishment, and estimate the nourishment volume required to re-fill the templates.

The following sections discuss, in detail, the results of the shoreline and volume change analysis for each analysis reach and their respective subreaches, showing the difference in behavior along various portions of the study area.

4.3.1 Wallops Island – South (Sta 20+00 to Sta 175+00)

The Wallops Island - South analysis reach extends from the southern end of the USACE project (Sta 175+00) south approximately 15,500 ft to Gargathy Inlet (Sta 20+00). The reach contains 14 transects with 2000 ft spacing at the south end, transitioning to 1000 ft spacing approaching the USACE project. Refer back to Figure 2-1 for a visualization of the described subreaches within the Wallops Island study area. Within the reporting period from February 2019 through September 2024, there was no beach nourishment on this portion of Wallops Island. A summary of average shoreline and volume changes between February 2019 and September 2024 for the Wallops Island - South analysis reach results are presented in Table 4-4.

Table 4-4. Average Shoreline and Volume Change for Wallops Island - South Analysis Reach (February 2019 – September 2024)

	Reach Length	Average Shoreline Change @ MHW (+1.5 ft NAVD88)	Average Volume Change Above +1.5 ft NAVD88	Cumulative Volume Change Above +1.5 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -10 ft NAVD88	Cumulative Volume Change Above -10 ft NAVD88	Average Volume Change Above -15 ft NAVD88	Cumulative Volume Change Above -15 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88
Reach (Stations)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	-47.5	-0.5	-7,911	-12.2	-191,454	-16.6	-262,053	-22.5	-354,171	-41.8	-658,565

Along the Wallops Island shoreline south of the USACE project, there was an overall average landward recession of the shoreline at MHW (+1.5 ft NAVD88) of -47.5 ft. Profile plots in Appendix C show significant erosion of the beach face from the berm around +6.0 ft NAVD88 down to approximately -5.0 ft NAVD88, encompassing the erosion at MHW. Figure 4-6 presents the shoreline change for each transect located within the Wallops Island – South analysis reach. As can be seen, the entire analysis reach experienced shoreline erosion at MHW, with the largest erosion occurring in the southern portion of the reach adjacent to Gargathy Inlet. The remainder of the reach experienced a smaller and fairly consistent magnitude of shoreline erosion.

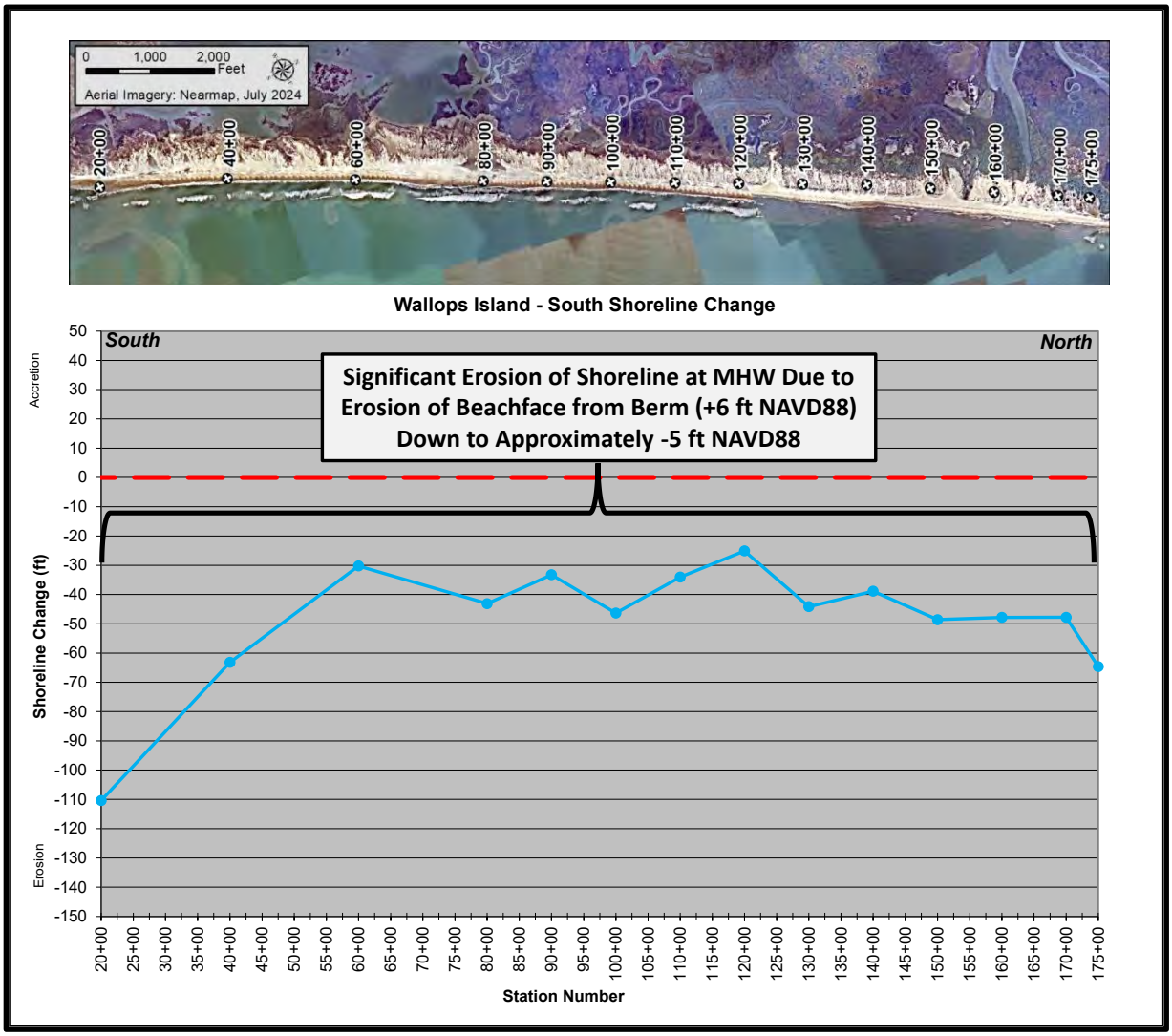


Figure 4-6. Wallops Island - South Shoreline Change at MHW (February 2019 – September 2024)

Volumetrically, the Wallops Island – South analysis reach experienced volume losses above all of the elevations analyzed (see Table 4-4). It should be noted that losses above MHW were much smaller than losses above the remaining elevations despite the significant shoreline erosion at MHW in this reach. As mentioned previously, profile plots in Appendix C show significant erosion of the beach face from the berm around +6.0 ft NAVD88 down to approximately -5.0 ft NAVD88, encompassing the shoreline at MHW. However, they also show growth of the dune above the berm elevation which offsets some of the volume losses between the berm and MHW. Volume losses above -5 ft NAVD88, -10 ft NAVD88, -15 ft NAVD88, and -20 ft NAVD88 grew above each elevation moving offshore, indicating that the sand has been removed from the system within the monitoring reach. In addition to erosion of the beachface from +6 ft NAVD88 down to approximately -5 ft NAVD88, the offshore profile beyond -15 ft NAVD88 appears to have deepened slightly. Figure 4-7 presents the volume change for each transect located within the Wallops Island – South analysis reach. As can be seen, offshore volume losses were largest to the south, adjacent to Gargathy Inlet, which is expected due to the dynamic nature of sediment transport around inlets. It appears that beach stability increases slightly moving north, away from the inlet. It should be noted that background erosion rates in this area are approximately -5.64 cy/ft/yr (see Table 4-3) and volume losses above -15 ft NAVD88 totaled -22.5 cy/ft (-354,171 cy) throughout the monitoring period. Given the 5.5 year timeframe between surveys, the average annual erosion rate throughout the monitoring period was slightly smaller than the background erosion rate.

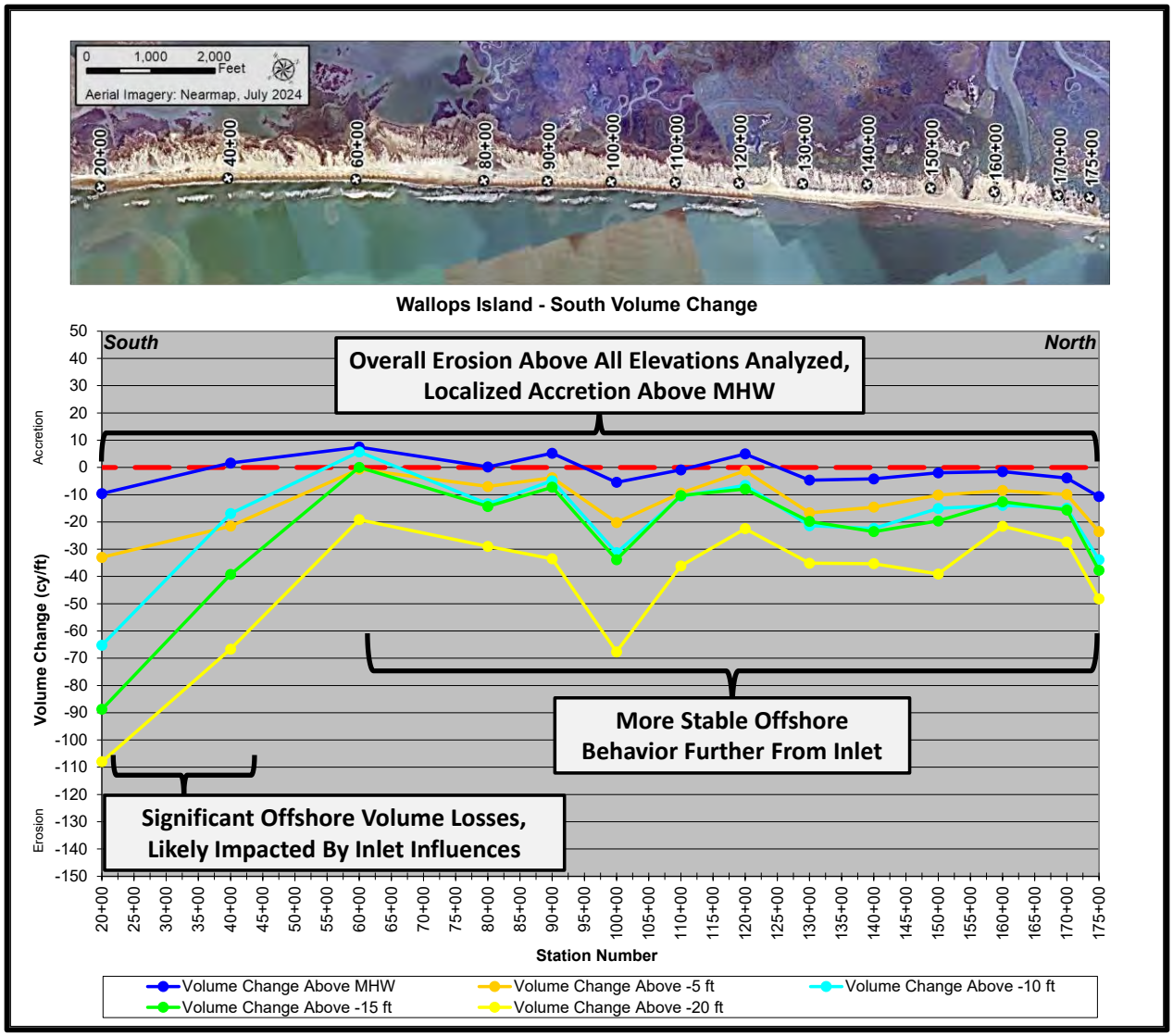


Figure 4-7. Wallops Island - South Volume Change (February 2019 – September 2024)

4.3.2 Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)

The Wallops Island – USACE Project analysis reach extends from Sta 180+00, located at the southern end of Bypass Rd, approximately 19,000 ft north to Sta 370+00. The reach is divided into four subreaches: Subreach 1 – Sta 180+00 to Sta 205+00, Subreach 2 – Sta 210+00 to Sta 290+00, Subreach 3 – Sta 295+00 to Sta 320+00, and Subreach 4 – Sta 325+00 to Sta 370+00. The Wallops Island – USACE Project reach encompasses 39 transects at 500 ft spacing. Refer back to Figure 2-1 for a visualization of the described subreaches within the Wallops Island - USACE Project analysis reach. The subreach extents differ slightly from the previous monitoring efforts completed from 2015 to 2019 and the revised delineations were based on the location of the 2020 renourishment as well as changes in profile morphology patterns since the nourishment project took place. Some areas of the beach have experienced significant erosion or accretion of the profile since project construction while other areas have been more stable, experiencing only minor changes.

As mentioned previously, within the assessed reporting period from February 2019 to September 2024, the USACE constructed a beach renourishment project consisting of placing approximately 1.3 Mcy of sand along approximately 14,000 of shoreline from Sta 180+00 to Sta 320+00 along with construction of five offshore breakwaters, three of which are located around Sta 215+00 and two of which are located around Sta 285+00.

A summary of average shoreline and volume changes between February 2019 and September 2024 for the Wallops Island – USACE Project analysis reach and its respective subreaches are presented in Table 4-5. As a reminder, in this portion of the study area, the change in position of the design berm elevation contour (+6.0 ft NAVD88) was also calculated to track this key feature of the project.

Table 4-5. Average Shoreline and Volume Change for Wallops Island - USACE Project Analysis Reach (February 2019 – September 2024)

	Reach Length	Average Shoreline Change @ +6.0 ft NAVD88	Average Shoreline Change @ MHW (+1.5 ft NAVD88)	Average Volume Change Above +1.5 ft NAVD88	Cumulative Volume Change Above +1.5 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -10 ft NAVD88	Cumulative Volume Change Above -10 ft NAVD88	Average Volume Change Above -15 ft NAVD88	Cumulative Volume Change Above -15 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88
Reach (Stations)	ft	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	-41.01	-43.5	-20.0	-59,877	-27.7	-83,026	-30.9	-92,661	-35.5	-106,628	-60.2	-180,610
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	7.81	28.6	3.2	27,135	16.3	138,865	27.9	237,046	35.6	302,803	28.6	243,201
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	-1.98	11.2	-0.7	-2,063	9.4	28,344	19.6	58,926	19.0	57,066	11.8	35,292
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	33.52	117.8	17.2	86,119	53.5	267,677	86.6	433,126	111.6	557,760	103.4	517,176
TOTAL - Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)	*19,500*	*5.4*	*37.7*	*2.6*	*51,315*	*18.0*	*351,859*	*32.6*	*636,436*	*41.6*	*811,001*	*31.5*	*615,059*

Along the Wallops Island – USACE Project analysis reach, the shoreline at the design berm elevation (+6.0 ft NAVD88) has experienced an overall average seaward advancement of +37.7 ft between February 2019 and September 2024, most of which occurred Subreach 4, a historically accretional area of the USACE project that did not receive any placement during the 2020 renourishment project. Despite placement during the 2020 renourishment project, Subreach 1, which has a historically high erosion rates (see Table 4-3), experienced significant landward recession at the berm elevation as compared to 2019, indicating that material placed in this reach during the 2020 project has likely already eroded. Conversely, Subreach 2, which also has historically high erosion rates (see Table 4-3), actually experienced a moderate seaward advancement at the berm elevation since 2019, indicating that some of the material placed during the 2020 project is still in place, most likely the result of the two sets of breakwaters constructed in this area in conjunction with the 2020 renourishment. Subreach 3 also experienced seaward advancement at the berm elevation as compared to 2019. This area of the USACE project has much lower historical erosion rates (see Table 4-3) and encompasses the portion of shoreline along the Wallops Island USACE project where erosional trends to the south transition to accretional trends to the north.

Along the Wallops Island – USACE Project analysis reach, the shoreline at MHW (+1.5 ft NAVD88) has experienced an overall minor seaward advancement of +2.6 ft between February 2019 and September 2024, with the largest advancement occurring in Subreach 4, a historically accretional area of the USACE project that did not receive any placement during the 2020 renourishment

project. Despite placement during the 2020 renourishment project, Subreach 1, which has a historically high erosion rates (see Table 4-3), experienced significant landward recession at MHW as compared to 2019, indicating that material placed in this reach during the 2020 project has likely already eroded. Subreach 2, which also has historically high erosion rates (see Table 4-3), actually experienced a minor seaward advancement at MHW since 2019, indicating that some of the material placed during the 2020 project is still in place, most likely the result of the two sets of breakwaters constructed in this area in conjunction with the 2020 renourishment. Subreach 3 experienced an almost negligible landward recession at MHW as compared to 2019. This area of the USACE project has much lower historical erosion rates (see Table 4-3) and encompasses a transitional point in the shoreline where erosional trends to the south transition to accretional trends to the north, often leading to lower average changes throughout the subreach.

Figure 4-8 presents the shoreline change at MHW (+1.5 ft NAVD88) and the design berm elevation (+6.0 ft NAVD88) for the Wallops Island – USACE Project analysis reach. As can be seen, Subreach 1 experienced landward recession at both MHW (+1.5 ft NAVD88) and the design berm elevation (+6.0 ft NAVD88) at almost every transect. There is a clear beneficial impact on the shoreline at MHW (+1.5 ft NAVD88) and the design berm elevation (+6.0 ft NAVD88) in Subreach 2 where the breakwaters are located, holding more of the nourishment material than the stretch of shoreline in between the breakwater fields. Transitional trends in Subreach 3 and accretional trends in Subreach 4 are also very apparent.

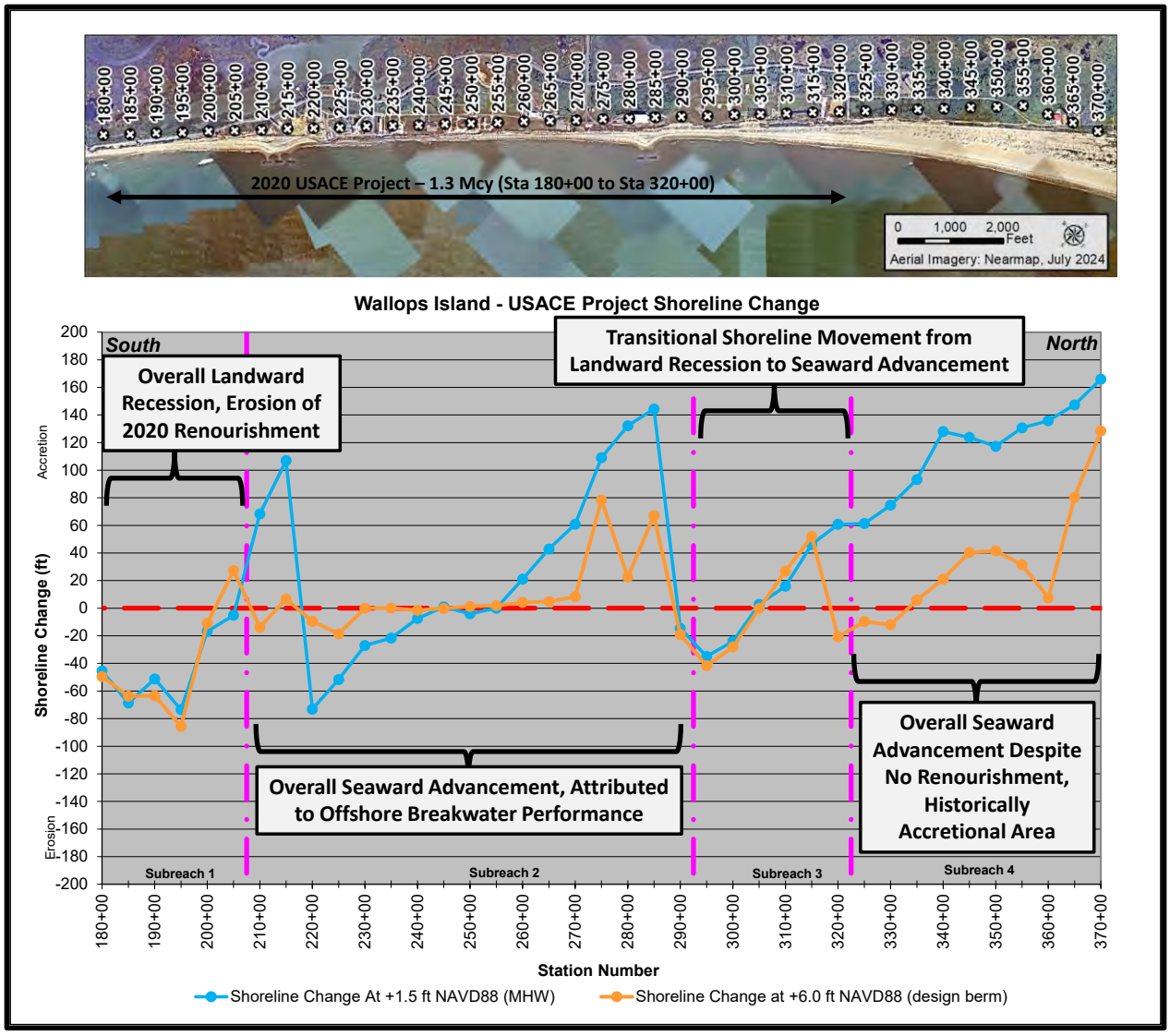


Figure 4-8. Wallops Island - USACE Project Shoreline Change at MHW and +6.0 ft NAVD88 (February 2019 – September 2024)

Volumetrically, Table 4-5 indicates an overall volume gain in the USACE project area above all elevations since 2019, indicating that a significant amount of the material placed during the 2020 renourishment project is still within the overall USACE project extents. However, a majority of the remaining material appears to have been transported north to Subreach 4 which had the largest volume gains but did not receive any placement in 2020. Despite placement during the 2020 renourishment project, Subreach 1, which has a historically high erosion rates (see Table 4-3), experienced significant volume erosion as compared to 2019, indicating that material placed in this reach during the 2020 project has likely already eroded. Conversely, Subreach 2, which also has historically high erosion rates (see Table 4-3), actually experienced a gain in volume since 2019, indicating that some of the material placed during the 2020 project is still in place, most likely the result of the two sets of breakwaters constructed in this area in conjunction with the 2020 renourishment. Subreach 3 also experienced volume gains as compared to 2019, indicating some of the nourishment material is still present. This area of the USACE project has much lower

historical erosion rates (see Table 4-3) and encompasses the portion of shoreline along the Wallops Island USACE project where erosional trends to the south transition to accretional trends to the north.

Figure 4-9 displays the volume change at each transect above the five elevations that were analyzed. As can be seen, Subreach 1 experienced volume losses at almost every transect. There is a clear beneficial impact on the beach in Subreach 2 localized where the breakwaters were constructed, holding more of the nourishment material than the stretch of shoreline in between the breakwater fields. Transitional trends in Subreach 3 and accretional trends in Subreach 4 are also very apparent.

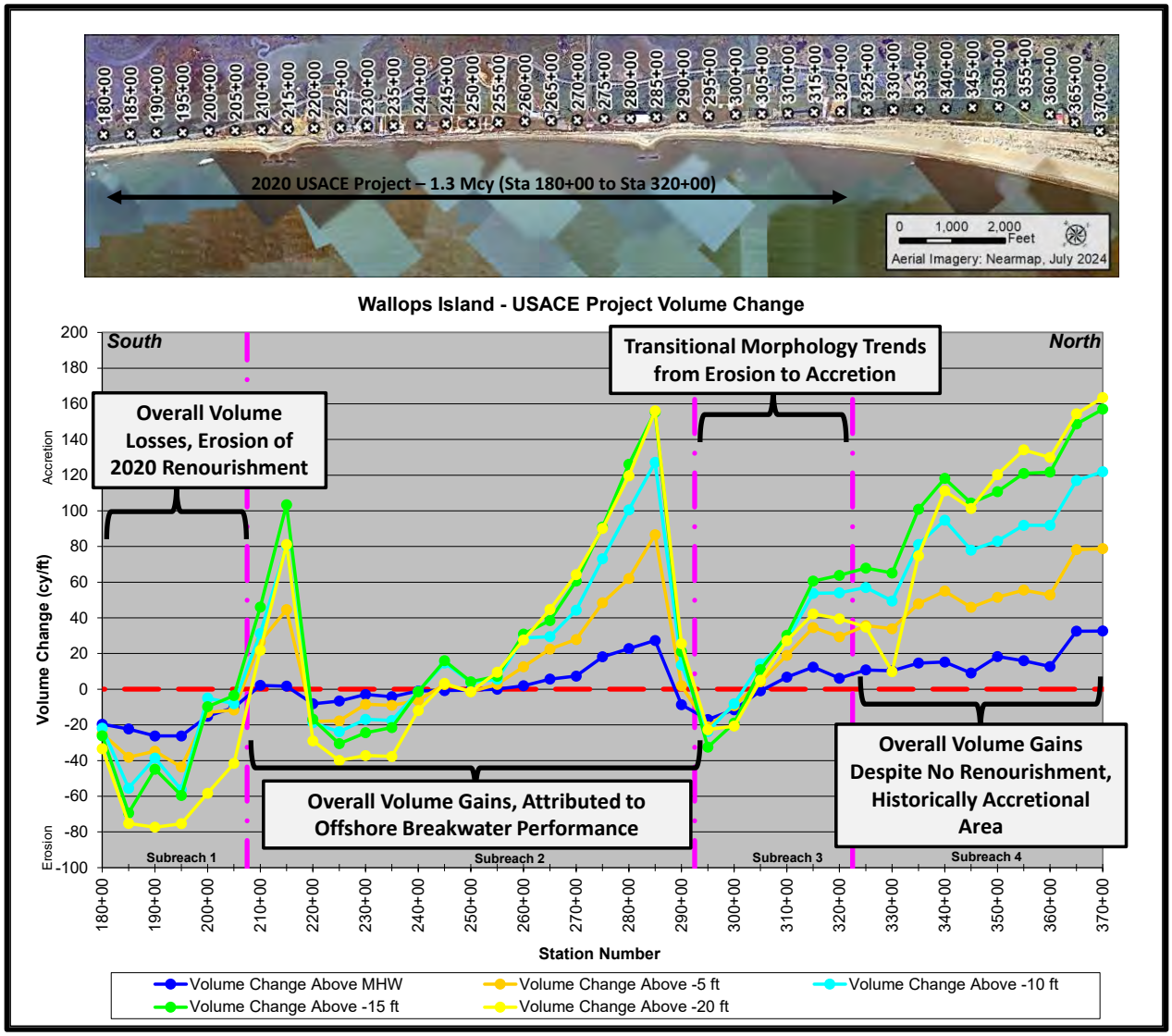


Figure 4-9. Wallops Island - USACE Project Volume Change (February 2019 – September 2024)

In order to take a closer look at the performance of the USACE project and begin developing plans for future nourishment placement and quantities, the September 2024 profiles were also compared to the USACE design and construction templates. The difference in shoreline position

at MHW (+1.5 ft NAVD88) and the design berm elevation (+6.0 ft NAVD88) as well as volume difference above MHW (+1.5 ft NAVD88), -5 ft NAVD88, -10 ft NAVD88, and -12 ft NAVD88 were calculated. Volume difference above -12 ft NAVD88 was added to the analysis because this is the approximate elevation of the toe of the fill, allowing for the most accurate estimates of volume surpluses and deficits as compared to the templates. Differences above -15 ft NAVD88 and -20 ft NAVD88 were excluded from these calculations due to the fact that these elevations are beyond the limits of sand placement.

Table 4-6 shows the average shoreline position and volume differences of the September 2024 survey as compared with the USACE design template. The design template is considered the minimum profile/volume that is allowed in order to still provide adequate protection to infrastructure. Therefore, any areas with a volume of material less than the design template need to be considered for renourishment. Overall, the total project contains more material than the design template, with a volume difference of approximately 2.17 million cy above -12 ft NAVD88 (typical toe of fill placement elevation), a majority of which is located in Subreach 4. Subreach 1 and Subreach 2 actually show a deficit of material as compared to the design template above all elevations analyzed, indicating that these areas are in imminent need of nourishment. On the contrary, Subreaches 3 and 4 show a surplus of material above all elevations analyzed as compared to the design template indicating these areas do not require immediate nourishment.

Table 4-6. Design Template Comparison

	Reach Length	Average Shoreline Difference @ +6.0 ft NAVD88	Average Shoreline Difference @ MHW (+1.5 ft NAVD88)	Average Volume Difference Above +1.5 ft NAVD88	Cumulative Volume Difference Above +1.5 ft NAVD88	Average Volume Difference Above -5 ft NAVD88	Cumulative Volume Difference Above -5 ft NAVD88	Average Volume Difference Above -10 ft NAVD88	Cumulative Volume Difference Above -10 ft NAVD88	Average Volume Difference Above -12 ft NAVD88	Cumulative Volume Difference Above -12 ft NAVD88
Reach (Profiles)	ft	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 210+00)	3,000	-63.4	-79.5	-25.6	-76,783	-46.4	-139,264	-32.3	-97,003	-19.9	-59,555
Wallops Island - USACE Project Subreach 2 (Sta 215+00 to Sta 295+00)	8,500	-62.9	-95.5	-23.8	-202,171	-45.8	-389,360	-33.2	-281,835	-22.0	-186,953
Wallops Island - USACE Project Subreach 3 (Sta 300+00 to Sta 320+00)	3,000	53.5	56.3	16.1	48,349	32.7	97,960	76.4	229,326	100.1	300,194
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	437.4	537.6	90.9	454,559	223.4	1,117,167	361.3	1,806,586	424.3	2,121,299
TOTAL - Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)	***19,500***	***83.2***	***92.6***	***11.5***	***223,954***	***35.2***	***686,502***	***85.0***	***1,657,075***	***111.5***	***2,174,985***

Figure 4-10 shows the volume difference between the design template and the September 2024 survey at each transect above all the elevations analyzed. Apparent from this figure are the large portion of Subreach 2, small portion of Subreach 1, and small portion of Subreach 3 which have receded landward beyond the design template. The net deficit of material above -12 ft NAVD88 as compared to the design template in Subreach 1 is approximately -59,555 cy, and -186,953 cy in Subreach 2, totaling -246,508 cy (see Table 4-6). However, due to profile behavior where some of the material eroded from above -5 ft NAVD88 has been captured at lower elevations of the design template down near the toe of fill, the largest net volume deficit to the design template actually occurs above -5 ft NAVD88 (see Figure 4-4) totaling -139,264 cy in Subreach 1 and -389,360 cy in Subreach 2 for a total of -528,624 cy. Furthermore, as can be seen in Figure 4-10, there are some transects in Subreach 1, Subreach 2, and Subreach 3 that contain a surplus of material and some that contain a deficit. Therefore, if only the transects containing a deficit of material in Subreach 1, Subreach 2, and Subreach 3 are considered, there is a total deficit of approximately -450,716 cy of material between the September 2024 survey

and the design template above -12 ft NAVD88. As mentioned previously, due to the behavior of the profile, there is a slightly larger total deficit of material above -5 ft NAVD88 of -591,301 cy in these subreaches.

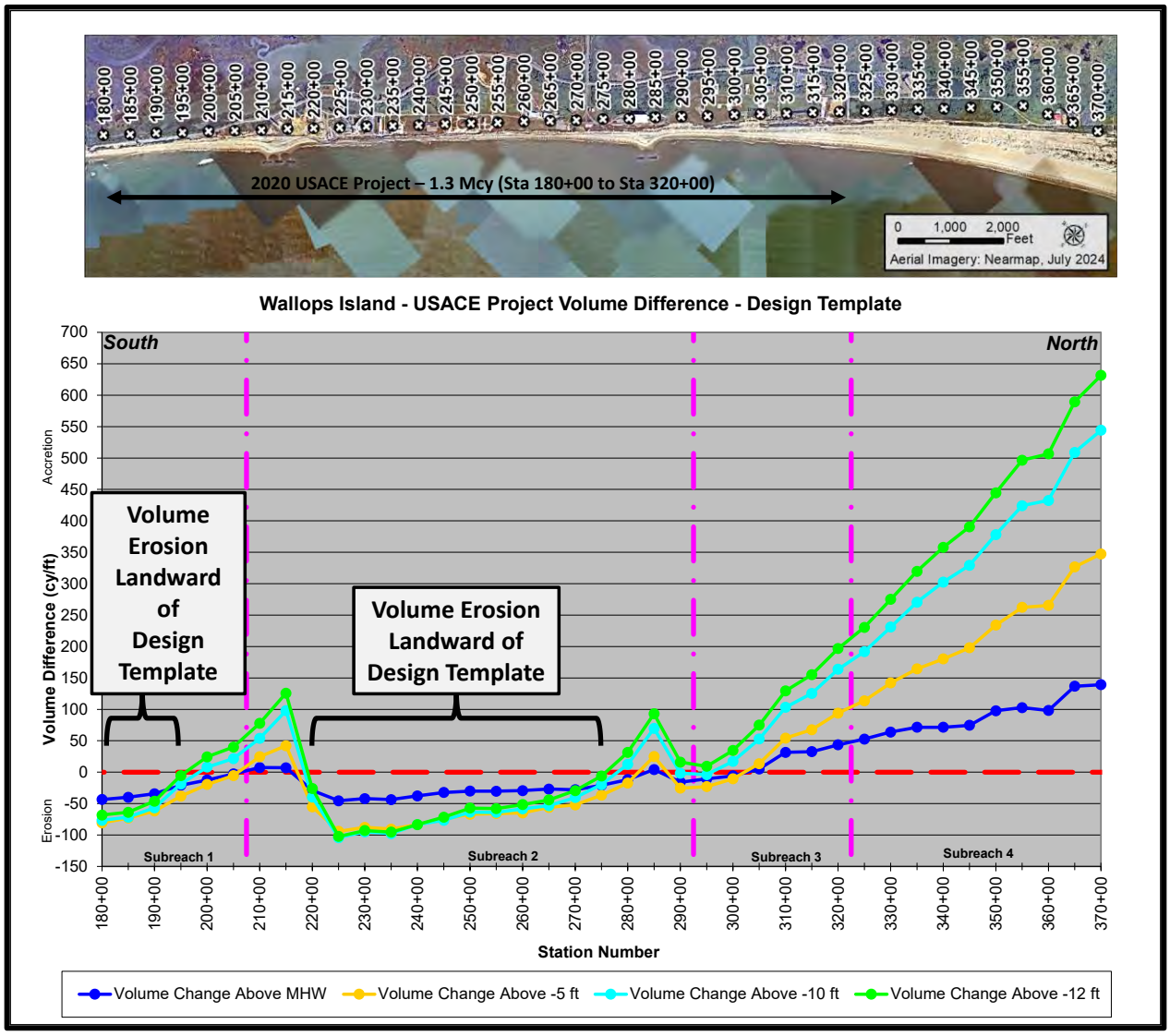


Figure 4-10. Volume Difference Between September 2024 and Design Template

A majority of the area which received material during the 2020 renourishment project (Subreaches 1, 2, and 3) has receded landward of the design template, which is supposed to establish a minimum amount of protection, significantly increasing vulnerability to the next storm event. However, the breakwaters appear to be performing well and are holding sand in the immediate area of construction, protecting the valuable infrastructure on land by keeping the minimum design template intact.

Table 4-7 shows the average shoreline position and volume differences of the September 2024 survey as compared with the USACE construction template. Overall, the total project contains more material than the construction template, with a volume difference of approximately

878,691 cy above -12 ft NAVD88 (typical toe of fill placement elevation), a majority of which is located in Subreach 4. Subreach 1 and Subreach 2 actually show a deficit of material as compared to the construction template above all elevations analyzed, indicating that these areas are in imminent need of nourishment. Meanwhile, there is a moderate deficit of material above -5 ft NAVD88 in Subreach 3 and a large surplus of material in Subreach 4 of approximately 1.8 Mcy. Again, it is likely that nourishment material being eroded from Subreach 1 and 2 is being transported north toward Subreach 4.

Table 4-7. Construction Template Comparison

	Reach Length	Average Shoreline Difference @ +6.0 ft NAVD88	Average Shoreline Difference @ MHW (+1.5 ft NAVD88)	Average Volume Difference Above +1.5 ft NAVD88	Cumulative Volume Difference Above +1.5 ft NAVD88	Average Volume Difference Above -5 ft NAVD88	Cumulative Volume Difference Above -5 ft NAVD88	Average Volume Difference Above -10 ft NAVD88	Cumulative Volume Difference Above -10 ft NAVD88	Average Volume Difference Above -12 ft NAVD88	Cumulative Volume Difference Above -12 ft NAVD88
Reach (Profiles)	ft	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 210+00)	3,000	-163.4	-179.5	-42.3	-126,783	-87.2	-261,486	-91.6	-274,781	-86.5	-259,556
Wallops Island - USACE Project Subreach 2 (Sta 215+00 to Sta 295+00)	8,500	-162.9	-195.5	-40.5	-343,837	-87.6	-744,917	-92.4	-785,538	-88.2	-749,914
Wallops Island - USACE Project Subreach 3 (Sta 300+00 to Sta 320+00)	3,000	-46.5	-43.8	-0.6	-1,652	-8.1	-24,263	17.2	51,549	33.4	100,194
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	337.4	437.6	74.2	371,225	182.7	913,463	302.1	1,510,290	357.6	1,787,967
TOTAL - Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)	***19,500***	***-16.8***	***-7.4***	***-5.2***	***-101,046***	***-6.0***	***-117,203***	***25.7***	***501,521***	***45.1***	***878,691***

Figure 4-11 shows the volume difference between the construction template and the September 2024 survey at each transect above all the elevations analyzed. Apparent from this figure are the large portions of Subreach 1 and Subreach 2, and small portion of Subreach 3 which have receded landward beyond the construction template. The net deficit of material above -12 ft NAVD88 as compared to the construction template in Subreach 1 is approximately -259,556 cy and -749,914 cy in Subreach 2, totaling -1,009,470 cy (see Table 4-7). However, due to the previously mentioned profile behavior where some of the eroded material has been captured at lower elevations of the construction template down near the toe of fill (see Figure 4-4), the largest net volume deficit to the construction template actually occurs above -10 ft NAVD88 totaling -274,781 cy in Subreach 1 and -785,538 cy in Subreach 2 for a total of -1,060,318 cy. Furthermore, as can be seen in Figure 4-11, there are some transects in Subreach 1, Subreach 2, and Subreach 3 that contain a surplus of material and some that contain a deficit. Therefore, if only the transects containing a deficit of material in Subreach 1, Subreach 2, and Subreach 3 are considered, there is a total deficit of approximately -1,102,346 cy of material between the September 2024 survey and the construction template above -12 ft NAVD88. As mentioned previously, due to the behavior of the profile, there is a slightly larger total deficit of material above -10 ft NAVD88 of -1,140,764 cy in these subreaches. This equates to approximately 88% of the 1.3 Mcy volume placement.

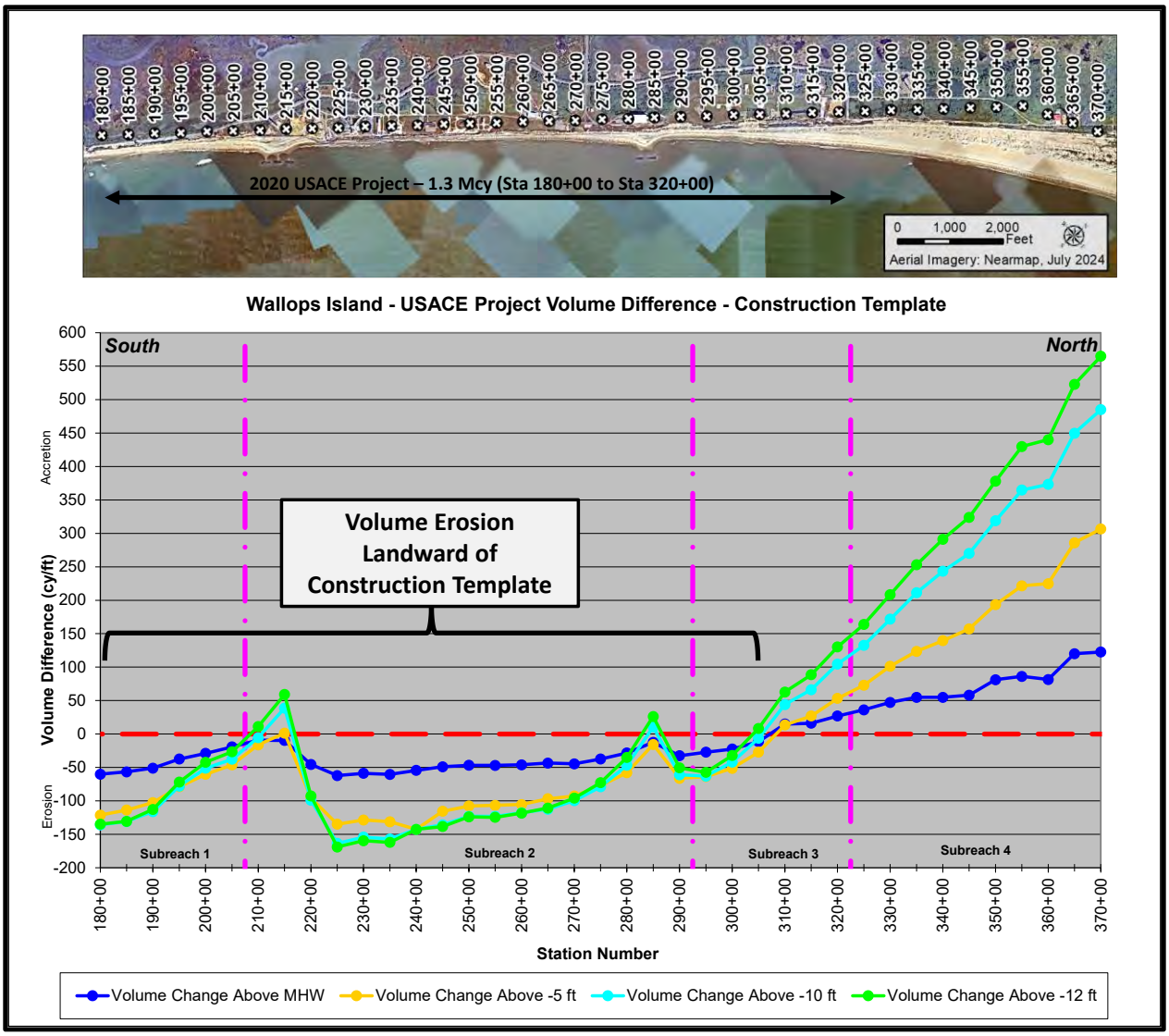


Figure 4-11. Volume Difference Between September 2024 and Construction Template

It is evident that considerable erosion has occurred since the 2020 renourishment project a majority of the area which received material during the 2020 renourishment project (Subreaches 1, 2, and 3) has shown considerable erosion, significantly increasing vulnerability to the next storm event. While the breakwaters appear to be performing well and are holding sand in the immediate area of construction, protecting the valuable infrastructure on land, the beneficial impacts are highly localized, allowing for the continued high loss rates of material along a majority of Subreaches 1 and 2.

4.3.3 Wallops Island – North (Sta 375+00 to Sta 475+00)

The Wallops Island – North analysis reach extends from the northern end of the USACE project at Sta 375+00 approximately 10,000 ft north towards Chincoteague Inlet, containing 14 transects at approximately 1000 ft spacing. It has been divided into three subreaches: Subreach 1 – Sta 375+00 to Sta 385+00, Subreach 2 – Sta 395+00 to Sta 445+00, and Subreach 3 – Sta 455+00 to Sta 475+00. The subreach extents differ slightly from the previous monitoring efforts completed

from 2015 to 2019 and the revised delineations were based on recent beach morphology trends and borrow area location. Refer back to Figure 2-1 for a visual representation of the analysis reach and its associated subreaches. This portion of the study area did not receive any nourishment during the reporting time period from February 2019 to September 2024 and is not included in the USACE project extents. However, approximately 1.3 Mcy of material was dredged landward of MHW in Subreach 2 (Sta 395+00 to Sta 445+00) for use in the 2020 renourishment project. Table 4-8 provides a summary of average shoreline and volume changes between February 2019 and September 2024 for the Wallops Island – North analysis reach and subreaches.

Table 4-8. Average Shoreline and Volume Change for Wallops Island - North Analysis Reach (February 2019 – September 2024)

	Reach Length	Average Shoreline Change @ MHW (+1.5 ft NAVD88)	Average Volume Change Above +1.5 ft NAVD88	Cumulative Volume Change Above +1.5 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -10 ft NAVD88	Cumulative Volume Change Above -10 ft NAVD88	Average Volume Change Above -15 ft NAVD88	Cumulative Volume Change Above -15 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88
Reach (Stations)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	181.7	37.3	65,321	83.7	146,480	126.1	220,714	166.0	290,436	188.5	329,872
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	149.4	-52.3	-313,620	-40.9	-245,543	-14.8	-88,555	24.1	144,849	107.9	647,692
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	-213.8	-23.7	-59,288	-69.8	-174,520	-117.6	-293,993	-181.3	-453,242	-211.6	-529,089
TOTAL - Wallops Island - North (Sta 375+00 to Sta 475+00 A)	*10,250*	*66.4*	*-30.0*	*-307,587*	*-26.7*	*-273,583*	*-15.8*	*-161,834*	*-1.8*	*-17,957*	*43.8*	*448,475*

The shoreline position at MHW showed an overall seaward advancement of +66.4 ft in the Wallops Island – North analysis reach located just to the north of the USACE project. Table 4-8 indicates the seaward advancement was confined to Subreach 1 and Subreach 2 while Subreach 3, which is adjacent to Chincoteague Inlet, experienced significant landward recession of the shoreline at MHW. This pattern aligns with historical erosion rates that show considerable accretion in Subreaches 1 and 2 due to longshore transport of material from the USACE project while Subreach 3 is extremely erosional due to proximity to the inlet (see Table 4-3). Figure 4-12 presents the shoreline change at each transect along the Wallops Island – North analysis reach. As can be seen, Subreaches 1 and 2 experienced seaward advancement of the shoreline at all transects since 2019 despite the excavation of material in Subreach 2 for the 2020 renourishment project.

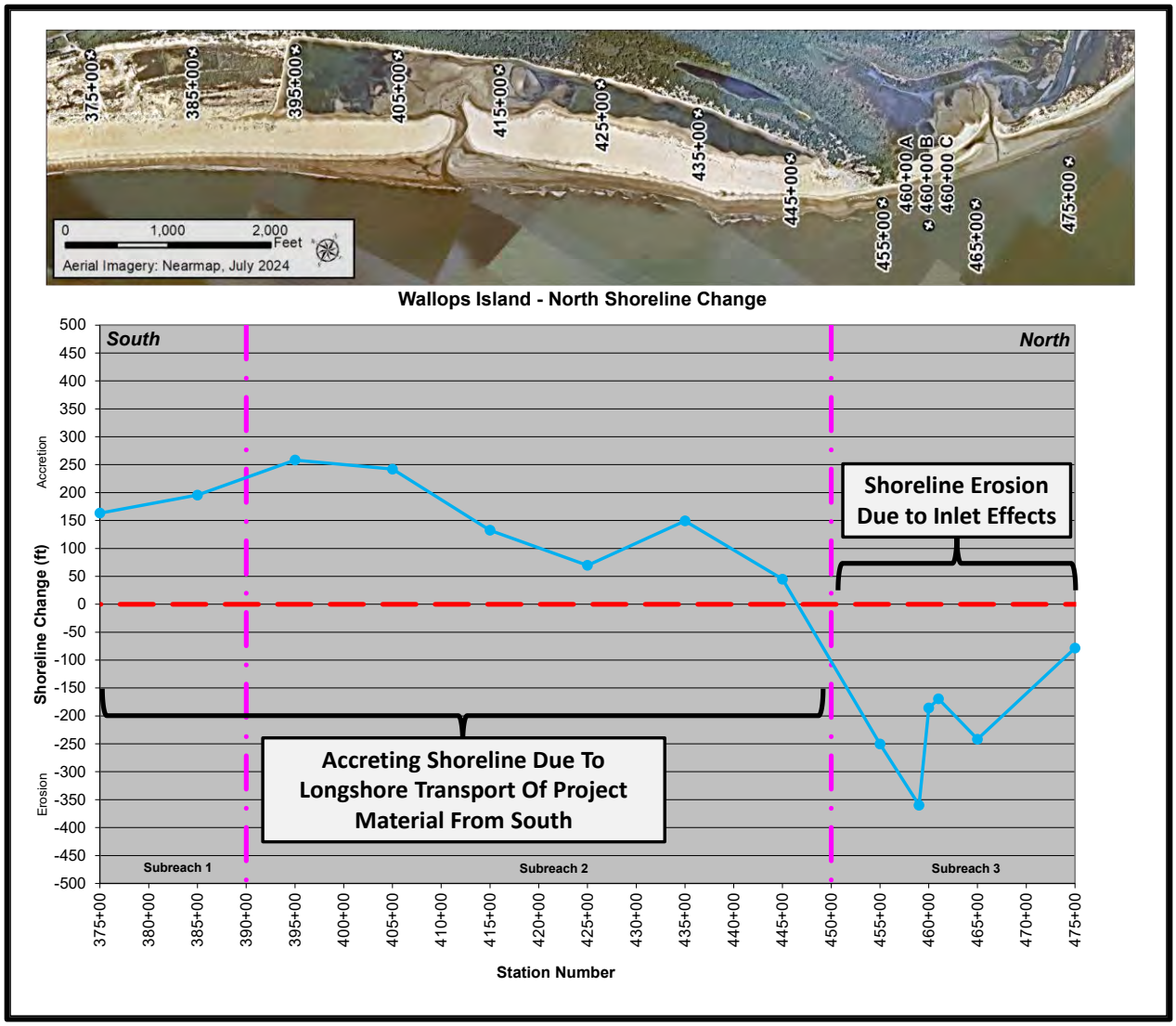


Figure 4-12. Wallops Island - North Shoreline Change at MHW (February 2019 – September 2024)

Volumetrically, Table 4-8 indicates several different morphological trends within the Wallops Island – North analysis reach. Wallops Island - North Subreach 1 experienced significant volume gains above all elevations from February 2019 to September 2024 which is typical behavior given the longshore transport from the immediately adjacent USACE project. Wallops Island – North Subreach 2 indicates volume losses above MHW, -5 ft NAVD88, and -10 ft NAVD88 but volume gains offshore above -15 ft NAVD88 and -20 ft NAVD88. This pattern is due to the excavation of material for the 2020 renourishment project being combined with typical accretional profile behavior in this area. The beach continued to show significant accretion, as is historically typical, seaward of the excavation limits due to sediment transport from the USACE project. However, the volume losses from the excavation itself outweigh the volume gains along the upper elevations of the profile, leading to net losses above MHW, -5 ft NAVD88, and -10 ft NAVD88. Moving further offshore, the volume gains begin to outweigh the losses from excavation, leading to net volume gains above -15 ft NAVD88 and -20 ft NAVD88. Wallops Island – North Subreach 3 experienced overall losses above all elevations analyzed which is typical for the shoreline

adjacent to Chincoteague Inlet. Figure 4-13 displays the unit volume change at each transect for the Wallops Island – North analysis reach. As can be seen, accretional trends continue from Subreach 4 of the USACE project into Wallops Island – North Subreach 1. Losses above MHW, -5 ft NAVD88, and -10 ft NVD88 due to the material excavation are very evident in Subreach 2 while Subreach 3 shows volume losses above all elevations.

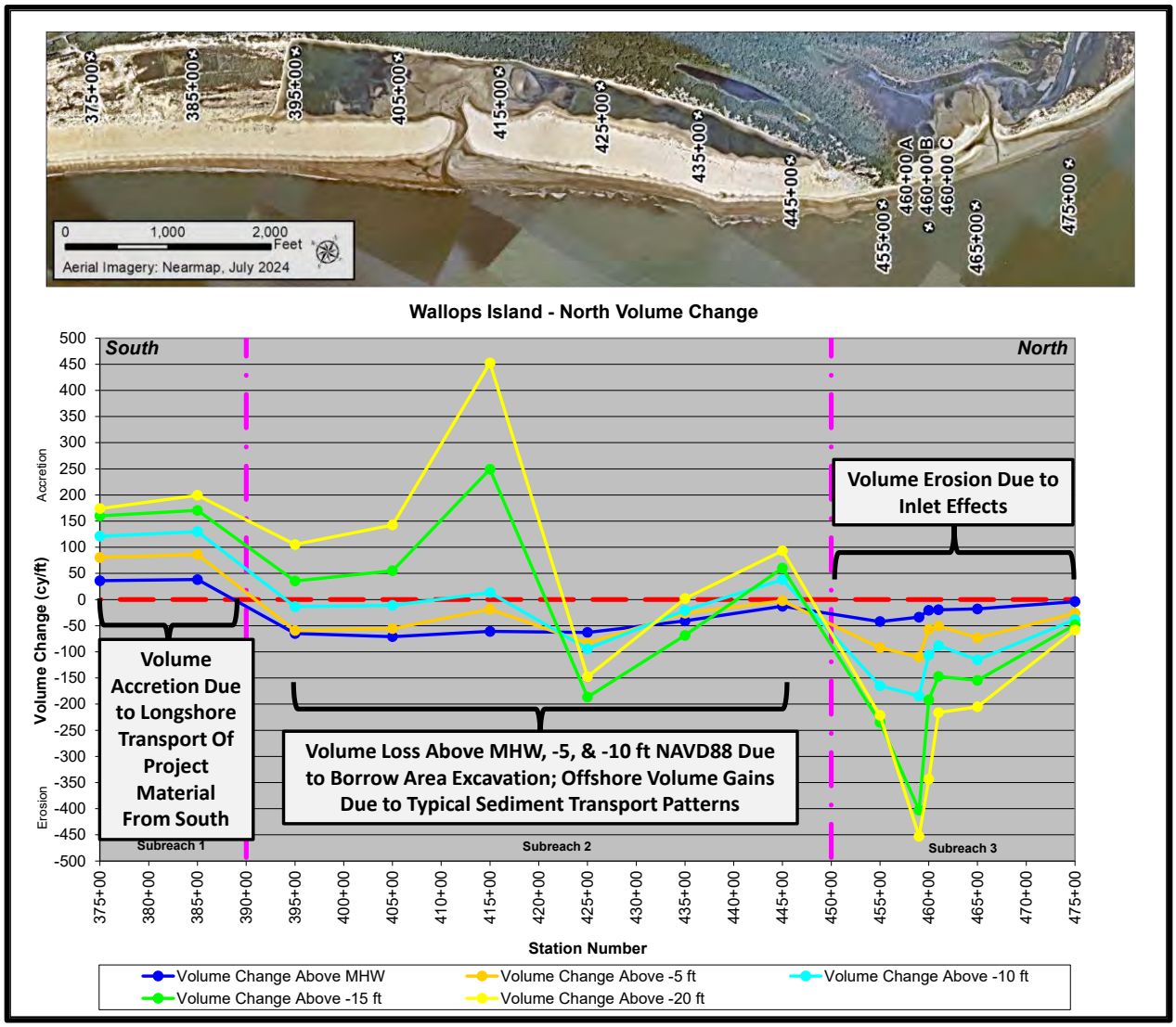


Figure 4-13. Wallops Island – North Volume Change (February 2019 – September 2024)

4.3.4 Assateague Island – Inlet, Hydro Only (Sta 600+00 to Sta 640+00)

In order to gain knowledge about the morphology of Chincoteague Inlet, a possible future source of nourishment material, the hydrographic portion of the monitoring transects adjacent to Chincoteague Inlet along Assateague Island (Sta 600+00 to Sta 640+00) were surveyed for future monitoring. Volume calculations were not performed but rather the profiles were qualitatively examined for changes in inlet channel location and possible shoaling. Results indicate a small

amount of shoaling since 2019 but an overall stable inlet channel. Figure 4-14 shows example profiles from Sta 600+00 and Sta 610+00, closest to the inlet entrance.

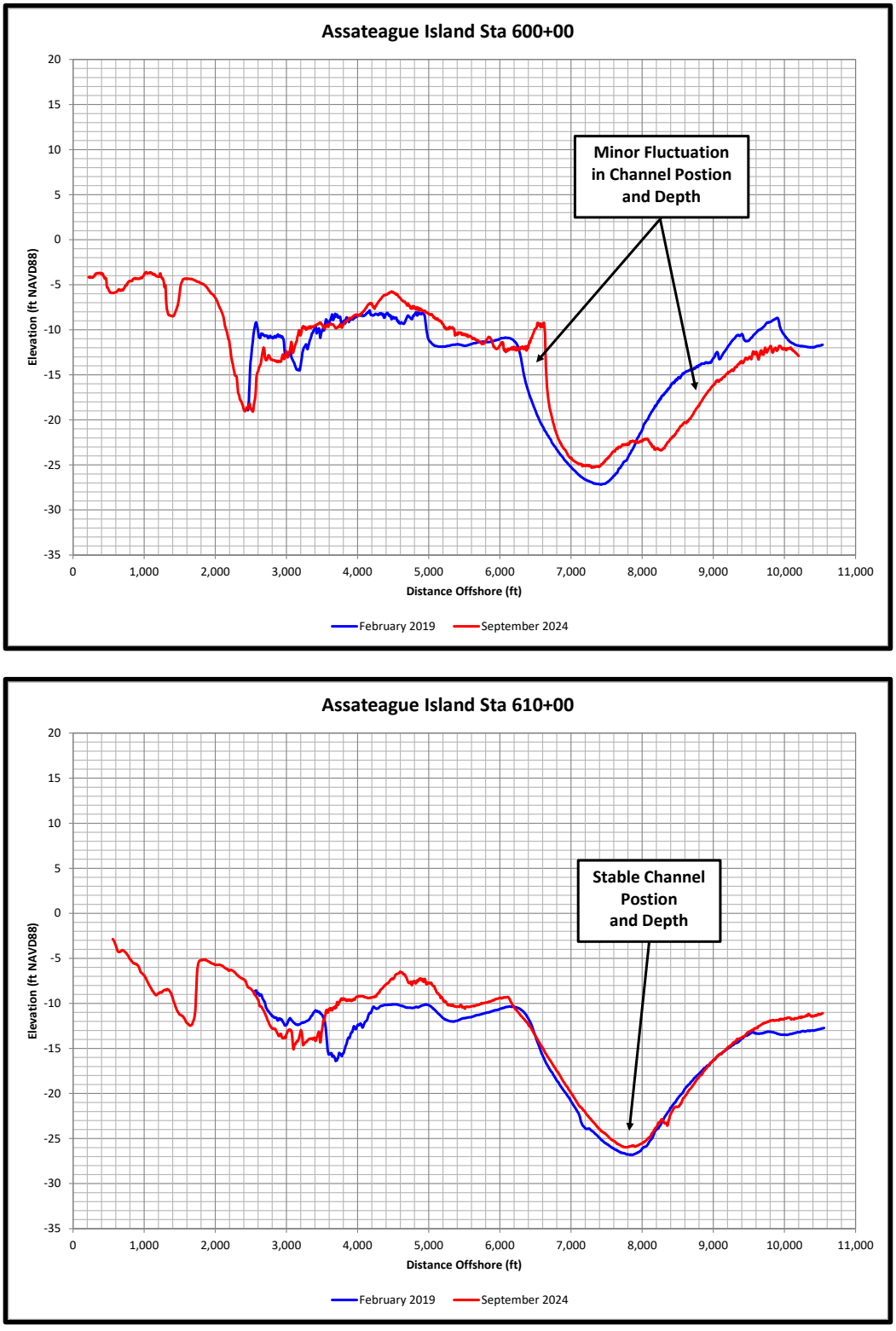


Figure 4-14. Chincoteague Inlet Example Profiles

4.4 Profile Analysis - Overall Study Area Trends

Table 4-9, Figure 4-15, and Figure 4-16 display the average analysis reach and subreach trends for the September 2024 survey extents so beach morphology patterns (erosion or accretion) and volume change magnitude can be compared from subreach to subreach, helping to identify areas of concern and other trends such as nodal zones. Apparent from these figures is the erosion along the southern portion of Wallops Island, accretion along the northern portion of Wallops Island, and erosion nearest Chincoteague Inlet. Subreaches 1 and 2 of the USACE project area continued to show significant volume losses, although the breakwaters were able to hold some of the nourishment material in the immediate vicinity. Subreach 3 continues to be a transition zone from erosion to accretion while Subreach 4 has maintained consistent accretion. In Wallops Island North, the beach has continued to accrete seaward despite the excavation of material for the borrow area.

Table 4-9. Wallops Island Shoreline and Volume Change Summary (February 2019 – September 2024)

	Reach Length	Average Shoreline Change @ MHW (+1.5 ft NAVD88)	Average Volume Change Above +1.5 ft NAVD88	Cumulative Volume Change Above +1.5 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -10 ft NAVD88	Cumulative Volume Change Above -10 ft NAVD88	Average Volume Change Above -15 ft NAVD88	Cumulative Volume Change Above -15 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88
Reach (Stations)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	-47.5	-0.5	-7,911	-12.2	-191,454	-16.6	-262,053	-22.5	-354,171	-41.8	-658,565
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	-43.5	-20.0	-59,877	-27.7	-83,026	-30.9	-92,661	-35.5	-106,628	-60.2	-180,610
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	28.6	3.2	27,135	16.3	138,865	27.9	237,046	35.6	302,803	28.6	243,201
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	11.2	-0.7	-2,063	9.4	28,344	19.6	58,926	19.0	57,066	11.8	35,292
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	117.8	17.2	86,119	53.5	267,677	86.6	433,126	111.6	557,760	103.4	517,176
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	181.7	37.3	65,321	83.7	146,480	126.1	220,714	166.0	290,436	188.5	329,872
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	149.4	-52.3	-313,620	-40.9	-245,543	-14.8	-88,555	24.1	144,849	107.9	647,692
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	-213.8	-23.7	-59,288	-69.8	-174,520	-117.6	-293,993	-181.3	-453,242	-211.6	-529,089
TOTAL - Wallops Island (Sta 20+00 to Sta 475+00 A)	*45,500*	*14.7*	*-5.8*	*-264,183*	*-2.5*	*-113,178*	*4.7*	*212,550*	*9.6*	*438,872*	*8.9*	*404,969*

Figure 4-17 and Figure 4-18 present the shoreline and volume changes per transect along the Wallops Island study area. These figures show an island wide view of erosion and accretion patterns.

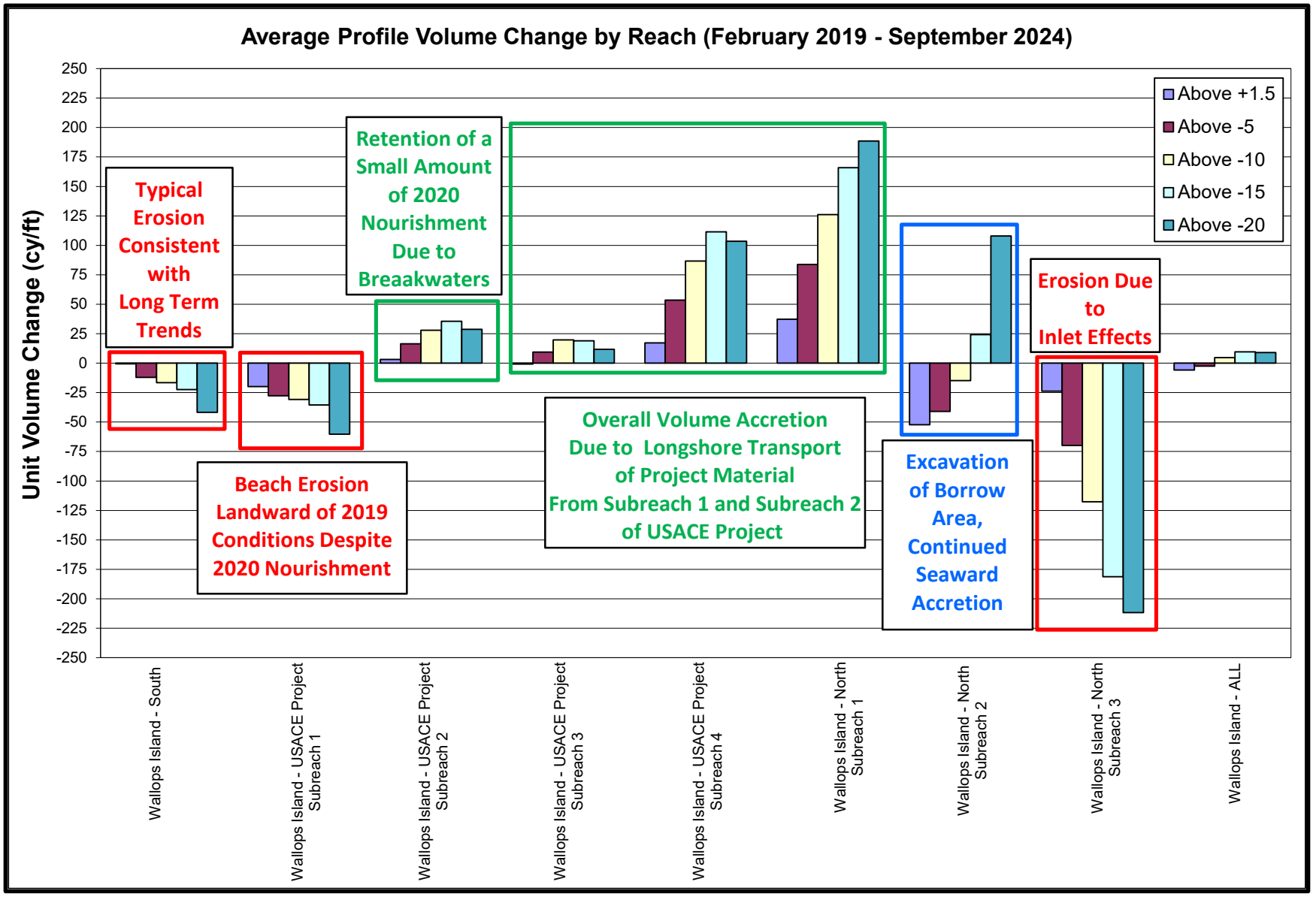


Figure 4-15. Average Unit Volume Change – Wallops Island

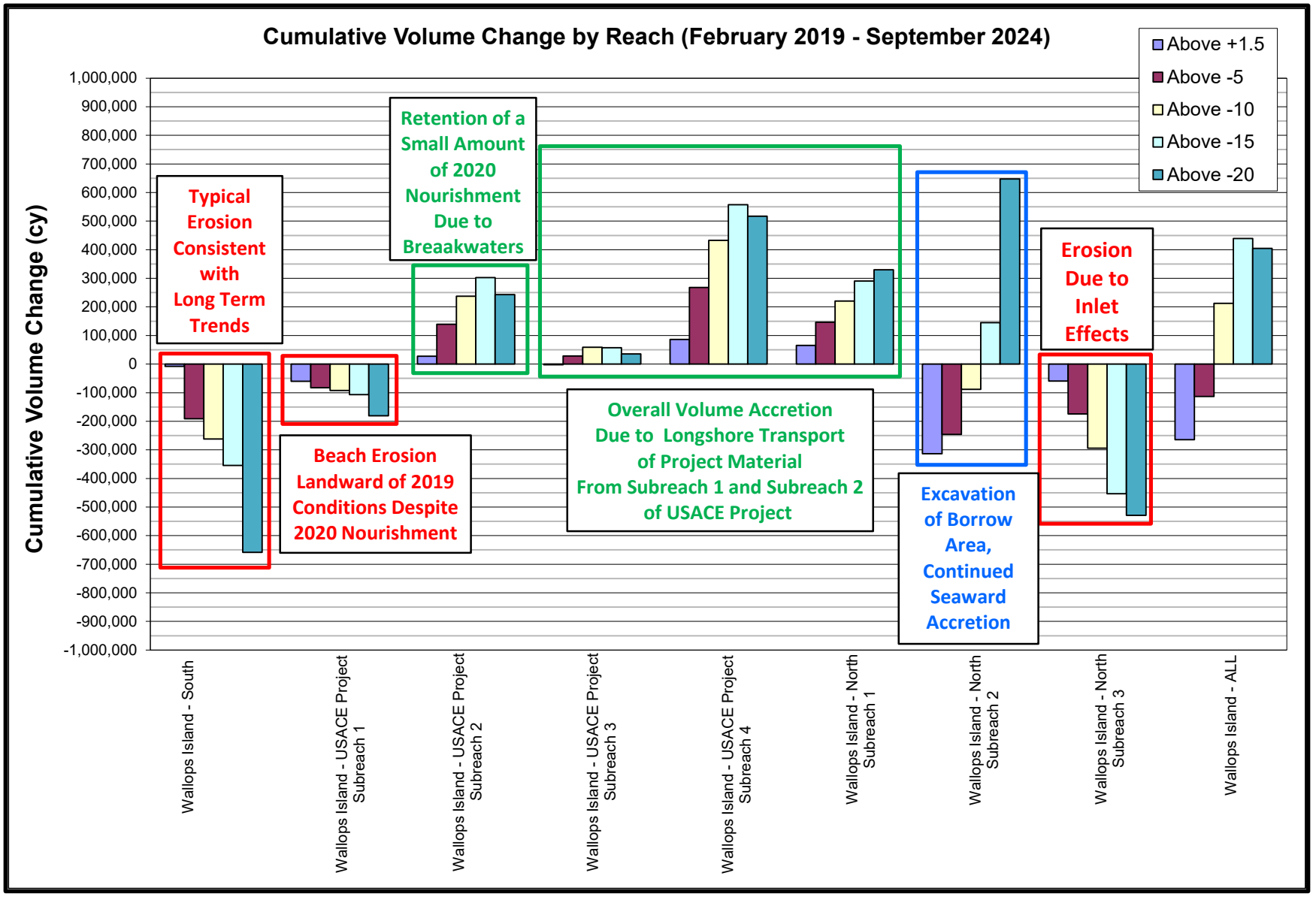


Figure 4-16. Cumulative Volume Change – Wallops Island

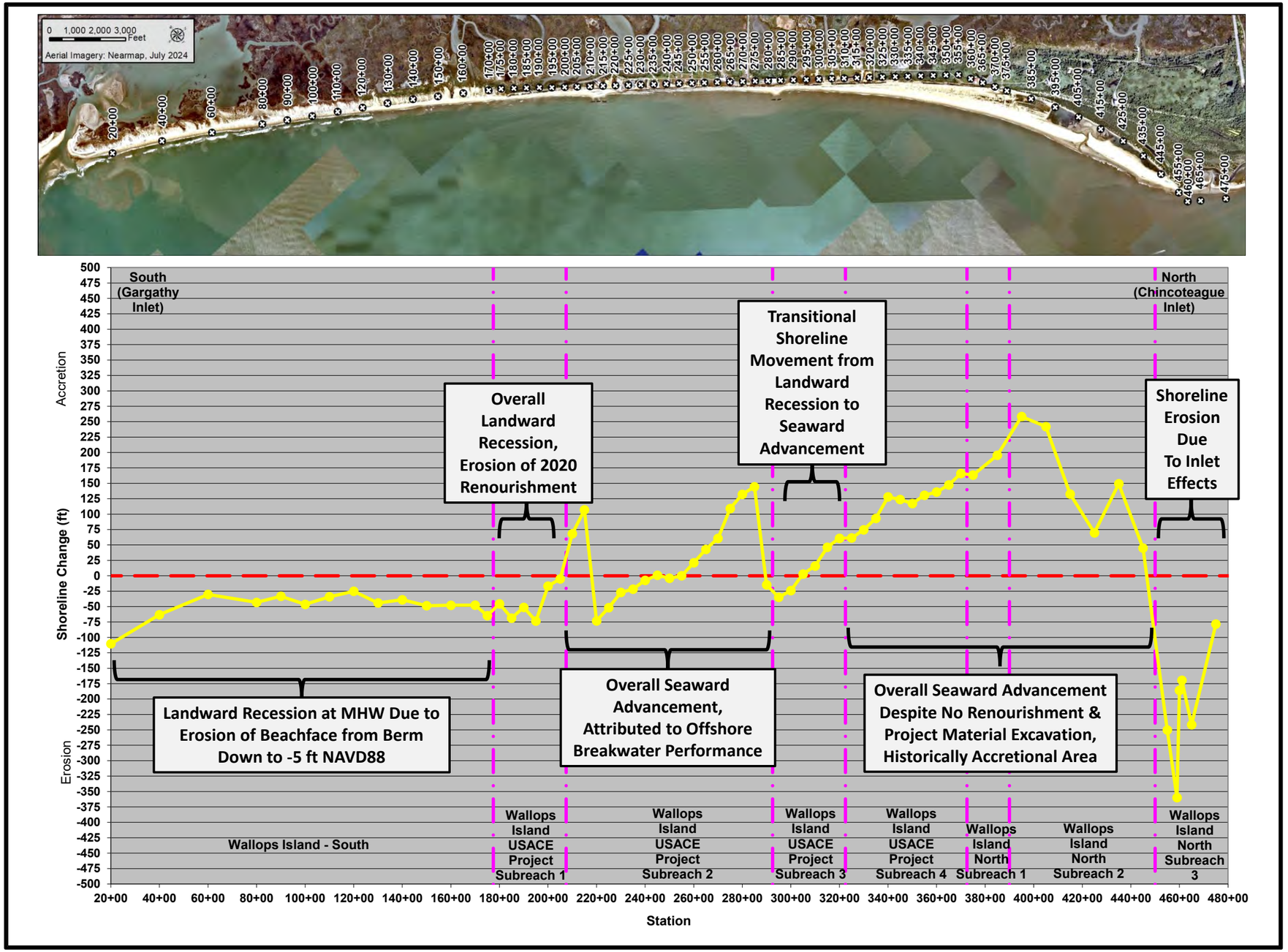


Figure 4-17. Wallops Island Shoreline Change at MHW (February 2019 – September 2024)

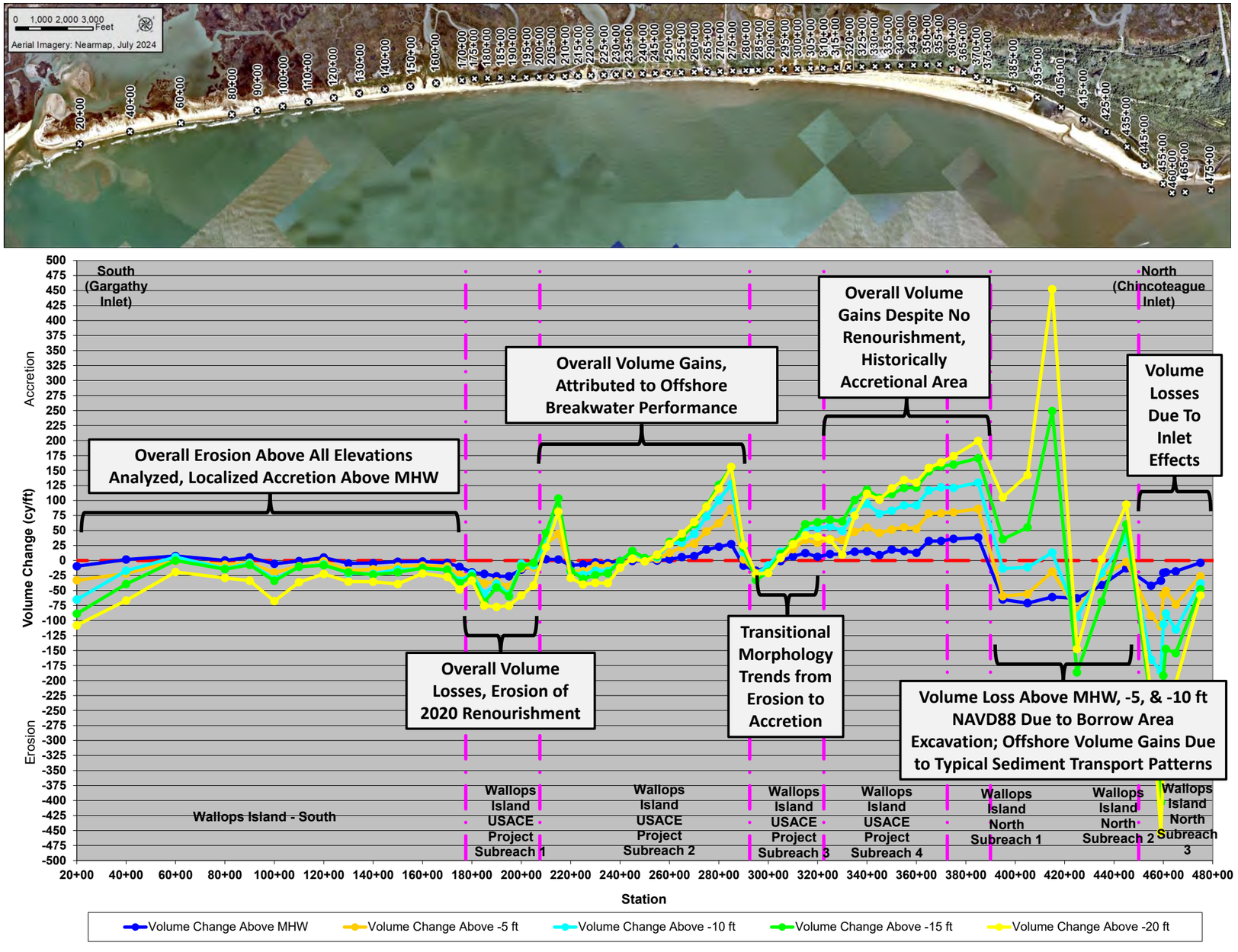


Figure 4-18. Wallops Island Volume Change (February 2019 – September 2024)

5.0 Summary

The US Army Corps of Engineers (USACE) Norfolk District constructed an engineered beach project placing 3.2 Mcy of sand along approximately 19,000 ft of shoreline on Wallops Island during Summer 2012. The project serves to protect a stretch of shoreline along which critical NASA infrastructure is located. Immediately after completion of the 2012 project, Hurricane Sandy impacted the area and significant loss to a portion of the project was experienced. Therefore, approximately 11,500 ft of shoreline was renourished during Summer 2014 with 682,000 cy of sand. As a requirement of the EIS associated with the engineered beach project, semi-annual (fall and spring) beach monitoring surveys and analyses commenced in Fall 2015 along Wallops Island extending to the north as far as Toms Cove / Assateague Island and to the south as far as Gargathy Inlet. Monitoring was completed in Spring 2019 after which the USACE Norfolk District designed a renourishment project based on the findings and recommendations. The renourishment project took place in 2020, placing roughly 1.3 Mcy of sand, which was excavated from a highly accretional area on the northern end of Wallops Island, along approximately 14,000 ft of shoreline and included construction of five offshore breakwaters to further protect critical infrastructure. In Fall 2024, the USACE requested an updated survey and analysis of the Wallops Island shoreline in order to assess performance of the 2020 renourishment project and breakwater construction and also to guide the timing and design of the next renourishment project.

This report utilizes survey data collected in February 2019 and September 2024 to compute the shoreline location change at +1.5 ft NAVD88, which is designated as the Mean High Water (MHW) elevation, and +6.0 ft NAVD88 (for the USACE project area only), which is designated as the design berm elevation. Volume changes were also calculated above +1.5 ft NAVD88 (MHW), -5 ft NAVD88 (wading depth), -10 ft NAVD88 (outer bar), -15 ft NAVD88 and -20 ft NAVD88. The last two elevations of -15 ft NAVD88 and -20 ft NAVD88 are believed to bracket the expected depth of closure.

Table 5-1 presents the average summary statistics calculated for each reach of shoreline in the study area along Wallops Island. Reaches and subreaches developed during the initial Fall 2015 monitoring period based upon profiles with similar characteristics (dune height, berm width, offshore slope, etc.), nourishment extents, and alignment of the shoreline were modified slightly for this report to better reflect more recent morphological changes to the beach resulting from the 2020 renourishment project, construction of offshore breakwaters, and excavation of sand from the northern portion of Wallops Island.

Table 5-1. Shoreline and Volume Change Statistics by Reach for Wallops Island (February 2019 – September 2024)

	Reach Length	Average Shoreline Change @ MHW (+1.5 ft NAVD88)	Average Volume Change Above +1.5 ft NAVD88	Cumulative Volume Change Above +1.5 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -10 ft NAVD88	Cumulative Volume Change Above -10 ft NAVD88	Average Volume Change Above -15 ft NAVD88	Cumulative Volume Change Above -15 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88
Reach (Stations)	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	-47.5	-0.5	-7,911	-12.2	-191,454	-16.6	-262,053	-22.5	-354,171	-41.8	-658,565
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	-43.5	-20.0	-59,877	-27.7	-83,026	-30.9	-92,661	-35.5	-106,628	-60.2	-180,610
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	28.6	3.2	27,135	16.3	138,865	27.9	237,046	35.6	302,803	28.6	243,201
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	11.2	-0.7	-2,063	9.4	28,344	19.6	58,926	19.0	57,066	11.8	35,292
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	117.8	17.2	86,119	53.5	267,677	86.6	433,126	111.6	557,760	103.4	517,176
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	181.7	37.3	65,321	83.7	146,480	126.1	220,714	166.0	290,436	188.5	329,872
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	149.4	-52.3	-313,620	-40.9	-245,543	-14.8	-88,555	24.1	144,849	107.9	647,692
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	-213.8	-23.7	-59,288	-69.8	-174,520	-117.6	-293,993	-181.3	-453,242	-211.6	-529,089
TOTAL - Wallops Island (Sta 20+00 to Sta 475+00 A)	*45,500*	*14.7*	*-5.8*	*-264,183*	*-2.5*	*-113,178*	*4.7*	*212,550*	*9.6*	*438,872*	*8.9*	*404,969*

The Wallops Island – South analysis reach experienced landward recession of the shoreline at MHW as well as moderate volume losses above all the elevations analyzed. Volume losses increased above each elevation moving offshore, indicating that the sand has been removed from the system within the monitoring reach, likely being transported south towards Gargathy Inlet. It should be noted that the average annual erosion rate throughout the monitoring period was slightly smaller than the background erosion rate.

The statistics indicate an overall volume gain in the Wallops Island - USACE Project analysis reach above all elevations since 2019, indicating that a significant amount of the material placed during the 2020 renourishment project is still within the overall USACE project extents. However, a majority of the remaining material appears to have been transported north to Subreach 4 which had the largest volume gains but did not receive any placement in 2020. Despite placement during the 2020 renourishment project, Subreach 1, which has a historically high erosion rates, experienced significant volume erosion as compared to 2019, indicating that material placed in this reach during the 2020 project has likely already eroded. Conversely, Subreach 2, which also has historically high erosion rates, actually experienced a gain in volume since 2019, indicating that some of the material placed during the 2020 project is still in place, most likely the result of the two sets of breakwaters constructed in this area in conjunction with the 2020 renourishment. Subreach 3 also experienced volume gains as compared to 2019, indicating some of the nourishment material is still present. This area of the USACE project has much lower historical erosion rates and encompasses the portion of shoreline along the Wallops Island USACE project where erosional trends to the south transition to accretional trends to the north.

Several different morphological trends were present within the Wallops Island – North analysis reach. Wallops Island - North Subreach 1 experienced significant volume gains above all elevations from February 2019 to September 2024 which is typical behavior given the longshore transport from the immediately adjacent USACE project. Wallops Island – North Subreach 2 indicates volume losses above MHW, -5 ft NAVD88, and -10 ft NAVD88 but volume gains offshore above -15 ft NAVD88 and -20 ft NAVD88. This pattern is due to the excavation of material for the 2020 renourishment project being combined with typical accretional profile behavior in this area.

The beach continued to show significant accretion seaward of the excavation limits due to sediment transport from the USACE project. However, the volume losses from the excavation itself outweigh the volume gains along the upper elevations of the profile, leading to net losses. Moving further offshore, the volume gains begin to outweigh the losses from excavation, leading to net volume gains. Wallops Island – North Subreach 3 experienced overall losses above all elevations analyzed which is typical for the shoreline adjacent to Chincoteague Inlet.

In order to take a closer look at the performance of the USACE project and begin developing concepts for future nourishment placement and quantities, the September 2024 profiles located in the project area (Sta 180+00 to Sta 370+00) were also compared to the USACE design and construction templates. The difference in shoreline position at MHW (+1.5 ft NAVD88) and the design berm elevation (+6.0 ft NAVD88) as well as volume difference above MHW (+1.5 ft NAVD88), -5 ft NAVD88, -10 ft NAVD88, and -12 ft NAVD88 were calculated. Volume difference above -12 ft NAVD88 was added to the analysis because this is the approximate elevation of the toe of the fill, allowing for the most accurate estimates of volume surpluses and deficits as compared to the templates.

Table 5-2 presents the shoreline position and volume difference between the September 2024 survey and the USACE design template above several elevations. Overall, the total project currently contains more material than the design template, with a net volume surplus of approximately 2.17 million cy above -12 ft NAVD88 (typical extent of fill placement), mostly located in Subreach 4. However, there are areas of the project in Subreaches 1, 2, and 3 which have receded landward of the design template. Due to profile behavior where material eroded from the upper portions of the profile has been captured at lower elevations of the design template in many locations, the largest net volume deficit to the design template actually occurs above -5 ft NAVD88 totaling -139,264 cy in Subreach 1 and -389,360 cy in Subreach 2 for a total of -528,624 cy. Furthermore, there are some transects in Subreach 1, Subreach 2, and Subreach 3 that contain a surplus of material and some that contain a deficit. Therefore, if only the transects containing a deficit of material in Subreach 1, Subreach 2, and Subreach 3 are considered, there is a total deficit of approximately -591,301 cy of material above -5 ft NAVD88 between the September 2024 survey and the design template.

Table 5-2. Design Template Comparison

	Reach Length	Average Shoreline Difference @ +6.0 ft NAVD88	Average Shoreline Difference @ MHW (+1.5 ft NAVD88)	Average Volume Difference Above +1.5 ft NAVD88	Cumulative Volume Difference Above +1.5 ft NAVD88	Average Volume Difference Above -5 ft NAVD88	Cumulative Volume Difference Above -5 ft NAVD88	Average Volume Difference Above -10 ft NAVD88	Cumulative Volume Difference Above -10 ft NAVD88	Average Volume Difference Above -12 ft NAVD88	Cumulative Volume Difference Above -12 ft NAVD88
Reach (Profiles)	ft	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 210+00)	3,000	-63.4	-79.5	-25.6	-76,783	-46.4	-139,264	-32.3	-97,003	-19.9	-59,555
Wallops Island - USACE Project Subreach 2 (Sta 215+00 to Sta 295+00)	8,500	-62.9	-95.5	-23.8	-202,171	-45.8	-389,360	-33.2	-281,835	-22.0	-186,953
Wallops Island - USACE Project Subreach 3 (Sta 300+00 to Sta 320+00)	3,000	53.5	56.3	16.1	48,349	32.7	97,960	76.4	229,326	100.1	300,194
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	437.4	537.6	90.9	454,559	223.4	1,117,167	361.3	1,806,586	424.3	2,121,299
TOTAL - Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)	***19,500***	***83.2***	***92.6***	***11.5***	***223,954***	***35.2***	***686,502***	***85.0***	***1,657,075***	***111.5***	***2,174,985***

Table 5-3 presents the shoreline position and volume difference between the September 2024 survey and the USACE construction template. Overall, the total project currently contains slightly

more material than the construction template, with a net volume surplus of approximately 878,691 cy above -12 ft NAVD88 (typical extent of fill placement), mostly located in Subreach 4. However, there are some large portions of the project which have eroded significantly from the construction template. Due to profile behavior where material eroded from the upper portions of the profile has been captured at lower elevations of the construction template in many locations, the largest net volume deficit to the construction template actually occurs above -10 ft NAVD88 totaling -274,781 cy in Subreach 1 and -785,538 cy in Subreach 2 for a total of -1,060,318 cy. Furthermore, there are some transects in Subreach 1, Subreach 2, and Subreach 3 that contain a surplus of material and some that contain a deficit. Therefore, if only the transects containing a deficit of material in Subreach 1, Subreach 2, and Subreach 3 are considered, there is a total deficit of approximately -1,140,764 cy of material above -10 ft NAVD88 between the September 2024 survey and the construction template.

Table 5-3. Construction Template Comparison

	Reach Length	Average Shoreline Difference @ +6.0 ft NAVD88	Average Shoreline Difference @ MHW (+1.5 ft NAVD88)	Average Volume Difference Above +1.5 ft NAVD88	Cumulative Volume Difference Above +1.5 ft NAVD88	Average Volume Difference Above -5 ft NAVD88	Cumulative Volume Difference Above -5 ft NAVD88	Average Volume Difference Above -10 ft NAVD88	Cumulative Volume Difference Above -10 ft NAVD88	Average Volume Difference Above -12 ft NAVD88	Cumulative Volume Difference Above -12 ft NAVD88
Reach (Profiles)	ft	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 210+00)	3,000	-163.4	-179.5	-42.3	-126,783	-87.2	-261,486	-91.6	-274,781	-86.5	-259,556
Wallops Island - USACE Project Subreach 2 (Sta 215+00 to Sta 295+00)	8,500	-162.9	-195.5	-40.5	-343,837	-87.6	-744,917	-92.4	-785,538	-88.2	-749,914
Wallops Island - USACE Project Subreach 3 (Sta 300+00 to Sta 320+00)	3,000	-46.5	-43.8	-0.6	-1,652	-8.1	-24,263	17.2	51,549	33.4	100,194
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	337.4	437.6	74.2	371,225	182.7	913,463	302.1	1,510,290	357.6	1,787,967
TOTAL - Wallops Island - USACE Project (Sta 180+00 to Sta 370+00)	***19,500***	***-16.8***	***-7.4***	***-5.2***	***-101,046***	***-6.0***	***-117,203***	***25.7***	***501,521***	***45.1***	***878,691***

It is evident that considerable erosion has occurred since the 2020 renourishment project and a majority of the area which received material during the 2020 renourishment project (Subreaches 1, 2, and 3) has shown considerable erosion, significantly increasing vulnerability to the next storm event. While the breakwaters appear to be performing well and are holding sand in the immediate area of construction, protecting the valuable infrastructure on land, the beneficial impacts are highly localized, allowing for the continued high loss rates of material along a majority of Subreaches 1 and 2.

To establish the long-term erosion and accretion patterns in the Wallops Island study area which will help to optimize future shoreline stabilization and restoration efforts, a background erosion rate was calculated for each subreach. The calculated background erosion rates remove the effects of the 2012, 2014, and 2020 nourishment events, thus enabling the determination of volumetric change that would occur without the projects, assisting in determining future nourishment quantities and timing. This report updates the erosion rates from February 2019 to include volume changes from February 2019 to September 2024. To accomplish this process, the volume changes above -15 ft NAVD88 for the February 2019 through September 2024 time period were added to the volume changes calculated for the previous monitoring reports spanning from 2011 through February 2019. The elevation of -15 ft NAVD88 represents the seaward limits of all of the sand placement occurring during the maintenance events. Nourishment volumes were then subtracted from total volume changes above -15 ft NAVD88. From this, the average annual background erosion rate was calculated. Table 5-4 shows the

documented placement volumes and volume change as well as the calculated background erosion rates for the defined reaches and subreaches.

Table 5-4. Average Annual Background Erosion Rates

Reach	Length (ft)	Total Nourishment Volume (cy) (Oct 2011 - Sept 2024)	Total Volume Change Above -15 ft NAVD88 (cy) (Oct 2011 - Sept 2024)	Cumulative Background Erosion (cy)	Annualized Cumulative Background Erosion Rate (cy/yr)	Average Annual Background Erosion Rate (cy/ft/yr)
Wallops Island - South (Sta 20+00 to Sta 175+00)	15,750	0	-1,150,188	-1,150,188	-88,888	-5.64
Wallops Island - USACE Project Subreach 1 (Sta 180+00 to Sta 205+00)	3,000	942,633	238,201	-704,432	-54,439	-18.15
Wallops Island - USACE Project Subreach 2 (Sta 210+00 to Sta 290+00)	8,500	2,670,793	816,018	-1,854,775	-143,340	-16.86
Wallops Island - USACE Project Subreach 3 (Sta 295+00 to Sta 320+00)	3,000	764,617	607,374	-157,243	-12,152	-4.05
Wallops Island - USACE Project Subreach 4 (Sta 325+00 to Sta 370+00)	5,000	826,085	2,221,113	1,395,028	107,810	21.56
Wallops Island - North Subreach 1 (Sta 375+00 to Sta 385+00)	1,750	0	953,566	953,566	73,693	42.11
Wallops Island - North Subreach 2 (Sta 395+00 to Sta 445+00)	6,000	-1,300,000	2,041,355	3,341,355	258,225	43.04
Wallops Island - North Subreach 3 (Sta 455+00 to Sta 475+00)	2,500	0	-1,351,594	-1,351,594	-104,453	-41.78
TOTAL - WALLOPS ISLAND (Sta 20+00 to Sta 475+00)	***45,500***	***3,904,128***	***4,375,845***	***471,717***	***36,455***	***0.80***

Subreach 1 and 2 of the Wallops Island – USACE Project analysis reach experience the highest background erosion rates in the project area. Based on the preliminary background erosion rates of -18.15 cy/ft/yr in Subreach 1, -16.86 cy/ft/yr in Subreach 2, and -4.05 cy/ft/yr in Subreach 3 it is possible that approximately 210,000 cy of material could be lost from these two reaches each year if the erosional trend continues.

In order to gain knowledge on the morphology of Chincoteague Inlet, a possible future source of nourishment material, the hydrographic portion of profiles along Assateague Island adjacent to the inlet were surveyed for future monitoring. Volume calculations were not performed but rather the profiles were qualitatively examined for changes in inlet channel location and possible shoaling. Results indicate that while there was a small amount of shoaling at the mouth of the inlet (Sta 600+00), the channel position and depth remained fairly stable between February 2019 and September 2024.

In conclusion, this Fall 2024 monitoring survey is the first monitoring survey performed since the semi-annual monitoring program from Fall 2015 to Spring 2019 was completed. During the 5.5 year time period since the last survey, the USACE placed approximately 1.3 Mcy along 14,000 ft of shoreline within the USACE project area and constructed five offshore breakwaters. Survey results indicate that in many locations along Subreach 1, Subreach 2, and the southern half of Subreach 3, beach profiles have receded landward of the 2019 survey, the design template, and the construction template despite the 2020 nourishment efforts, significantly increasing vulnerability to the next storm event. As of the Fall 2024 survey, it is estimated that the volume deficit to the construction template is approximately -1,140,764 cy, equivalent to 88% of the

2020 project volume. It should be noted that the two breakwater fields appear to be holding sand well in the immediate vicinity, but positive impacts do not extend very far alongshore. In addition, the area north of the USACE project which was excavated as a borrow source for the 2020 project appears to be continuing to accrete seaward of the excavation limits in line with historical accretion patterns.

APPENDIX A

Geodynamics

Survey Report

Wallops Island, VA
Shoreline Monitoring and Analyses Program:
Beach Profile Monitoring
and
Unnamed Shoal A: Multibeam Survey
Fall 2024



DESCRIPTIVE REPORT

Submitted to:

US Army Corps of Engineers ®

NASA

Submitted by:

geodynamics
AN NV5 COMPANY

Contract # W9123619D0017
Project # W9123624F0059

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Beach Profile Monitoring Survey

1.0 Introduction

The following report documents all field survey methods and the resultant quality assurance and quality control parameters used to assess and document the overall data accuracy. This report is necessarily technical and intended to be a supplement to the analysis report through illustrating long-term methodologies that provide repeatability and confidence in the calculations made over time. Any questions pertaining to information herein can be handled upon request.

1.1 Project Description

Geodynamics was contracted by the U.S. Army Corps of Engineers, Norfolk District to perform a topographic and bathymetric beach profile survey of Wallops Island and southern Assateague Island. The work conducted in Fall of 2024, was performed on the modified line plan from prior years (2017), focusing on the surveying and mapping of designated onshore and offshore profiles primarily on Wallops Island in front of the NASA facility and seawall. This modified line plan included elevation and positioning data collected along a total of 72 profile stations. Five of these profiles extend from Assateague Island, near the inlet, and contain bathymetric data only. All survey designs were approved by the client.

1.2 Survey Area

The survey was conducted on 72 profiles across approximately 9 miles of coastline along Wallops Island and 0.75 miles of an offshore section in front of Assateague Island near the inlet. The seaward extent of the profiles reached a minimum baseline length of the 2019 survey or to depths of -22 ft NAVD88, as stated in the Scope of Work (SOW). The survey bounds are approximately 37°52’32.45” N, 075°23’29.46.2” W (Northeast Corner), and 37°46’43.29” N, 075°31’59.44” W (Southwest Corner)

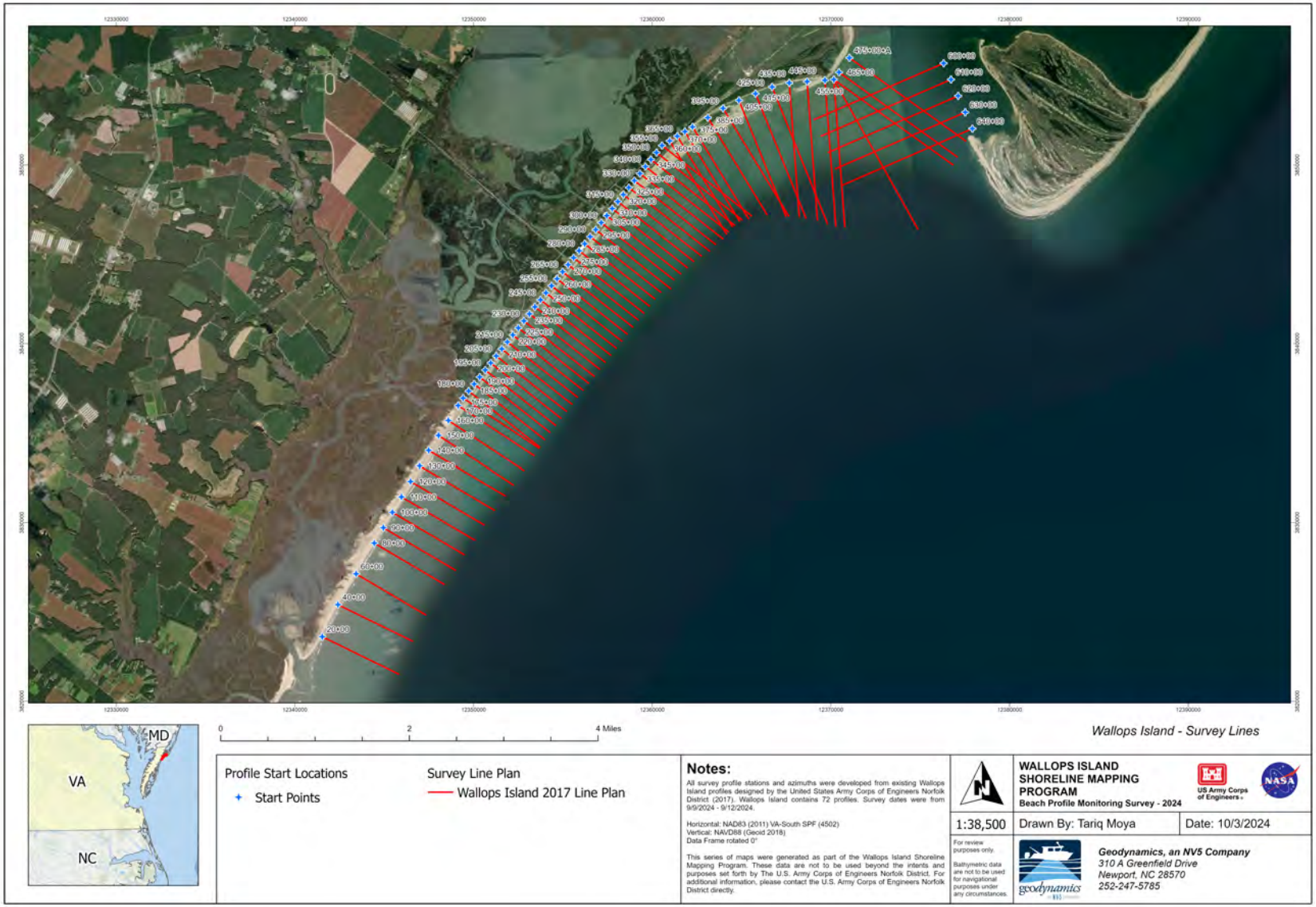


Figure 1. Survey area for the Wallops Island Beach Profile Monitoring Survey.

1.3 Survey Objectives

As outlined in the official SOW (APPENDIX G: SCOPE OF WORK), the specific goals of the survey were to perform topographic-bathymetric beach profile surveys along pre-designated sections of Wallops Island. This completed dataset was then used to generate the following deliverables: corrected beach profile data in XYZ text file format, profile data as an ESRI ArcGIS shape file, MLS-derived beach face digital elevation model (DEM), a 1.5 ft MHW contour, FDGC compliant Metadata, and pertinent Quality Assurance / Quality Control (QA/QC) section for the written survey report. The client will use this dataset to establish a baseline understanding of the health of the beach along the revetment, identify trends of the sediment transport along the beach, and identify the suitability of the borrow area as a potential resource for beach nourishment purposes in the future.

1.4 Survey Logistics

Data acquisition occurred between September 8th and September 12th, as weather and sea conditions allowed. Due to the tidal regime and bathymetric features throughout the survey area, special planning was made to acquire data in each region for a given weather/tide scenario. The table below (Table 1) outlines survey activities.

Table 1. Summary of Survey Activities

Date	Julian Day	Activity
9/8/2024	252	Crew Mobilized from Geodynamics to Chincoteague, VA.
9/9/2024	253	The survey team arrived at Wallops Island, established survey control on W-115, benchmark checks, completed the MLS survey, and began topographic and bathymetric profile collection.
9/10/2024	254	Continuation of topo-bathy profile collection. The Hydro team completed all hydro surf zone collection.
9/11/2024	255	Continuation of topo surf zones and dunes. The Hydro team completed the offshore survey.
9/12/2024	256	Recoveries for topo dunes. Breakdown of the base station, recovery of all survey equipment, and demobilization back to Geodynamics.

1.5 Survey Conditions

Figure 2 displays graphs of NOAA-predicted and verified tides for Ocean City Inlet, MD (Station ID: 8570283) as well as surface wind and air temperature throughout the survey.

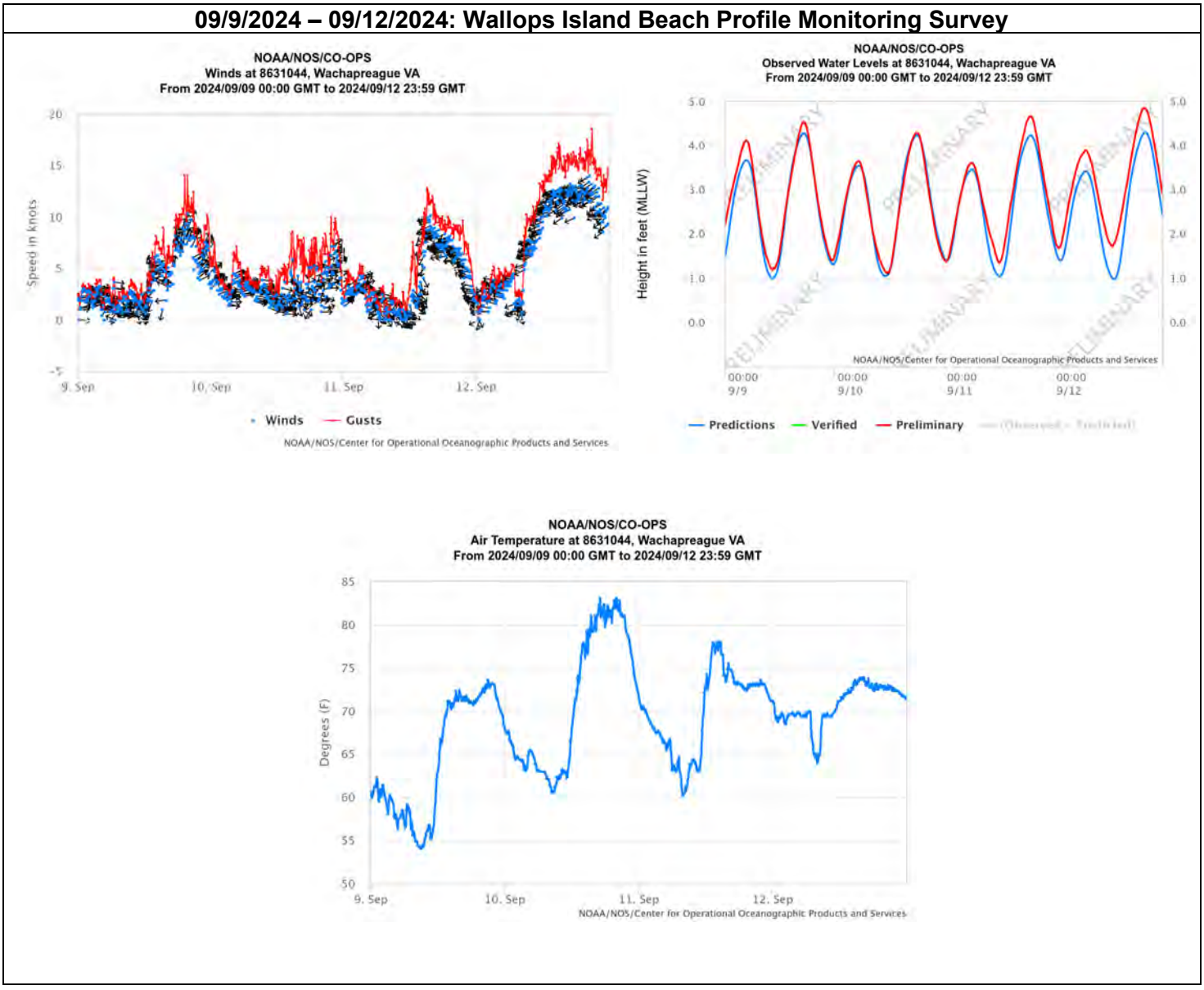


Figure 2. Atmospheric and tidal records for survey days.

1.6 Survey Personnel

All survey crew throughout the surveys were provided by Geodynamics. These personnel contributed to the vessel mobilization, data collection, vessel demobilization efforts, processing, reporting, QA-QC, and final certification (Table 2).

Table 2. List of Survey Personnel and Responsibilities

Survey Participant	Title	Affiliation
Dave Bernstein	VP of Hydrospatial Operations / CH / GISP / PLS	Geodynamics
Kurt Baker	Program Manager	Geodynamics
Brandon Barnette	Acquisition Manager	Geodynamics
Kyle Neumuller	Processing Manager	Geodynamics
Tariq Moya	Project Lead / Lead Processor	Geodynamics
Owen Reuther	Field Surveyor	Geodynamics
Davis Batten	Field Surveyor / Vessel Operator	Geodynamics
Sam Bradtke	Vessel Operator / Field Surveyor / Data Processor	Geodynamics

1.7 Navigation and Positioning

All data points obtained during hydrographic and topographic survey activities have associated geographic locations to facilitate database entry and to display these data within a GIS framework. All elevations/soundings were collected with Real Time Kinematic (RTK) GNSS corrections to provide the accuracies requested per the SOW. RTK-GNSS corrections were generated from a Global Navigation Satellite System (GNSS) enabled Trimble Zephyr II antenna with a ground plane receiver and a Trimble R10 both of which broadcasted via 8.5 dB gain UHF antenna from a base station installed by Geodynamics. The base station location was based on the area to be surveyed and the extent of UHF transmission (Table 3, Figure 3). Table 4 highlights the different equipment used for the base setup. Corrections for the hydrographic survey were received over the internet via the Virginia Leica SmartNet network. HYPACK utilized an X/Y grid system based on the North American Datum of 1983 (NAD83), Virginia State Plane Survey Feet Zone 4502, and reduced from the ellipsoid using Geoid 2018.

1.8 Vertical Datum

The vertical datum for the final survey data is the North American Vertical Datum of 1988 (NAVD88). The ellipsoid-based real-time vertical water level corrections were reduced to NAVD88 by integrating a local Geoid 2018 model.

1.9 Horizontal Datum

The horizontal datum for the final data product is projected in the North American Datum 1983 (NAD83-2011); Virginia State Plane South Zone 4502, Survey Feet.

Table 3. RTK-GNSS Base Station Coordinates

Base station ID	Latitude	Longitude	Ellipsoid Height (NAD83)	Orthometric Height
W-115	37° 50' 46.81096" N	75° 28' 27.97949" W	-33.919 m	2.714 m

Table 4: RTK-GNSS Base Station Equipment

Base Station ID	Receiver	Antenna	Radio	Radio Broadcasting
W-115_Base	R7	Zephyr II Geodetic	TDL 450	8.5 dB UHF Antenna



W-115 Base

Figure 3. Photo showing the "W-115" base.

2.0 Singlebeam Data Acquisition and Processing

2.1 Equipment

2.1.1 Survey Vessel

The R/V Echo served as the primary survey platform for nearshore singlebeam data acquisition (Figure 4, Table 5). The R/V Echo is specifically designed to be a vessel of opportunity for shallow water inshore and coastal ocean mapping. The R/V Echo is equipped with a thru-hull transducer that is tightly coupled with an inertial navigation system (INS) for positioning and elevation. On-the-fly sound speed sensors and customized computer systems allow seamless logging of bathymetric data.



Figure 4. R/V Echo

Table 5. R/V Echo Vessel Specifications

Dimensions:	21' x 9' x 1.2’
USCG:	Designated Research Vessel
Flag:	U.S.
Registry:	North Carolina
Official Number:	NC 7341 DT
Tonnage:	1
Lab space:	1 open console operator station
Max Speed:	30 knots
Min. survey speed:	2.5 knots
Propulsion:	1 x 200 HP Yamaha 4-Stroke Outboard Motor - 2021
Auxiliary Power:	24v DC battery bank and 12v DC parallel battery banks
Fuel capacity:	60 gallons
GPS:	Simrad
Sounder:	Lowrance StructureScan
Compass:	n/a
Radar:	n/a
Autopilot:	n/a
VHF:	Icom 25 watt
Internet:	Pepwave Max BR1 Mini

2.1.2 Hardware

2.1.2.1 Hardware Systems Inventory

Hardware utilized throughout the project for singlebeam data acquisition can be seen in Table 6.

Table 6. Singlebeam Hardware Systems Inventory

	Hardware Equipment	**Manufacturer**	**Model**
Horizontal & Vertical Control	RTK Radio Modem	Trimble	PDL 450L
	RTK Radio Antenna	Pacific Crest	n/a
	Primary GNSS Antenna	Trimble	Zephyr Model 2
	Secondary GNSS Antenna	Trimble	Zephyr Model 2
	Cellular Internet	Peplink	Pepwave Max BR1 Mini
	POS MV	Applanix	SurfMaster
Echo Sounding	StructureScan (while in transit)	Simrad	1.7.0
	ODOM CV100	ODOM	CV100
	Operator Station	OnLogic	Karbon 700
Attitude Positioning	Inertial Motion Unit (IMU)	Applanix	SurfMaster
	Primary GNSS Antenna (port)	Trimble	Zephyr Model 2
	Secondary GNSS Antenna	Trimble	Zephyr Model 2
Sound Speed	Sound Profile Velocimeter	SonTek	CastAway-CTD

2.1.2.2 Sonar Equipment

An Odom CV100 singlebeam sonar system was used to acquire singlebeam bathymetry data during the topo-bathy profile survey (Figure 5). The CV100 system operates at frequencies in the 200 kHz band: ideal for shallow depths. The transducer forms a 4-degree conical beam. With an operational depth range from <30 cm to 600 m and a ping rate of up to 20 Hz, the CV100 is ideal for shallow water surveys (Table 7).

Table 7. CV100 specification

Frequencies.	200 kHz / 33 kHz
Maximum ping rate.	Up to 20 Hz
Heave compensation	Yes
Depth resolution	1 cm
Transducer	Airmar SMSW200-4a



Figure 5. Odom CV100 digital echosounder mounted on the R/V Echo.

2.1.2.3 Sound Velocity Equipment

The SonTek CastAway-CTD was used during the survey to obtain accurate sound velocity profiles throughout the survey area (Figure 6). The unit acquires latitude and longitude internally before and after each profile. Conductivity, temperature, salinity, and sound speed are plotted versus depth on the unit, and it transmits data wirelessly for processing. Additionally, sound speed data can be exported into a HYPACK-compatible format (.vel file).



Figure 6. SonTek CastAway-CTD sound speed profiler.

2.1.3 Software

2.1.3.1 Software Systems Inventory

Software utilized throughout the project for singlebeam data acquisition and processing can be seen in Table 8.

Table 8. Singlebeam Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2022
	Odom E-Chart	1.4.0
	POSView	10.2
	CastAway-CTD	V1.5
	VA Leica SmartNet	2013.11.24
Data Processing	HYPACK	2019
	POSPac	9.1
	ArcGIS Pro	3.3.0
	Surfer	9
	MS Office	2018

The HYPACK software suite was used during survey preparation to create survey line plans and evaluate the overall survey scheme. The initial line plan was created in HYPACK using a line spacing designed to acquire survey data over pre-determined profiles. HYPACK was also used during the survey to record sounding and position data, log targets of importance, and provide the captain with line tracking.

The ODOM eChart software was used as a start-up interface to establish communications with the echosounder, check/verify essential echosounder settings, and provide transmit and receive gain controls of the singlebeam echosounder.

The POSView software by Applanix was used with the POS MV system. The software provides the interface to view, monitor, and record tightly coupled integration of the attitude measurements from the IMU and position and heading measurements recorded by the GNSS receiver. The recorded POSPac file, which contained all attitude, positioning, heading, and error estimates provides a method to post-process attitude and navigation data in the event of RTK-GNSS cycle slips.

ArcMap and ArcGIS Pro are complete Geographic Information Systems (GIS) software packages. All survey area maps, coverage extents, and final chart products were created using ArcGIS software.

2.2 Acquisition Quality Control

2.2.1 Singlebeam Data Acquisition and Monitoring

At the start of each survey day, a series of pre-survey protocols were run to aid in quality control and to determine any possible errors/issues prior to surveying. For hydro, the GAMS parameters and POS MV installation parameters located under the installation settings of the POS MV were all checked prior to enabling Ethernet logging of POSPac data.

Data is collected at vessel speeds of approximately 3 - 10 kt. The HYPACK data acquisition software provides data waterfalls and coverage indicators, which allowed for real-time monitoring of the data quality and coverage. Data displays in HYPACK Survey were used to monitor all survey parameters and the quality of data being recorded.

Sound speed profiles were acquired routinely and when the survey vessel moved to a different location within the survey area. Each successive sound speed cast was compared and assessed to determine the optimal casts per reach of profiles.

2.2.2 Singlebeam Calibration Checks

The R/V Echo has a built-in transducer in the rear of the starboard hull. Geodetic and mechanical bar index checks have been performed to calibrate for a constant, electronic offset, inherent in all singlebeam systems (Figure 7). Please refer to APPENDIX C: SINGLEBEAM ECHOSOUNDER CALIBRATION REPORT for more details.



Figure 7. Image illustrating the mechanical bar check of sonar index.

A more recent technique to calibrate sonars for sound velocity is a digital bar check, or sound speed cast. Similar in theory to performing a mechanical bar check, digital bar checks are a safer and more efficient alternative, and are critical to sonar data acquisition in shallow, inter-tidal, coastal zones. Therefore, in order to maintain the best data quality across vast areas in this dynamic coastal environment, the traditional mechanical bar check is only used to verify the sonar system index since corrections are made to the transducer, not the waterline, and sound speed profiles correct the sounder for speed of sound in the water column.

2.3 Singlebeam Data Processing

2.3.1 Processing Workflow

Figure 8 illustrates the workflow in singlebeam sonar data processing.

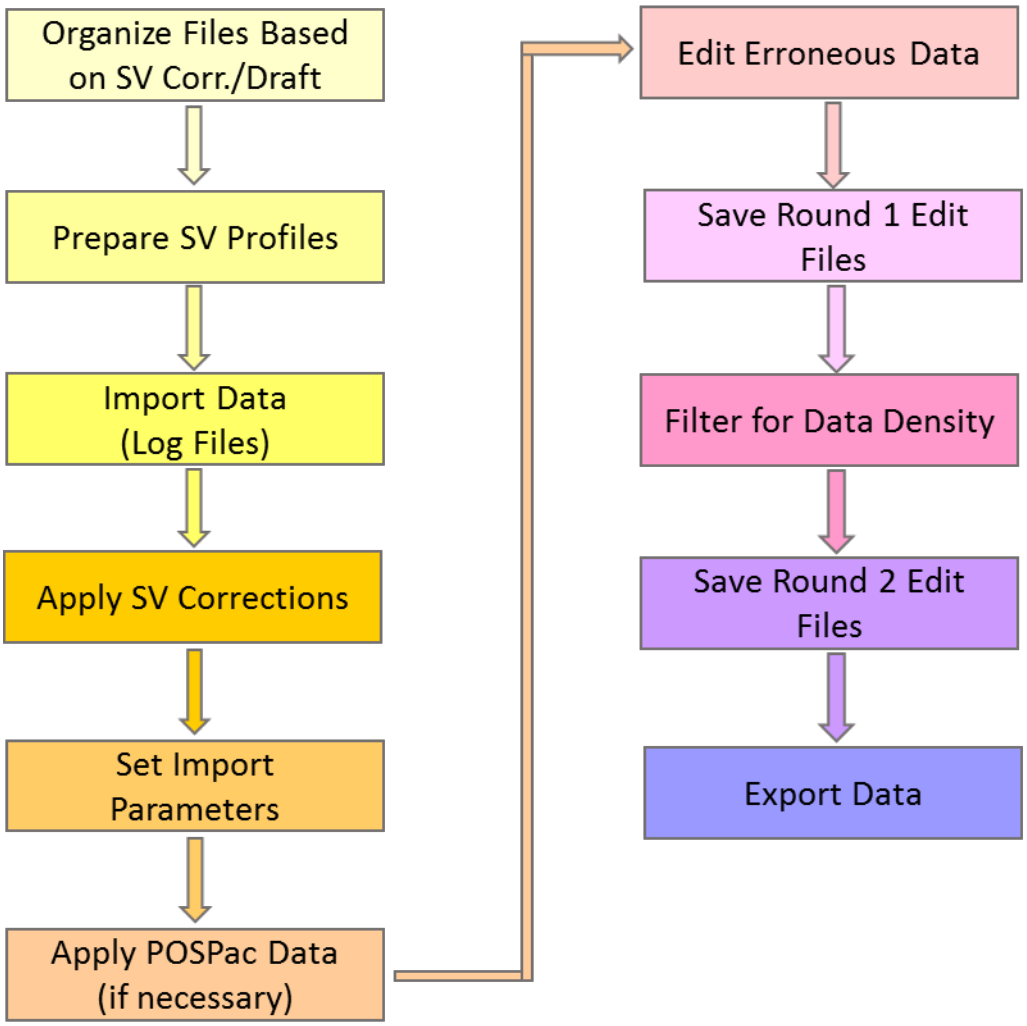


Figure 8. HYPACK singlebeam data processing workflow.

2.3.2 Corrections to Soundings

2.3.2.1 POS MV Correctors

The Applanix POS MV unit was set up to receive phase-differential RTK position offsets from the Leica SmartNet. This configuration allowed the POS MV to integrate decimeter positional solutions with highly accurate vessel attitude positions obtained from the IMU. When the GAMS is online, positional solutions are received from five or more satellite fixes with a Positional Dilution of Precision (PDOP) equal to or less than three. When these conditions are not satisfied, the GAMS solution becomes dormant. The GAMS program continues to track satellites while in this state but does not process the phase-differential corrections in real time.

A verification of the GAMS system was conducted before the start of the project. The values in use for this survey were obtained from a GAMS calibration that followed the auto-start procedure laid out in the POS MV Installation and Operation Guide. The GAMS parameters in the setup menu were initially set to zero, except for the heading calibration threshold which was set to 0.500°. The vessel then made aggressive figure-8 maneuvers until the GAMS solution came online and the values in the parameter setup menu were automatically updated. This calibration remains valid until vessel offsets are changed.

Due to inherent and common problems associated with RTK-GNSS, such as cycle slips, high DOP periods, and data gaps, the POSPac data is routinely post-processed in the Applanix POSPac software suite. This process is used to verify and provide QA for Real-Time corrections.

2.3.2.2 Dynamic Draft Correctors

Dynamic draft is the summation of the static draft, settlement, and squat corrections and is a required corrector for echo sounders. The dynamic draft was accounted for by using RTK-GNSS ellipsoid-based vertical corrections. The combined correctors work to continuously factor out the static draft, settlement, and squat of the survey vessel.

2.3.2.3 Sound Speed Correctors

Sound speed profiles were taken at the start of each survey day, and again throughout the day as warranted by the survey area and water properties. Sound speed profiles were also acquired when the survey vessel moved to a different location in the survey area (Figure 9). Each sound speed cast was assessed in processing to determine water properties in a specific zone of the survey area.

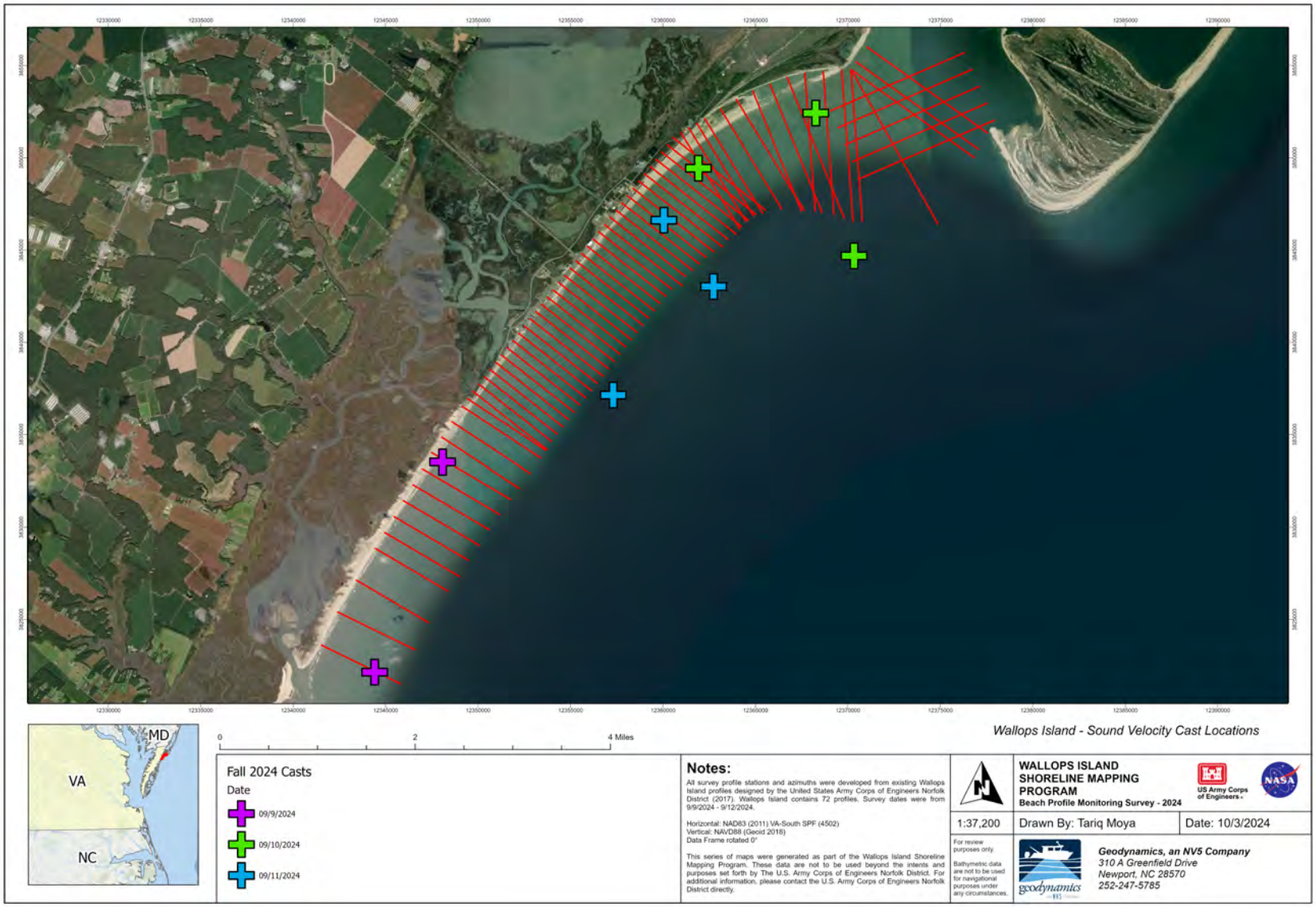


Figure 9. Sound speed profile locations for singlebeam survey operations.

2.3.2.4 Water Level Correctors

RTK-GNSS based tidal measurements were continuously recorded throughout the survey by HYPACK Survey. The GPS height determined by the POS MV was integrated into the raw singlebeam sonar data during data acquisition in real-time. After importing the raw singlebeam data in HYPACK, the GPS tide was merged with the heave such to provide accurate tidal corrections and subtract vessel heave from the final elevations.

3.0 Topographic Data Acquisition and Processing

3.1 Equipment

3.1.1 Topographic Equipment

A Trimble R10 RTK-GNSS rover backpack system was used to acquire topographic profile data during the survey. The Trimble R10 RTK-GNSS receiver integrates GNSS observables with RTK network corrections to provide centimeter-level position and elevation. The RTK-GNSS data is output from the R10 receiver at 10 Hz to the Trimble T7 data acquisition tablet PC (Table 9).

3.1.2 Hardware Systems Inventory

Table 9. Backpack Topographic Hardware Systems Inventory

Hardware Equipment	Manufacturer	Model
Acquisition PC	Trimble	T7
GNSS Receiver	Trimble	R10
GNSS Antenna	Trimble	R10

3.1.3 Horizontal and Vertical Control Equipment

Horizontal and vertical positioning for topographic data was provided by the RTK-GNSS base station with corrections from “W-115”. The base station utilized a Trimble R7 receiver, Zephyr Geodetic Model II GPS antenna, and a TDL 450 radio to collect and broadcast corrections to roving users via an 8.5 dB gain radio antenna.

Horizontal and vertical positioning for topographic data was acquired by a Trimble R10 RTK-GNSS system. The topographic rover received and integrated the differential corrections from the RTK-GNSS base station for centimeter-level positioning.

3.2 Software

3.2.1 Software Systems Inventory

Software utilized throughout the project for the backpack topographic method can be seen in Table 10.

Table 10. Backpack Topographic Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2022
Data Processing	HYPACK	2022
	ArcPro	3.3.2
	MS Office	2024

3.2.1.1 Data Acquisition Software

HYPACK was used during the survey to collect topographic data, as well as for in-field quality control and real-time quality assessment.

3.2.1.2 Data Processing Software

HYPACK was used to manipulate and process the topographic data. The Singlebeam Editor in HYPACK was used to import, clean, and thin the data.

The ArcGIS software package was utilized for all survey area maps, coverage extents, and final chart products.

3.3 Backpack Topographic Data Processing

Topographic data processing in HYPACK Singlebeam Editor software follows the general procedure illustrated in Figure 11.

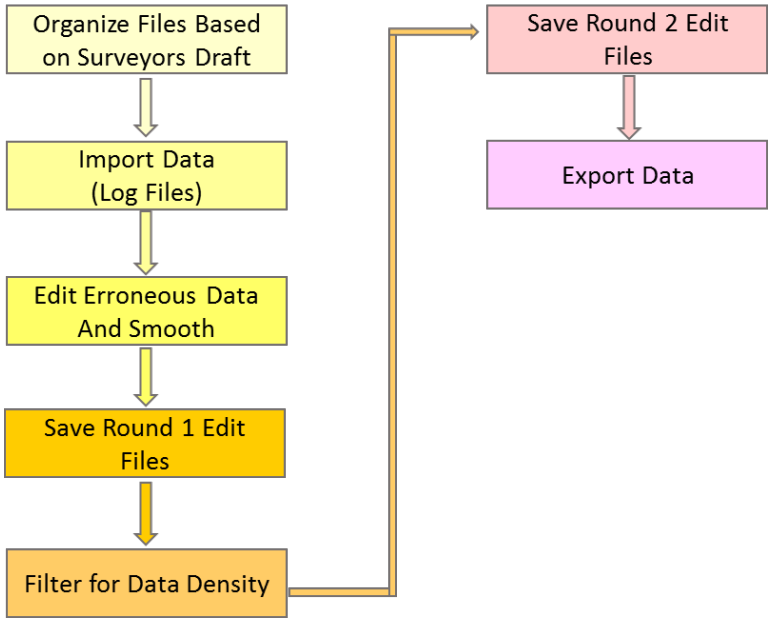


Figure 10. HYPACK topographic data processing workflow

4.0 Mobile Laser Scanner Data Acquisition and Processing

4.1 Equipment

4.1.1 Vehicle and Scanning Equipment

Mobile Laser Scanner (MLS) topographic data were collected using a RIEGL VMZ-400i 3D laser scanning system. The MLS was mounted on a Kubota UTV approximately eight feet above the terrain (Figure 12). This system is aided by an internal navigation and motion reference unit. The MLS and POS LV were integrated into RiAcquire, a comprehensive software suite utilized for survey acquisition. POSView was utilized to monitor real-time GNSS health as well as log all navigation/attitude data for post-processing. The MLS was set up to scan the human eye field of view (from 70-130 degrees) at a scanning resolution of 0.180° at 300 kHz measurement rate and a high-speed scan rate. Additionally, for most of the survey, the MLS was set up in radar mode, therefore, the laser rotates a full 360° during data collection.



Figure 11. The Kubota Sidekick UTV with the custom mount for MLS acquisition.

4.1.2 Vertical and Horizontal Control Equipment

Horizontal, vertical, and vessel attitude for MLS data were provided by the VMZ-400i system, recorded in POS-LV, and corrected in post-processing using Applanix POSPac software. This system provides roll and pitch accuracy to 0.01°, heading to 0.02° (with a 2m antenna baseline), and heave accuracy to 5 cm or 5% (whichever is greater).

4.1.3 Hardware Systems Inventory

Table 11. MLS Hardware Systems Inventory

Hardware Equipment	Manufacturer	Model
Laser Scanner	Riegl	VZ-400i 3D
Acquisition CPU	Dell	Rugged Laptop
Cellular Internet	Verizon	Jetpack 5G
Inertial Motion Unit (IMU)	Riegl	VMZ-400i
Position Compute System (PCS)	Riegl	VMZ-400i
Primary GNSS Antenna (aft)	Trimble	AT1675-540TS
Secondary GNSS Antenna	Trimble	AT1675-540TS

4.1.4 MLS Acquisition and Processing Software

Ri-Acquire software suite was used to collect MLS data and provide real-time QC and QA of the MLS data.

POS-LV software by Applanix was used with the Reigl VMZ-400i system. The software provides a tightly coupled integration of the attitude measurements recorded by the IMU and the position measurements recorded by the GNSS. RiAcquire allowed the survey technician to monitor the attitude and positioning accuracy throughout the survey. RiAcquire also logged a trajectory file using POS-LV as a pass-through software which contained all error estimates for attitude and positioning.

The POSPac MMS software by Applanix was used to post-process attitude and navigation data collected in RiAcquire. A smoothed best estimate of trajectory file was generated using the initial trajectory file corrected using PPK-GNSS solutions via bast station static data. Additionally, RiProcess was used to integrate the post-processed GNSS solution, add additional motion corrections, export LAS files, and manipulate and process the laser scanner data in both 2D and 3D. ArcGIS Pro was also utilized for all survey area maps, coverage extents, and final chart products, as well as for manipulating and filtering LAS files.

Table 12. MLS Software Systems Inventory

	Software	Version
Data Acquisition	Ri-Acquire	2.6.2.220600
	LV POSView	11.0
Data Processing	ArcGIS Pro	3.3.0
	POSPac MMS	8.7
	Ri-Process	1.9.5

4.2 MLS Data Acquisition

Pre-survey checks were conducted to ensure the laser was mounted properly. Integrated systems were tested at Geodynamics facility prior to on-site mobilization.

At the start of the survey day, a series of pre-survey protocols were run to aid in QC and to determine any possible errors/issues prior to surveying. The POS-LV installation parameters located under the installation settings of the POS-LV were all checked prior to enabling Ethernet Logging of POSPac data.

All laser data acquisition was completed using RiAcquire software. Data acquisition was performed at speeds of approximately 7 knots along the main beach face, between the bottom of the first dune and the waterline. The RiAcquire data acquisition software produced a constantly updated chase view and coverage tracking, which allowed for real-time monitoring of data coverage. Data displays in RiAcquire software and POS-LV were used to monitor all survey parameters and data quality.

4.3 Data Processing

4.3.1 Processing Workflow

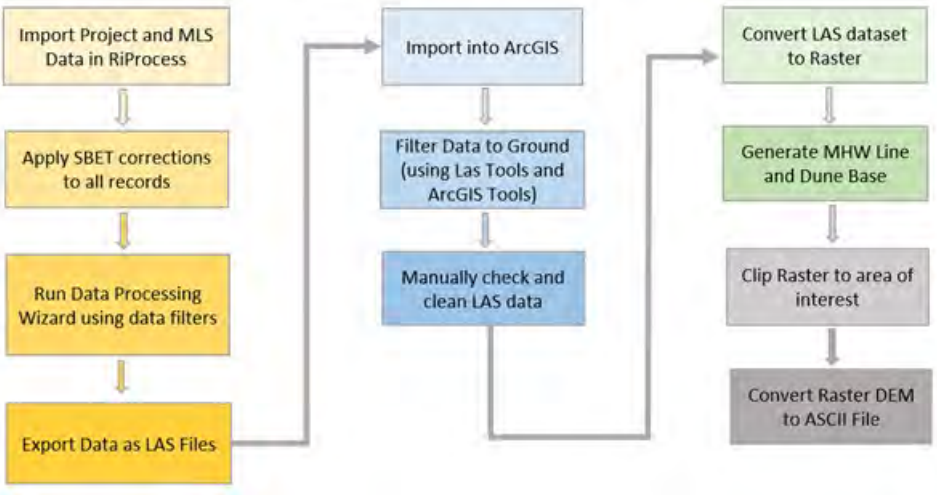


Figure 12. MLS data processing workflow

RXP files collected in RiAcquire were imported into RiProcess, the main MLS processing software. In RiProcess, the post-processed navigation and position data (SBET file) were incorporated, and additional motion corrections were applied. Filters were then run on the data to remove noise and excess data (intensity filters, range filters, reflectance filters, and an isolated point classifier). Once major noise and artifacts were removed, the files were exported into a LAS format. Next, the LAS files were imported into ArcGIS Pro and a combination of LAS tools and internal ArcGIS Pro tools were utilized to bring the data to the ground (removing people on the beach, structures, vegetation, etc.). A DEM surface was then generated in ArcGIS Pro using the LAS to Raster tool. This surface was then used to delineate the 1.5 ft MHW contour.

4.3.2 Corrections to Laser Data

4.3.2.1 Sensor Offsets

The vehicle offsets are measured with respect to the vehicle's reference point, located at the top center of the IMU. Vehicle offsets are input to POSView ensuring accurate merging of the IMU data with the MLS data.

4.3.2.2 Positioning Correctors

The PCS software computes velocity, roll, pitch and true heading from the accelerometer and gyro outputs. These sensed accelerations and rates of rotation are calculated into measurements of velocity, heading, and track of the vessel through complex algorithms. When the GNSS Azimuth Measurement Subsystem (GAMS) is online, positional solutions were being received from five or more satellite fixes with a Positional Dilution of Precision (PDOP) equal to or less than three. When these conditions were not satisfied, the GAMS solution becomes dormant. The GAMS program continues to track satellites while in this state but does not process the phase-differential corrections real-time. Verification of a prior GAMS system calibration was conducted at the start of survey to ensure the correct values were used for acquisition.

5.0 Topo-Bathy Profile Merging and MHW Contour Development

5.1 Topo-Bathy Merging

Topographic and bathymetric portions of the profiles were merged in HYPACK following independent processing procedures. Overlap was assessed and cleaned for consistency where necessary.

Rigorous QA-QC assessments were performed on the final topo-bathy profiles to ensure accurate data products. For topographic data in the less variable dune areas, current data was overlaid with previous data, and the horizontal and vertical alignment was evaluated. For hydrographic data in the furthest offshore sections, elevations were compared where notable change is unlikely. Profile elevation data was generated in formats outlined by the SOW.

Completed profiles for Wallops Island are shown in Figure 14. The following maps illustrate the depths and extents of the topo-bathy profiles. The merged topo-bathy profiles were examined one by one to review the overlap of topographic and hydrographic data to guarantee reliable surf zone data and overlap (Figure 15).

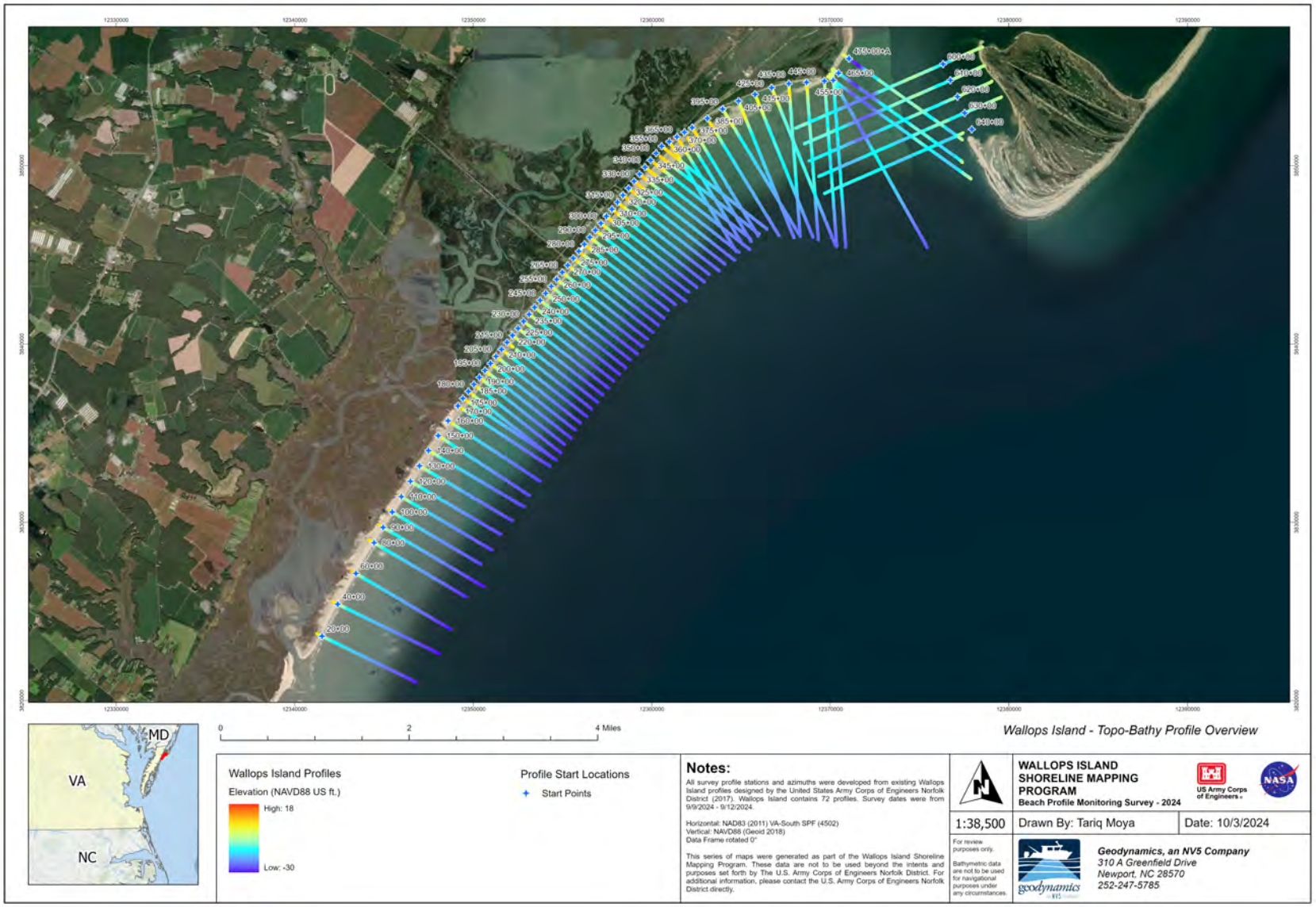


Figure 13. Topo-bathy profiles for Wallops Island.



Figure 14. Typical Topo-Bathy overlap.

5.2 Beach-Wide DEM

A generalized beach-wide DEM was created for this project along a specified survey reach (profile stations 180+00 to 475+00) (Figure 16). The extents of the survey were determined by the client. The DEM was generated at a 1 ft resolution and was derived solely using the MLS data. The laser beach-face DEM was clipped to the MHW contour line and dune base and then exported as an Esri ArcGrid file.



Figure 15. Beach-wide DEM for Wallops Island and 1.5ft MHW Contour. DEM utilizes MLS data.

5.3 MHW Contour

The MHW contour was created in ArcGIS using the "Contour" tool. A contour was made for the MHW value (1.5 ft NAVD88) and delineated from the MLS data. The contour was then examined for breaks, splits, or other inconsistencies created during the gridding process using manual editing techniques within ArcGIS. Once the 1.5ft MHW contour was extracted from the MLS dataset (encompassing stations 180+00 to 475+00), it was then combined with the MHW contour which was extracted from the finalized profile data (stations 20+00 to 175+00). The ArcGIS "Merge" tool was used to join the two datasets together to form one seamless contour line. This was done to ensure that the entire 1.5 ft MHW contour was encapsulated throughout the entire survey area. Landward extents for the dataset were delineated based on LiDAR coverage.

5.4 Topo-bathy Profile and MLS Overlap Comparison

A statistical comparison was made between the MLS DEM and the finalized profiles. In ArcGIS the MLS-derived DEM were extracted to the finalized profiles using the "Extract Values to Points" tool. An elevation difference was then calculated between the overlapping profile data points and the beach-wide DEM's raster values. The data showed good agreement.

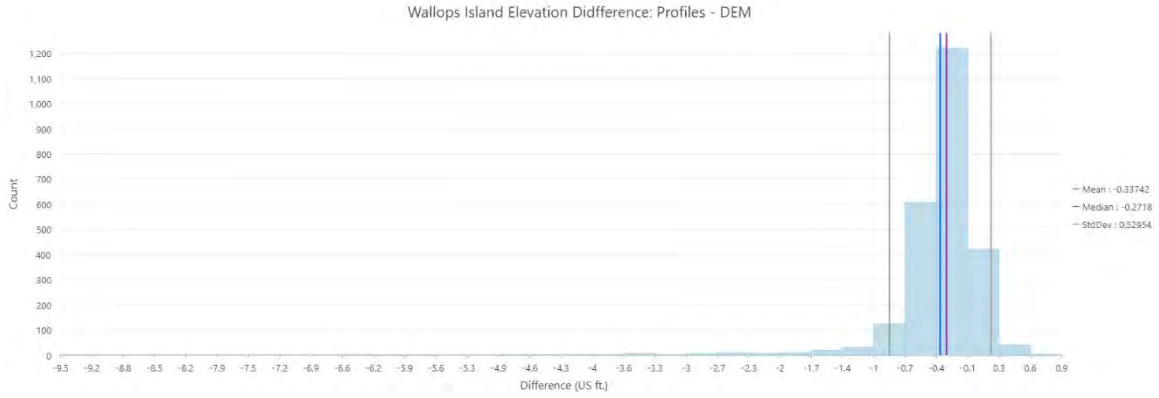


Figure 16. Statistical comparison of the Wallops Island Profile data to the MLS-derived DEM.

5.5 Crossline Validation

An additional means of validating hydrographic datasets is comparing two perpendicular datasets. This method resolves any potential dimensional control offsets in the vessel configuration that go unnoticed when collected in the same direction repeatedly. Numerous crosslines were collected for this survey. Figure 18 represents a crossline collected at the southernmost end of the survey area, in the offshore portions of profiles for Wallops Island. The crossline shows excellent agreement with the profile, validating the vessel configuration and software setup.

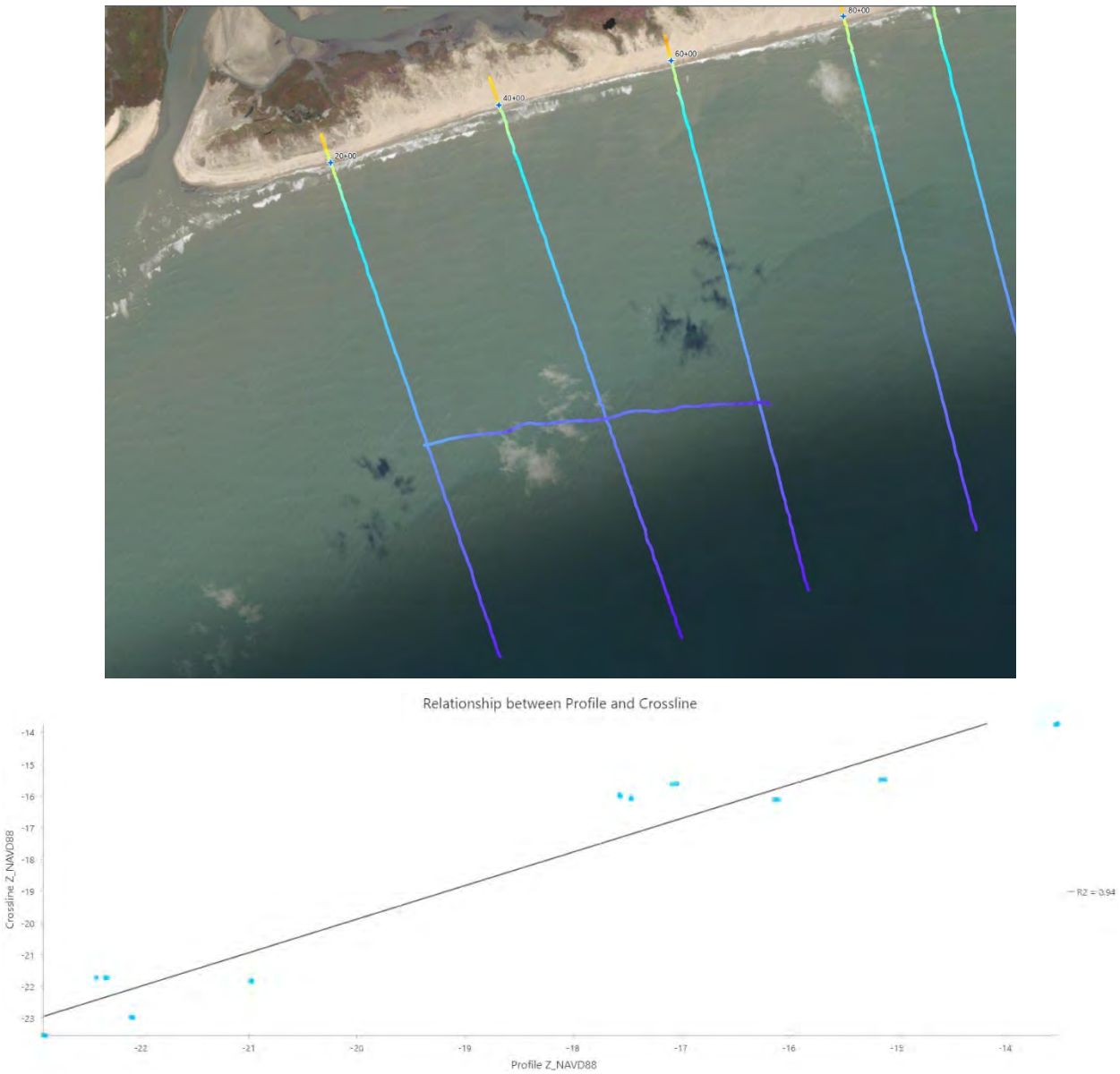


Figure 17. The top image displays a crossline collected off Wallops Island for this survey. The bottom graph displays the crossline statistics generated in ArcGIS Pro for this example.

Unnamed Shoal A Multibeam Survey

6.0 Introduction

6.1 Project Description

Geodynamics was also contracted to perform a comprehensive multibeam survey (100% coverage) of Unnamed Shoal A, located approximately 11 miles offshore of Chincoteague inlet. This work utilizes hydrographic surveying techniques that meet or exceed the criteria outlined in the Bathymetric Survey Requirements for BOEM Marine Minerals Lease Areas (borrow areas), Dec 2023. The bathymetric data were used to generate a 0.5m gridded surface of the seafloor.

6.2 Survey Area

The survey was conducted on Unnamed Shoal A located approximately 11 miles offshore of Chincoteague Inlet. The provided coordinates for the borrow area are as follows:

Easting	***Northing***
12427773.52	3847107.91
12435765.58	3853885.92
12437525.96	3850699.86
12429716.01	3843592.24

The survey area was extended at least 100 m past the specified boundary of the borrow area.

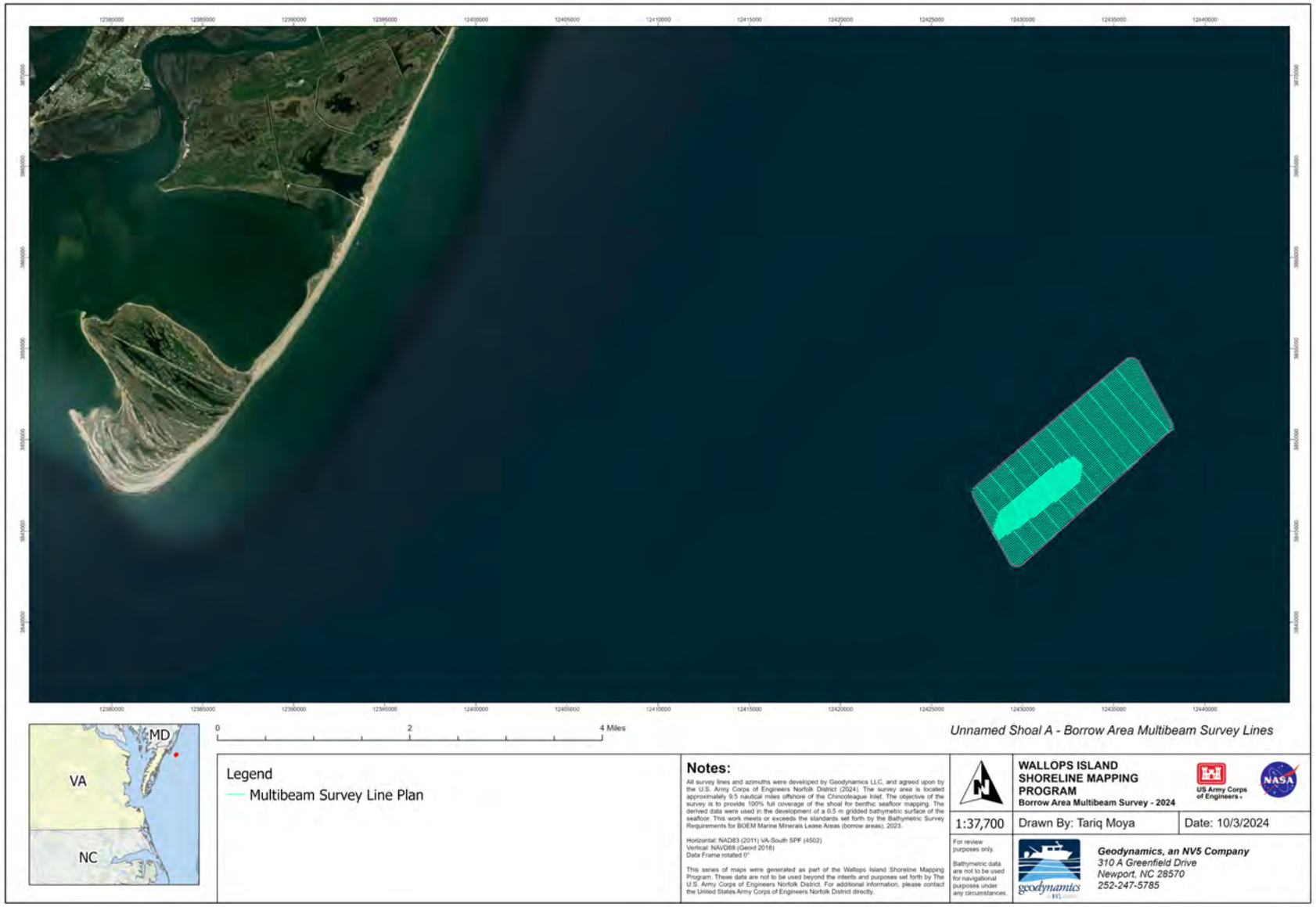


Figure 18. Survey Area for the Multibeam Borrow Area Survey

6.3 Survey Logistics

Data acquisition occurred between October 15th and October 23rd, as weather and sea conditions allowed.

Table 13: Summary of survey activities

Date	Julian Day	Activity
10/15/2024	289	Crew mobilized from Geodynamics to Chincoteague, VA. Established survey control and collected MBES data over USACE data and profile data as a means of QC for our vessel systems.
10/16/2024	290	Hydro team on standby for weather
10/21/2024	295	Hydro team began MBES acquisition of the borrow area
10/22/2024	296	Hydro team completed MBES acquisition of the borrow area, as well as conducted QC verification lines of pre-existing USACE data and over Wallops Island offshore profile data.
10/23/2024	297	Survey crew demobilized from Chincoteague, VA to Geodynamics.

6.4 Survey Conditions

Figure 20 displays graphs of NOAA-predicted and verified tides for Ocean City Inlet, MD (Station ID: 8570283), surface wind, and air temperature throughout the survey.

10/15/2024 – 10/22/2024: Multibeam Borrow Area Survey

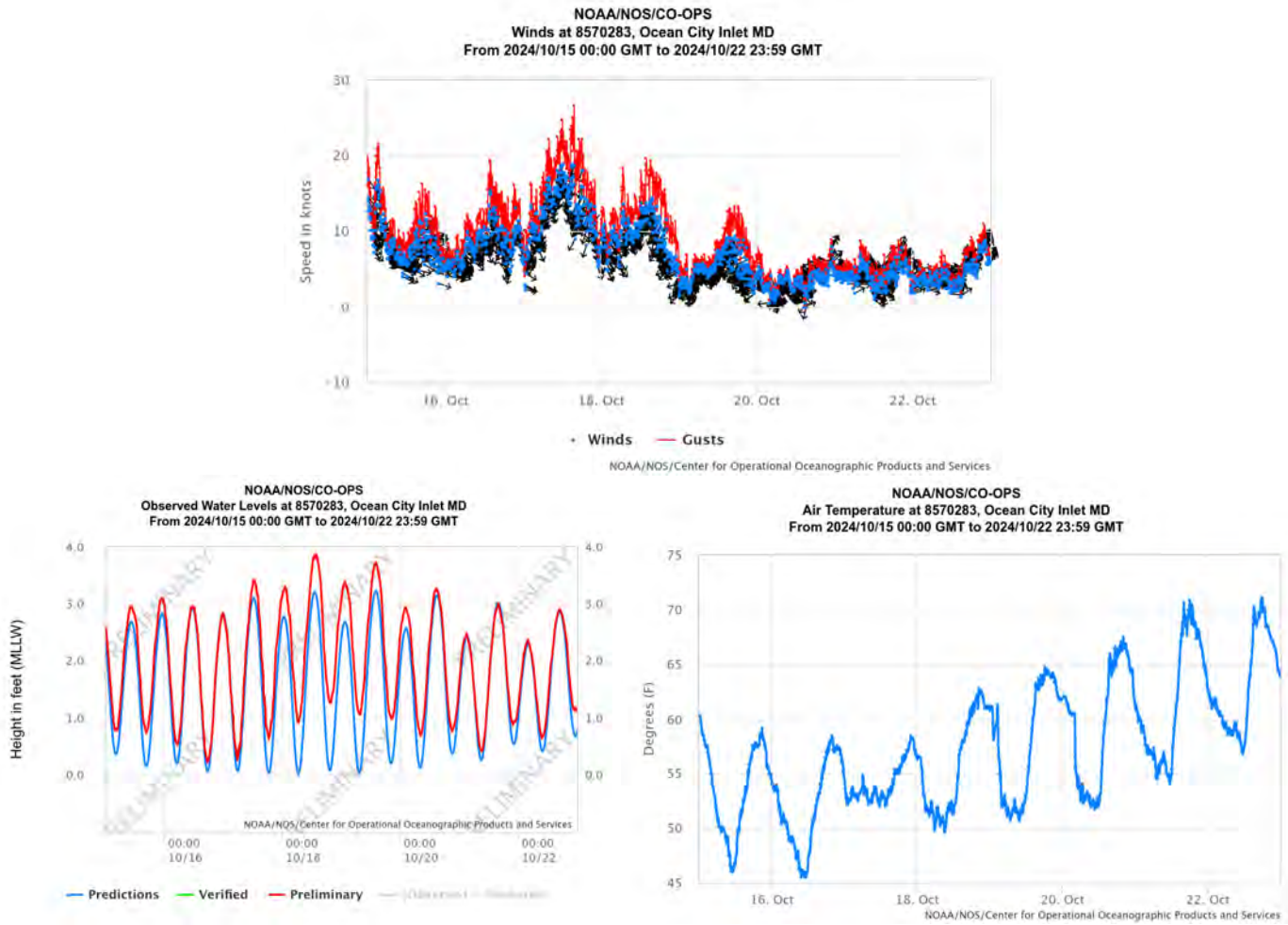


Figure 19. Atmospheric and tidal records for survey days.

6.5 Survey Personnel

All survey crew throughout the surveys were provided by Geodynamics. These personnel contributed to the vessel mobilization, data collection, vessel demobilization efforts, processing, reporting, QA-QC, and final certification.

Table 14. List of Survey Personnel and Responsibilities

Survey Participant	Title	Affiliation
Dave Bernstein	VP of Hydrospatial Operations / CH / GISP / PLS	Geodynamics
Kurt Baker	Program Manager	Geodynamics
Brandon Barnette	Acquisition Manager	Geodynamics
Kyle Neumuller	Processing Manager	Geodynamics
Tariq Moya	Project Lead / Lead Processor	Geodynamics
Davis Batten	Field Surveyor / Vessel Operator	Geodynamics
Michael Amoah	Data Processor	Geodynamics

6.6 Navigation and Positioning

Horizontal and vertical corrections were provided by Trimble's CenterPoint RTX real-time GNSS correction service. Positioning and navigation data was logged from the onboard POS MV and post-processed using Applanix POSPac software to further improve positional accuracies. Due to cell coverage and distance from shore, cellular or radio based RTK corrections were not an option for the borrow area MBES survey.

7.0 Multibeam Data Acquisition and Processing

7.1 Equipment

7.1.1 R/V Sounder

The R/V Sounder was the primary survey platform for offshore multibeam data acquisition (Figure 21,Table 15). The antennas and survey instruments on the R/V Sounder were accurately measured prior to mobilization. These offsets and orientations remain valid until the vessel/sensor positions are reconfigured. Verification surveys are performed annually and as necessary on the survey vessels to calibrate the survey systems and confirm the alignment of offsets. Verification surveys were performed during mobilization of Sounder prior to the start of the survey.



Figure 20. R/V Sounder

Table 15. R/V Sounder Vessel Specification.

Dimensions:	23' x 9' x 1.2’
USCG:	Designated Research Vessel
Flag:	U.S.
Registry:	North Carolina
Reg No:	NC 8356 EY
Tonnage:	1
Lab space:	3-Sided Console
Lavatory:	N/A
Max Speed:	35 knots
Min. Survey Speed:	2.5 knots
Propulsion:	1 x 300HP Yamaha Outboard Motor (2022)
Auxiliary Power:	12v DC battery banks with inverter
Fuel Cap.:	85 gallons
GPS:	Simrad
Magnetic Compass:	n/a
Radar:	n/a
Autopilot:	Simrad
VHF:	ICOM
Internet:	Pepwave BR1 Pro

7.1.2 Hardware Systems Inventory

Hardware utilized throughout the project can be seen in Table 16.

Table 16. Multibeam Hardware Sytems Inventory.

	Hardware Equipment	Manufacturer	Model
Echo Sounding (MBES)	Sonar Transducer	Kongsberg	EM 2040P-SV MkII
	Echosounder Topside Unit	Kongsberg	EM2040P
	Operator Station	Geodynamics Built	"Custom"
Attitude Positioning	Inertial Motion Unit (IMU)	Applanix	IMU-38
	Position Compute System (PCS)	Applanix	POS MV 320 v5
	Primary GPS Antenna (port)	Trimble	GA830
	Secondary GPS Antenna (starboard)	Trimble	GA830
	Cellular Internet (for VRS)	Verizon	Pepwave BR1 Pro
Sound Speed	Surface Sound Velocimeter	AML Oceanographic	Micro-X
	Sound Profile Velocimeter	AML Oceanographic	Base X_2

7.1.3 Sonar Equipment

Multibeam survey data was collected with a Kongsberg EM2040P system. The EM2040P system consists of a Kongsberg EM2040P topside unit and an EM2040P-SV MkII sonar head (Figure 22, Figure 23). The EM2040P sonar head was over-the-side-mounted on the R/V Sounder using a universal sonar mount (USM) Hightower. Additional specifications for the EM2040P-sonar head are listed below in Table 17.

Table 17. Kongsberg EM2040P-SV-MkII Specifications.

Frequencies.	200kHz – 700kHz
Resolution	10.5mm
Maximum ping rate	50 Hz
No. of beams per ping	512 (Single Swath) – 1024 (Dual Swath)
Depth Range	1m – 550m (at 200kHz)
Beam Pattern	Equiangular, Equidistant, High Density, Ultra-High Density
Swath Coverage Sector	170°
Max Coverage	830m (at 200kHz)



Figure 21. Kongsberg EM2040P Topside Unit mounted on the R/V Sounder.



Figure 22, Kongsberg EM2040P-SV MkII Multibeam Echo Sounder mounted on R/V Sounder.

7.1.4 Software Systems Inventory

Software utilized throughout the project can be seen in Table 18.

Table 18. Multibeam Software Systems Inventory

	Software	Version
Data Acquisition	Hypack	2022 Q3
	POSView	11.40
	Sailfish	1.4.8.0
	SIS	4.3.2
	Sound Speed Manager	
Data Processing	ArcPro	3.3.2
	MS Office	365
	Caris Hips and Sips	11.4.26
	Sound Speed Manager	
	POSPac	9.1

7.1.4.1 Data Acquisition Software

The HYPACK software suite was used during survey preparation to create survey line plans and evaluate the overall survey scheme. The line plan was created in HYPACK using line spacing that ensured all coverage requirements were met as outlined in the SOW. HYPACK HYSWEEP was also used during the survey to provide a navigation display and coverage tracking.

The Kongsberg Seafloor Information System (SIS) software was used as a start-up and user interface to establish communications with the echosounder, check/verify and monitor essential echosounder settings, and provide real-time coverage, record all bathymetry and position data. The POSView software by Applanix was used with the POS MV system. The software provides the interface to view, monitor, and record tightly coupled integration of the attitude measurements from the IMU and position and heading measurements recorded by the GNSS. The recorded POSPac file which contained all attitude, positioning, heading, and error estimates provides a method to post-process attitude and navigation data in the event of RTK-GNSS cycle slips.

ArcMap and ArcGIS Pro are complete Geographic Information Systems (GIS) software packages. All survey area maps, coverage extents, and final chart products were created using ArcGIS software.

7.2 Multibeam Data Acquisition

Bathymetry was collected on the R/V Sounder with an over-the-side deployment. The R/V Sounder collected bathymetry with a Kongsberg EM2040P system. The precise positioning of the MBES head to the IMU was established during dimensional control surveys in September 2022. The patch test and verification surveys were conducted to ensure self-alignment (sensor bias with respect to heading, pitch, and roll errors) as well as comparison against previously validated bathymetric data, both internal (Geodynamics) and external (USACE).

Throughout the survey, multiple dynamic factors were monitored to ensure accurate and precise bathymetric data. The POS MV provided real-time vessel attitude, tide, and water levels for both real-time monitoring and post-processing. Sound velocity profiles were collected via an AML 3 LGR sound speed profiler (Figure 24), processed in Sailfish, and loaded directly into SIS for accurate beam forming and sound speed correction during acquisition. Sound speed near the surface was monitored in real-time at the sonar heads using an AML Micro SV. When the sound speed at the head changed by more than 2 m/s from the profile collected, another profile was acquired. All attitude, position, SV, and sounding data were recorded in SIS.



Figure 23. AML 3 LRG Sound Speed Profiler.



Figure 24. Over-the-side, MBES deployment system on R/V Sounder.

7.3 Multibeam Data Processing

7.3.1 Processing Workflow

All bathymetric survey data were processed using CARIS Hydrographic Information Processing Systems (HIPS) and Sonar Information Processing System (SIPS) software and gridded in a Combined Uncertainty and Bathymetry Estimator (CUBE) surface at a final resolution of 0.5 m. Figure 26 illustrates the workflow in multibeam sonar data processing.

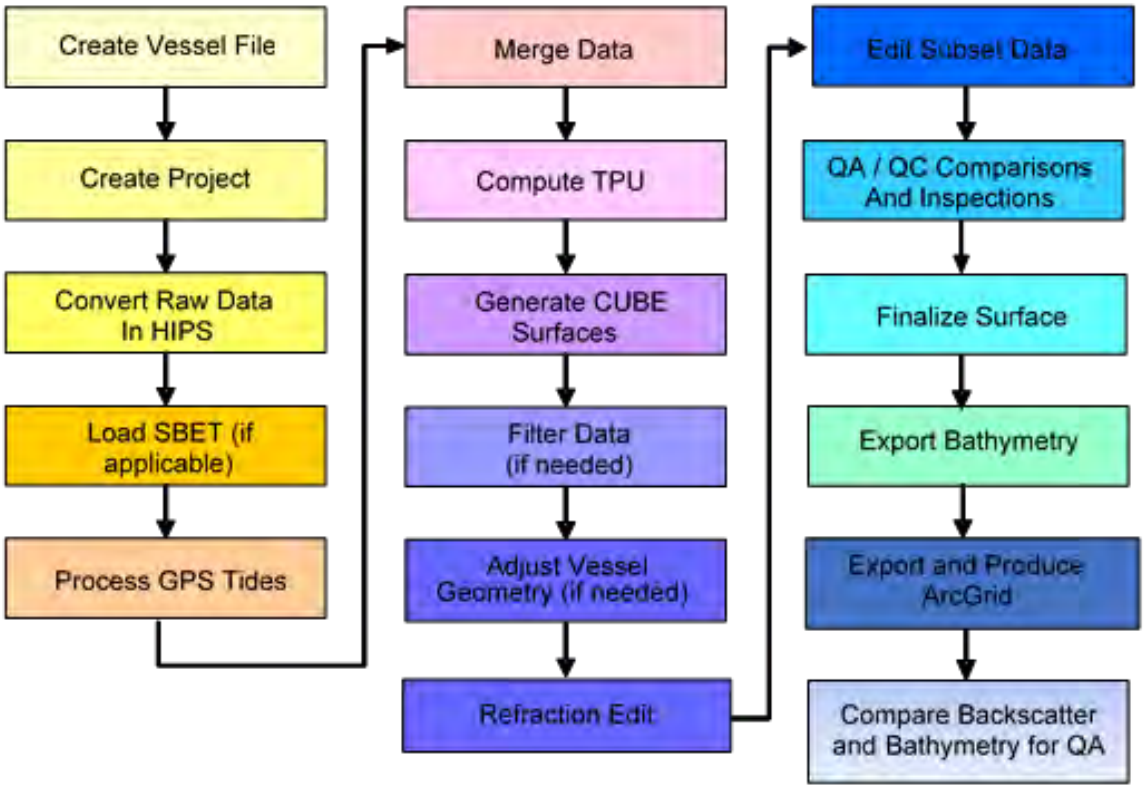


Figure 25. Major Steps in Bathymetric Data Processing

The CARIS vessel configuration file, called the HIPS Vessel File (HVF), is an Extensible Mark-up Language (XML) file that can describe details of the installation and calibration of the instruments installed and their precise positioning relative to each other and the vessel's reference frame. Embedded information within the HVF is used by multiple processes in CARIS to merge sensor offsets and calculate sounding uncertainty. For this project, measured sensor offsets and calculated patch test offsets were applied in SIS and POSView software prior to acquisition, therefore, the "apply" option for the offset values in the HVF was set to "no." However, sensor offsets are still placed in the HVF as well as other manufacturer specifications to properly account for the total propagated uncertainty (TPU). The raw multibeam bathymetry data collected in SIS provides rough estimates of water depth and bathymetry. To view the raw data and water levels as it was collected, a zero-tide must be applied which neglects all tidal influences on depths. Corrections applied to the raw data in real-time included sound speed corrections from the most recent and appropriate sound speed cast, as well as initial heave,

pitch, roll, and heading corrections from the POS MV. These corrections become fully integrated during the processing steps.

Tidal observation data must be loaded for every track line before the soundings can be viewed as corrected depths and positions, correcting for astronomical and meteorological changes in water levels. Real-time tidal and water level changes were corrected by computing “GPS Tides” in CARIS. This procedure uses the GNSS height and vessel heave to dynamically deduct the vessel’s vertical displacement through the water column as well as correct for the astronomical changes in water level heights throughout the survey.

A CUBE surface is a model that uses multiple hypotheses to represent potential depth variances along the seafloor based on a TPU that is calculated in CARIS. The CARIS TPU module computes horizontal and vertical uncertainty values, requiring user-entered offsets, estimated error values for the tide, sound speed measurements, and published errors from equipment specifications. TPU calculations are used in the CUBE algorithm to calculate a surface where ‘nodes’ or ‘tiles’ are assigned to soundings with the lowest vertical uncertainties and are internally self-consistent. Upon initial QC inspections and reviews for targets or features on the seafloor, a combination of swath and surface filters was executed in CARIS to reduce manual editing.

The final stage of multibeam processing is to manually “clean” or remove erroneous data inherent to all echo sounders. This is commonly due to aeration, multiples, outer swath noise, or sound velocity artifacts. Soundings were edited using a combination of Subset Editor and Swath Editor. Swath Editor provides the processor with the ability to review and clean individual lines, providing a slice that preserves both large and small-scale features in the swath and reveals true outliers. The erroneous data were flagged as rejected so as to not be included in the final surface. The Swath Editor also provides a means for reviewing the navigation and attitude data for spikes or gaps. Subset Editor was used as a means of reviewing the data and cleaning erroneous soundings. Overlapping lines are loaded into the Subset Editor, providing the processor with a confidence check for detecting features, assessing systematic errors, flagging fliers, and reviewing rejected soundings. This technique provides the user flexibility to review the data in both 2-dimensional (2D) and 3-dimensional (3D) views. Surfaces were constantly recomputed and reviewed for remaining fliers and cleaned, as necessary.

The 0.5 m CUBE surface was exported after final QC review as a floating point GeoTiff raster in NAD83 (2011) VA State Plane Meters, NAVD88 (m), and converted to VA State Plane Survey Feet and NAVD88 survey feet and is provided as a raster dataset compatible in ArcGIS Pro 3.0 software. A map visualizing the bathymetric surface can be seen below in Figure 27.

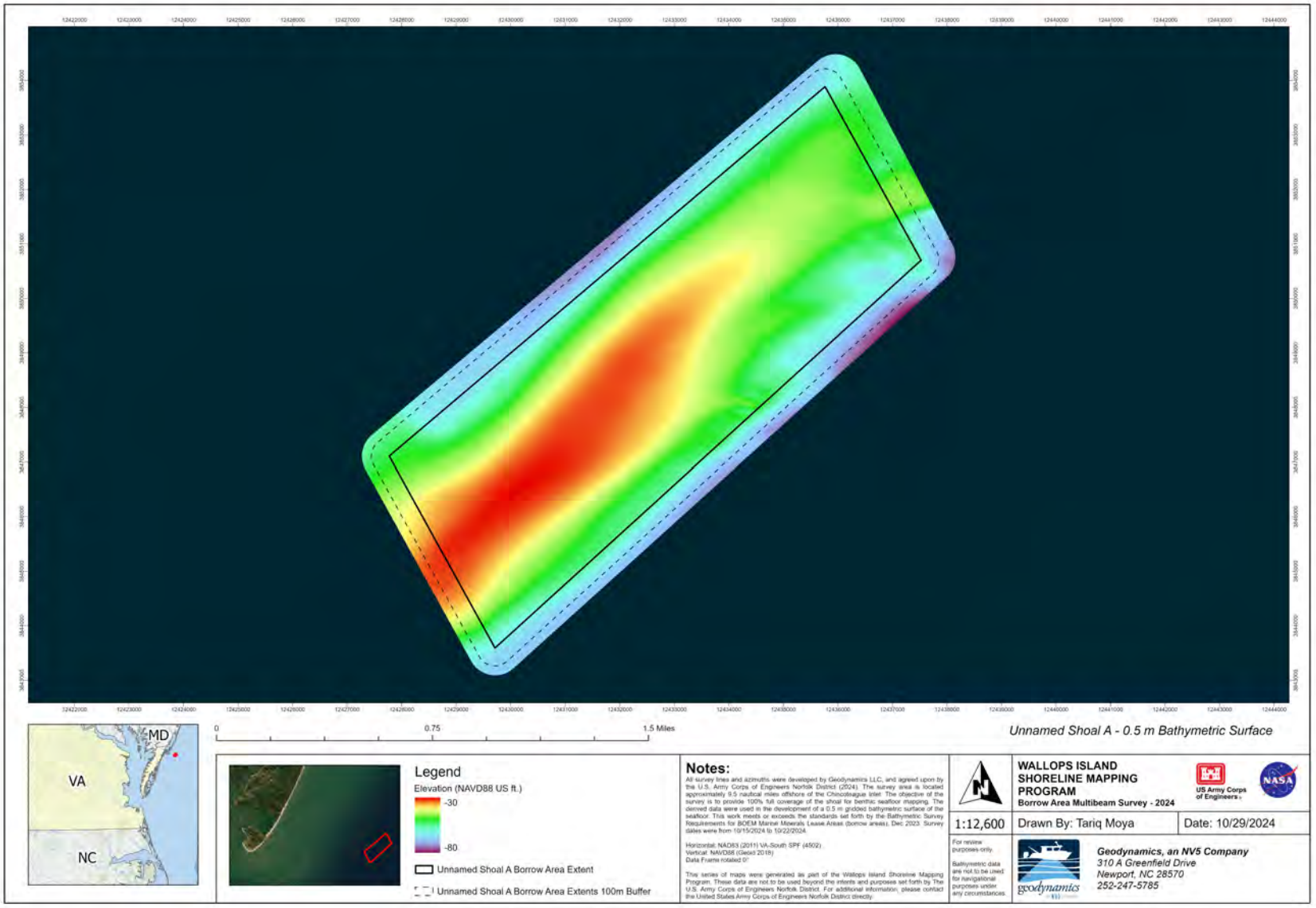


Figure 26. Gridded Bathymetric Surface

8.0 Concluding Remarks

8.1 Beach Monitoring Survey

Survey data collected for the Wallops Island Shoreline Monitoring and Analyses Program project meets and exceeds the requirements outlined in the project SOW, which includes utilizing survey techniques to meet or exceed the criteria for *Navigation and Dredging Support Surveys of Hard Bottoms* as outlined in the U.S. Army Corps of Engineers (USACE) Hydrographic Surveying Manual, EM 1110-2-1003 and in the CETN II-38 *Beach and Nearshore Survey Technology* Technical Note.

The topographic-bathymetric profiles along Wallops Island showed excellent agreement with prior surveys. All attempts were made to meet topographic and hydrographic extents for the most recent survey, the Spring 2019 annual survey. Any notable obstructions causing missing data (>10ft), or large offline distances (differing from previous years) are documented. For further questions about these and other obstructions, please refer to the 2024 Obstruction Report.

The application of MLS data to collect mid-beach portions of data, generate the MHW contour, and aid in beach-wide DEM development was successful and improved the overall product accuracy. This dataset will provide a thorough means to assess shoreface erosion in the following years and in the event of a major storm. It should be noted that landward of the dune base may contain some vegetation and coastal seawall structures and therefore, should not be used in volumetric analysis. However, the beach face seaward of the dune base is adequate for such use. Also, on the north end of Wallops Island in the vicinity of Pad 0B, the mean high water (MHW) line has migrated west to the revetment, and the beach is now submerged at low tide, therefore no LiDAR data was able to be collected in the approximate area of profiles 220+00 to 250+00.

On Wallops Island, certain sections were closed for hazardous operations, movement of military ordinance, and military G/ATOR testing operations and could not be surveyed. As a result, no photographs could be taken of these obstructions for the sake of confidentiality as not to reveal the specifics of classified government property. These obstructions can be found on profile 265+00. There were also several profiles where extents could not be met or gaps in the data occurred due to natural phenomena, such as large vegetation walls, and exposed rocky outcrops to the extent that topographic data could not be collected. These obstructions can be found on profiles: 175+00, 180+00, 185+00, 190+00, 195+00, 205+00, 235+00, 245+00, 300+00, 305+00, 320+00, 325+00, 335+00, 340+00, 345+00, 350+00, 355+00, 360+00, 365+00, and 375+00.

Several other obstructions were caused by various man-made structures such as rock walls, seawalls, breakwaters, facility fences, ongoing construction, buildings, and towers. These obstructions can be found on profiles: 200+00, 210+00, 215+00, 220+00, 225+00, 230+00, 235+00, 240+00, 245+00, 250+00, 255+00, 260+00, 265+00, 270+00, 275+00, 280+00, 285+00, 300+00, 305+00, 310+00, 315+00, 320+00, 325+00, 345+00, 355+00, 360+00, and 365+00. Three obstructions were also filed for areas at the southern end of Assateague Island where hydrographic extents could not be met due to the shoaling of the area. These obstructions can be found on profiles: 465+00, 475+00+A, 600+00, and 640+00. There are also gaps in the dataset caused by breakwaters. These obstructions can be found on profiles: 215+00 and 285+00.

8.2 Borrow Area Multibeam Survey

The comprehensive multibeam survey of the Unnamed Shoal A borrow area was completed. As outlined in the official SOW, the 100% coverage requirements were met yielding a clean dataset.

The survey data collected, extended at least 100m past the specified borrow area boundary. For QA/QC measures and to ensure the accuracy of all survey systems on the R/V Sounder, QA/QC verification lines were run over existing USACE data in the Chincoteague Inlet as well as over Wallops offshore beach profile data in areas where the two datasets overlapped. For the SBES portion of the beach monitoring survey, Leica Smartnet was used as the primary source of RTK-GNSS corrections source via an NTRIP client. During the first day of data collection, it was determined that the Trimble RTX GNSS Network would be a better source for RTK-GNSS corrections due to the Smartnet's connection limitations while surveying offshore. Verification lines were again run over the existing USACE data as well as the offshore beach profile lines for Wallops Island to ensure accuracies and roll offsets had not changed, as well as check for any discrepancies because of using the two different corrections sources. As another form of QA/QC "Roll Lines" were run at the end of each day of survey within the survey area. Roll lines are lines that run in a reciprocal direction over pre-existing data, this data is then brought into Caris HIPS and SIPS where comparisons could be made. After processing, the final surface was exported at a 0.5 m resolution. All observed depths ranged from -30 to -78 ft NAVD88.

8.2.1 Multibeam Data Quality Results

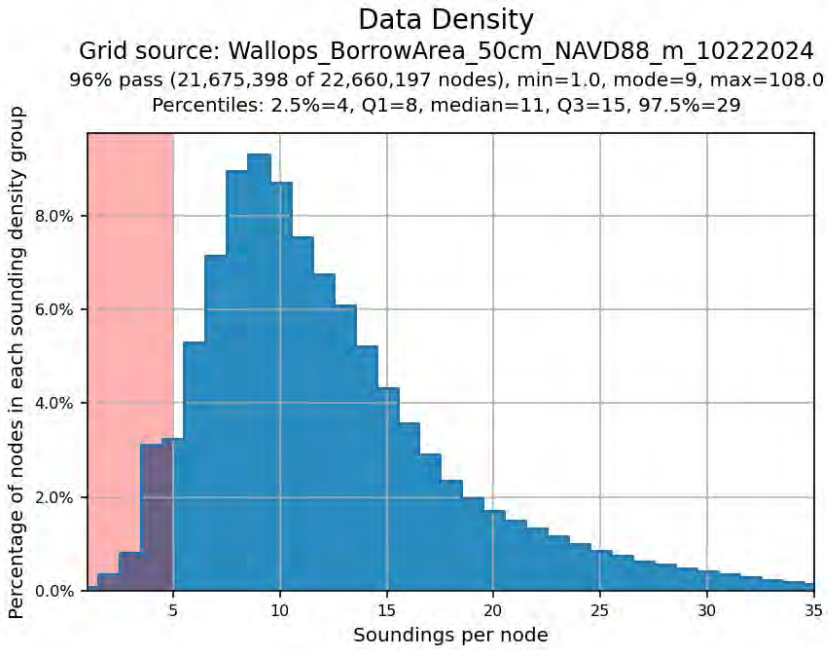


Figure 27: Overall data density exceeds project specifications.

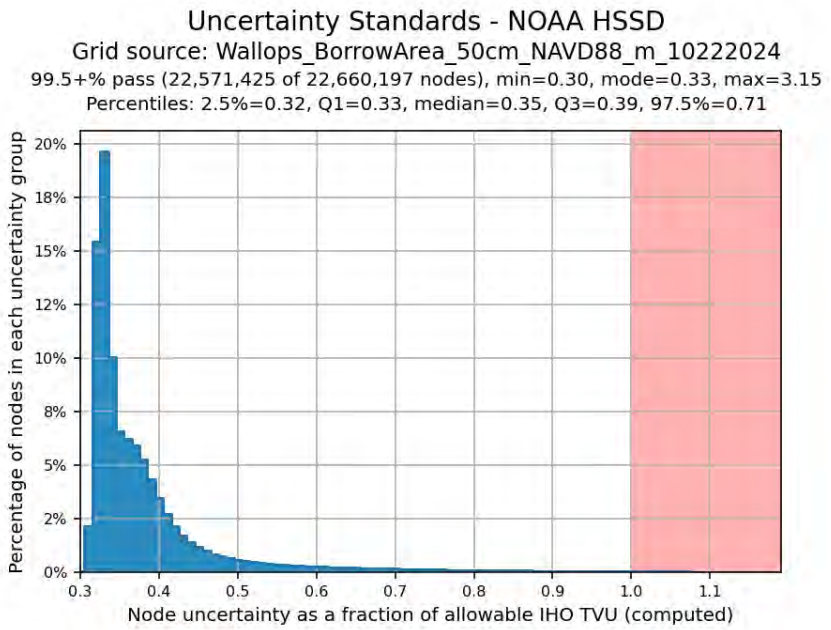


Figure 28: Overall uncertainty standards exceeded project specifications

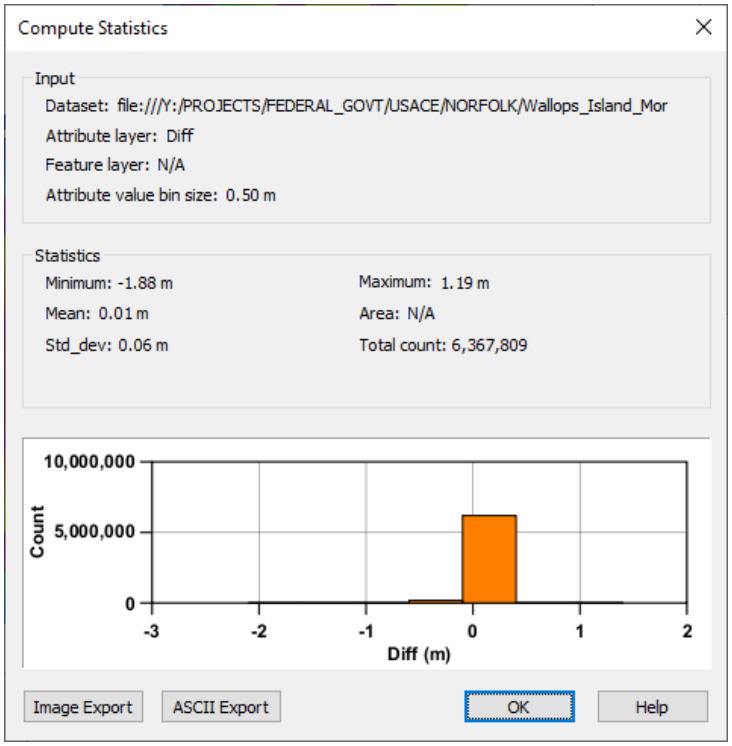


Figure 29: Mainscheme to crossline comparison were within TVU specifications for the project.

APPENDIX A: SURVEY ACTIVITY LOGS

Daily Survey Field Notes

Date:	9/8/2024	**Day of Year:**	252	
Time SOS (local):	10:30	**Time EOS (local):**	18:00	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Wallops Island			
Hydro Crew:	Sam Bradtke	Davis Batten		
Topo Crew:	Tariq Moya	Owen Reuther		

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	0 - 0.5 ft
Wind Speed:	5-10 KT	**Chop:**	0 - 0.5 ft
Wind Direction:	SSE	**Temp:**	60-70 F
Temp:	70-80 F		

Survey Activities

Control

N/A

Topo

Survey team mobilized from Geodynamics in Morehead city to Chincoteague, VA.

Hydro

Survey team mobilized from Geodynamics in Morehead city to Chincoteague, VA.

Daily Survey Field Notes

Date:	9/9/2024	**Day of Year:**	253	
Time SOS (local):	6:00	**Time EOS (local):**	20:30	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Wallops Island			
Hydro Crew:	Sam Bradtke	Davis Batten		
Topo Crew:	Tariq Moya	Owen Reuther		

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	0 - 0.5 ft
Wind Speed:	5-10 KT	**Chop:**	0 - 0.5 ft
Wind Direction:	SSE	**Temp:**	60-70 F
Temp:	70-80 F		

Survey Activities

Control

Base station was established at W-115. Benchmarks J-421 and K-421 were checked with Leica and the base station with good results.

Topo

Survey crew established the base station and checked benchmarks. Survey operations were focused on the south end of Wallops Island due to "activity" the next few days. Dune and surfzones profiles were completed from 0+20 to 215+00. Lidar survey of the beach was also completed

Hydro

Surf zone profiles were acquired from 270+00 to 20+00. After that, offshore profiles were completed from 20+00 to 60+00.

Daily Survey Field Notes

Date:	9/10/2024	**Day of Year:**	254	
Time SOS (local):	6:00	**Time EOS (local):**	19:00	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Wallops Island			
Hydro Crew:	Sam Bradtke	Davis Batten		
Topo Crew:	Tariq Moya	Owen Reuther		

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	0.5 - 1.0 ft
Wind Speed:	10-15 KT	**Chop:**	0.5 - 1.0 ft
Wind Direction:	SSE	**Temp:**	60-70 F
Temp:	70-80 F		

Survey Activities

Control

Benchmarks J-421 and K-421 were checked with Leica and the base station before and after survey activities with good results.

Topo

Surf zone profiles were collected around morning low tide for profiles 280+00 to 475+00. Upon completion, dune profiles were collected.

Hydro

Surf zone profiles were completed from 275+00 to 475+00. Offshore profiles were completed from 310+00 to 475+00 and 600+00 to 640+00.

Daily Survey Field Notes

Date:	9/11/2024	**Day of Year:**	255	
Time SOS (local):	6:00	**Time EOS (local):**	19:00	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Wallops Island			
Hydro Crew:	Sam Bradtke	Davis Batten		
Topo Crew:	Tariq Moya	Owen Reuther		

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	0.5 - 1.0 ft
Wind Speed:	10-15 KT	**Chop:**	0.5 - 1.0 ft
Wind Direction:	SE	**Temp:**	60-70 F
Temp:	70-80 F		

Survey Activities

Control

Benchmarks J-421 and K-421 were checked before and after survey with Leica and the base station with good results.

Topo

Surf zone profiles were collected around morning low tide for profiles 220+00 to 245+00. Surf zone and dune recoveries were made.

Hydro

Off shore profiles were competed for 60+00 to 305+00.

Daily Survey Field Notes

Date:	9/12/2024	**Day of Year:**	256	
Time SOS (local):	7:00	**Time EOS (local):**	21:30	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Wallops Island			
Hydro Crew:	Sam Bradtke	Davis Batten		
Topo Crew:	Tariq Moya	Owen Reuther		

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	1-2 ft
Wind Speed:	10-15 KT	**Chop:**	1-2 ft
Wind Direction:	NNE	**Temp:**	60-70 F
Temp:	70-80 F		

Survey Activities

Control

Benchmarks J-421, K-421, WFF 09 were checked before and after survey activities with good results. Upon completion of the survey, the base station was taken down.

Topo

Recoveries were made on dune profiles. The base station was disassembled. Survey crew demobilized back to Geodynamics.

Hydro

Survey crew demobilized back to Geodynamics.

Daily Survey Field Notes

Date:	10/15/2024	**Day of Year:**	289	
Time SOS (local):	6:40	**Time EOS (local):**	18:40	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Chincoteague, VA			
Hydro Crew:	Davis Batten	Tariq Moya		
Topo Crew:				

Atmospheric Conditions		**Water Conditions**	
Sky:	Overcast	**Swell:**	1-2 ft
Wind Speed:	15-20 KT	**Chop:**	0 - 0.5 ft
Wind Direction:	NE	**Temp:**	50-60 F
Temp:	50-60 F		

Survey Activities

Control

Benchmarks BM03 and BBDX45 and were checked before and after the survey with the Leica SmartNet with good results.

Topo

N/A

Hydro

Survey crew mobilized from Geodynamics to Chincoteague to conduct the multibeam borrow area survey. Hydro Team began working in the furthest offshore extent of the survey area. A QC line was run along some USACE data in the channel.

Daily Survey Field Notes

Date:	10/16/2024	**Day of Year:**	290	
Time SOS (local):	6:20	**Time EOS (local):**	10:15	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Chincoteague, VA			
Hydro Crew:	Davis Batten	Tariq Moya		
Topo Crew:				

Atmospheric Conditions		**Water Conditions**	
Sky:	Partly Cloudy	**Swell:**	3-4 ft
Wind Speed:	15-20 KT	**Chop:**	2-3 ft
Wind Direction:	N	**Temp:**	50-60 F
Temp:	50-60 F		

Survey Activities

Control

Benchmark BBDX45 was checked at the beginning of survey operations with good results.

Topo

N/A

Hydro

Hydro team went out to survey site, but sea conditions were too rough to survey in. They then retreated to safer waters to conduct QC verification lines over some pre-existing USACE data as well as the profile data

Daily Survey Field Notes

Date:	10/21/2024	**Day of Year:**	295	
Time SOS (local):	6:30	**Time EOS (local):**	18:20	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Chincoteague, VA			
Hydro Crew:	Davis Batten	Tariq Moya		
Topo Crew:				

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	2-3 ft
Wind Speed:	0-5 KT	**Chop:**	0.5 - 1.0 ft
Wind Direction:	NNE	**Temp:**	50-60 F
Temp:	60-70 F		

Survey Activities

Control

Benchmark BMO3 was checked prior to survey with good results.

Topo

N/A

Hydro

Hydro crew transited out to the borrow area survey site and began surveying the eastern most lines in the survey area. At the end of the day prior to coming back to the dock QC roll lines were collected over the data collected to ensure that no roll errors were present in the data. RTK corrections for the RV Sounder were changed from the Leica SmartNet to Trimble RTX.

Daily Survey Field Notes

Date:	10/22/2024	**Day of Year:**	296	
Time SOS (local):	6:50	**Time EOS (local):**	16:20	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Chincoteague, VA			
Hydro Crew:	Davis Batten	Tariq Moya		
Topo Crew:				

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	2-3 ft
Wind Speed:	0-5 KT	**Chop:**	0.5 - 1.0 ft
Wind Direction:	NNE	**Temp:**	50-60 F
Temp:	60-70 F		

Survey Activities

Control

N/A

Topo

N/A

Hydro

Hydro team completed mbes acquisition of the borrow area. After the borrow area survey was completed, QC verification lines were run in channel across Wallops Profiles and pre-existing USACE data to compare roll offsets as well as to compare corrections and data between the Leica SmartNet and Trimble RTX.

Daily Survey Field Notes

Date:	10/23/2024	**Day of Year:**	297	
Time SOS (local):	8:00	**Time EOS (local):**	17:15	
Project:	Wallops Island Shoreline Monitoring & Analyses Program: Beach Monitoring Survey			
Survey Location:	Chincoteague, VA			
Hydro Crew:	Davis Batten	Tariq Moya		
Topo Crew:				

Atmospheric Conditions		**Water Conditions**	
Sky:	Clear	**Swell:**	1-2 ft
Wind Speed:	0-5 KT	**Chop:**	0.5 - 1.0 ft
Wind Direction:	NNE	**Temp:**	50-60 F
Temp:	60-70 F		

Survey Activities

Control

N/A

Topo

N/A

Hydro

Hydro team demobilized all survey equipment and returned to Geodynamics.

APPENDIX B: HYDROGRAPHIC SURVEY CONRTOL CALIBRATION

Survey Control

Project Timeframe:	9/8/2024 - 10/22/2024			
Project:	Wallops Island Shoreline Mapping Program: Beach Profile Monitoring Survey & Analyses 2024			
Survey Location:	Wallops Island, Virginia			
Survey Crew:	Owen Reuther	Tariq Moya		
	Sam Bradtke	Davis Batten		
			Units	***Repeater Use:***
Coordinate System/Units:	NAD83 VA State Plane South		SPF	No
Vertical:	NAVD88	**Geoid:** 2018		

	Receiver	GPS Antenna	Radio	Radio Broadcasting
Base station Equipment:	Trimble R7	Zephyr II Geodetic (55971)	TDL 450	8.5 dB UHF Antenna

Notes: The base station was located on TBM W-115. Multiple NGS benchmarks were checked to verify W-115. An external electrical outlet approximately 250' away from the base station provided power. Crew set the RTK radio antenna on the raised wooden structure to provide excellent correction reception throughout the survey area. Geodynamics was restricted to using VHF 451.80 kHz throughout the survey. The Leica SmartNet was also utilized throughout the survey to provide RTK-GNSS differential corrections to the R/V Echo and R/V Sounder. To verify the vertical accuracies of the SmartNet system, multiple NGS benchmarks were checked each day of the survey. For the Borrow area survey the Leica SmartNet as well as Trimble RTX were used to provide real-time RTK-GNSS corrections to the R/V Sounder.

Base Station Information

Designation:	W-115
PID:	N/A
H Order:	N/A
V order:	N/A
Geoid:	2018
State Plane Coordinates	
Easting (X):	12356422.77
Northing (Y):	3845715.954
Z:	8.904
WGS-84 Coordinates	
Longitude:	75° 28' 27.97949"
Latitude:	37° 50' 46.81096"
Elevation (m):	-33.919





Notes: Base W-115 was established due to its location and mast elevation for entire survey area coverage.

The following tables display coordinate and site information on any benchmarks checked for this project

Base Station Information

Designation:	Leica SmartNet
PID:	N/A
H Order:	N/A
V order:	N/A
Geoid:	2018
State Plane Coordinates	
Easting (X):	N/A
Northing (Y):	N/A
Z:	N/A
WGS-84 Coordinates	
Longitude:	N/A
Latitude:	N/A
Elevation (ft):	N/A



Notes: Network of continually operating base stations used to provide real-time kinematic corrections to survey units via the internet. Used to provide RTK-GNSS differential corrections to the survey vessel R/V Echo and R/V Sounder.

Base Station Information

Designation:	Trimble RTX
PID:	N/A
H Order:	N/A
V order:	N/A
Geoid:	2018
State Plane Coordinates	
Easting (X):	N/A
Northing (Y):	N/A
Z:	N/A
WGS-84 Coordinates	
Longitude:	N/A
Latitude:	N/A
Elevation (ft):	N/A



Notes: Trimble RTX correction service is a real-time Precise Point Positioning (PPP) technology that uses Trimble's global network of reference stations to accurately generate space state representation models of the ionosphere and troposphere to mitigate atmospheric biases, as well as accurate GNSS satellite ephemeris data to mitigate clock and orbit biases. Used to provide RTK-GNSS corrections to the survey vessel R/V Sounder.

Benchmark Station Reference

Designation:	J 421
PID:	FW0197
H Order:	N/A
V order:	1st Class I
Geoid:	2018
State Plane Coordinates	
Easting (X):	N/A
Northing (Y):	N/A
Z:	4.820





Notes: This benchmark is located on the seaward shoulder of N. Seawall Rd, just south of the Naval facility on Wallops Island. The benchmark is roughly in line with planned line 325+00.

Benchmark Station Reference

Designation:	K 421
PID:	FW0198
H Order:	N/A
V order:	1st Class I
Geoid:	2018
State Plane Coordinates	
Easting (X):	N/A
Northing (Y):	N/A
Z:	4.990





Notes: Benchmark is located across from the beach access on N. Seawall Rd, approximately 200 yards north of the northern Naval Facility.

Benchmark Station Reference

Designation:	WFF 09
PID:	N/A
H Order:	N/A
V order:	N/A
Geoid:	2018
State Plane Coordinates	
Easting (X):	12356366.810
Northing (Y):	3846440.207
Z:	6.391





Notes: The published coordinates and elevation for WFF 09 currently refer to a 24-hr OPUS session performed on the October 2016 survey.

Benchmark Station Reference

Designation:	BM03
PID:	BBHQ05
H Order:	N/A
V order:	N/A
Geoid:	2018
State Plane Coordinates	
Easting (X):	12375780.009
Northing (Y):	3866961.615
Z:	4.386







Notes: Benchmark is located on across from the Curtis Merrit Harbor Marina on the grass divider in the parking lot.

Benchmark Station Reference

Designation:	TAYLOR
PID:	BBDX56
H Order:	N/A
V order:	N/A
Geoid:	2018
State Plane Coordinates	
Easting (X):	12385245.272
Northing (Y):	3880145.028
Z:	2.923







Notes: The station is located in the front southeast corner of the property at 4339 Main Street where the wooden bulkhead instersects Main Street and is set flush with the ground surface. The mark is a 60" aluminum cap monument driven into the fround and set in concrete.

Benchmark Report									
Date	**Time**	**Weather**	**Benchmark**	**N**	**E**	**Z**	**ΔN**	**ΔE**	**ΔZ**
9/9/2024	14:30:00	Clear	J 421	3848788.107	12358433.11	4.656	N/A	N/A	0.164
	Base station Used: Leica SmartNet								
9/9/2024	14:46:00	Clear	K 421	3852175.186	12361909.98	4.849	N/A	N/A	0.141
	Base station Used: Leica SmartNet								
9/9/2024	15:07:00	Clear	K 421	3852175.204	12361909.95	4.898	N/A	N/A	0.092
	Base station Used: W-115								
9/9/2024	15:13:00	Clear	J 421	3848788.147	12358433.09	4.768	N/A	N/A	0.052
	Base station Used: W-115								
9/10/2024	7:12:00	Clear	J 421	3848788.163	12358433.1	4.778	N/A	N/A	0.042
	Base station Used: W-115								
9/10/2024	20:32:00	Clear	J 421	3848788.068	12358433.07	4.717	N/A	N/A	0.103
	Base station Used: Leica SmartNet								
9/11/2024	13:50:00	Clear	K 421	3852175.217	12361909.93	4.881	N/A	N/A	0.109
	Base station Used: W-115								
9/11/2024	13:48:00	Clear	J 421	3852175.171	12361909.99	4.832	N/A	N/A	-0.012
	Base station Used: Leica SmartNet								
9/12/2024	9:52:00	Clear	WFF 09	3846440.177	12356366.79	6.452	0.030	0.018	-0.061
	Base station Used: W-115								
9/12/2024	9:58:00	Clear	WFF 09	3846440.14	12356366.79	6.509	0.067	0.021	-0.118
	Base station Used: Leica SmartNet								
10/15/2024	13:56:00	Overcast	BM03	3866961.542	12375780.07	4.443	0.073	-0.059	-0.057
	Base station Used: Leica SmartNet								
10/15/2024	15:37:32	Overcast	TAYLOR	3880145.01	12385245.28	2.844	0.018	-0.010	0.079
	Base station Used: Leica SmartNet								
10/16/2024	7:06:46	Partly Cloudy	TAYLOR	3880145.058	12385245.29	2.819	-0.030	-0.013	0.104
	Base station Used: Leica SmartNet								
10/21/2024	6:50:48	Clear	BM03	3866961.621	12375780.08	4.397	-0.006	-0.072	-0.011
	Base station Used: Leica SmartNet								
						STD Difference:	0.026	0.002	0.091

APPENDIX C: SINGLEBEAM ECHOSOUNDER CALIBRATION REPORT

R/V ECHO July 2019

GeoDynamics

ODOM CV100 CALIBRATION

Contact: Geodynamics
210 A Greenfield Drive
New port, NC 28570
252-247-5785
www.GeoDynamicsGroup.com

SYSTEM INFORMATION

Vessel:	R/V Echo	**Sonar Type:**	ODOM CV100
Date:	7/26/2019	**Sonar Head Serial #(s):**	n/a
Personnel:	Willey, J., Rao, R., Gray,Z.	**PU Serial #:**	26068
		Sonar Software:	eChart
Positioning System	POSMV WM V5	**Sonar Frequency:**	200 kHz
POSMV Serial #	6577	**Swath Width:**	4°
GPS Antennas	AT1675-540TS (2 antennas)	**Sound Speed Sensor at Sonar:**	n/a
IMU Type	37	**Sound Speed Profiler:**	SontTek Castaway CTD
			Pressure sensor 304496

CALIBRATION DETAILS

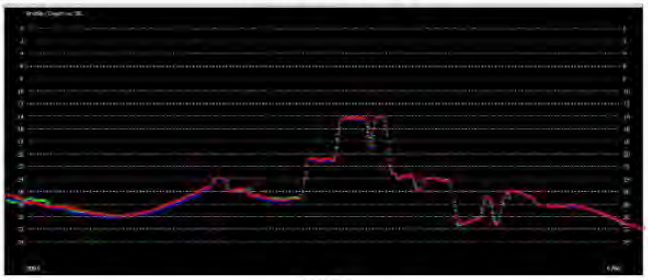
Location:	Morehead City Harbor
Weather	Clear skies, 80-90°
Wind	5-10 kts NNE
Seas	0' swell, 0-0.25' chop
Sound Speed (avg)	1540 m/s

Approximate Position:	**Deg**	**Min**	**Sec**
Lat:	34°	43'	06"
Long:	76°	42'	18"

GNSS Corrections

GPS Correction:	RTK-GNSS		
Correction Type:	CMR+		
Station Name	BEAUFORT CORS ARP		
Coordinates:	**Deg**	**Min**	**Sec**
Lat:	34°	43'	08.50895" N
Long:	76°	40'	18.99140" W
Ellips. Height (m) :	-27.858		

Calibration Check Image



Sonar Offsets / Biases

	X (m)	Y (m)	Z (m)
Position	0.000	0.000	0.000
Draft	0.000	0.000	0.000
Index	0.000	0.000	0.090

POSMV Configuration

Lever Arms	**X (m)**	**Y (m)**	**Z (m)**
Ref. to IMU Lever Arm	0.000	0.000	0.070
Ref. to Primary GPS	0.016	-0.01	-2.063
Ref. to Vessel Lever Arm	-0.292	0.745	0.648
Ref. to Sensor 1	-0.292	0.745	0.648
Ref. to COG	0.000	0.000	0.290
	X (deg)	**Y (deg)**	**Z (deg)**
IMU w.r.t. Ref. Frame	0.000	0.000	-0.001

Note: The Sensor 1 offset is referenced to the sonar head.

GAMS Parameters

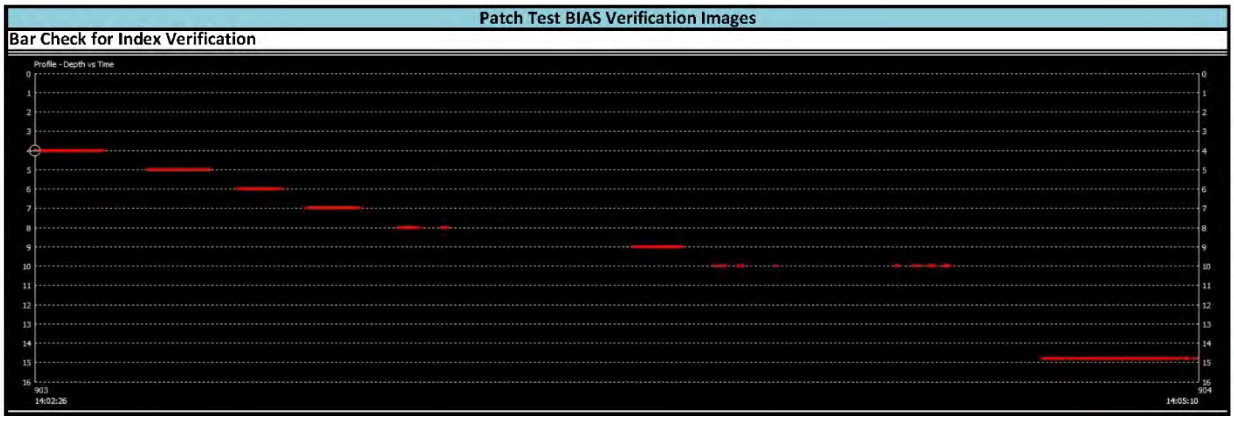
Two Antenna Sep (m)	1.997	**Baseline Vector**		
Heading Cal.Threshold	0.500	**X (m)**	**Y (m)**	**Z (m)**
Heading Correction (deg)	0.000	1.997	0.015	0.003

Index Check

Bar Value (ft)	Sonar Value (ft)	(Sonar value derived from the mean depth of bar below transducer)
3.0	3.0	
6.0	6.0	
9.0	9.0	
15.0	15.0	

Notes:

The image above consists of three different singlebeam datasets from 2017-present conducted by Geodynamics on the R/V Echo. All datasets were collected using an Odom CV100. All singlebeam surveys were collected using RTK-GPS with corrections from a local temporary basestation. A hard bottom feature that does not vary from year to year is found along this profile which is why it was chosen to represent accurate and precise configuration parameters for the vessel's equipment. The three different colors show three consecutive years of surveying this same profile. The dataset comparison produced exceptional results with corrections from the basestation set up on 865 8559 Tidal 1.


Patch Test BIAS Verification Images
Bar Check for Index Verification
Profile - Depth vs Time
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
903
14:02:26
904
14:05:10

APPENDIX D: SOUND VELOCITY X-CHANGE SENSOR CALIBRATION REPORT

SonTek
a xylem brand

9940 Summers Ridge Road
San Diego, CA 92121
Tel: (858) 546-8327
support@sontek.com

CALIBRATION CERTIFICATE

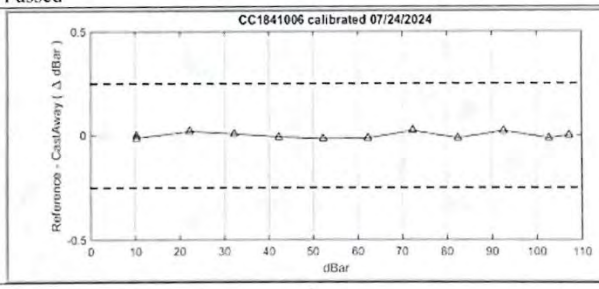
SYSTEM INFO

System Type	CastAway-CTD
Serial Number	CC1841006
Firmware Version	1.63
Date	07/29/2024

POWER CONSUMPTION

Standby Mode (A)	0.2086 / PASS
Supply Voltage	2.9V

CALIBRATION

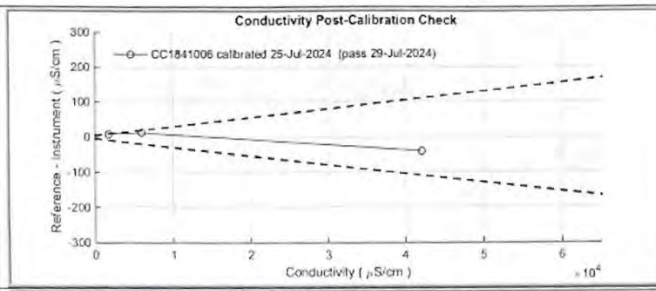
GPS	Passed
Pressure	

SonTek

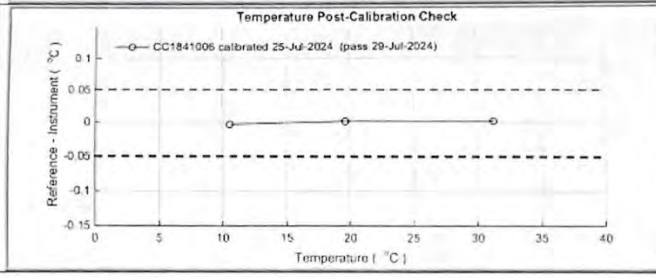
a xylem brand

9949 Summers Ridge Road • San Diego, CA 92121 • Telephone (858) 546-8327 • Fax (858) 546-8150 • Internet: www.sontek.com

Conductivity



Temperature



Verified by: JCADENA
This report was generated on: 7/31/2024

ATTENTION: New Warranty Terms as of March 4, 2013

This system is covered under a two year limited warranty that extends to all parts and labor for any malfunction due to workmanship or errors in the manufacturing process. The warranty is valid only if you properly maintain and operate this system under normal use as outlined in the User's Manual. The warranty does not cover shortcomings that are due to the design, or any incidental damages as a result of errors in the measurements.

SonTek will repair and/or replace, at its sole option, any product established to be defective with a product of like type. CLAIMS FOR LABOR COSTS AND/OR OTHER CHARGES RESULTING FROM THE USE OF SonTek GOODS AND/OR PRODUCTS ARE NOT COVERED BY THIS LIMITED WARRANTY.

SonTek DISCLAIMS ALL EXPRESS WARRANTIES OTHER THAN THOSE CONTAINED ABOVE AND ALL IMPLIED WARRANTIES, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR A PARTICULAR PURPOSE. SonTek DISCLAIMS AND WILL NOT BE LIABLE, UNDER ANY CIRCUMSTANCE, IN CONTRACT, TORT OR WARRANTY, FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND, INCLUDING BUT NOT LIMITED TO LOST PROFITS, BUSINESS INTERRUPTION LOSSES, LOSS OF GOODWILL, OR LOSS OF BUSINESS OR CUSTOMER RELATIONSHIPS.

If your system is not functioning properly, first try to identify the source of the problem. If additional support is required, we encourage you to contact us immediately. We will work to resolve the problem as quickly as possible.

If the system needs to be returned to the factory, please contact SonTek to obtain a Service Request (SR) number. We reserve the right to refuse receipt of shipments without SRs. We require the system to be shipped back in the original shipping container using the original packing material with all delivery costs covered by the customer (including all taxes and duties). If the system is returned without appropriate packing, the customer will be required to cover the cost of a new packaging crate and material.

The warranty for repairs performed at an authorized SonTek Service Center is one year.

AML OCEANOGRAPHIC

Certificate of Calibration

Serial Number: 212348
Calibration Date: 2023-05-09
Calibration Type: Sound Velocity (SVx2)
RMSE: 0.003

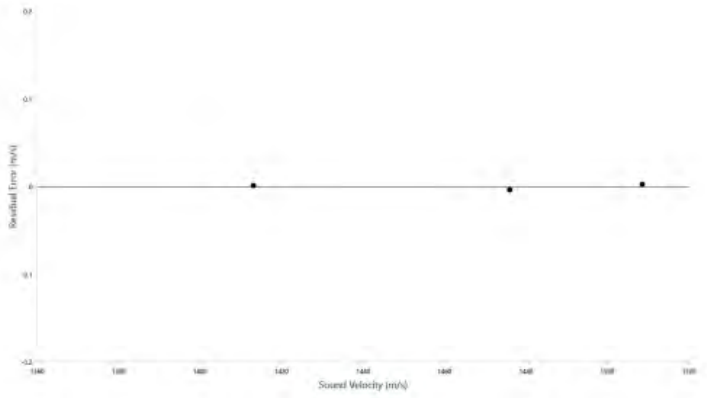
Calibration Range: 1413.094 to 1508.572 m/s
Sensor Range: 1375-1625 m/s
Standard: Hart Scientific 1560

Calibration Data

Reference (m/s)	Sensor Output	Sensor Calculated (m/s)	Residual (m/s)
1508.5722	3410.79	1508.5746	0.0025
1476.0068	3486.07	1476.0032	-0.0036
1413.0939	3641.28	1413.0951	0.0012

Sensor Coefficients

A = 6.624676E-2
B = -9.998855E-1



AML OCEANOGRAPHIC

Certificate of Calibration

Serial Number: 308832
Calibration Date: 2023-05-03
Calibration Type: Pressure (Px2)
RMSE (%FS): 0.008

Calibration Range: -0.017 to 100.649 dBar
Sensor Range: 100 dBar
Standard: Paro Scientific 785

Calibration Data

Reference (dBar)	Sensor Output	Sensor Calculated (dBar)	Residual (% F.S.)
-0.0171	844709.61	-0.0190	-0.0019
20.5285	2225610.03	20.5329	0.0044
40.6967	3578380.09	40.6985	0.0018
60.9648	4935011.69	60.9521	-0.0127
81.0874	6282585.33	81.0995	0.0120
100.6486	7588158.88	100.6450	-0.0036

Sensor Coefficients

A = -1.257383E+1
E = 1.485500E-5
I = 9.363438E-15
M = -9.723016E-23

Equation: $P = A + E*x + I*x^2 + M*x^3$



APPENDIX E: R/V SOUNDER MULTIBEAM PATCH AND VERIFICATION REPORT

Geodynamics

SONAR SYSTEM CALIBRATION

Site Info

Site Location	Morehead City Harbor, NC	
Weather	Sunny	
Wind	5-10mph	SE
Temperature	80°-90°F	
Seas	0-1ft	
Site Coordinates		
Lat:	34° 42' 40.80	
Long:	76° 41' 36.66	

Site Overview



System Info

Vessel	**Sounder**						**Notes**
Sonar	**Sonar Head**	**Sonar Cable**	**Kongsberg PU**	**SIS Version**			
	EM Ti 2040P-SV MkII 4002	EM2040C 15m Cable NOP200504-8	EM2040P 60018 Compact	4.3.2 build 31 Rel 1.6.0			
Motion	**PCS/IMU Combined**		**Cable**	**Pri Antenna**	**Secondary Antenna**	**POSView Version**	**Firmware V**
	POSMV Surfmaster One 113359		N/A	GA830 22804	GA830 22911	11.0	11.0
Sound Speed	**Surface Sound Speed Sensor**	**Surface Sound Speed**	**Sound Speed Profiler**	**Sound Speed Profiler Sensor**	**Sound Speed Software**	**Sound Speed Software Version**	**Note**
	SV.Xchange 210845	AML-1 A10067	AML-3 A30529	SV.Xchange 210837	Sailfish	1.4.3	
Computer	**Workstation**	**Windows Version**	**Graphics Card**		**Ram**		
	Cincoze	Windows 10 Pro	AMD FirePro SDI (0x682C)		32GB		

Operation Info

Date:	08/06/2024		
Personnel:	Owen Reuther, Ben Sumners, Kent Mosier		
Sonar Frequency:	300KHz	**GPS Correction:**	NC VRS RTK-GNSS
Beam Angle:	68/68	**Correction Type:**	RTCM3
Vessel:	Sounder	**Station Name:**	n/a (NCBE)

Results

Patch Test Values (SIS / Qinsy)

	Roll	Pitch	Yaw	Latency
Sonar Head 1	0.500	3.200	0.000	0.000
Attitude 1, Com2	0.000	0.000	0.000	0.000
Timing	0.000	Sec		
Attitude Delay	0.000	mSec		

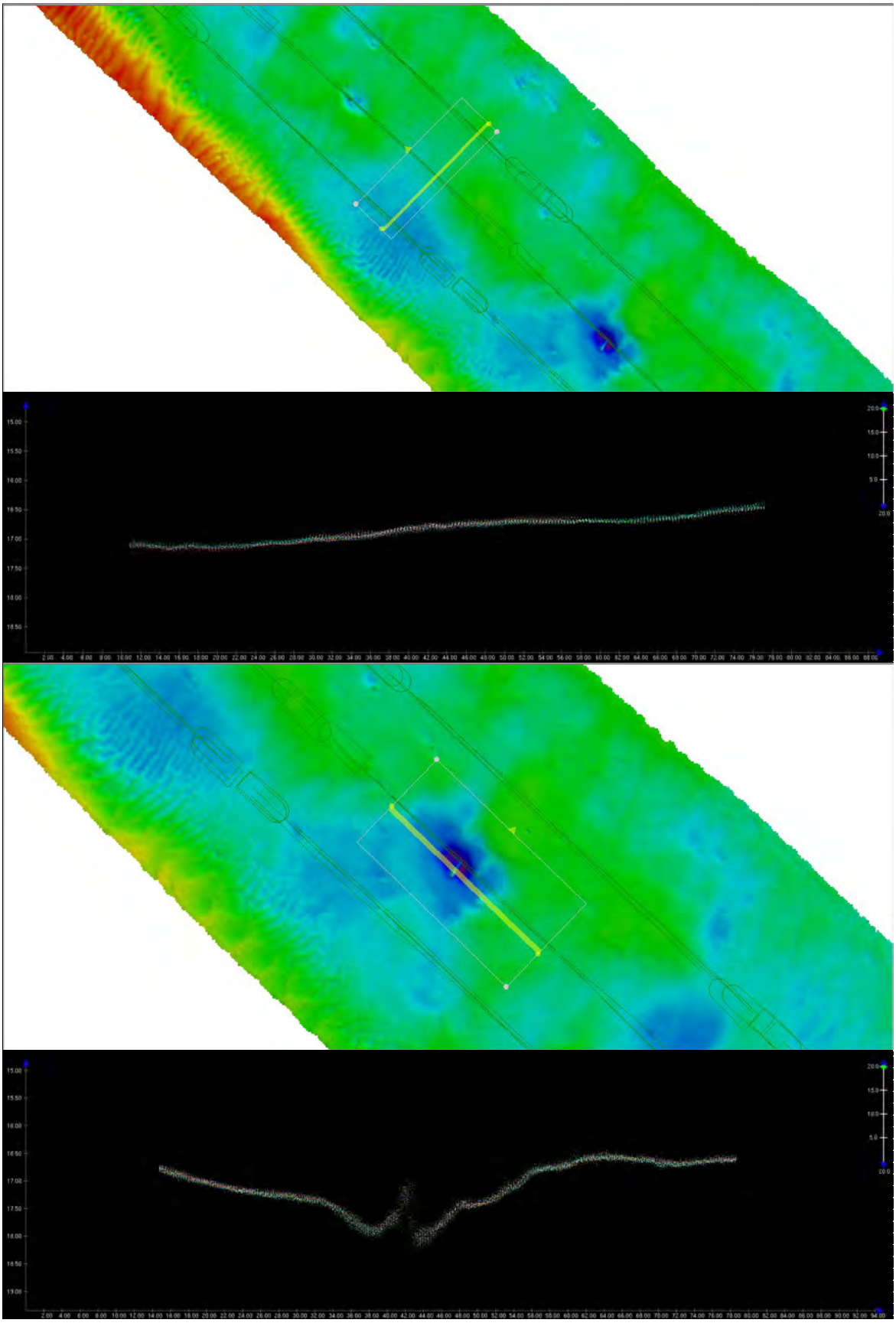
POSMV Configuration				**Sonar Offsets / Biases (SIS / Qinsy)**			
Lever Arms	**X (m)**	**Y (m)**	**Z (m)**				
Ref. to IMU Target	0.000	0.000	0.000		**X (m)**	**Y (m)**	**Z (m)**
Ref. to Primary GNSS	-0.084	-0.965	-2.140	**Sonar Head 1 Position**	0.000	0.000	0.000
Ref. to Vessel Lever Arm	0.986	-1.560	0.873	**Waterline**	0.000	0.000	-0.700
Ref. to Sensor 1	0.986	-1.560	0.873				
IMU w.r.t. Ref. Frame (°)	0.000	0.000	0.000				
Target to Sensing Center	0.000	0.000	0.053				

GAMS Parameters

Two Antenna Sep (m)	2		**Baseline Vector**	
Heading Cal.Threshold	0.500	**X (m)**	**Y (m)**	**Z (m)**
Heading Correction (deg)	0.000	0.012	2.013	0.012

Photos/Images & Notes

RV Sounder was surveyed for dimensional control at Geodynamics on 9/6/2022. The resulting lever arms and mounting angles were incorporated and a full patch test was conducted on 8/06/2024. The patch test site is in the Morehead City Harbor over large debris on a relatively flat seabed. The protruding debris and accompanying depressing are utilized for pitch and yaw corrections while the flat bed is used for roll corrections. This site also serves as a verification site as Geodynamics often performs calibrations on other vessels and equipment in this area, showing good vertical alignment with previous data.



APPENDIX F: LASER PATCH AND VERIFICATION DOCUMENT

RIEGL® LASER MEASUREMENT SYSTEMS

System Test and Calibration Protocol

MLS

RIEGL VMZ-400i
System Test and Calibration Protocol

IMU/GNSS unit S/N: 2224819
Scanner S/N: H2222207

Author	*RIEGL* Laser Measurement Systems GmbH
Customer	RIEGL USA
Date	Nov 24, 2021
Issue	01
Pages	7

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www.riegl.com

RIEGL® LASER MEASUREMENT SYSTEMS

RIEGL VMZ-400i
System Test and Calibration Protocol

CONTENT

1 SYSTEM CONFIGURATION 3
2 CALIBRATION AND TEST CONDITIONS 4
3 SYSTEM CALIBRATION 6
3.1 IMU/GNSS calibration parameters 6
3.2 Scanner calibration parameters 6

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RIEGL LASER MEASUREMENT SYSTEMS

RIEGL VMZ-400i
System Test and Calibration Protocol

1 SYSTEM CONFIGURATION

Please note that for a correct system identification the serial numbers of the IMU/GNSS unit and the VZ scanner are required. The system calibration provided in this protocol is only valid for the specific combination of IMU/GNSS unit and VZ scanner as listed below:

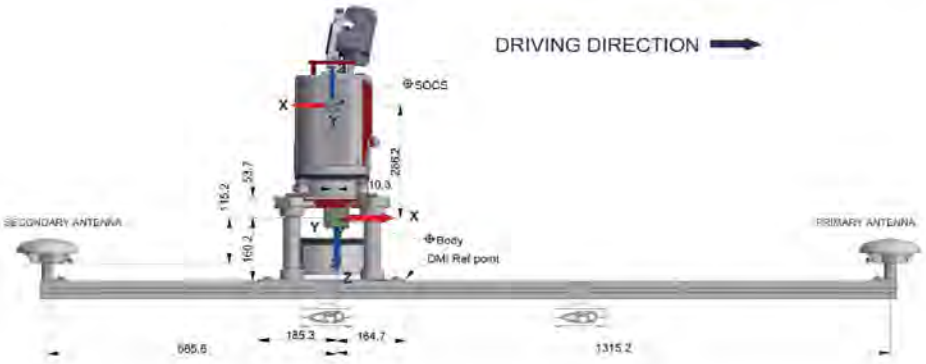
[X]	**VMZ IMU/GNSS unit: S/N** 2224819 **GNSS Antenna:** 540 TS **IMU:** IMU-82	
[X]	**GPS Azimuth Measurement Subsystem (GAMS)**	
[X]	**Distance Measurement Indicator (DMI)**	
[X]	**Scanner VZ-400i:** S/N H2222207	

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2 CALIBRATION AND TEST CONDITIONS

A modular calibration workflow allows independent parameter identification under well-defined conditions. This includes diverse calibration procedures under laboratory conditions, in-house bench tests as well as an in-field calibration and validation, taking "real world" mobile laser scanning conditions into account. The system calibration is valid for different setups of the VMZ such as vertical and horizontal mounting.

The following configuration shows the default vertical setup of the VMZ. The settings that are applied to the IMU/GNSS stack at system delivery refer to this vertical default setup.



The system's transformation parameters refer to the BODY coordinate system as shown in the CAD drawing. Origin, axis, and angles are defined as follows:

origin	center of IMU
x-axis	pointing into driving direction
y-axis	pointing to right side w.r.t. driving direction
z-axis	pointing downwards
roll	right-hand grip rule rotation around x-axis
pitch	right-hand grip rule rotation around y-axis
yaw	right-hand grip rule rotation around z-axis

The GNSS antenna lever arm for the **vertical setup** is already stored to the internal IMU/GNSS system configuration and it is automatically considered in the software for processing attitude and position data. If operating the VMZ in any other position or in horizontal orientation, the system setting has to be changed according to the manual or to the specific user setup. The DMI lever arm and scale factor are not pre-defined.

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Note that the DMI lever arm has to be measured during the system installation referring to the external DMI reference point. Mounting the VMZ on a different vehicle or different position requires redetermination of the DMI lever arm and scale factor.

GNSS antenna lever arm used for calibration run (default vertical setup)

	X [m]	Y [m]	Z [m]
GNSS antenna lever arm	1.3152	-0.001	0.057

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3 SYSTEM CALIBRATION

The system calibration is based on corresponding objects in several records acquired by multiple passes. The calibration parameters are provided on the configuration CD as part of the VMZ system delivery.

Since a VMZ system provides flexible setup positions, it is important to carefully configure the system parameters on the acquisition computer as well as in post-processing. This includes Applanix LV POSView and POSPac as well as RiACQUIRE and RiPROCESS settings. Please follow the instructions in the user manual to configure IMU to GNSS lever arms, DMI lever arms and mounting matrixes.

3.1 IMU/GNSS CALIBRATION PARAMETERS

There are no orientation offsets for the IMU coordinate system w.r.t. the BODY coordinate system to be applied for a VMZ system. For a VMZ system these two coordinate frames are treated as strictly identical. Therefore, the mounting matrix equals the identity matrix, and the offsets for orientation corrections are set to zero.

1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

roll offset [deg]	0.0
pitch offset [deg]	0.0
yaw offset [deg]	0.0

3.2 SCANNER CALIBRATION PARAMETERS

Mounting matrix of the VZ scanner with respect to the BODY coordinate system:

Values on gray background are based on mechanical drawings, values on yellow background are determined from in-field calibration routines.

-1	0	0	-0.01027
0	1	0	-0.0011
0	0	-1	-0.2862
0	0	0	1

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Mounting offsets of VZ scanner with respect to the BODY coordinate system:

roll offset [deg]	-0.03561
pitch offset [deg]	-0.02978
yaw offset [deg]	-0.32530

Please note that the roll/pitch/yaw boresight calibration is consistent for vertical and horizontal setup and is applied to both orientations. When operating the system in a horizontal setup, please follow the user manual and processing workflow instructions for further details.

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APPENDIX G: SCOPE OF WORK

Section 00800 - Special Contract Requirements

ACCOUNTING AND APPROPRIATION DATA

AA: 96X31220000 082422 32304B06H2099990 NA 96444
AMOUNT: $199,183.00

ACRN	CLIN/SLIN	CIN	AMOUNT
AA	0001	W26GLG417006340001	$150,751.00
	0002	W26GLG417006340001	$48,432.00

STATEMENT OF WORK

SCOPE OF ARCHITECT-ENGINEER SERVICES

PROJECT TITLE: Wallops Island Shoreline Mapping Program: Beach Monitoring Survey & Analyses

INSTALLATION: Wallops Island, VA

1. **Project Description.**
Basic Requirement: The field work shall primarily consist of surveying and mapping of designated onshore and offshore profiles previously established along Wallops Island, VA on a single survey to be conducted early 2024. The profile work includes elevation and positioning data collected along specified azimuths at specified intervals from the existing 2011 established US Army Corps of Engineers (USACE) profiles stations and then modified from the 2015-2016 field surveys. The final 2017- 2018 profile stationing is shown in Figure 1. Field data derived from the beach profile monitoring elements of the project will be assimilated and analyzed to assess observed trends in shoreline / volume change to understand past project performance and the need for future beach re-nourishment or to design and / or monitoring other shore stabilization efforts. In addition to the beach profiles, an ATV-guided laser scan will be performed to adequately resolve nearshore features and coastal structures.

Bid Option 1: Perform a comprehensive multibeam survey of UNNAMED SHOAL A, the proposed offshore borrow area located approximately 11 miles offshore of Chincoteague Inlet, shall be conducted to provide 100% coverage of the shoal.

2. **Roles and Responsibilities.** The A-E shall complete this scope of work under the supervision of the US Army Corps of Engineers (USACE) Norfolk District (NAO).

- Norfolk District Project Manager (PM): The Norfolk District PM serves as the primary point of contact throughout the life of the project. The Norfolk District PM is responsible for the successful execution of the project.
- Norfolk District Technical Manager (DTM): The Norfolk District DTM shall coordinate design reviews to verify compliance with criteria and project requirements.
- Contracting Officer Representative (COR): The Norfolk District COR serves as the point of contact for the AE.

3. **Project Survey Control.** For the contract period, all work shall be relative to the current North American Datum (NAD) of 1983 (2011) Virginia State Plane Survey Feet in the horizontal plane and the

North American Vertical Datum (NAVD) of 1988 Survey Feet in the vertical plane and will use the local geoid model (Geoid 18) to transform Global Navigation Satellite System (GNSS) based ellipsoidal heights to orthometric elevations. The NOAA V-Datum model will be used for the calculation of datum derived shorelines such as Mean High Water (MHW). A detailed geodetic control site calibration will be performed prior to all shoreline mapping activities to document the Real-Time Kinematic (RTK) GNSS network accuracy, to determine base station location (if the existing Wallops station cannot be used), assess accuracy at range and to establish daily benchmark "check-in" points (Figure 2). The contractor shall report all information on horizontal and vertical control, site calibration results and daily control checks used during each survey.

4. Beach Profile Surveys – A-E Services

The following schedule of Architect-Engineer Services is required for this delivery order:

Architect-Engineer Services		Base or Option?	To be completed by…	
			A-E	USACE Norfolk
3.1	Kick-Off Meeting	Base	X	
4.1	Topographic Data Collection	Base	X	
4.2	Mobile Laser Scanning Data Collection	Base	X	
4.3	Hydrographic Data Collection	Base	X	
4.4	Borrow Area Survey	Option	X	
8.	Analyses	Base	X	
9.1	Written Survey Report	Base	X	

4.1. Kick off meeting. The A-E shall set-up and facilitate a site visit meeting to discuss the scope of work with the project delivery team, to include the Norfolk District PM, TM, and Engineering Design Team, and other appropriate stakeholders, within 7 days of the NTP. This meeting should be attended by the A- E's PM and other disciplines deemed necessary by the A-E.

4.2. Topographic Data Collection. The topographic profile data acquisition for this project will consist of elevation and positioning data collected along specified azimuths at specified intervals on the existing profile stationing design (Figure 1). In general, the landward extent of topographic data collection will mirror the extents of the previous data; however, profiles that extend across the seawall may be noncontiguous in areas unsafe to transit. However, all efforts will be made to achieve accurate elevations across the seawall where suitable. Elevations shall be continuously collected using backpack assisted GNSS platforms and processed elevations shall be at a spacing not to exceed 5 feet and all data will be collected within +/- 20 feet of the profile line. All topographic data collected from the berm to a depth sufficient to meet overlap requirements shall be collected no greater than 4 hours bounding the low tide. The contractor will perform the topographic surveys in a manner to limit acts that may cause erosion or damage to existing dunes or vegetation. The contractor shall utilize RTK- GNSS surveying techniques that meet or exceed the criteria for GPS Real Time Kinematic Topographic Survey Procedures outlined in the U.S. Army Corps of Engineers Topographic Surveying Manual, EM 1110-1- 1005 and in the CETN II-38 Beach and Nearshore Survey Technology Technical Note. The contractor shall provide a record of vertical and horizontal calibrations performed prior to and during each survey to be included in the final survey report.

4.3. Mobile Laser Scanning (MLS) Data Collection (Nearshore Features and Coastal Structures). An ATV-mounted MLS shall be utilized along Wallops Island encompassing Stations 180+00 to 475+00 for the following purposes:

1) Resolve, characterize, and assign elevations of coastal structures along the reach (e.g., seawall/geo textile tubes, breakwaters, etc.).
2) Aid in the identification of the Mean High Water (MHW) contour along the subject reach.
3) Collect elevation data along the beach face sufficient to produce a generalized Digital Elevation Model (DEM) of the subject reach, incorporating all coastal structures.

For all purposes, MLS topographic data shall be continuously collected utilizing a survey grade terrestrial laser scanner set to collect data in either 2D (constant azimuth) or 3D/radar (varying azimuth) mode compensated for motion with an internal motion unit and positioned utilizing the project survey control previously defined.

Mean High Water (MHW) Contour: For this project, the MHW at all reaches has been defined to be the 1.5' elevation (NAVD88) contour. MLS data shall be collected sufficient to identify this contour.

Generalized DEM: The MLS shall collect data along the MLS reach for the purpose of creating a broad DEM encompassing the survey area from the dune base to an area offshore. The MLS data shall be sufficient to map the major morphological features of the beach face and coastal structures.

All reasonable efforts shall be made to capture elevation data sufficient to complete a high-resolution DEM of the subject reach, including multiple passes of coastal structures as warranted. However, it is understood that high water and coastal structures of high relief may restrict the ability of the MLS to capture adequate elevation data points. For these scenarios, any gaps or "holidays" in the final data set shall be noted.

4.4. Hydrographic Data Collection. The hydrographic data collection for this project will consist of bathymetric data collected along specified azimuths at specified intervals along the established profile stationing. The offshore extent of hydrographic data collection on the established profile will be a minimum of 5000' from the baseline or -22' NAVD 88 whichever is furthest. Soundings shall be continuously collected using a survey-grade 200 kHz digital echo sounding device compensated for motion, sound speed and positioned with RTK- GNSS corrections. All processed soundings shall be at a spacing not to exceed 10 feet and all data will be collected within +/- 25 feet of the profile. All
hydrographic data collected in the surf zone, sufficient to meet overlap requirements, shall be collected no greater than 4 hours bounding the high tide. The contractor shall utilize hydrographic surveying techniques that meet or exceed the criteria for Navigation and Dredging Support Surveys of Hard Bottoms as outlined in the U.S. Army Corps of Engineers Hydrographic Surveying Manual, EM 1110- 2-1003 (2013). Post-processing of attitude and navigation data collected from the survey vessel is acceptable and encouraged, especially when the accuracy and repeatability of the final bathymetry is improved. The contractor shall provide a record of vertical and horizontal calibrations performed prior to and during each survey to be included in the final survey report.

4.5. Borrow Area Survey (OPTION). A comprehensive multibeam survey shall be conducted to provide 100% coverage of UNANNAMED SHOAL A, the proposed dredging borrow area located approximately 11 miles offshore of Chincoteague Inlet (Figure 3). The multibeam survey shall adhere to "Bathymetric Survey Requirements for BOEM Marine Minerals Lease Areas (borrow areas), Dec 2023" (attached Appendix A1). The survey shall extend 100 meters beyond the specified limits of the borrow area and produced a gridded surface with resolution of 0.5 meters.

5. General Beach Profile QA/QC & Survey Requirements

5.1. RTK-GNSS Requirements. The contractor will primarily utilize Real-Time GNSS corrections from the established base station network. For the contract period, "Geoid18CONUS" shall be used to reduce GNSS-based ellipsoidal heights to orthometric elevations. Update rates from the GNSS receiver to the data collection processor shall operate at a minimum of 5 Hz to a maximum of 20 Hz and masking angles are not to exceed 15 degrees. The contractor is required to augment the Hydrographic RTK- GNSS data with appropriate heave, pitch, and roll corrections from an inertial navigation system. Static GNSS observables will be acquired at the base station during each hydrographic survey to allow for hydrographic position and attitude post-processing. The contractor shall provide a record of vertical and horizontal RTK-GNSS calibrations performed during the initial site calibrations and the daily RTK- GNSS "check-in" calculations to be included in the final survey report. The contractor will coordinate with the NASA Wallops Island survey manager for appropriate frequencies and RTK correction source.

5.2. Sound Speed. Sound speed profiles used to account for water density variations, will be collected within the USACE standard requirement of 2 casts per day minimum. However, additional sound speed profiles shall be acquired in and around tidal inlets and when noticeable change in surface water properties occur to increase overall accuracy. Sound speed profiles are used to vertically calibrate the echo sounder's two-way travel time in the water properties found onsite during the survey.

Corresponding documentation will be included in the final survey report.

5.3. Sonar Calibration. The echo sounder shall be calibrated such to provide the most accurate and repeatable soundings possible. Echo sounder index and draft calibrations should be performed at least once per year / project and if any system changes are made. Echo sounder calibrations will be documented and included in the final survey report.

5.4. Line Tracking, Overlap & Temporal Requirements. All hydrographic and topographic data collection shall conform to the latest USACE Standards for Coastal Engineering Surveys for Beach Renourishment and Shoreline Protection Structures (EM 1110-2-1003 Chapter 11). These elements of the survey will be documented in QC sections of the final survey report.

5.5. Quality Control. Data for each profile line and the overall survey shall be quality-control checked, but not limited to the following concerns:

- Profile coverage from landward limits to seaward limits including overlap
- Capture of all features along profile
- Required accuracies
- Required horizontal and vertical datum
- Proper motion sensor and sound speed corrections
- Data collection within required offset limits
- Cross lines over a minimum of 3 profiles within each survey compartment collected at different tide stages to determine consistency

5.6. Systems Calibration and Checks. The contractor shall calibrate and check both topographic and hydrographic systems in accordance with all appropriate USACE Standards. A digital log containing the results of all calibrations and checks shall be provided for the final survey report.

6. **Field Survey Clearances and Coordination.** The contractor shall acquire all Clearances necessary to obtain the required data. Clearances and coordination for Wallops Island ground surveys will go directly through the NASA Wallops Flight Facility project manager. Prior to all survey activities that use RTK-GNSS mandatory coordination with the Wallops Island frequency manager is required. Detailed and frequent scheduling communication between the contracted survey manager(s) and Wallops is essential to ensure coordination between the monitoring efforts and the ongoing missions of the Facility. All necessary Wallops contacts will be advised initially on the target month and then informed once the weather window is known, and mobilization begins.

Any surveys conducted between March 15 and August 31 must coordinated daily with the WFF Environmental Office for endangered species nest locations and take avoidance. Surveys conducted on Assawoman Island (south of Wallops Island) must be coordinated daily with the U.S. Fish and Wildlife Services' Chincoteague National Wildlife Refuge for nest locations and take avoidance. Pre-March 15, contact (e-mail) John Kasbohm and Kevin Holcomb (USFWS) letting them know that contractors will be conducting topographic and bathymetric surveys during specified survey dates.

The Contractor shall provide a safety plan for NASA and USACE approval prior to commencing work. NASA Protective Services guidelines must be adhered to (base conduct, prohibited areas, badging) and restrictions/approvals may be required based on the equipment used for the survey (i.e.- RF Frequency Approval for a base-station, handhelds, Laser approval if used). Launch Ops may impact survey activities and NASA will work with the contractor to schedule the site survey to best fit the range ops. Partial access during ops can be arranged and is mission specific, with specific areas off-limits (coordination with NASA required throughout the survey). Primary NASA contact for the survey is Mike Balance (michael.w.ballance@nasa.gov, 757-824-1248). Secondary contact is John Saecker (john.r.saecker@nasa.gov, 757-824-1695).

7. **Required Deliverables**. The contractor is required to deliver corrected profile data in XYZ text file format, profile data as an ESRI ArcGIS shape file, complete metadata, all pertinent QC information, and a final written survey report.

7.1. Profile Data. All profiles shall be fully edited for erroneous data (spikes), motion, tides, and sound speed. Overlap on each profile will be analyzed for the specifications and that the data are in the proper vertical and horizontal datums.

7.1.1. ASCII Data Files. An ASCII text file of the final data shall be delivered with a descriptive header containing the following eight (8) columns:

- Profile Area and number (ex. WI_01, AI_15, etc)
- Survey Type using numerator tag (ex. Topo 1 or Hydro 2)
- Date
- Time (UTC)
- Easting (X)
- Northing (Y)
- Elevation (Z)
- Distance from Beginning of Line (DBL)

7.2. GIS Compatible Files. The contractor shall deliver profile data in a format compatible with ESRI ArcGIS 10.1 or higher and in such a manner as to easily import into the USACE coastal GIS database.

7.2.1. Profile Point Data. Profile and potential tie line data shall be provided as a point shapefile.

7.2.2. Laser Scan Data. An ESRI grid (raster data product) shall be created directly from the processed laser data collected in the MLS reach described above. The laser elevation data will be gridded at the highest resolution possible.

7.2.3. MHW Contour. The mean-high-water (MHW) contour will be extracted from the profile lines and supplemental tie lines (where allowed) data that will be provided as an ESRI shapefile.

7.3. Metadata Record. An FGDC or ISO 19115 compliant metadata record for each survey shall be created using ESRI ArcGIS ArcCatalog 10.5 or higher. Appropriate information shall be entered in all required fields. The metadata record shall be submitted with all other digital files required in the deliverable.

8. **Analyses**. Data derived from the field monitoring elements of the project will be assimilated and analyzed to assess observed trends in shoreline / volume change to understand past project performance and the need for future renourishment projects (volumes, placement locations and intervals).

8.1. Shoreline Analyses. Shoreline change will be computed between subsequent surveys for the MHW contour (entire survey extent) and design berm elevation (project area only). A comparison of shoreline position will also be made at these elevations for the given survey versus the design and construction templates to track the performance of the project and to help in determining required nourishment intervals.

8.2. Volumetric Analyses. Volume change above multiple elevations for both the aerial and sub-aerial beach, out to the depth of closure between subsequent surveys will also be computed at each survey transect. Cumulative volume change for reaches/sub-reaches and the entire study area to be calculated from volume change at each transect. A comparison of volume change will also be made at these elevations for the given survey versus the design and construction templates to track the performance of the project and to help in determining required nourishment intervals.

8.3. Trends Analyses. Shoreline / Volume change trend analysis will be used to determine relatively stable locations along the beach as well as erosional hotspots, accretional areas and longshore transport direction

/ nodal points over time. Identification of these trends will help to gain a better understanding of the cross-shore/longshore sediment transport patterns and their impacts on project performance and will be used in the planning of future nourishment projects for a more optimal shoreline management system. Over time and by integrating historical datasets, these analyses will also help to determine healthy shoreline volumes and nourishment triggers that also may be used in the future to guide projects. An analysis and documentation of the long-term trends will be completed and incorporated into the final report.

9. **Reporting.** Data derived from the field monitoring elements of the project will be assimilated and analyzed to assess observed trends in shoreline / volume change to understand past project performance and the need for future renourishment projects (volumes, placement locations and intervals).

   9.1. Written Survey Report. Four bound copies of the comprehensive written report summarizing all pertinent data collection / QC activities and analyses shall be submitted. Two copies to the District and two copies to NASA. The following items shall generally be included in the final report:

      9.1.1. Profile Survey & Data QC:
      - Dates and times of each data collection activity
      - Atmospheric conditions including temperature, wind direction, wind speed, tide stage, and wave conditions for each day of data collection activity
      - All horizontal and vertical control used to include monument name, establishing agency, date established, description, and published horizontal and vertical values
      - Temporary Bench Marks (TBM) descriptions with vertical values (if applicable)
      - Record of horizontal and vertical calibration of the survey vessel and daily topographic benchmark checks for each survey
      - All field notes including descriptions of obstructions preventing data collection along specified azimuths
      - General description of all equipment used

      9.1.2. Analyses
      - Executive summary
      - Shoreline change – individual transects, sub-reach average, and study area (island wide) average
      - Unit volume change - individual transects, sub-reach average, and study area (island wide) average
      - Cumulative volume change – sub-reach and study area (island wide)
      - Project Performance- quantify berm width and / or volume remaining to both design and construction templates
      - Trends analysis – identify stable/accretional areas, areas of concern (hotspots), and nodal zones
      - Conclusions and recommendations

10. **Other NASA Requirements:** Contractor must follow all badging and protective services requirements while on the facility. Access may be subject to mission constraints (i.e.- temporary hazard areas due to launch or pre-launch activities) if not coordinated with the NASA PM. Coordinate schedule with NASA PM to minimize mission impacts to the project. Work inside fenced pad locations must be coordinated with NASA prior to entry. Access/Permission to Assawoman Island (not NASA owned) is the responsibility of the contractor. Coordinate with NASA PM for Plover nest locations and restrictions while working in those immediate areas. Laser and RF NASA forms shall be submitted by the contractor to the NASA PM and are required for all separate RF emitting devices (i.e.-GPS Base Station) and all laser devices. These forms shall be submitted to the NASA PM at the start of the project. A safety plan shall be submitted for the work and approved by NASA prior to work commencing, inclusive of a JHA Job Hazard Analysis for various features of work. If the bid option is awarded, nautical constraints during launches could be implemented. Coordinate work with the NASA PM for minimal impacts.

11. **Schedule of Work & Completion Times.** Upon award of contract and weather permitting, fieldwork for the Wallops Island profile surveys should commence within 45 calendar days of task order award. The draft report shall be submitted within 60 days of completion of field data acquisition and Final report, including all data deliverables, submitted within 90 days. **The A-E is required to meet the deadlines for submittals. This task order Period of Performance in 180 calendar days.**

The following schedule is provided with contract milestones, starting from the notice to proceed and ending with the award of the construction contract.

Activity	# of Calendar Days	Notes
Notice to Proceed (NTP)	1	
Kick Off Meeting	7	
Topographic, Laser Scanning, Hydrographic Surveys	45	
Draft Survey Submittal	60	
Draft Survey Review	15	
Final Survey Electronic Submittal	15	

NOTE: Safety of the field crews is the priority, followed by data quality and timeliness of schedule respectively. The contractor is to use judgment on the exact days of data collection for both safety and data quality concerns and scheduling of surveys will be coordinated in advance with Wallops Island. Data analysis, documentation, and computer files should be delivered to the USACE Norfolk District no later than 90 days following field data acquisition which is understood to be solely dictated by the weather, tide stage and surface / upper-level conditions. This schedule is subject to adjustment by Wallops Island as it pertains to Facility missions and the contractor for documented conditions beyond the control of the parties hereto.

12. **Deliver To**. All Draft and final deliverables shall be provided to:
Chris Parker
Contracting Officer Representative USACE–Norfolk District 803
Front Street
Norfolk, VA 23510-1096

13. **Points of Contact:**

USACE Norfolk District Design Technical Lead (DTL):
U.S. Army Engineer District, Norfolk
ATTN: CENAO-EC-ED (Nick Ingold)
803 Front Street
Norfolk, VA 23510-1096

Phone: (757) 201-7260
Email: nicholas.w.ingold@usace.army.mil

USACE Norfolk District Project Manager (PM):
U.S. Army Engineer District, Norfolk ATTN:
CENAO-PM-J (John McCormick) 803 Front
Street
Norfolk, VA 23510-1096

Phone: (757) 201-7682
Email: john.w.mccormick2@usace.army.mil

USACE Norfolk District Contracting Officer's Representative (COR):
U.S. Army Engineer District,
Norfolk ATTN: CENAO-EC-
ED (Chris Parker) 803 Front
Street
Norfolk, VA 23510-1096

Phone: (757) 201-7869
Email: christopher.parker@usace.army.mil

USACE Norfolk District Contracting Officer (KO):
U.S. Army Engineer District,
Norfolk ATTN: CECT-NAO
(Stormie Wicks) 803 Front
Street
Norfolk, VA 23510-1096

Phone: (757) 201- 7215
Email: stormie.b.wicks@usace.army.mil

USACE Norfolk District (A-E Invoicing):
U.S. Army Engineer District,
Norfolk ATTN: CENAO-EC-
ED
Phone: (757) 201- 7723
Email: CENAO.ECAEInvoicing@usace.army.mil

14. **Surveying Criteria and Specifications:**

15.2. Norfolk District Design Guide, dated 27 May 2010, located at: http://www.nao.usace.army.mil/Portals/31/docs/engineering/DesignGuideManual_UP DATED_052710.pdf

15.3. U.S. Army Corps of Engineers Design Criteria, located at: ht tp:/ / www .w bdg.o rg/ ff c/ a rm y -co e

15.4. ERDC/ITL TR-12-1 A/E/C Graphics Standard, Release 2.0, located at: http://www.wbdg.org/FFC/AECCAD/ERDCITL_TR12-1_r2.pdf

15.5. ERDC/ITL TR-12-6 A/E/C CAD Standard, Release 6.0, located at: http://www.wbdg.org/FFC/AECCAD/ERDCITL_TR12-6_r6.pdf

15.6. ProjNet (DrChecks), located at: https://www.projnet.org

15.7. Federal Acquisition Regulation (FAR), located at: https://www.acquisition.gov/FAR/.

15.8. EP 715-1-7 Architect-Engineer Contracting in USACE (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerPamphlets/EP_715-1-7.pdf?ver=2013-08-22-094139-520), provides guidance and procedures for contracting architect- engineer (A/E) services in accordance with the Brooks Architect-Engineer Act and referenced acquisition regulations.

15.9. U.S. Army Corps of Engineers Geospatial Data and Systems, EM 1110-1-2909 http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-1-2909.pdf?ver=2013-09-04-161046-587

15.10. U.S. Army Corps of Engineers Control and Topographic Surveying Manual, EM 1110-1- 1005 http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-1-1005.pdf?ver=2014-04-01-094204-880

15.11. U.S. Army Corps of Engineers Hydrographic Surveying Manual, EM 1110-2-1003 http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1003.pdf?ver=2014-01-06-155809-307

15.12. User Guidelines for Single Base Real Time GNSS Positioning, published by the National Geodetic Survey, dated August 2011, Version 2.1, available at: https://www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v2.1.pdf

15.13. National Geodetic Survey Guidelines for Real Time GNSS Networks, v. 2.0, dated March 2011, available at: http://www.ngs.noaa.gov/PUBS_LIB/NGS.RTN.Public.v2.0.pdf

15.14. Methods of Practice and Guidelines for Using Survey-Grade Global Navigation Satellite Systems (GNSS) to Establish Vertical Datum in the United States Geological Survey, Chapter 1 of Section D, Field Survey Methods, Book 11, Collection and Delineation of Spatial Data, available at: https://pubs.usgs.gov/tm/11d1/tm11-D1.pdf

15.15. Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, available at: http://www.ngs.noaa.gov/PUBS_LIB/GeomGeod.pdf

15.16. FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems, available at: http://www.ngs.noaa.gov/FGCS/tech_pub/Fgcsvert.v41.specs.pdf

15.17. Guidelines for Establishing GPS-Derived Orthometric Heights (NGS-59), found at: http://www.ngs.noaa.gov/PUBS_LIB/NGS592008069FINAL2.pdf

15.18. EM 385-1-1: USACE Safety and Health Requirements – English http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_385-1-1.pdf?ver=2015-04-09-142531-467 (2014Nov 30)

15.19. Bathymetric Survey Requirements for BOEM Marine Minerals Lease Areas (borrow areas), Dec 2023

APPENDIX B

MHW SHORELINE

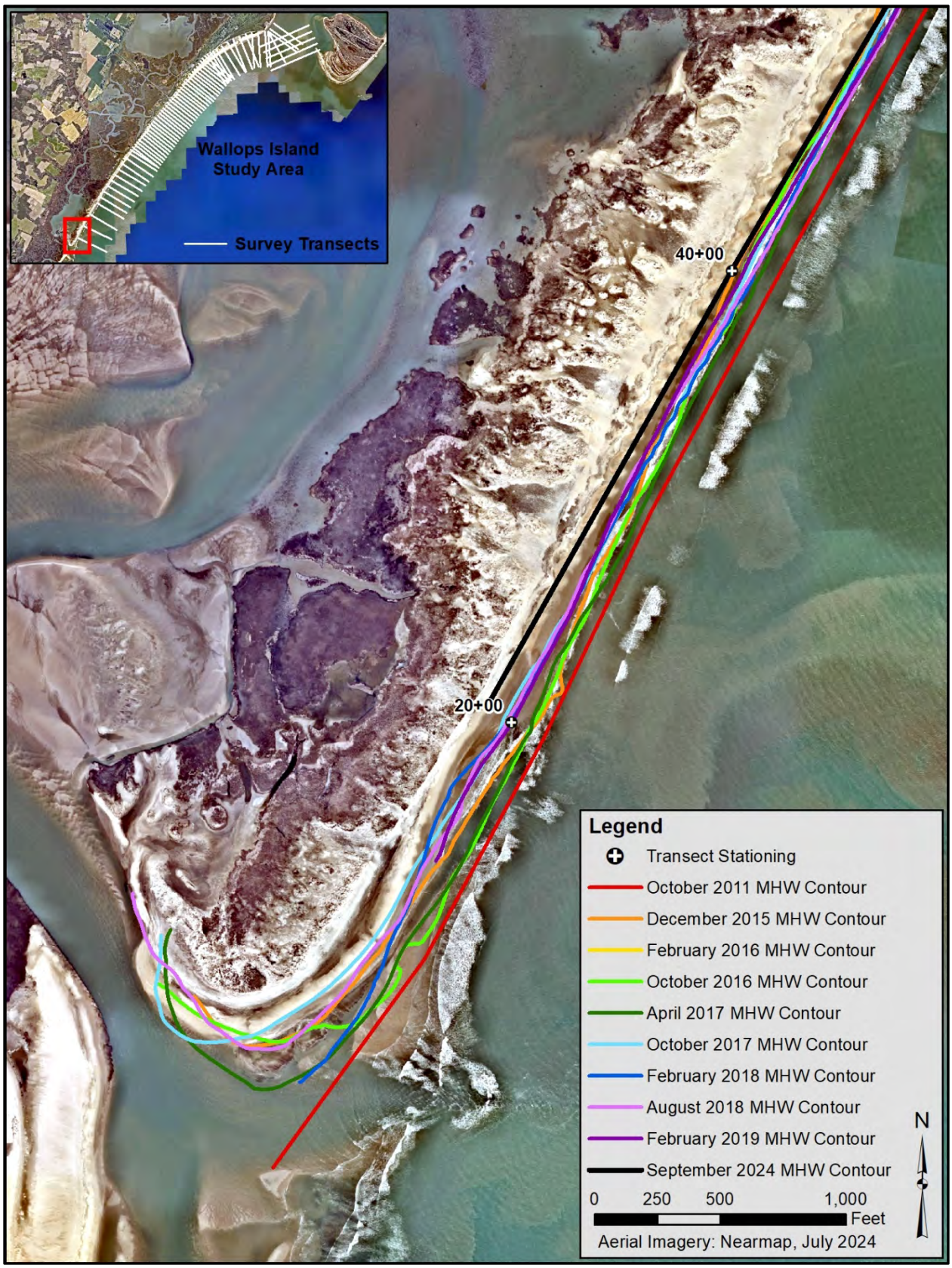


Figure B-1. MHW Shorelines 2011 - 2024 (Sta 0+00 to Sta 50+00)

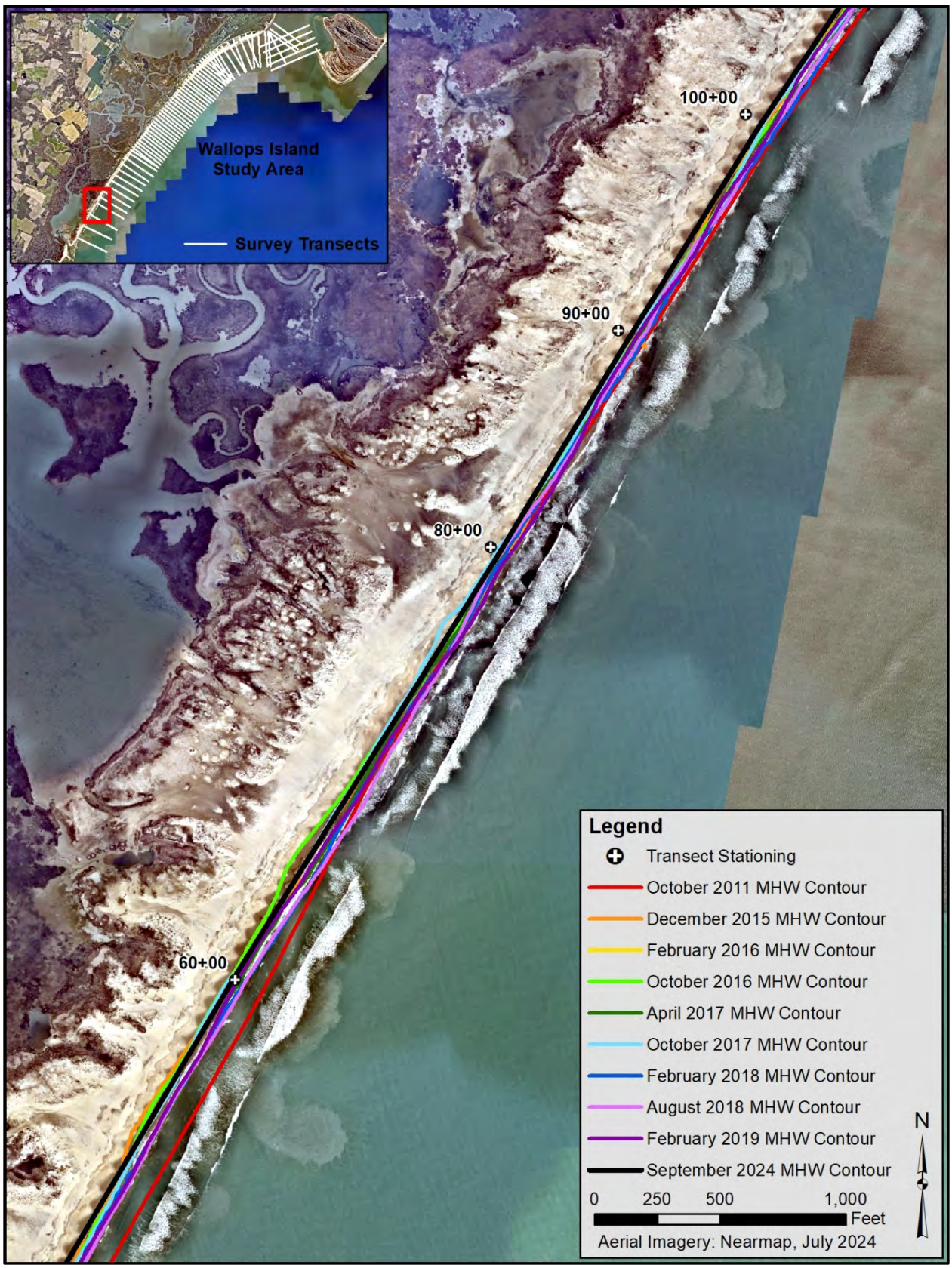


Figure B-2. MHW Shorelines 2011 - 2024 (Sta 50+00 to Sta 100+00)

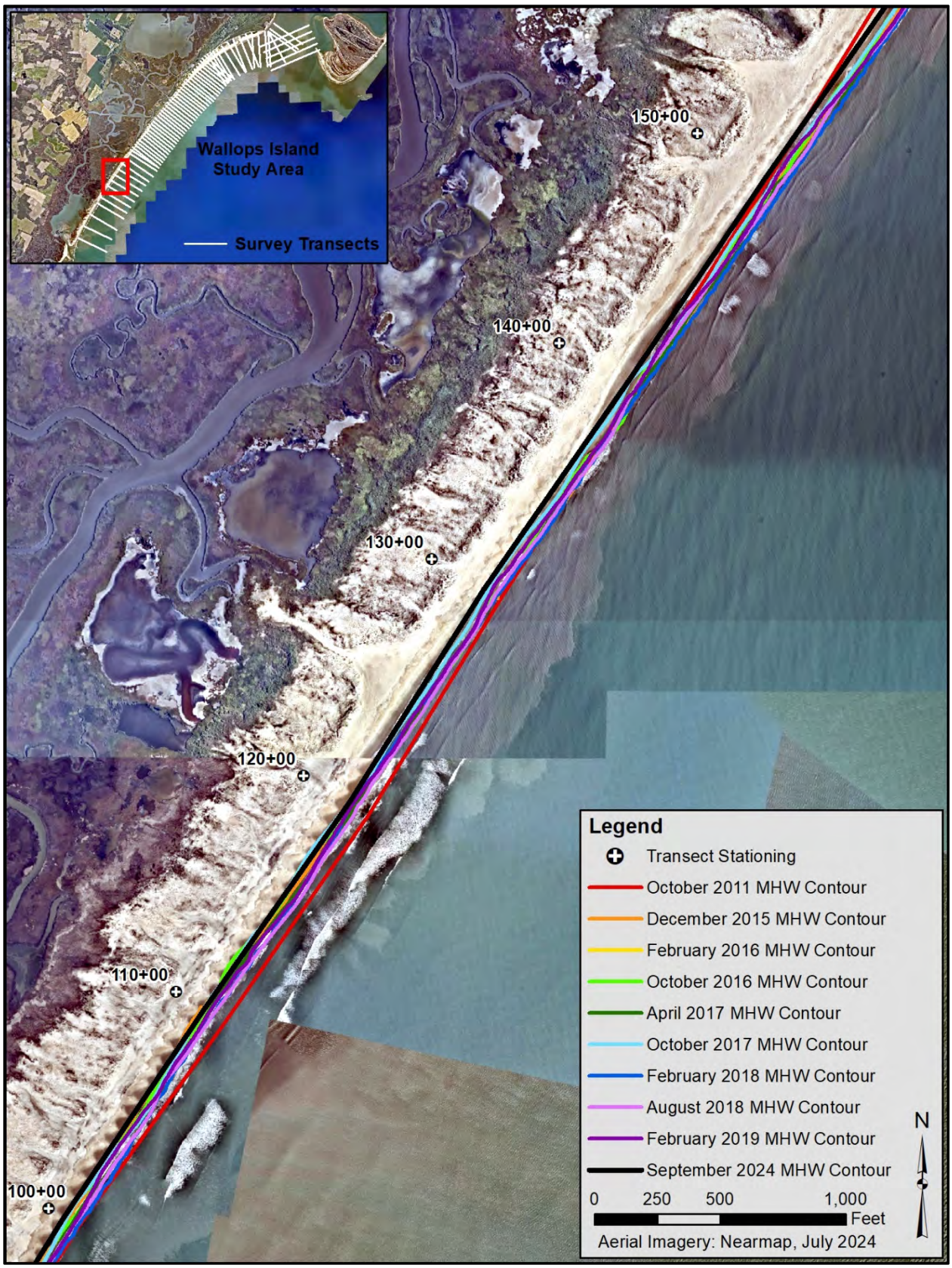


Figure B-3. MHW Shorelines 2011 - 2024 (Sta 100+00 to Sta 150+00)

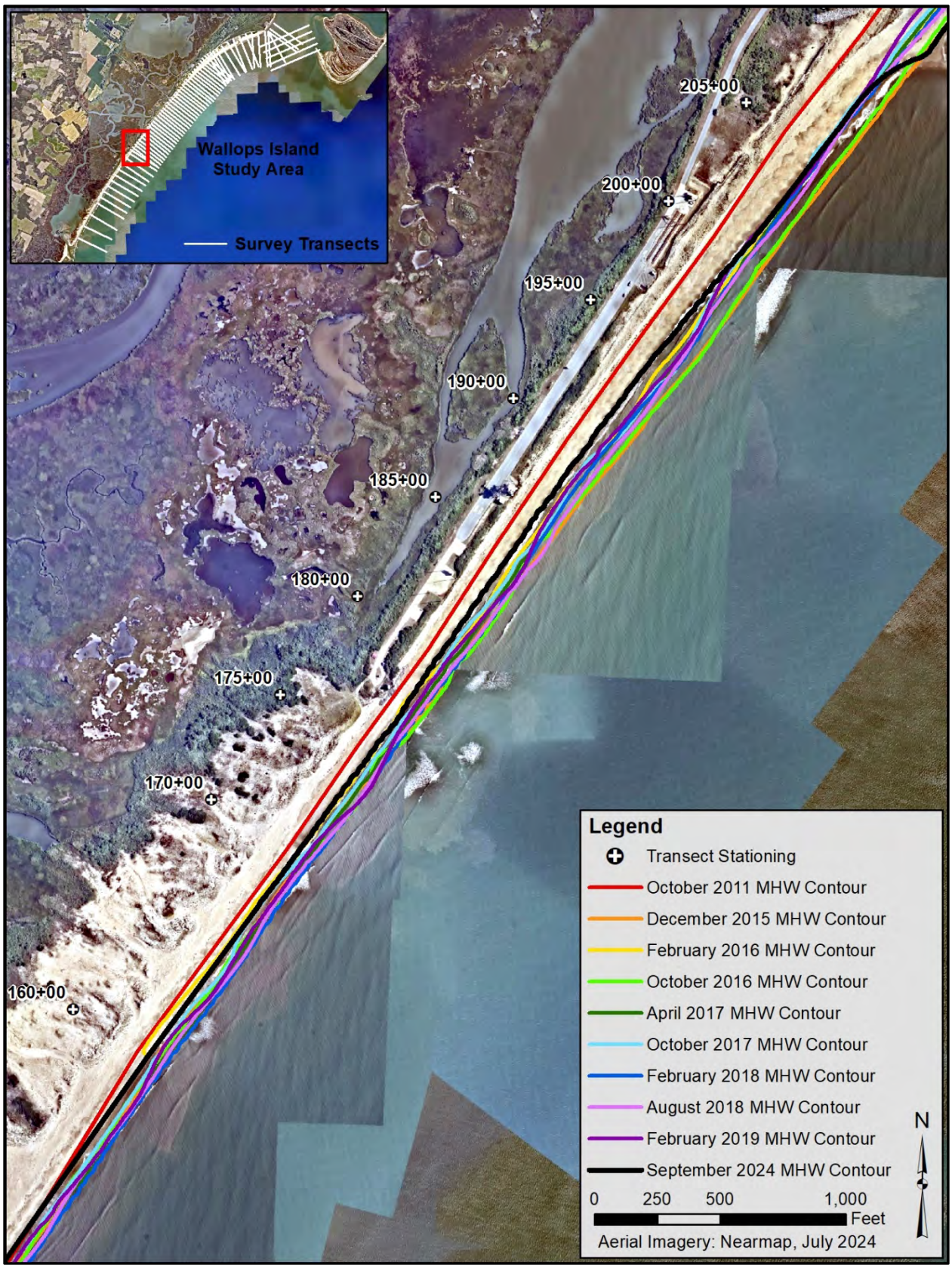


Figure B-4. MHW Shorelines 2011 - 2024 (Sta 160+00 to Sta 205+00)



Figure B-5. MHW Shorelines 2011 - 2024 (Sta 210+00 to Sta 255+00)

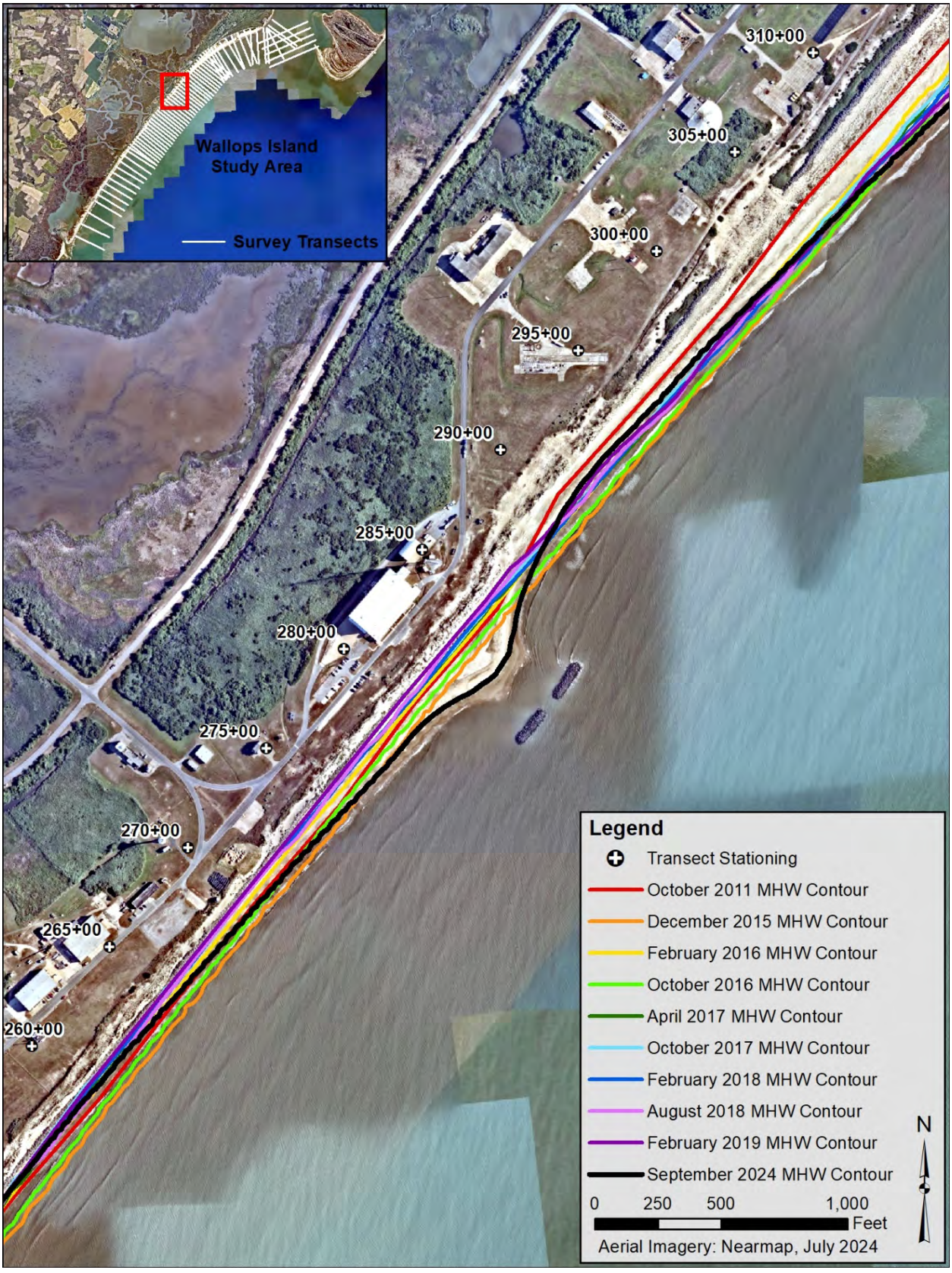


Figure B-6. MHW Shorelines 2011 - 2024 (Sta 260+00 to Sta 310+00)

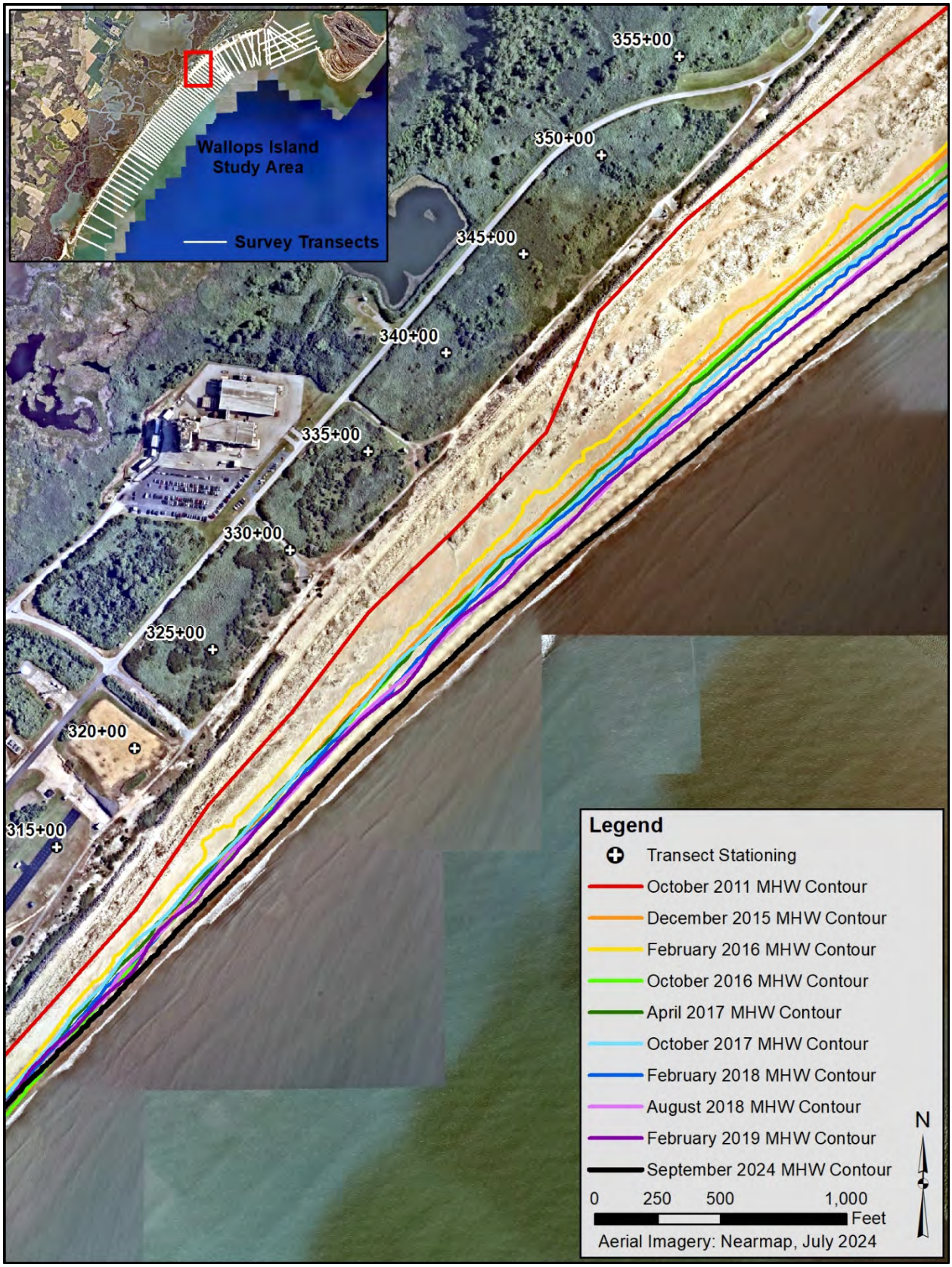


Figure B-7. MHW Shorelines 2011 - 2024 (Sta 315+00 to Sta 355+00)



Figure B-8. MHW Shorelines 2011 - 2024 (Sta 360+00 to Sta 400+00)

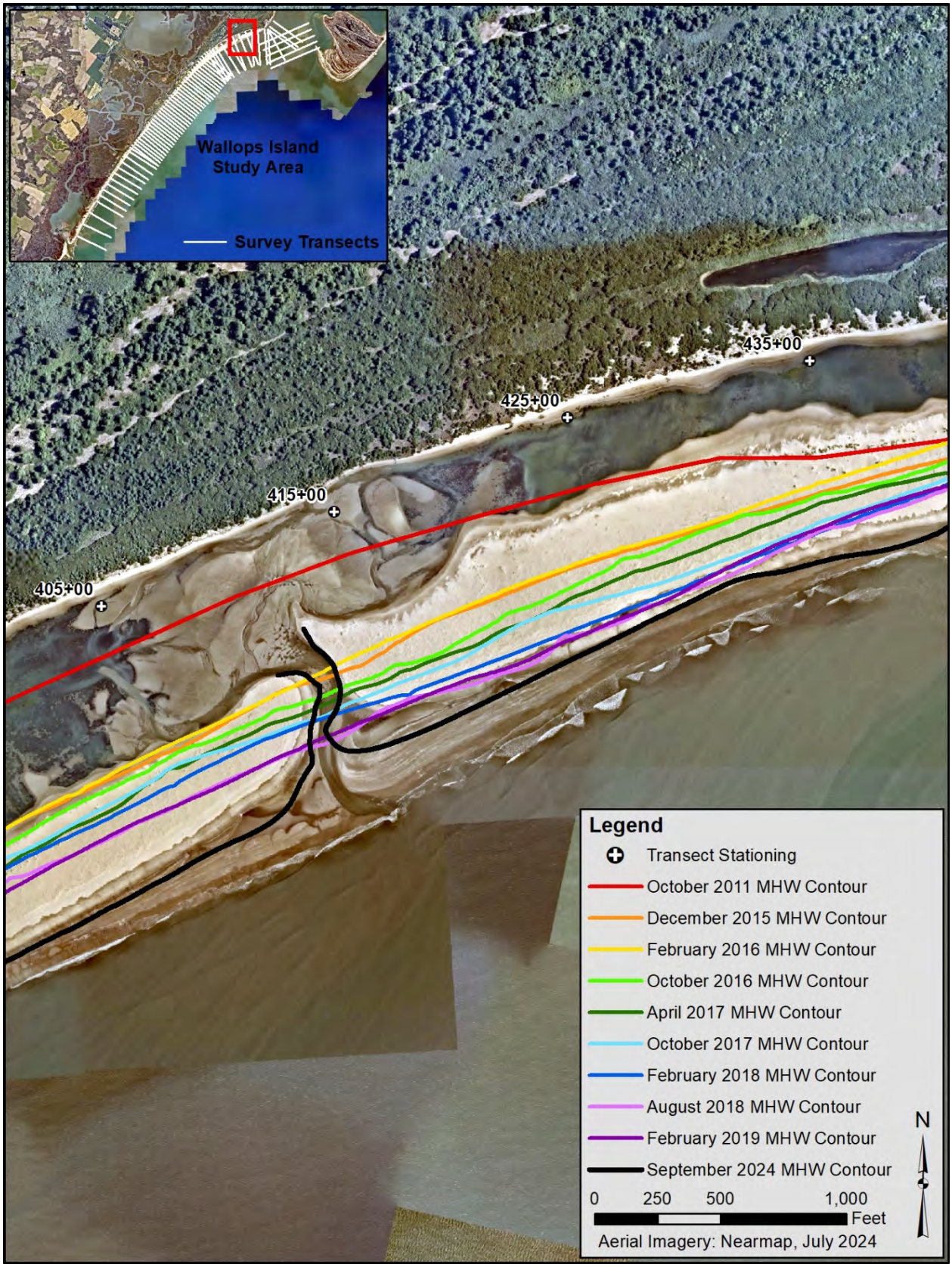


Figure B-9. MHW Shorelines 2011 - 2024 (Sta 405+00 to Sta 440+00)

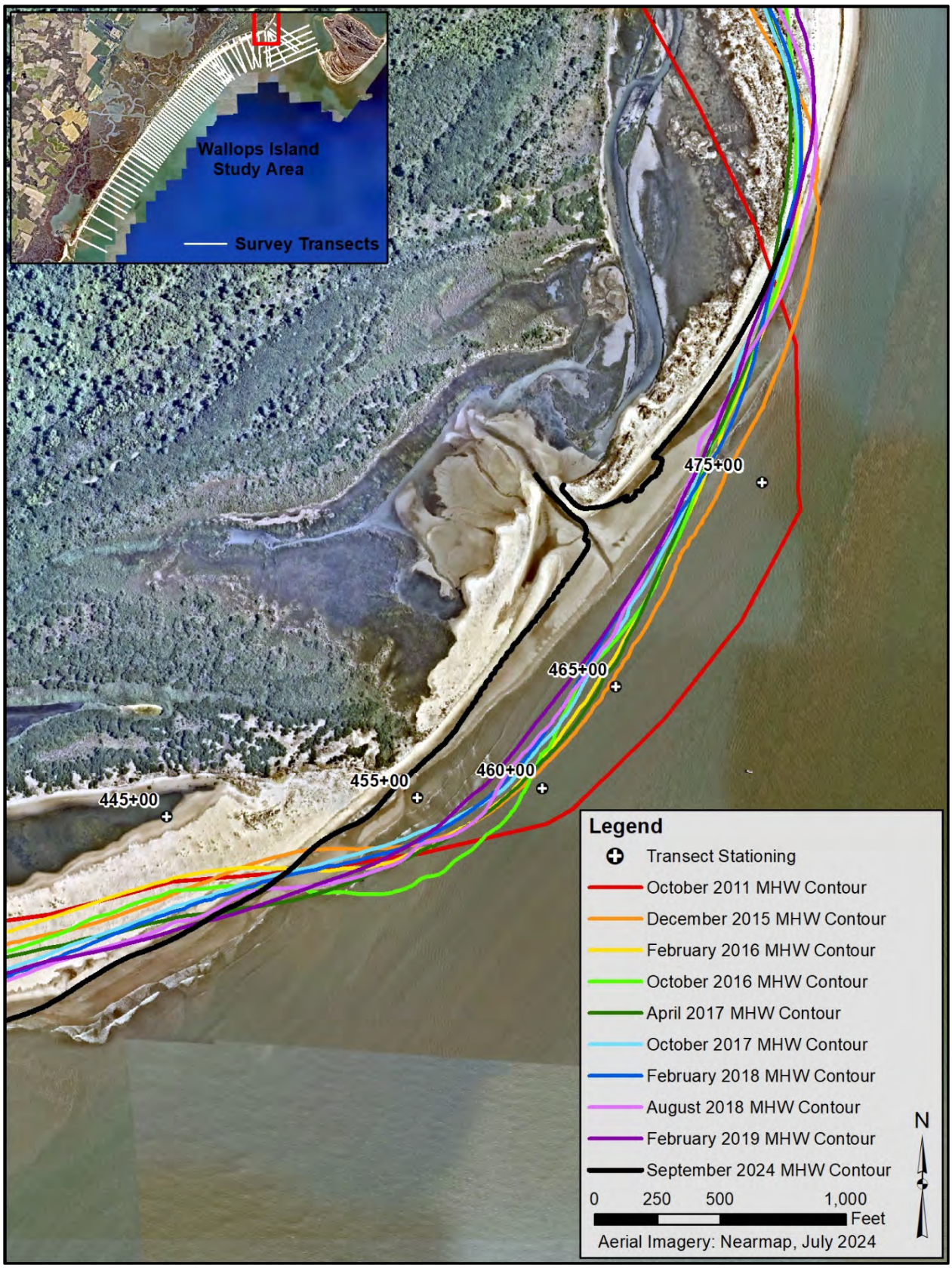


Figure B-10. MHW Shorelines 2011 - 2024 (Sta 440+00 to Sta 475+00)

APPENDIX C

Profile Plots

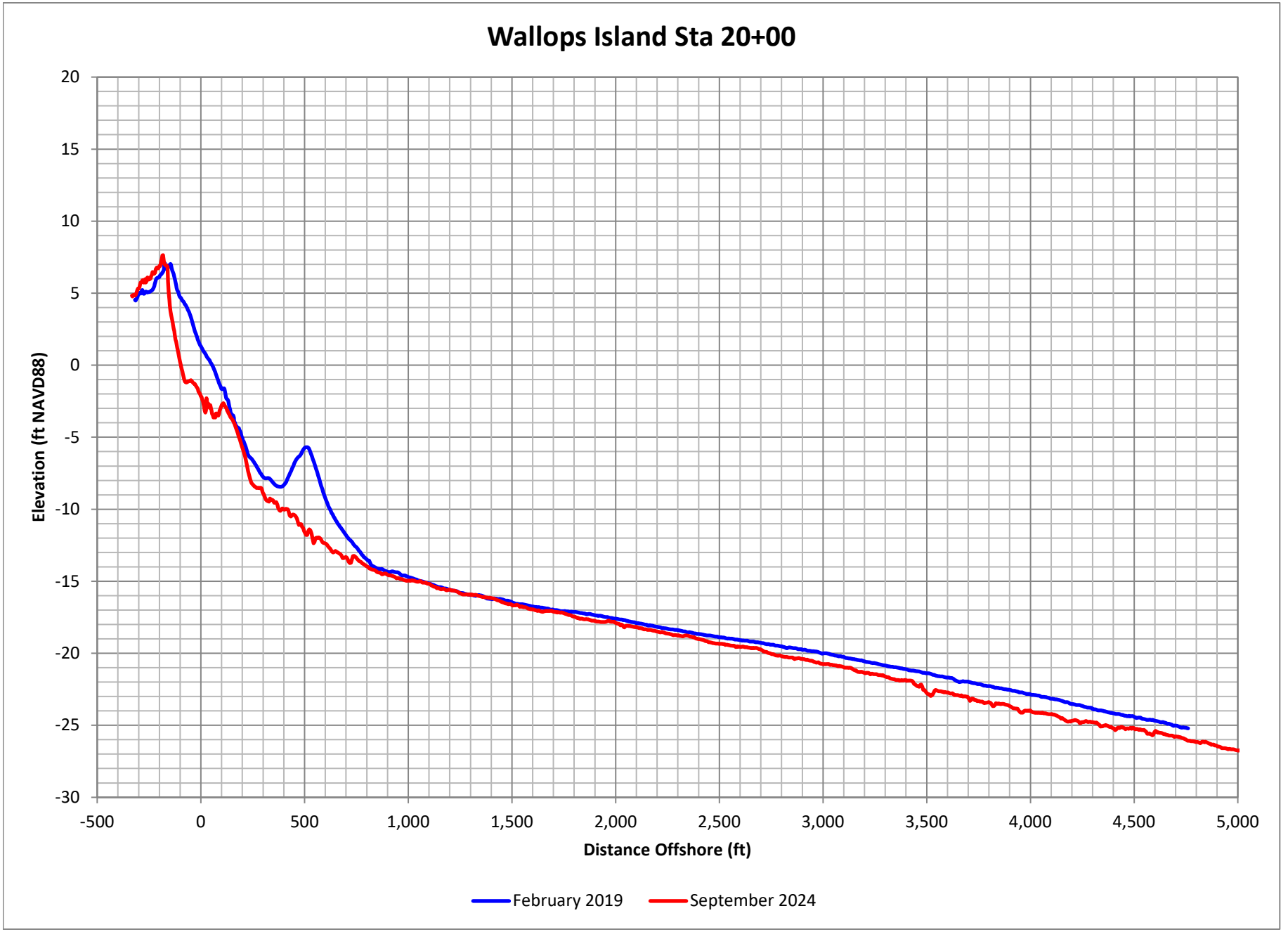


Figure C-1. Wallops Island Profile Comparison Plot

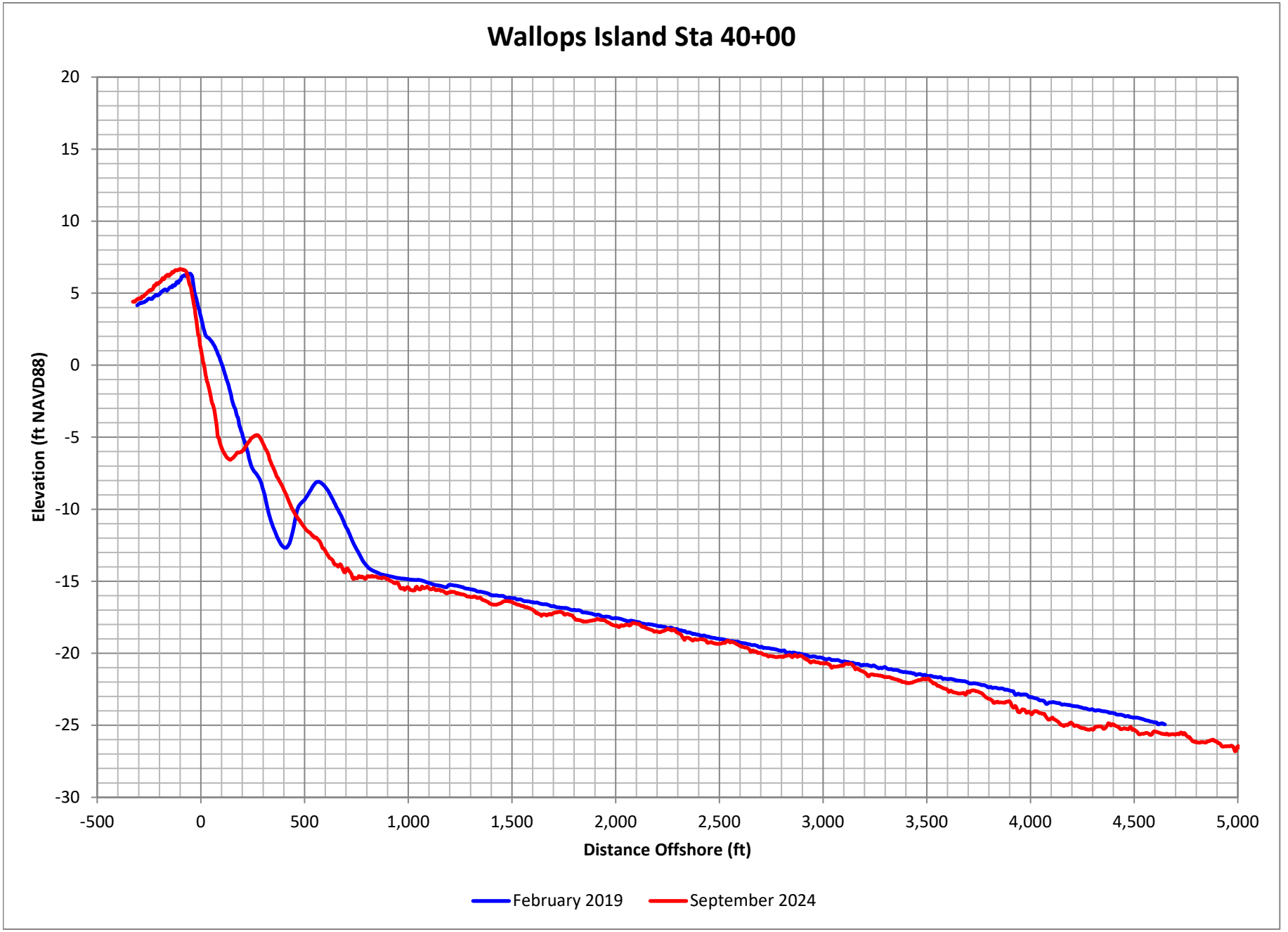


Figure C-2. Wallops Island Profile Comparison Plot

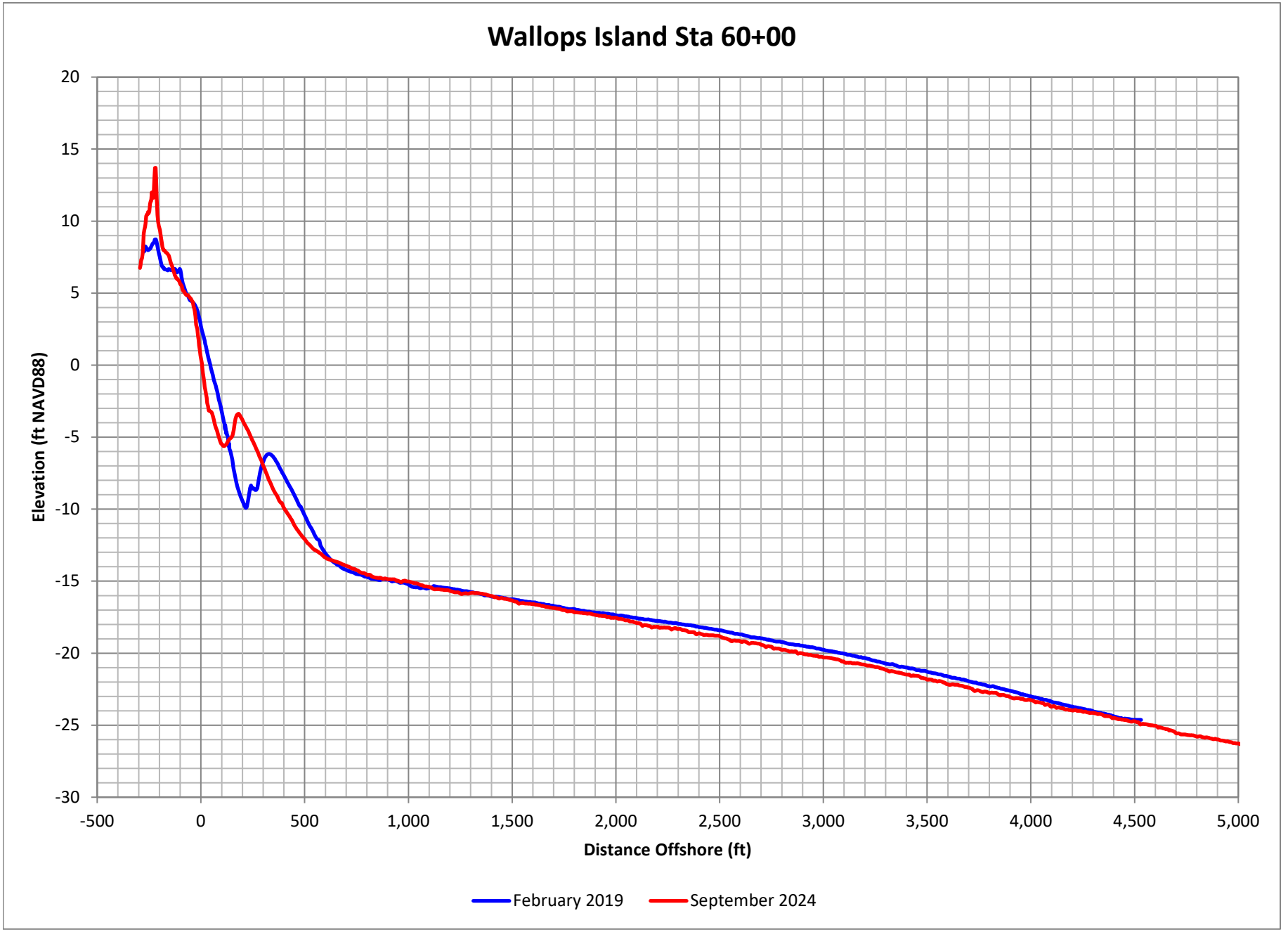


Figure C-3. Wallops Island Profile Comparison Plot

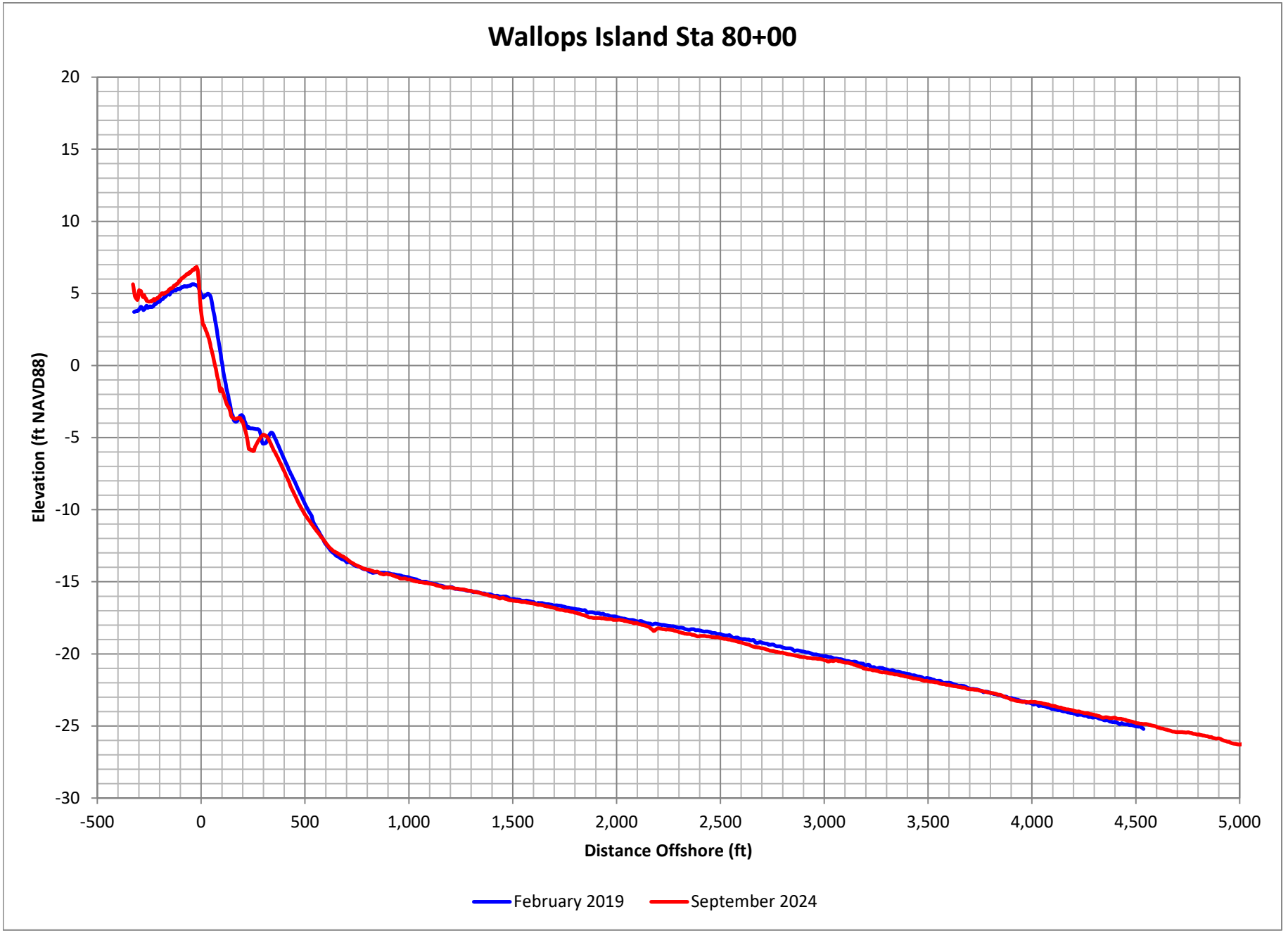


Figure C-4. Wallops Island Profile Comparison Plot

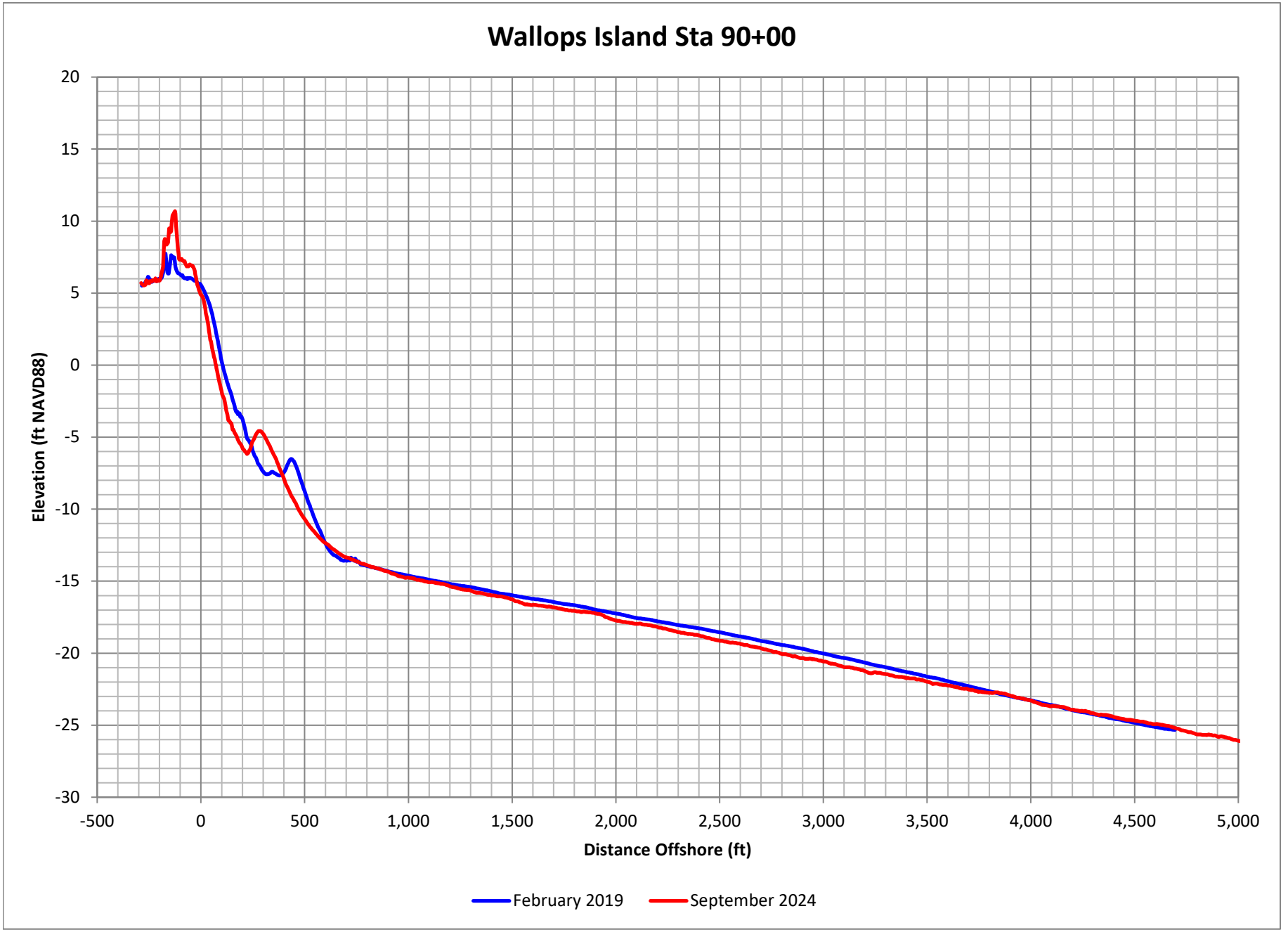


Figure C-5. Wallops Island Profile Comparison Plot

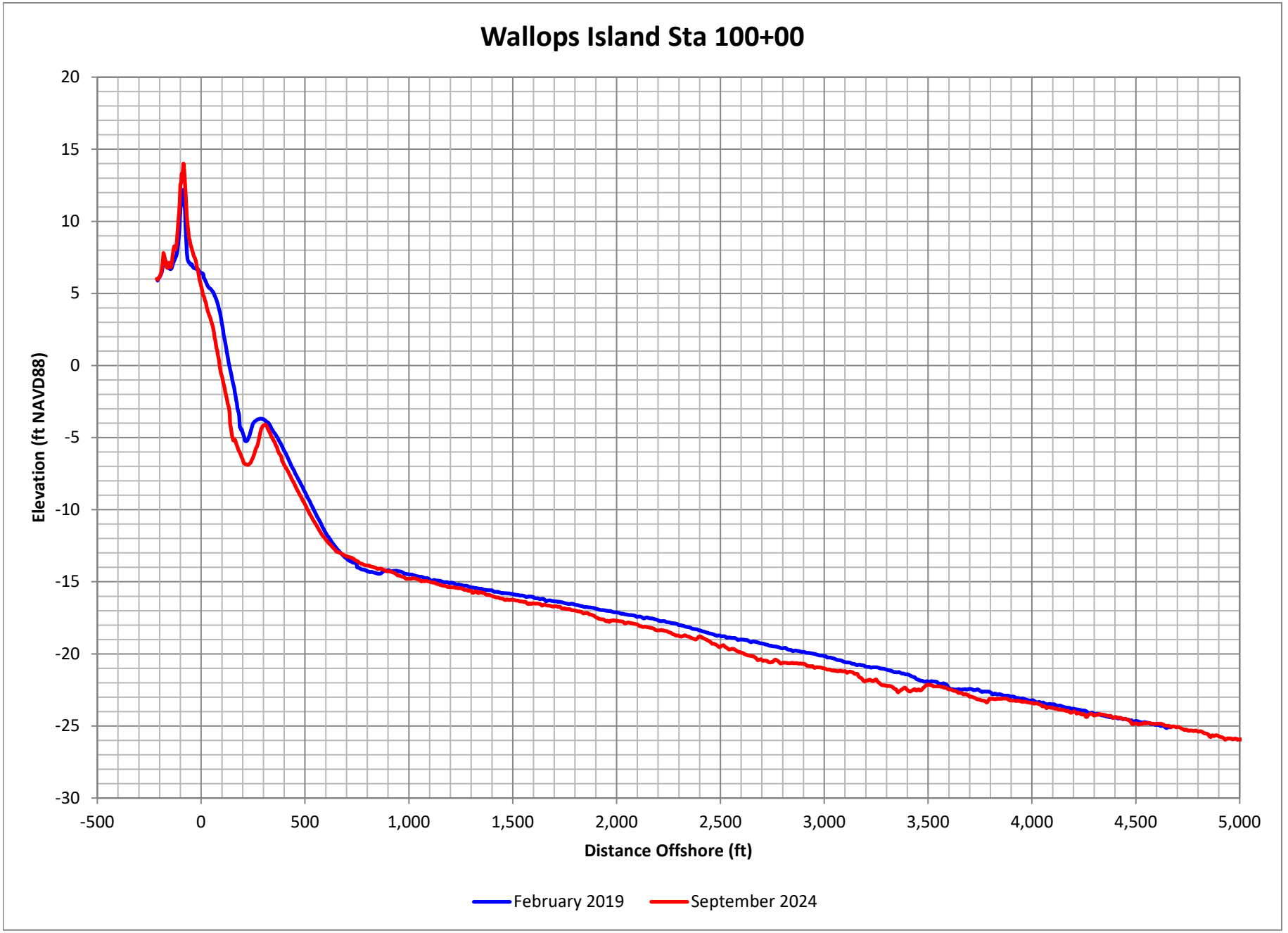


Figure C-6. Wallops Island Profile Comparison Plot

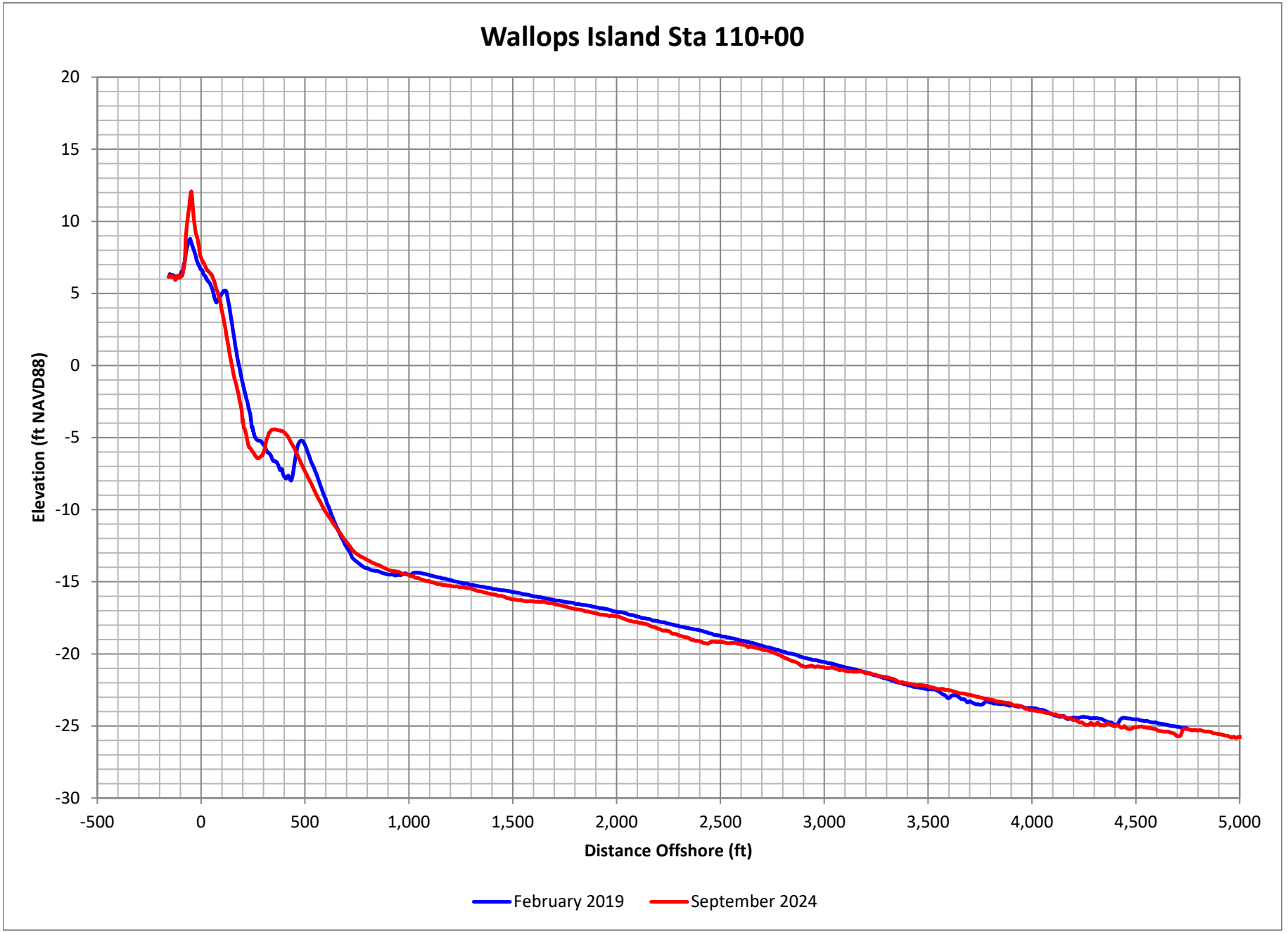


Figure C-7. Wallops Island Profile Comparison Plot

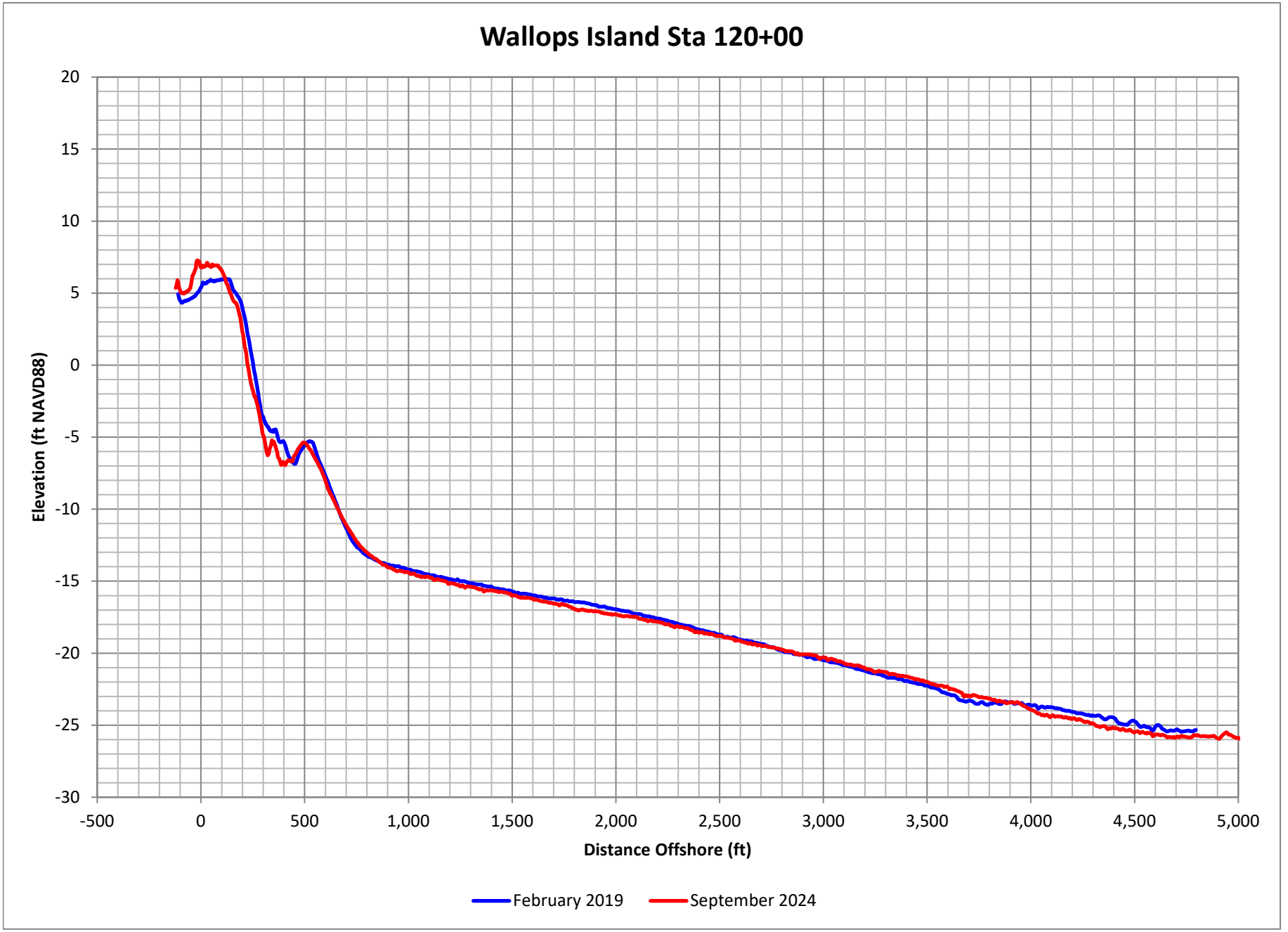


Figure C-8. Wallops Island Profile Comparison Plot

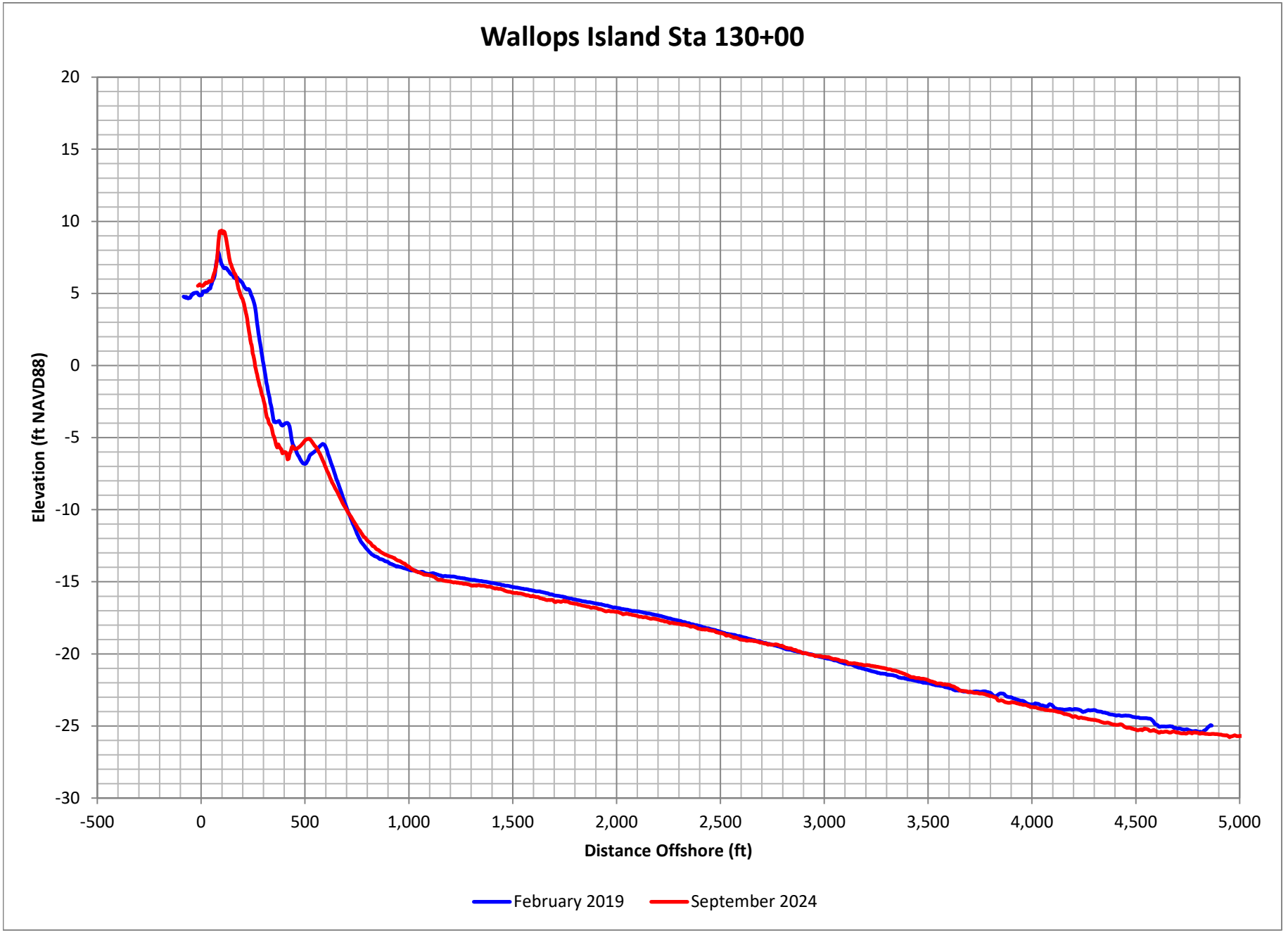


Figure C-9. Wallops Island Profile Comparison Plot

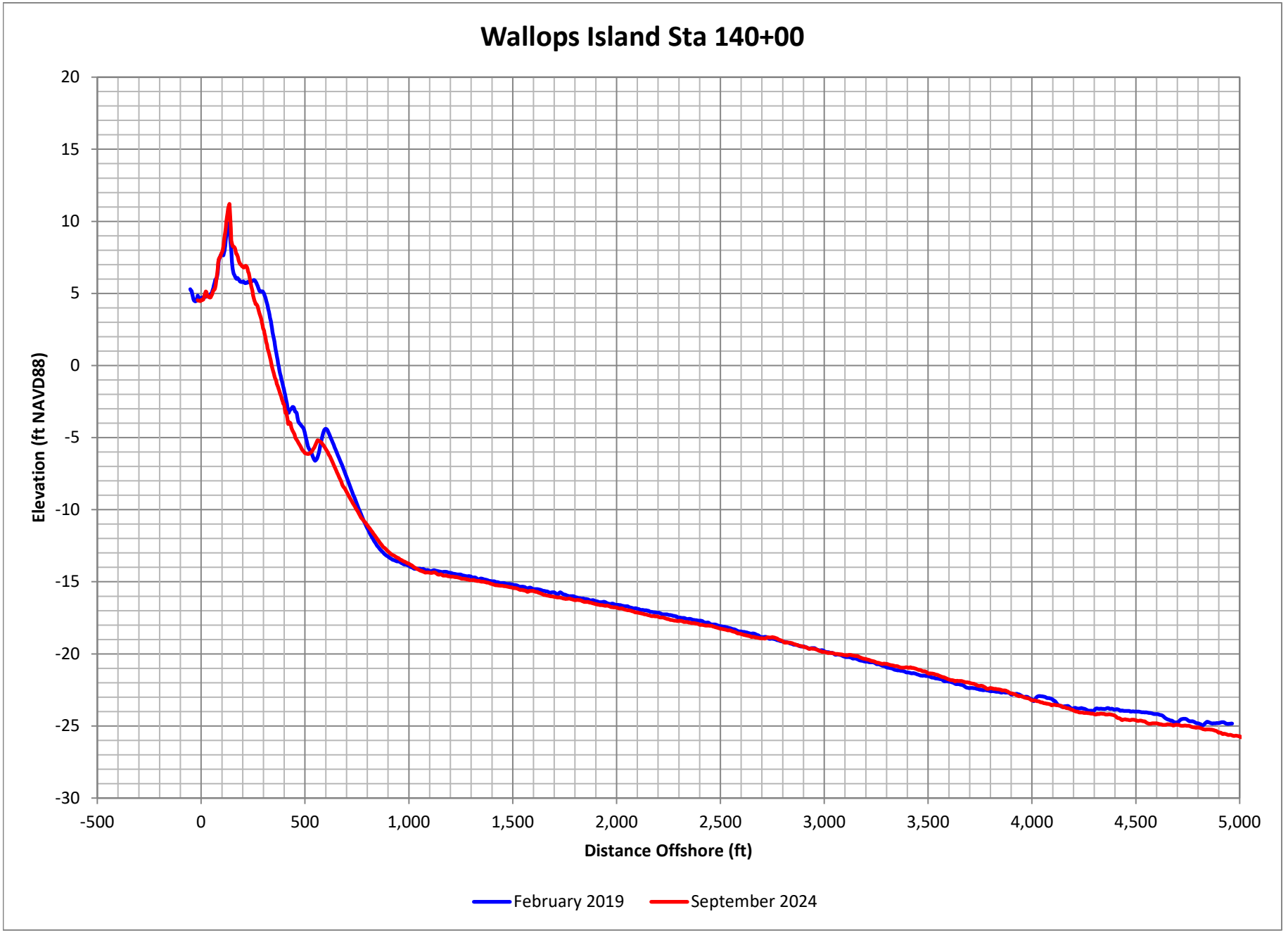


Figure C-10. Wallops Island Profile Comparison Plot

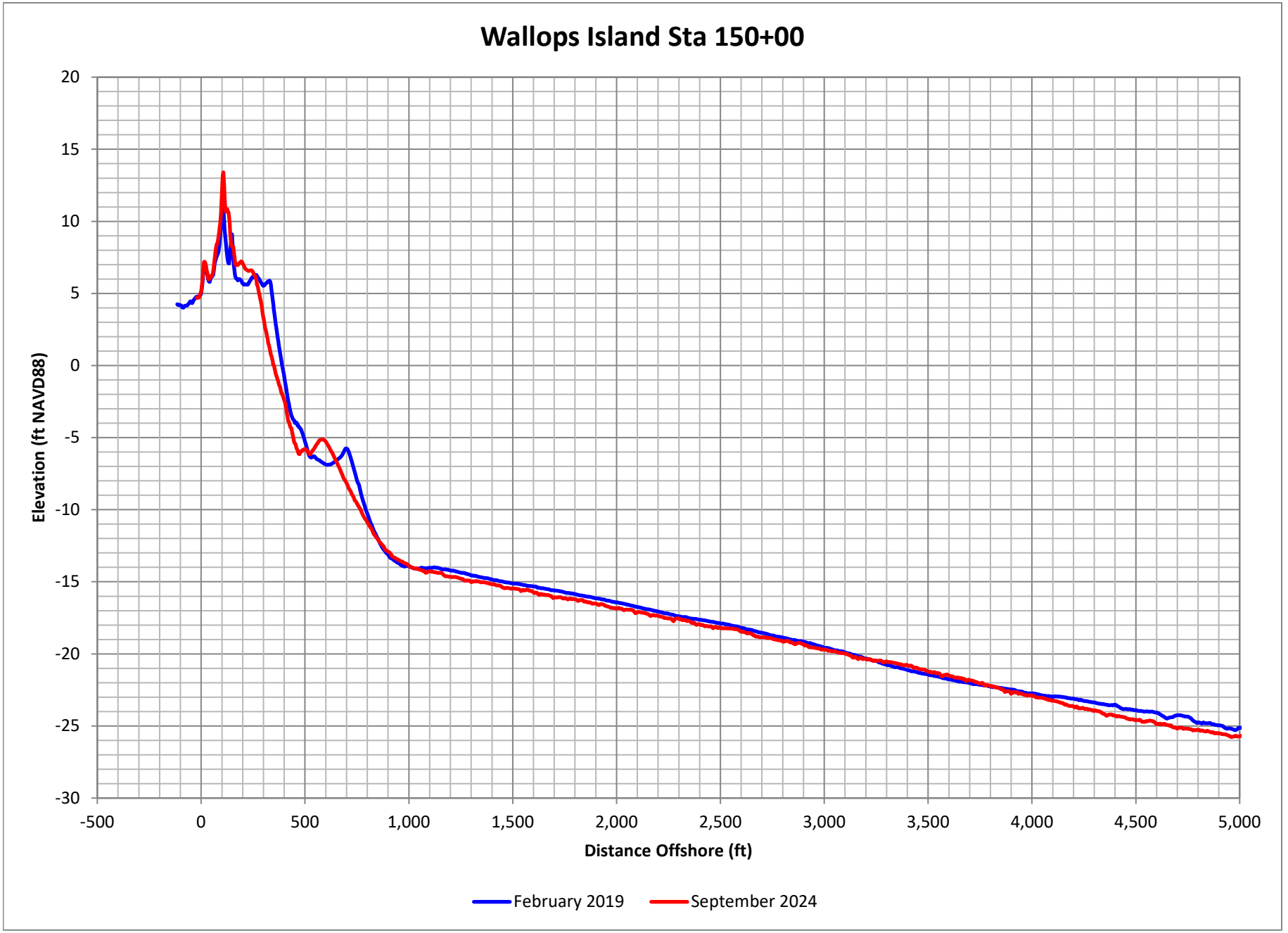


Figure C-11. Wallops Island Profile Comparison Plot

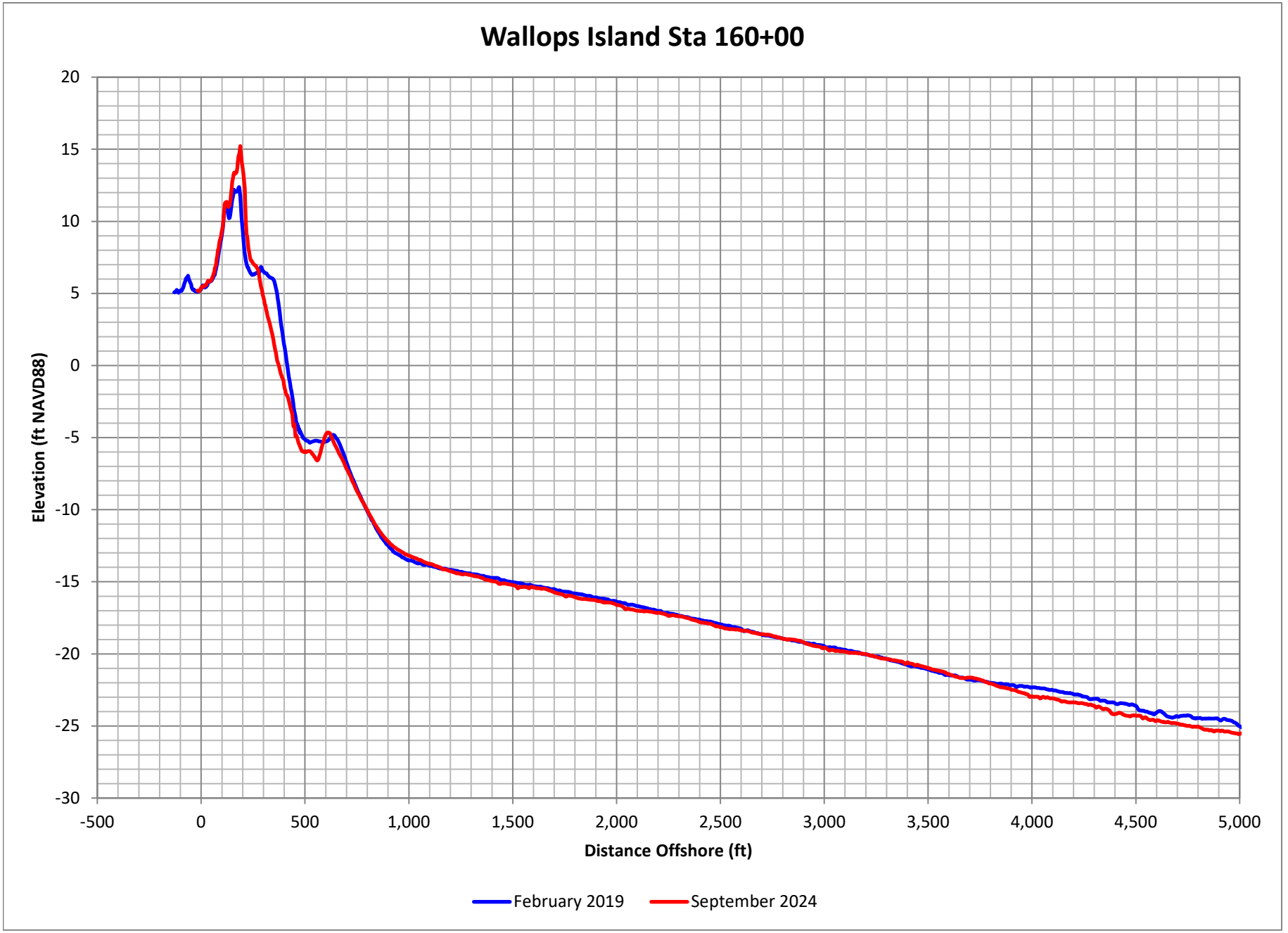


Figure C-12. Wallops Island Profile Comparison Plot

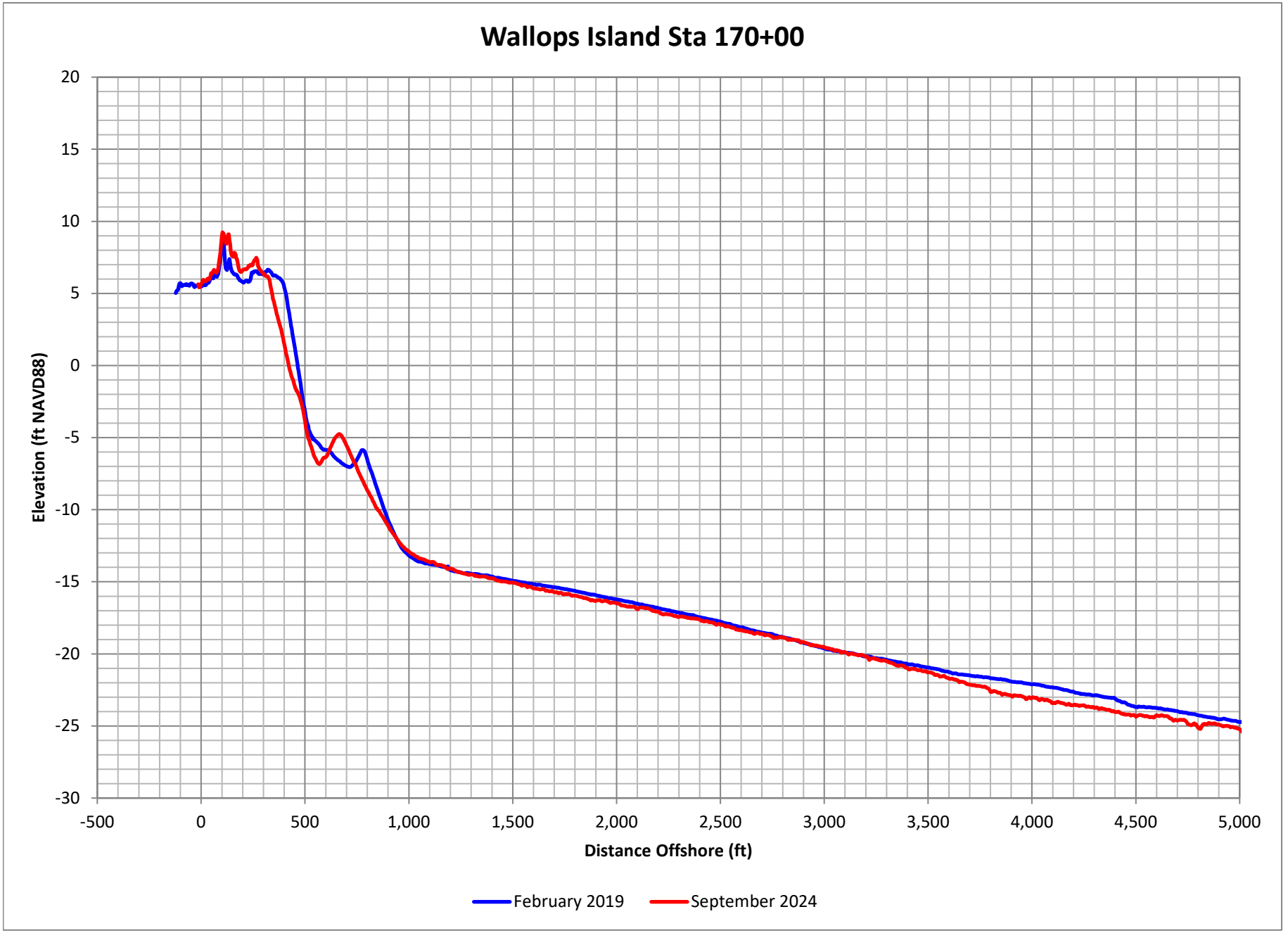


Figure C-13. Wallops Island Profile Comparison Plot

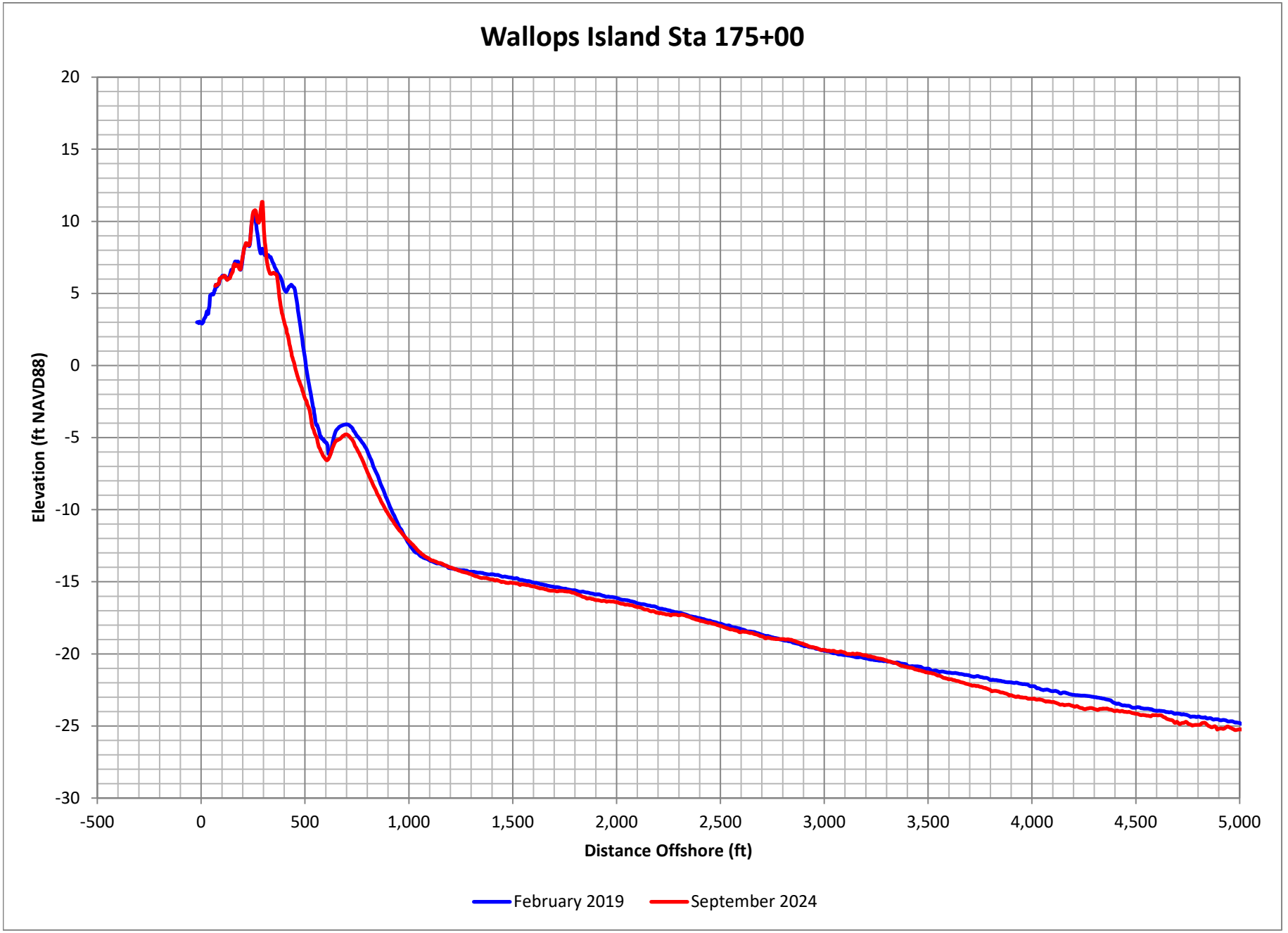


Figure C-14. Wallops Island Profile Comparison Plot

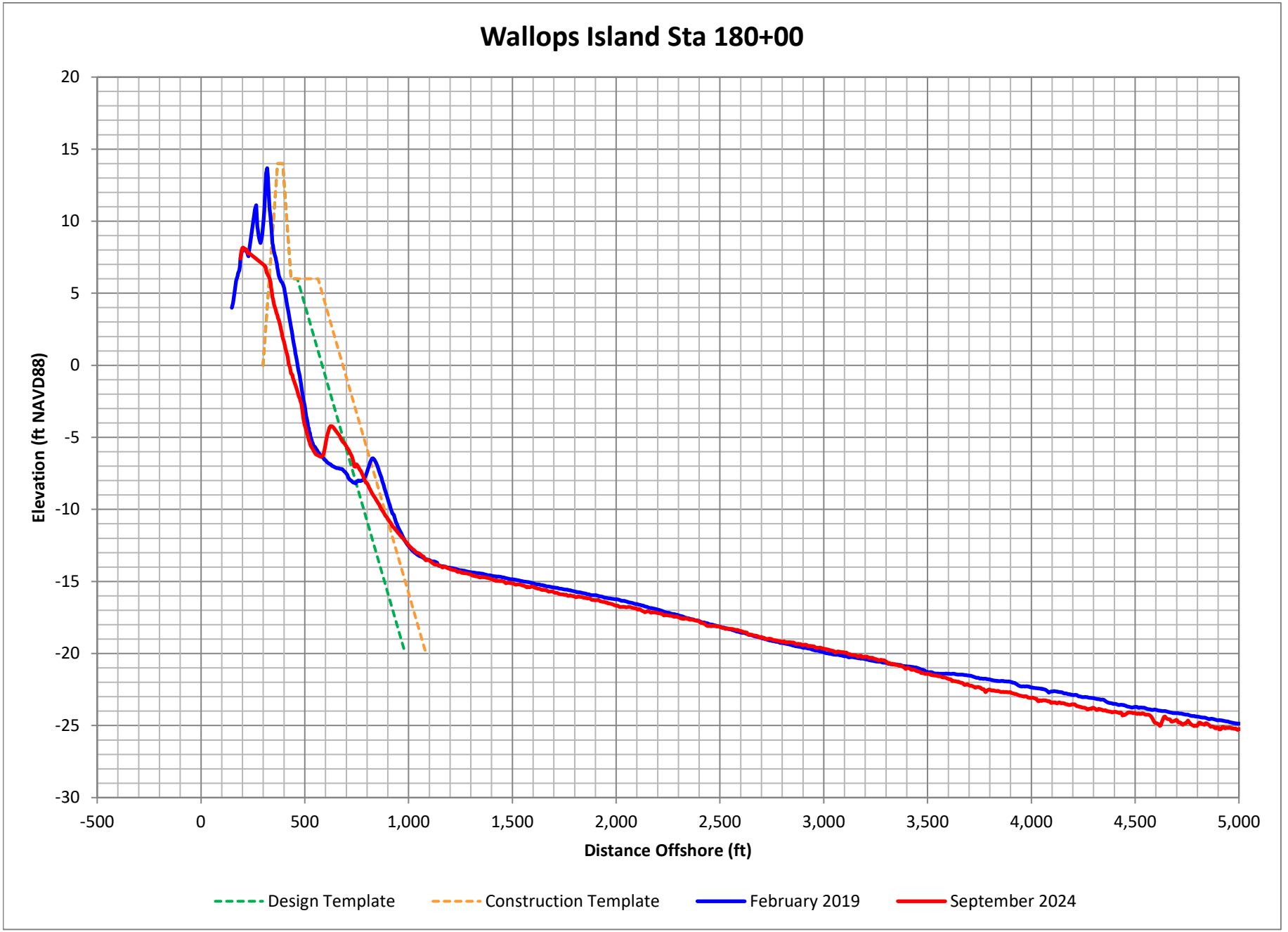


Figure C-15. Wallops Island Profile Comparison Plot

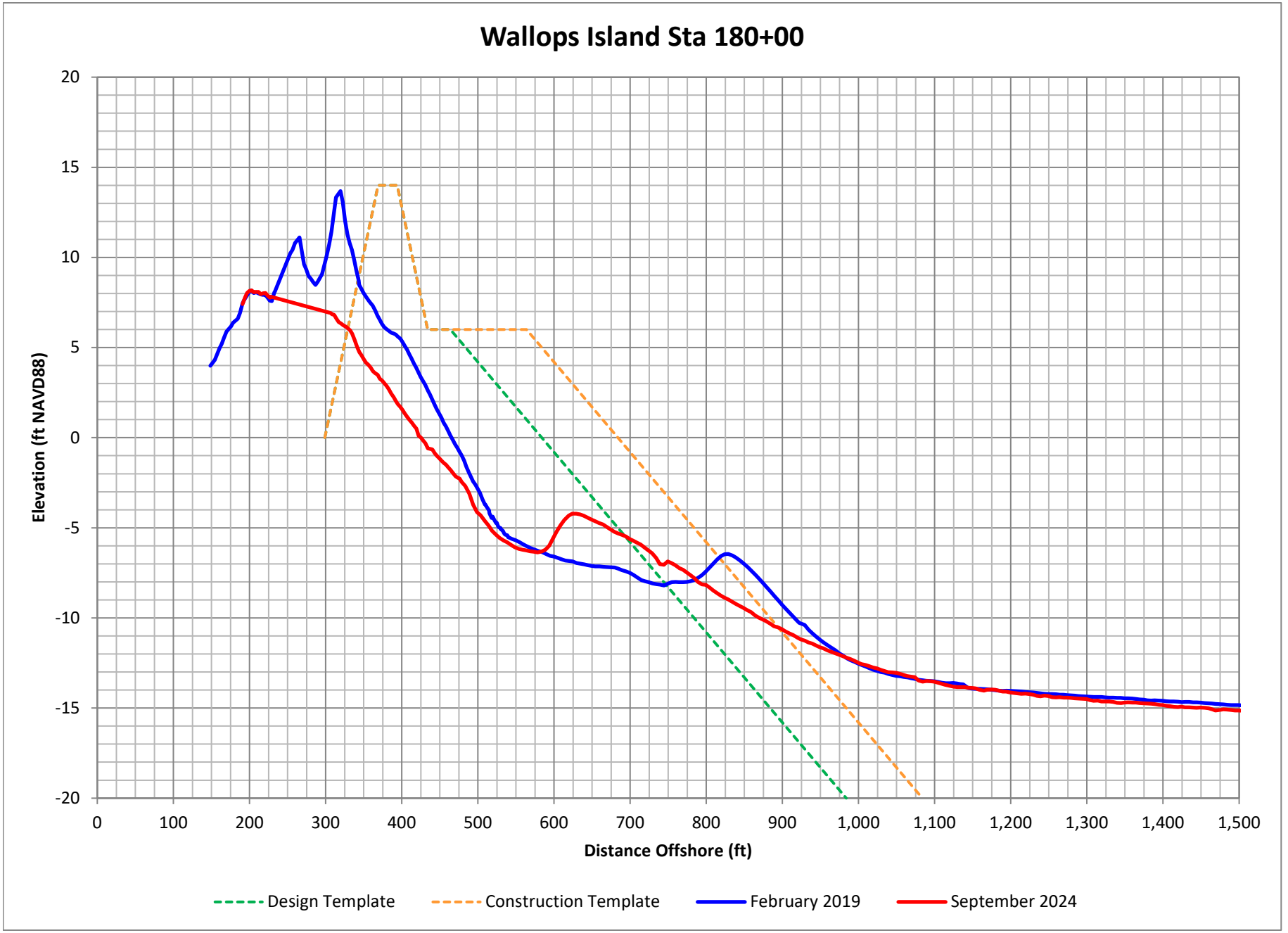


Figure C-16. Wallops Island Profile Comparison Plot

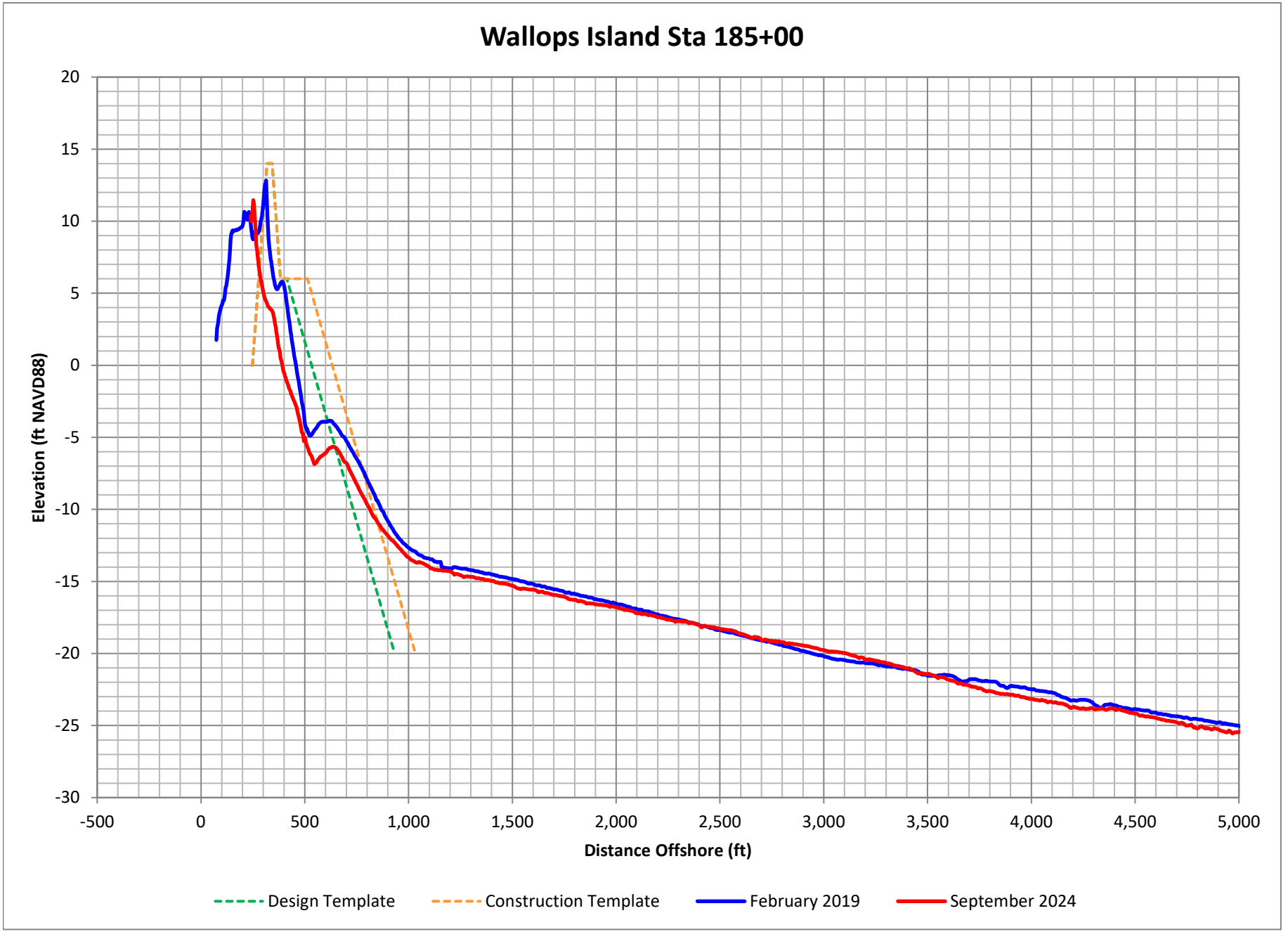


Figure C-17. Wallops Island Profile Comparison Plot

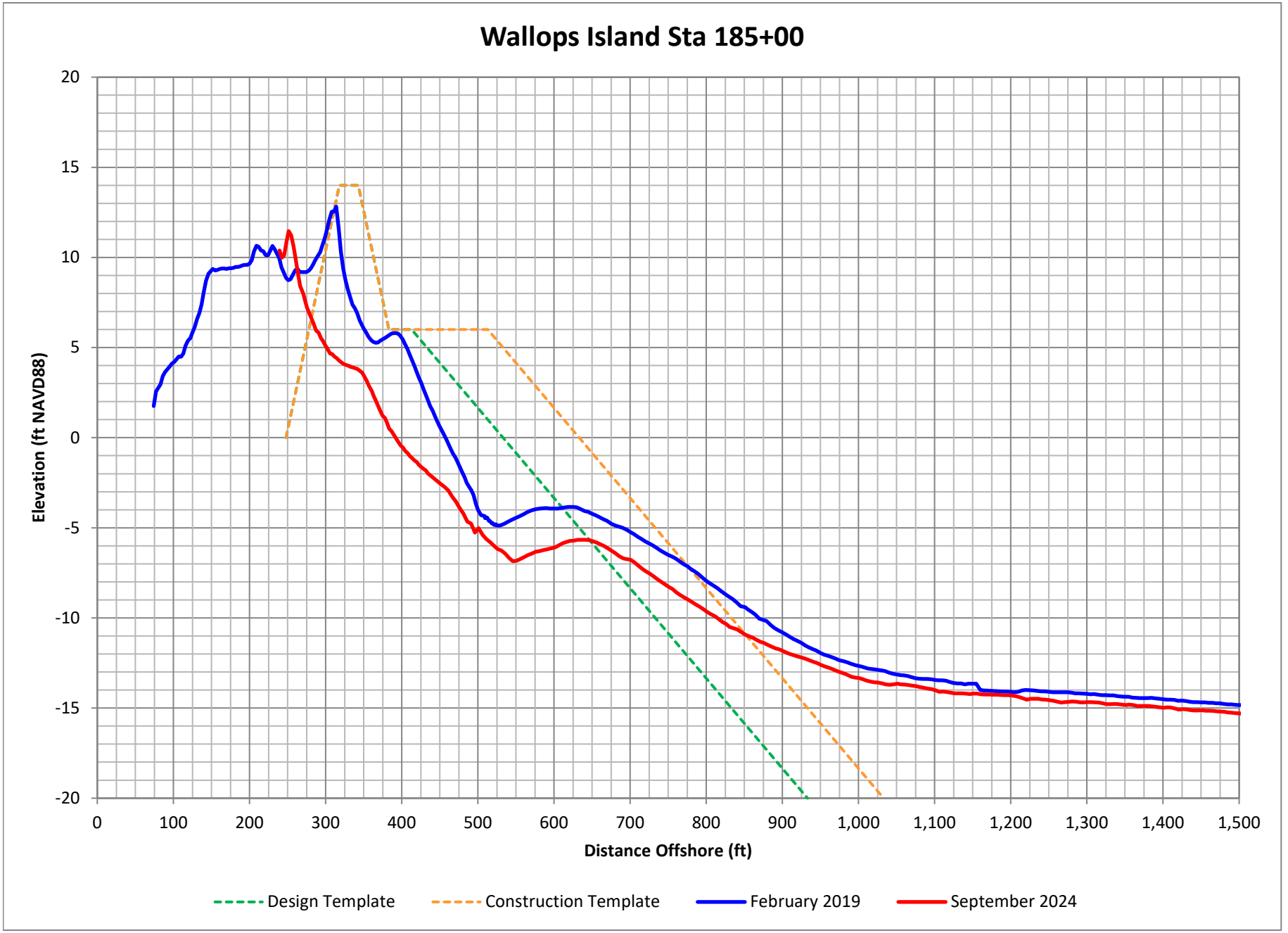


Figure C-18. Wallops Island Profile Comparison Plot

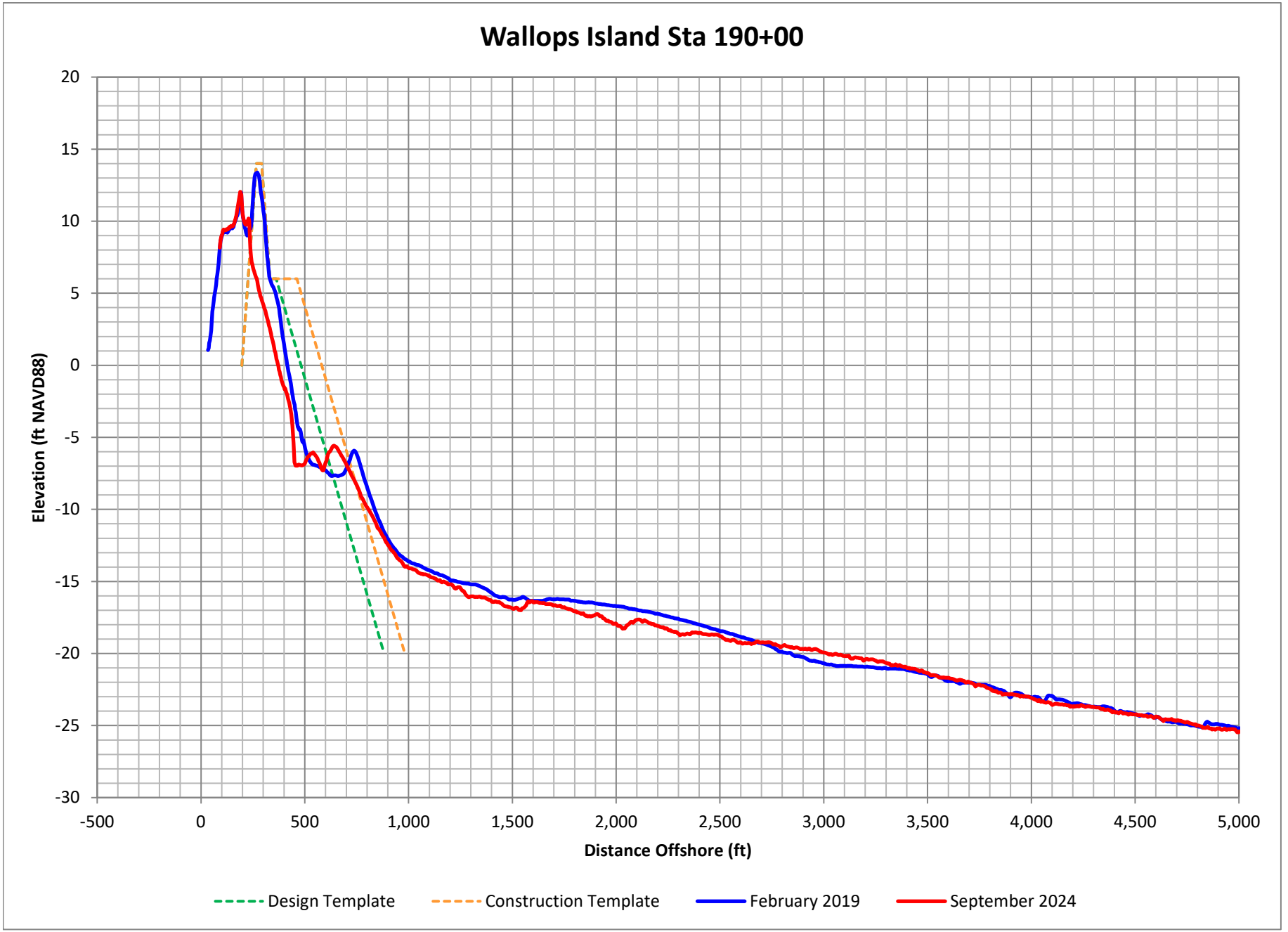


Figure C-19. Wallops Island Profile Comparison Plot

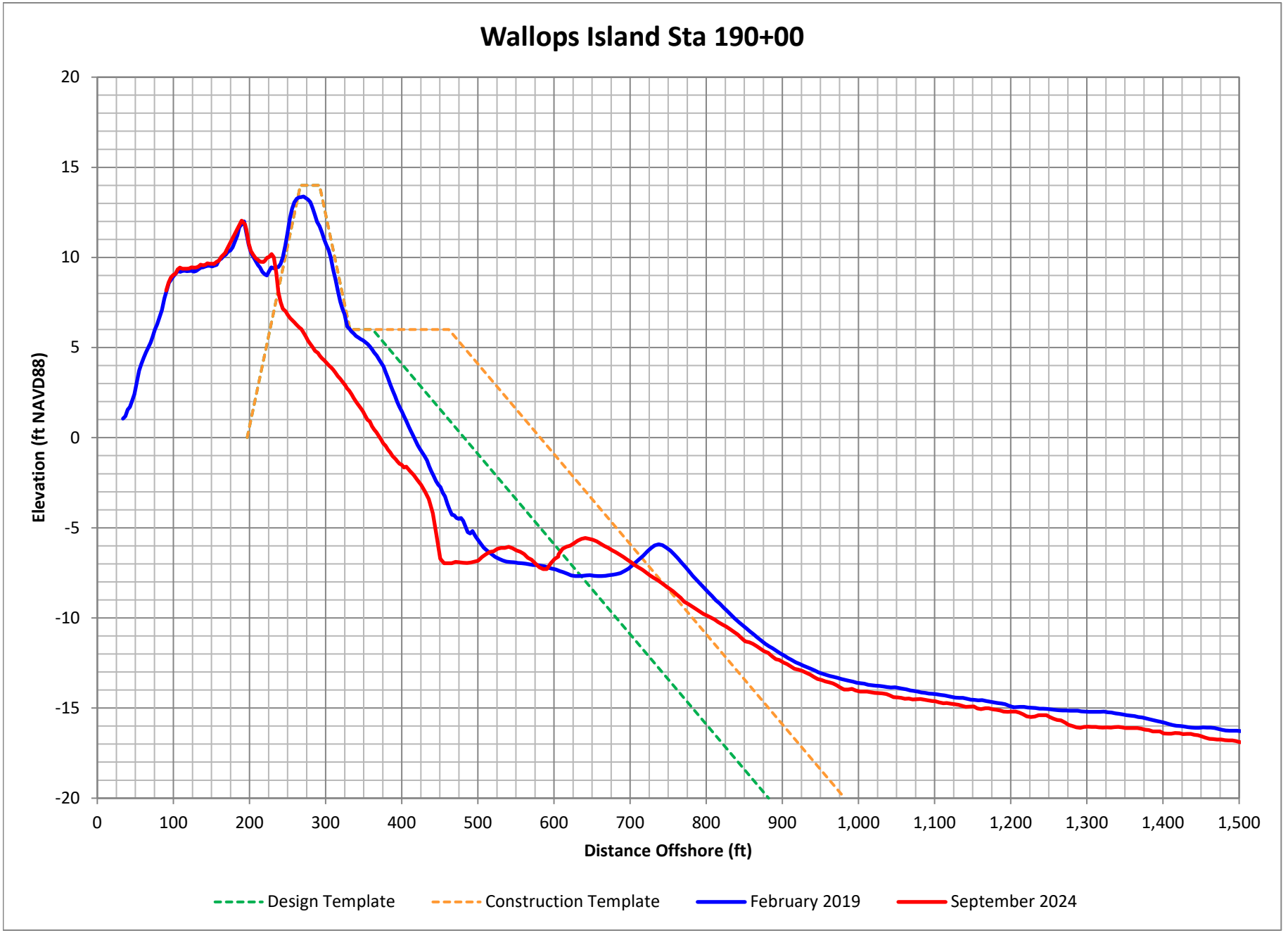


Figure C-20. Wallops Island Profile Comparison Plot

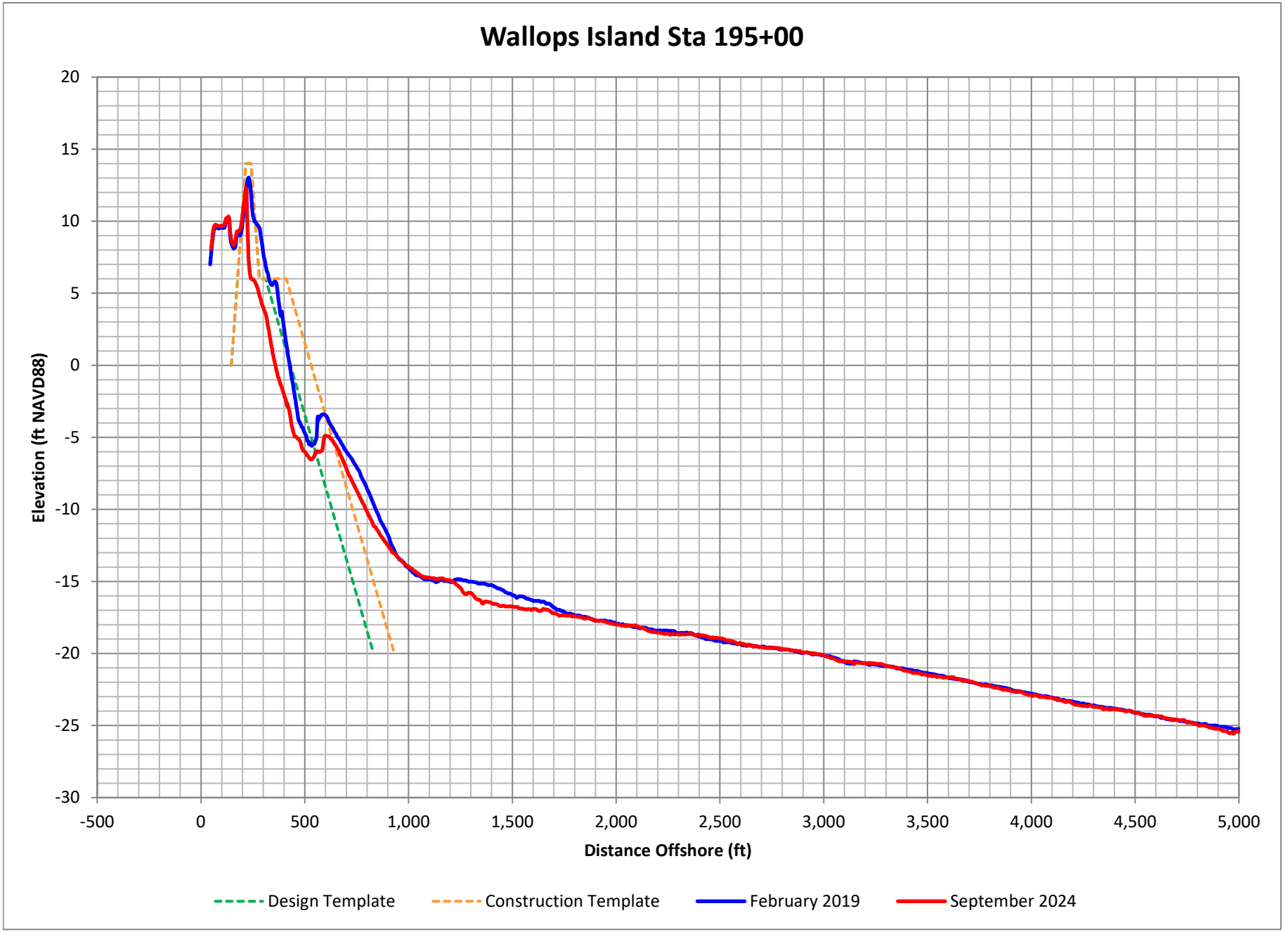


Figure C-21. Wallops Island Profile Comparison Plot

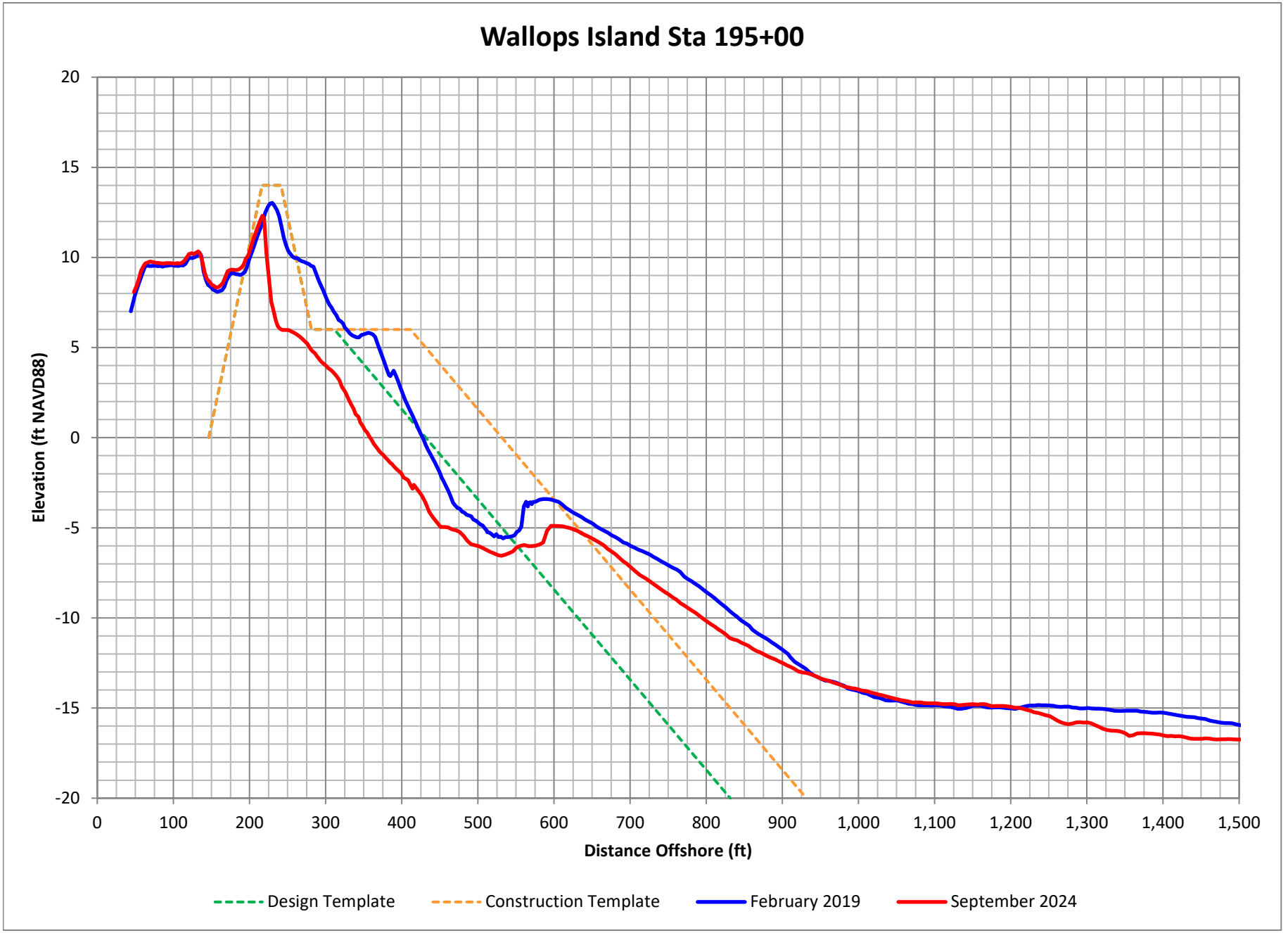


Figure C-22. Wallops Island Profile Comparison Plot

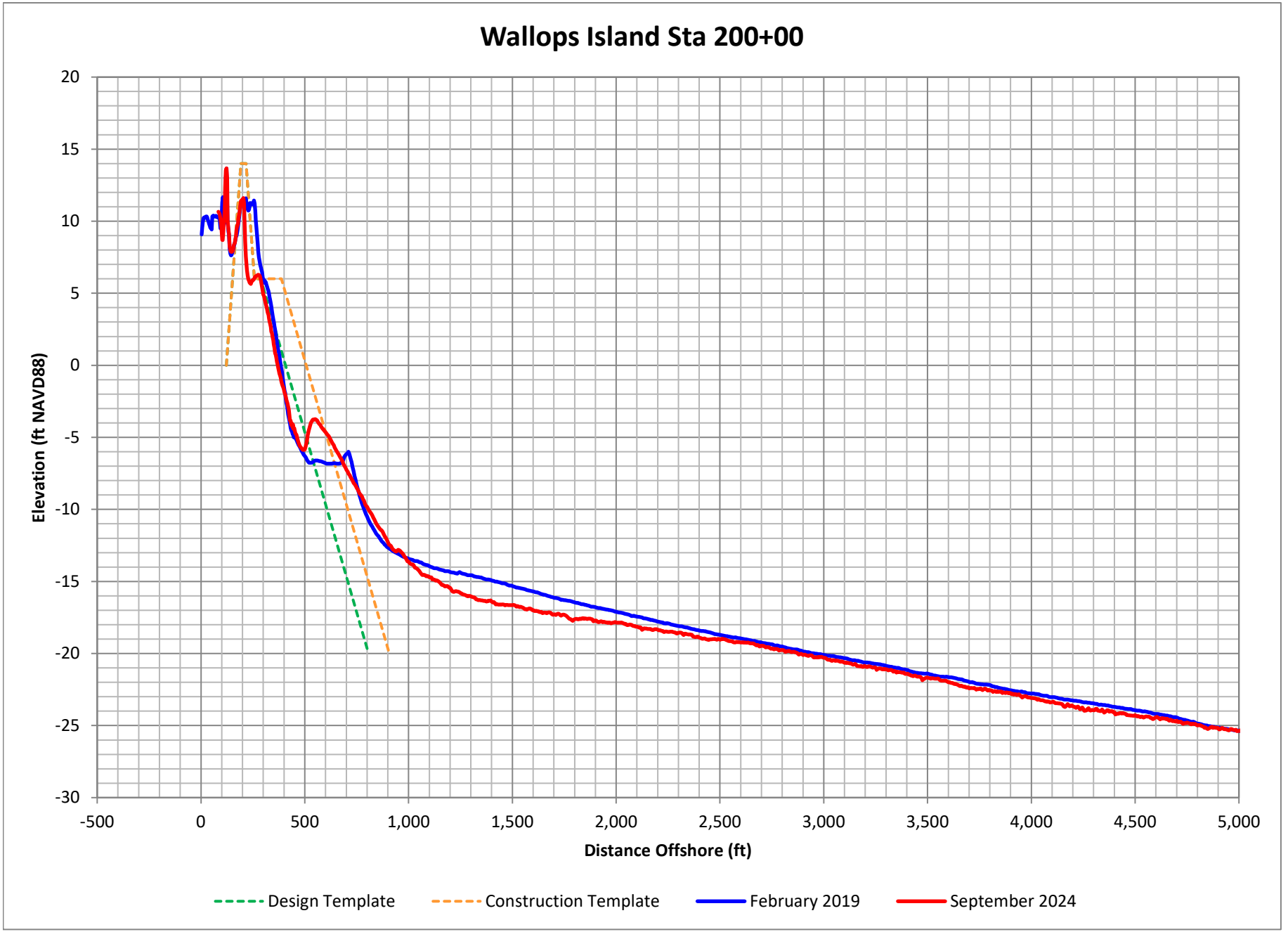


Figure C-23. Wallops Island Profile Comparison Plot

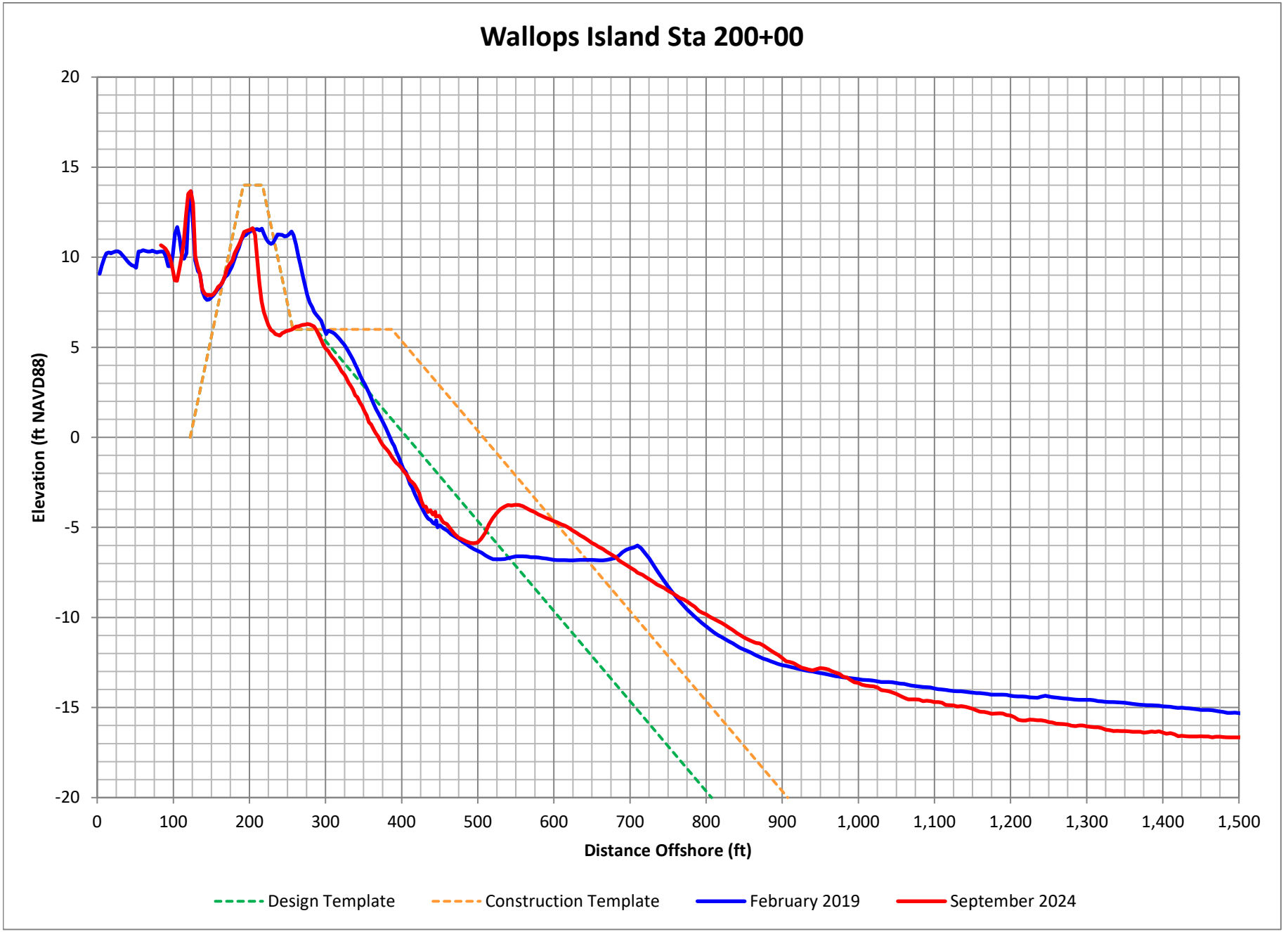


Figure C-24. Wallops Island Profile Comparison Plot

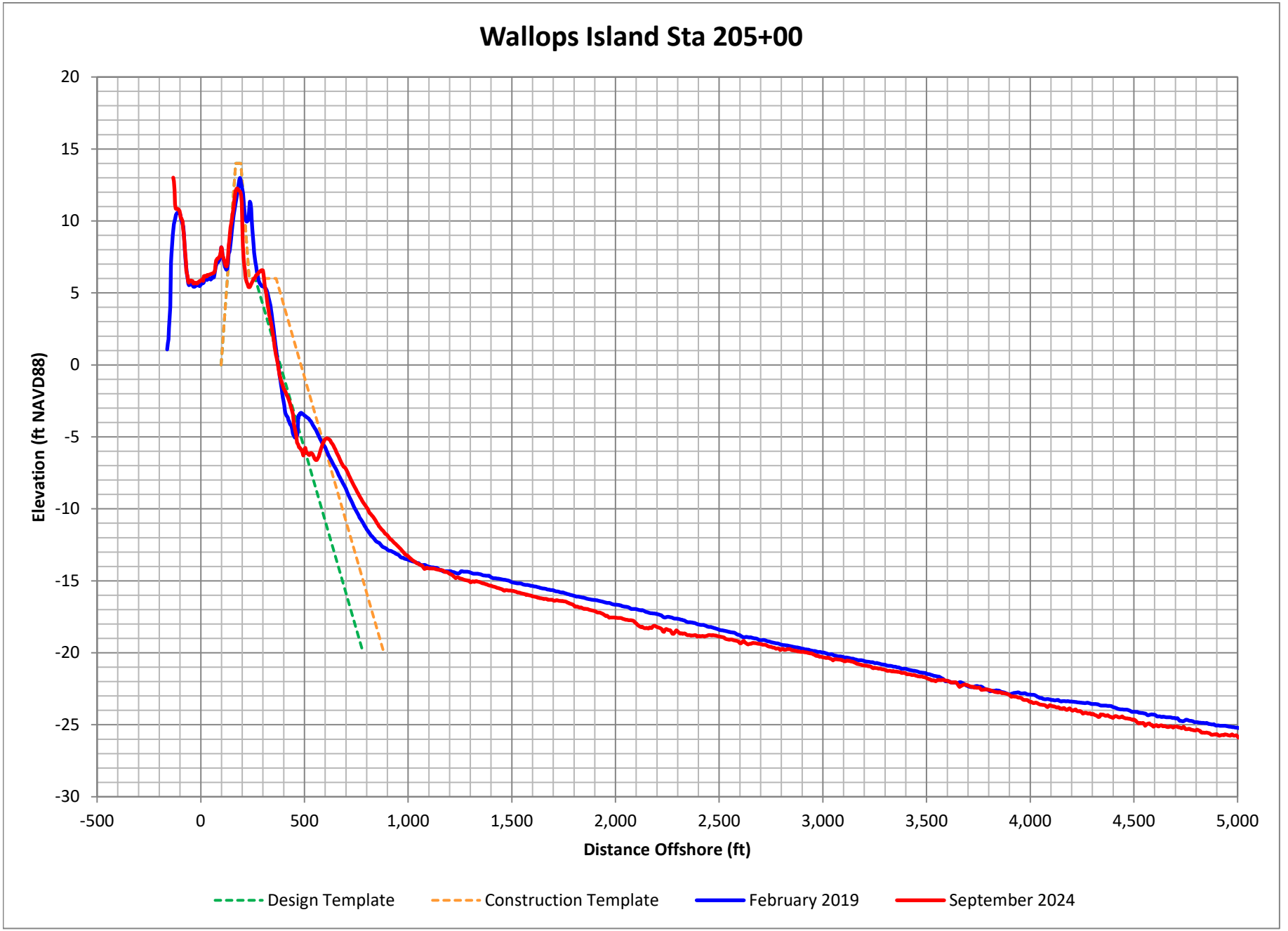


Figure C-25. Wallops Island Profile Comparison Plot

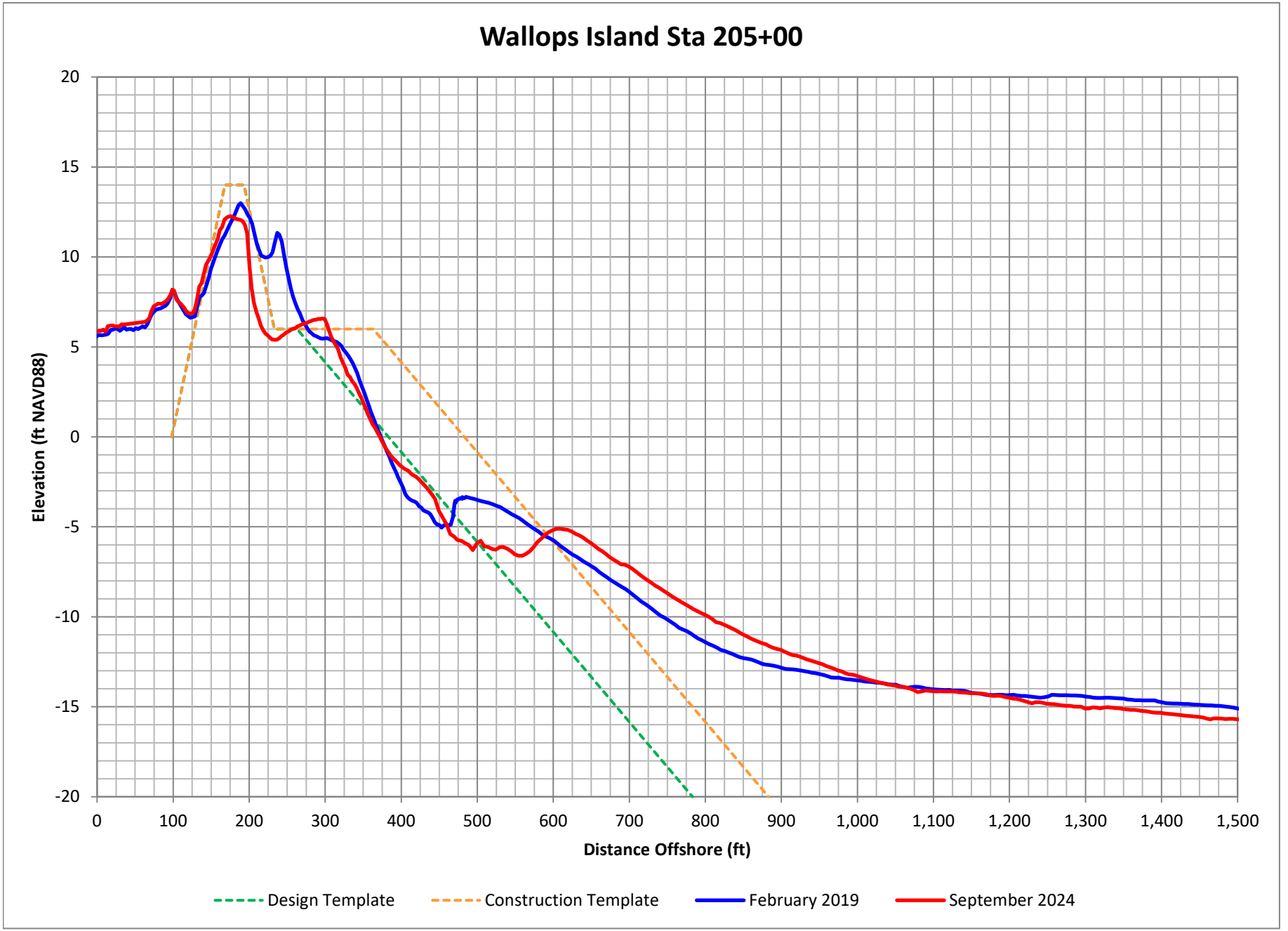


Figure C-26. Wallops Island Profile Comparison Plot

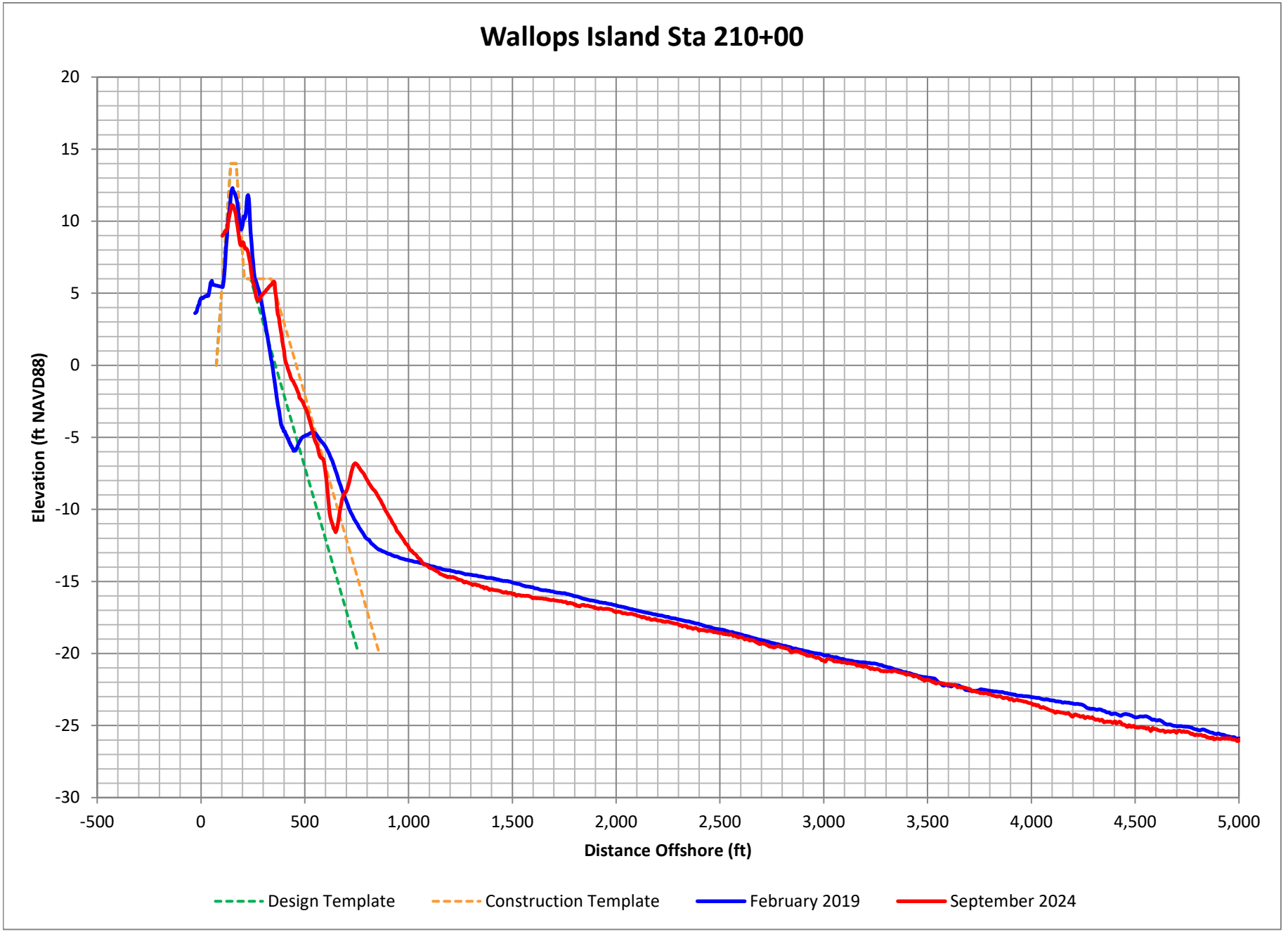


Figure C-27. Wallops Island Profile Comparison Plot

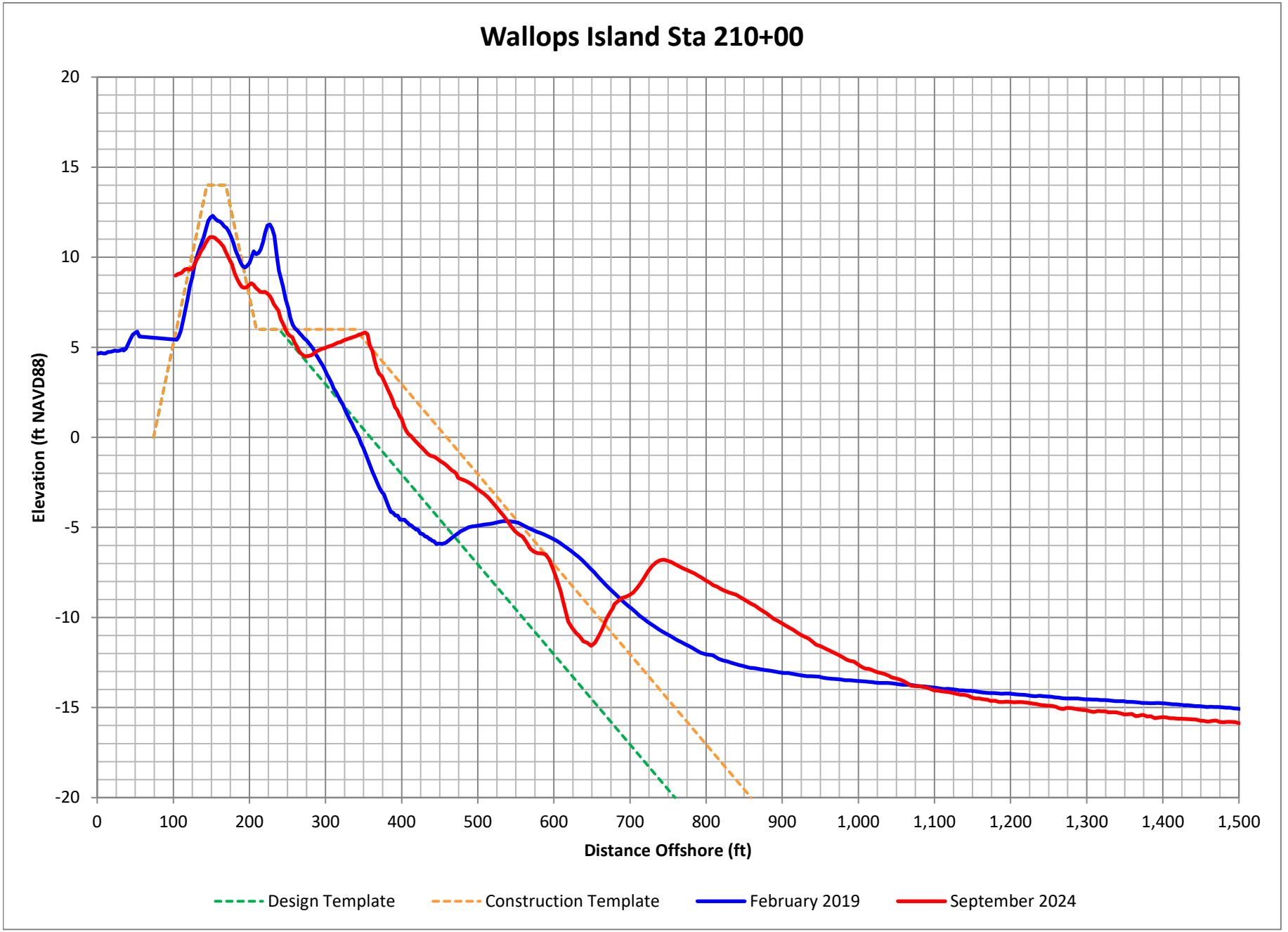


Figure C-28. Wallops Island Profile Comparison Plot

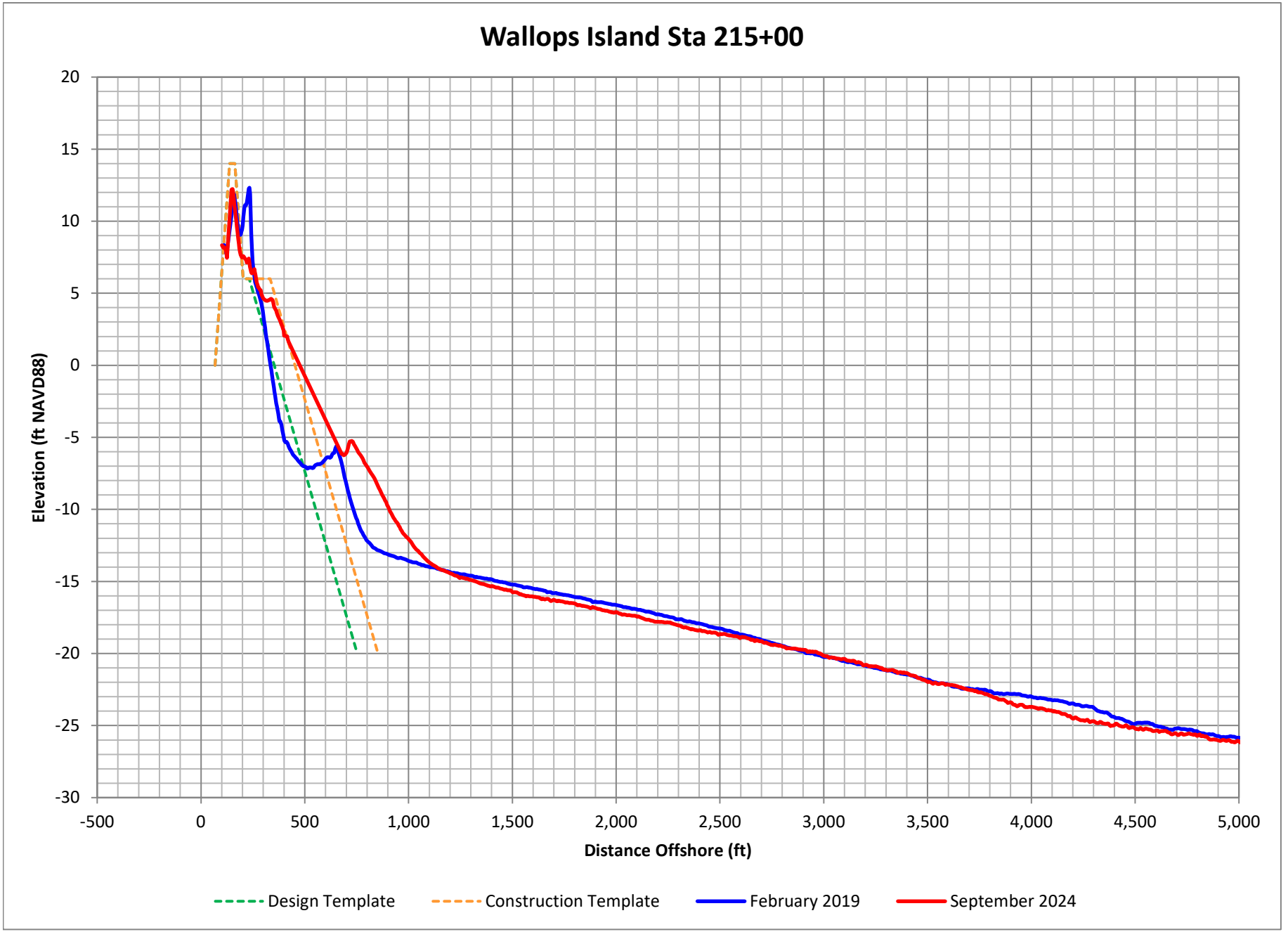


Figure C-29. Wallops Island Profile Comparison Plot

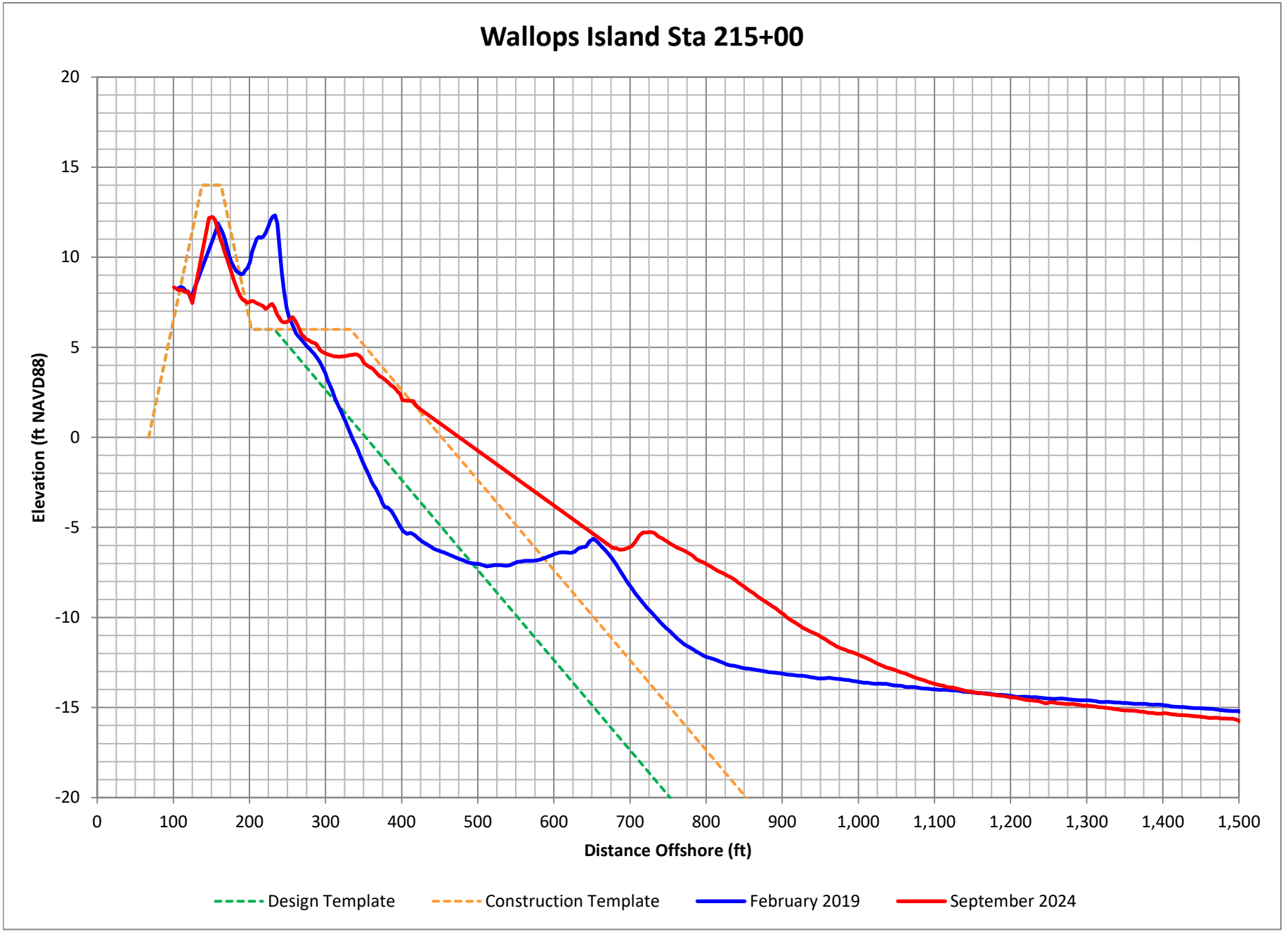


Figure C-30. Wallops Island Profile Comparison Plot

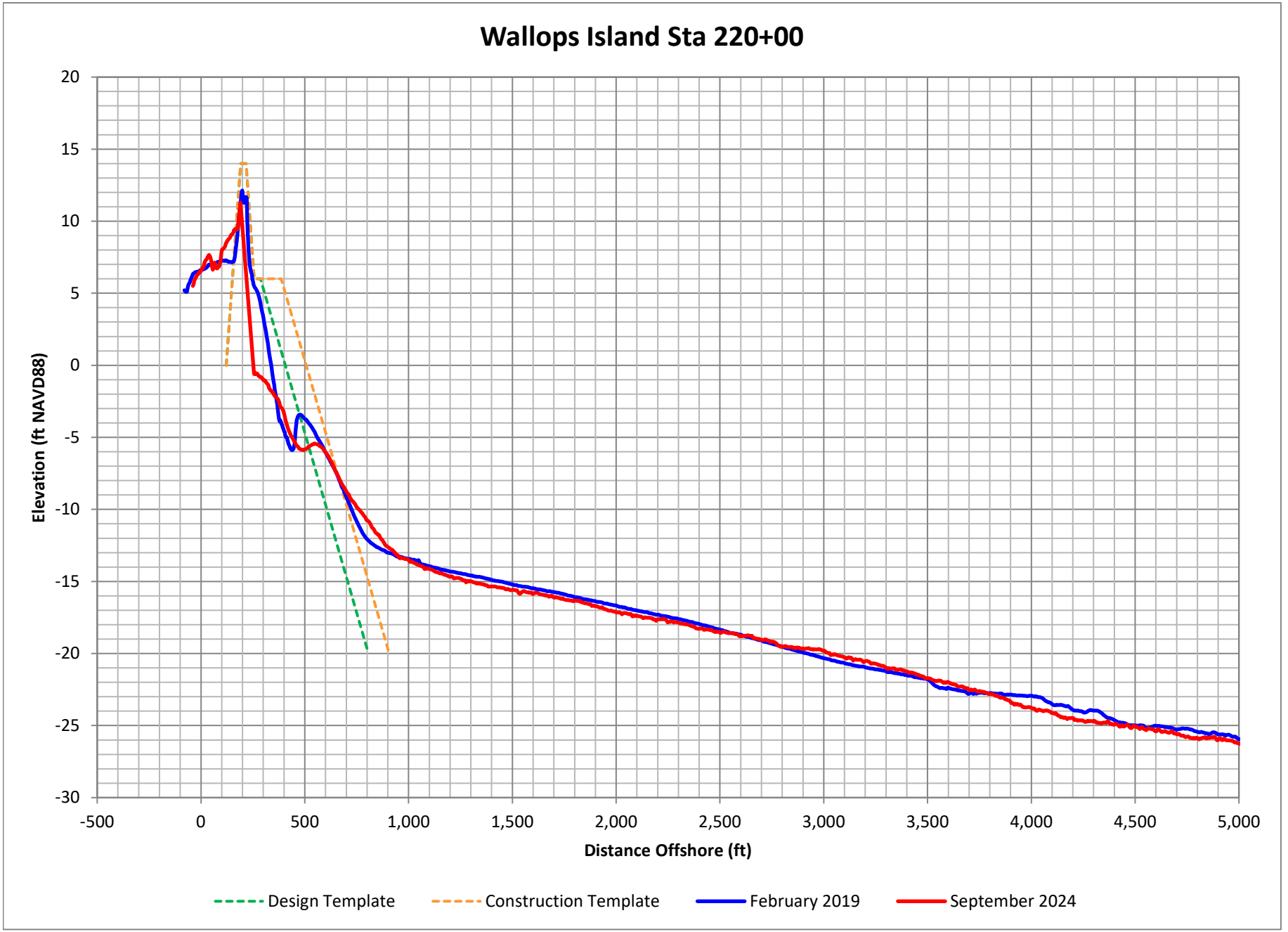


Figure C-31. Wallops Island Profile Comparison Plot

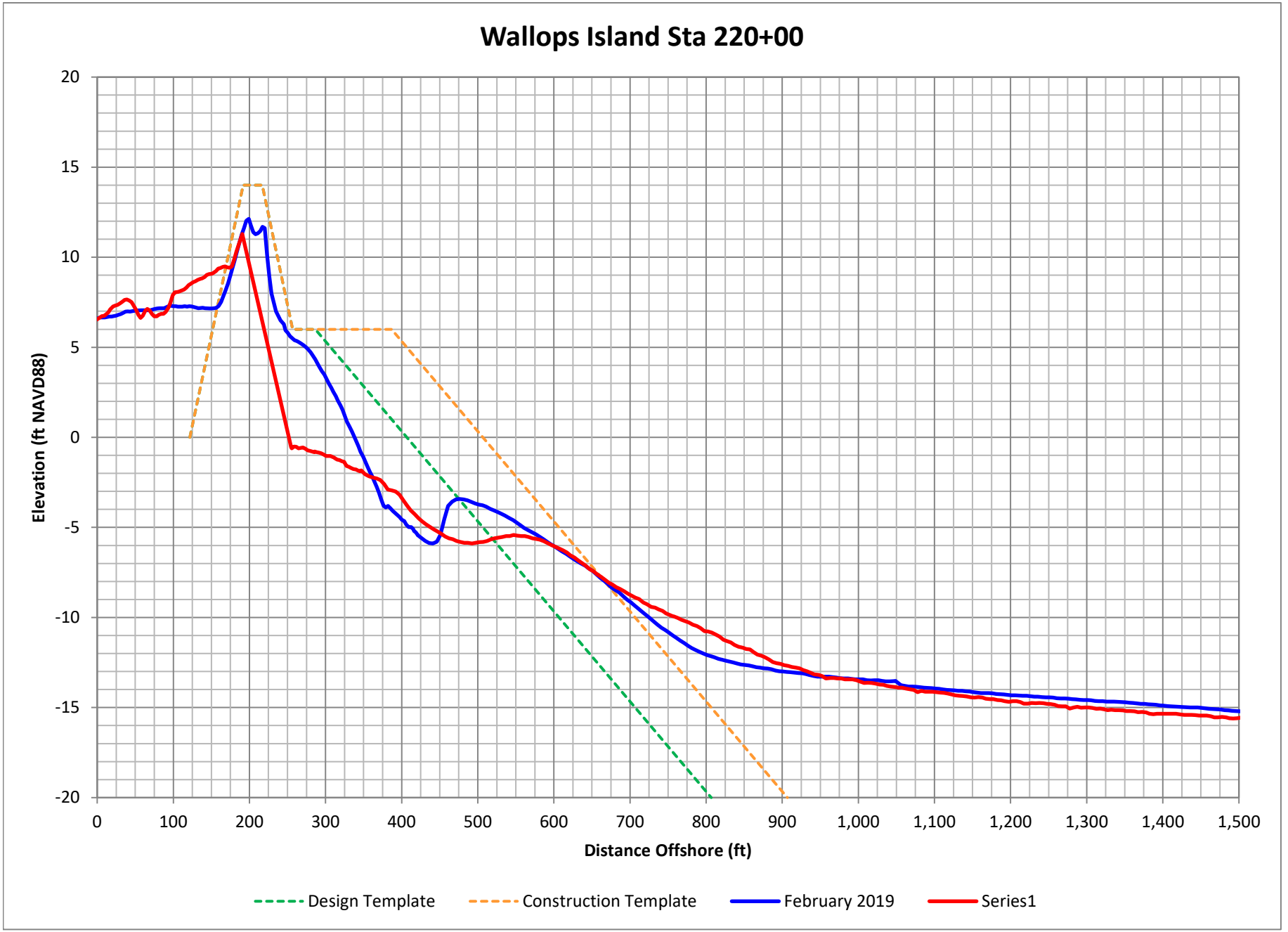


Figure C-32. Wallops Island Profile Comparison Plot

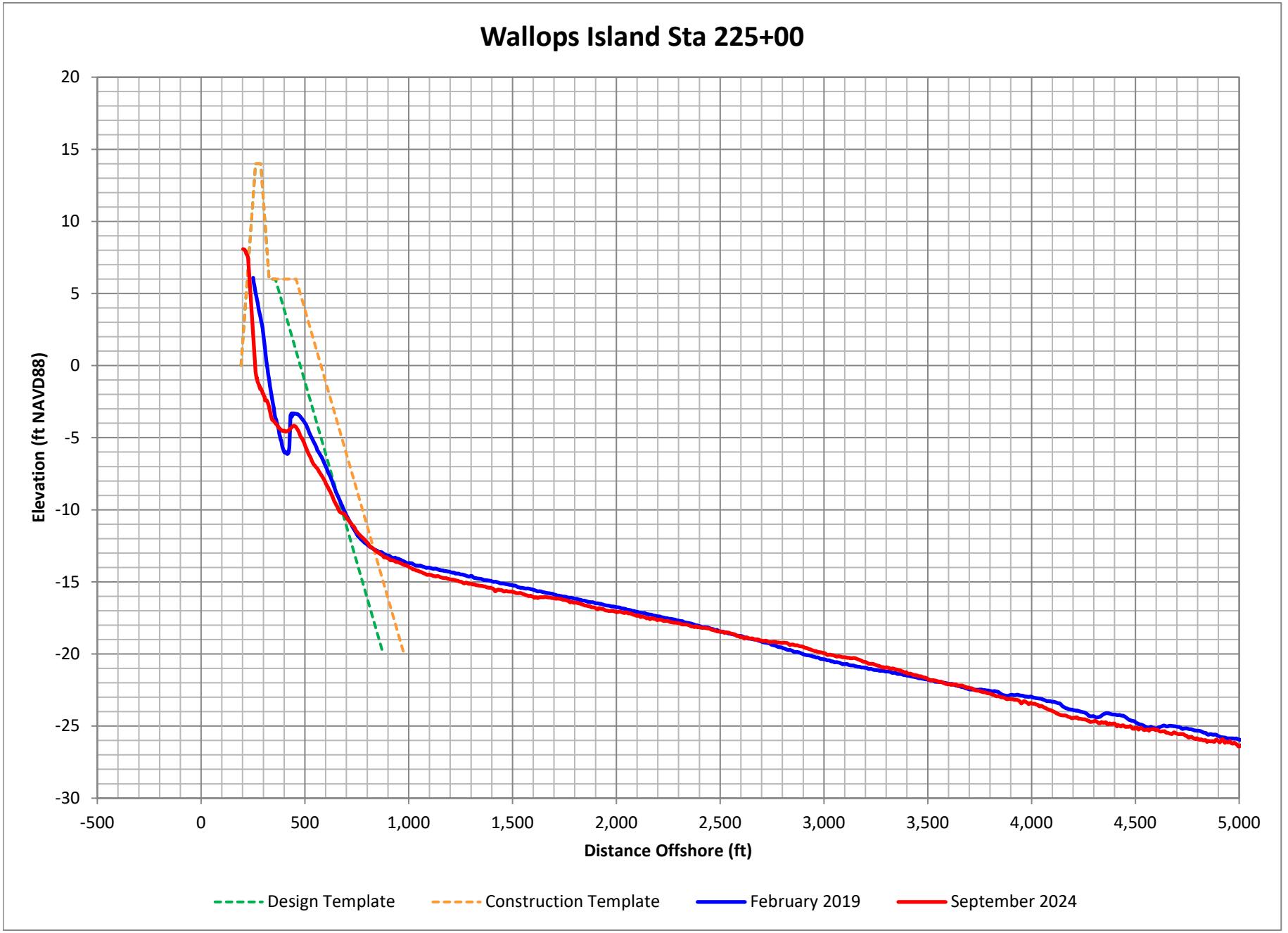


Figure C-33. Wallops Island Profile Comparison Plot

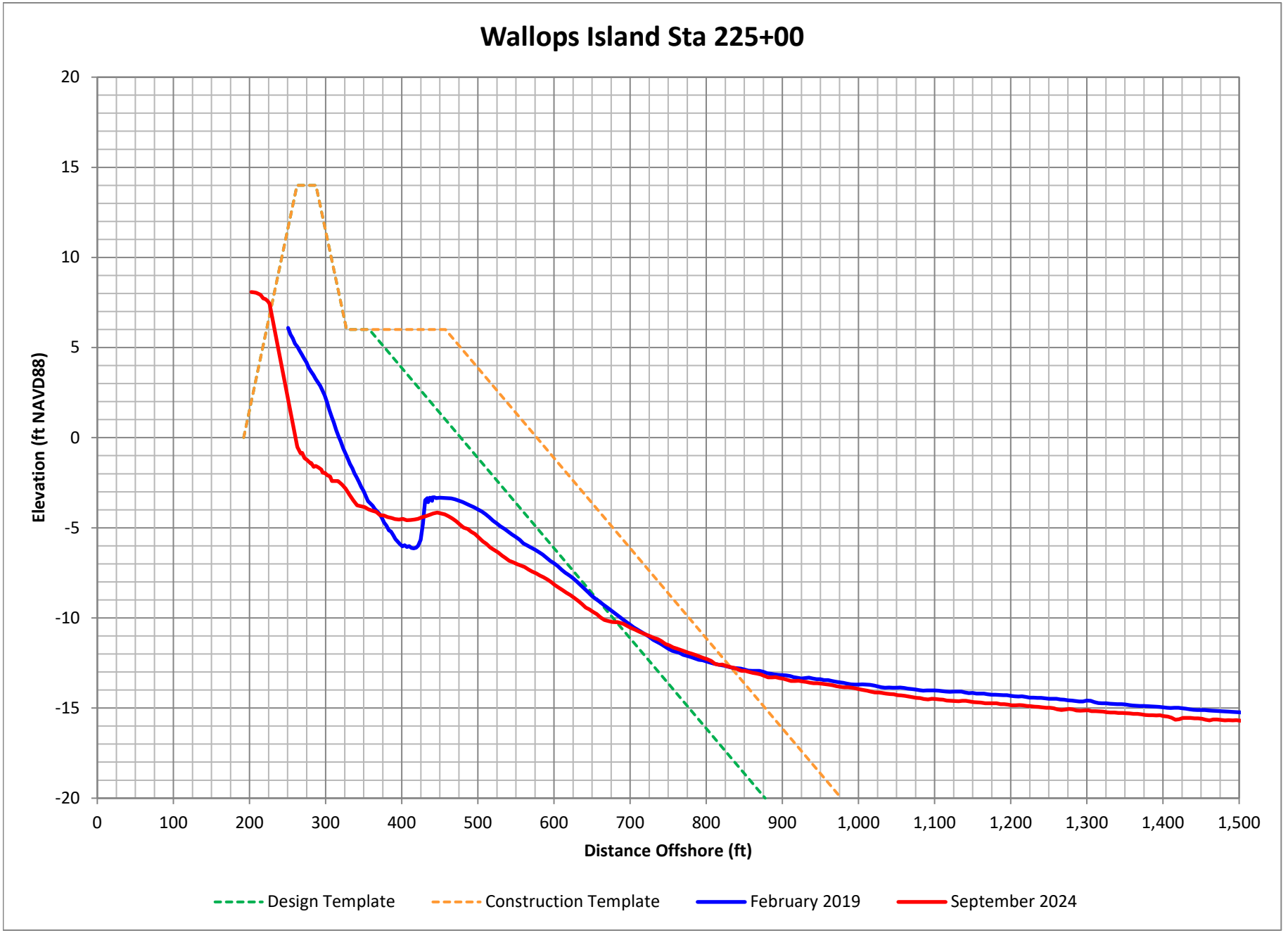


Figure C-34. Wallops Island Profile Comparison Plot

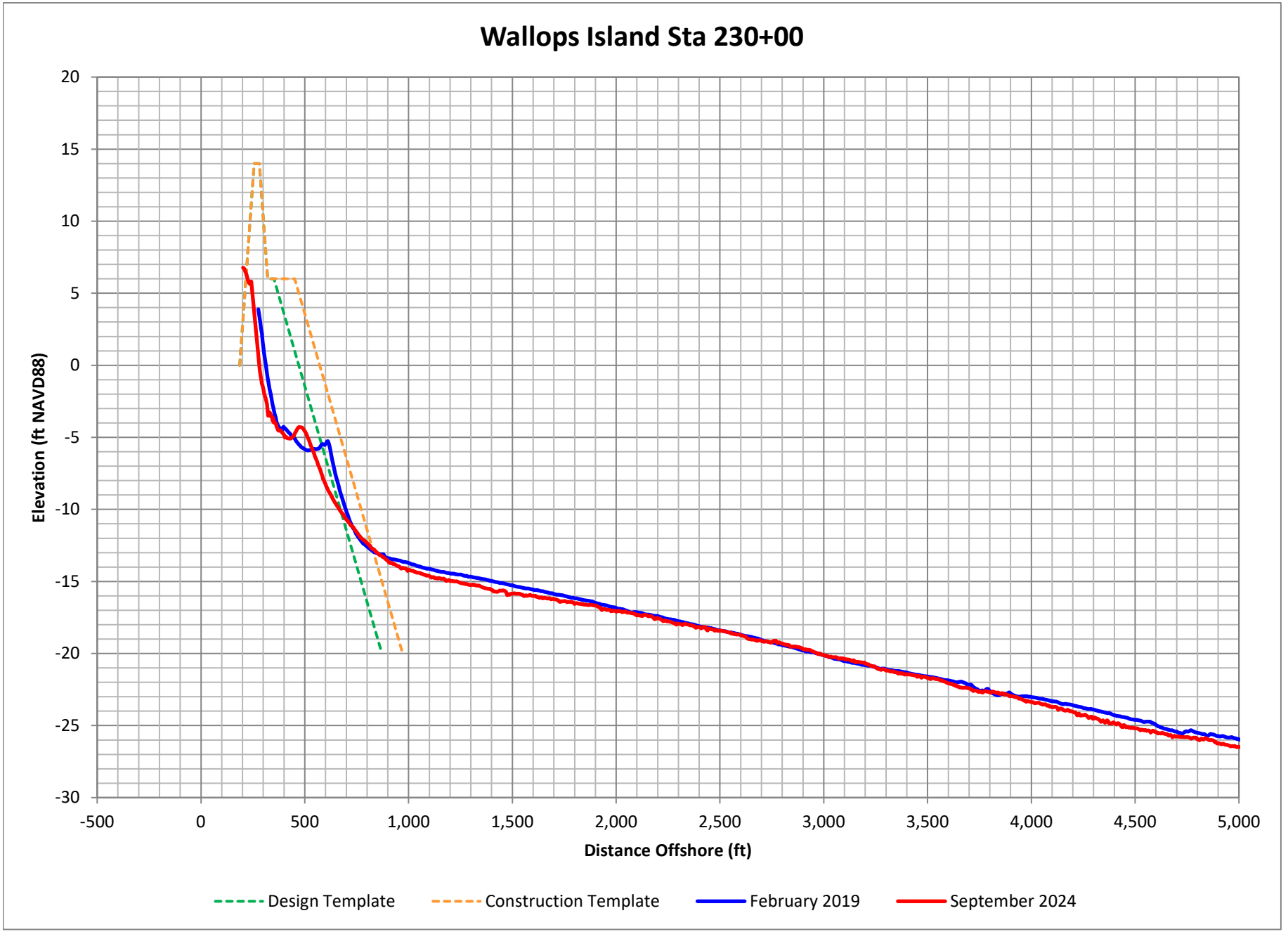


Figure C-35. Wallops Island Profile Comparison Plot

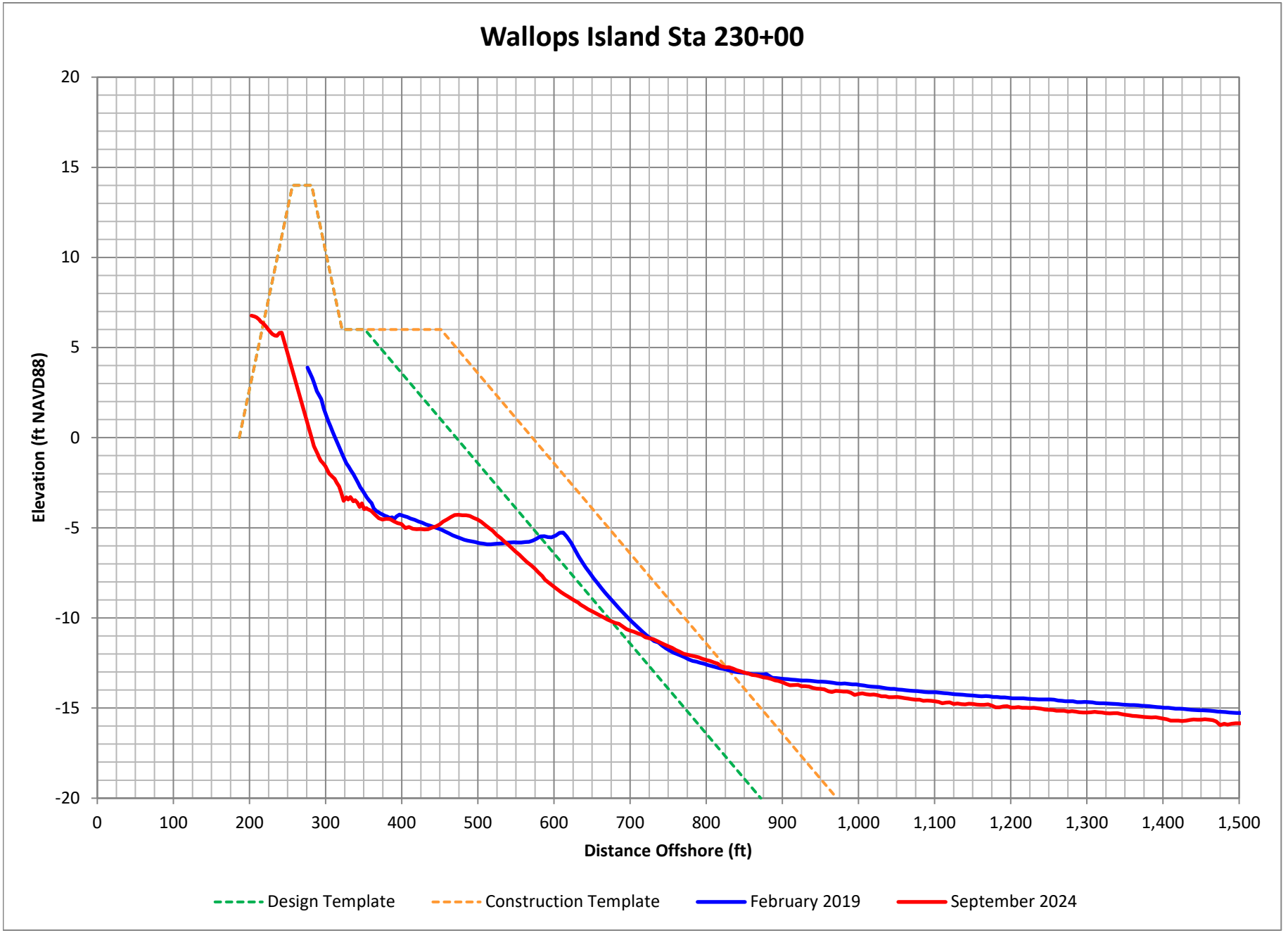


Figure C-36. Wallops Island Profile Comparison Plot

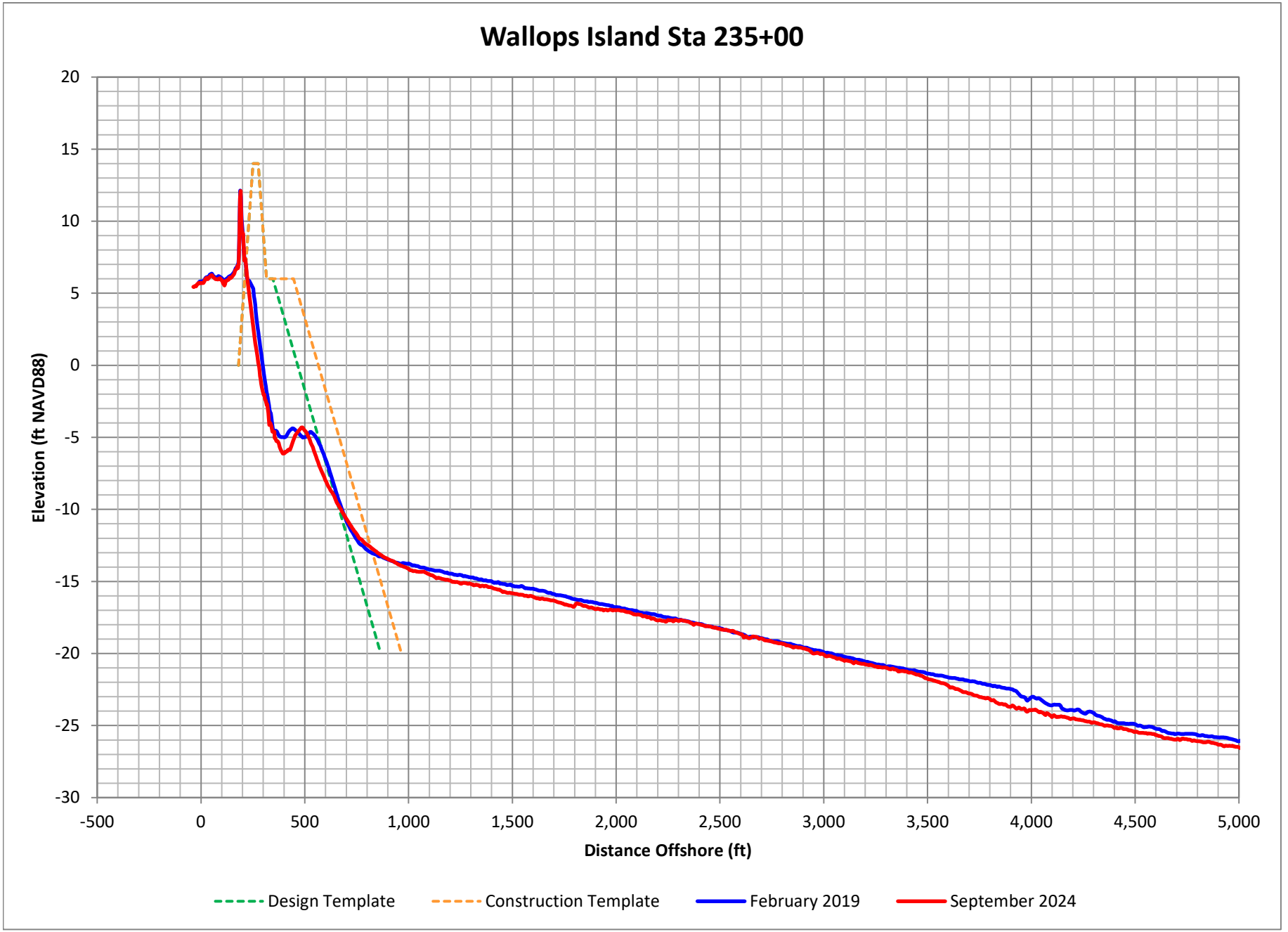


Figure C-37. Wallops Island Profile Comparison Plot

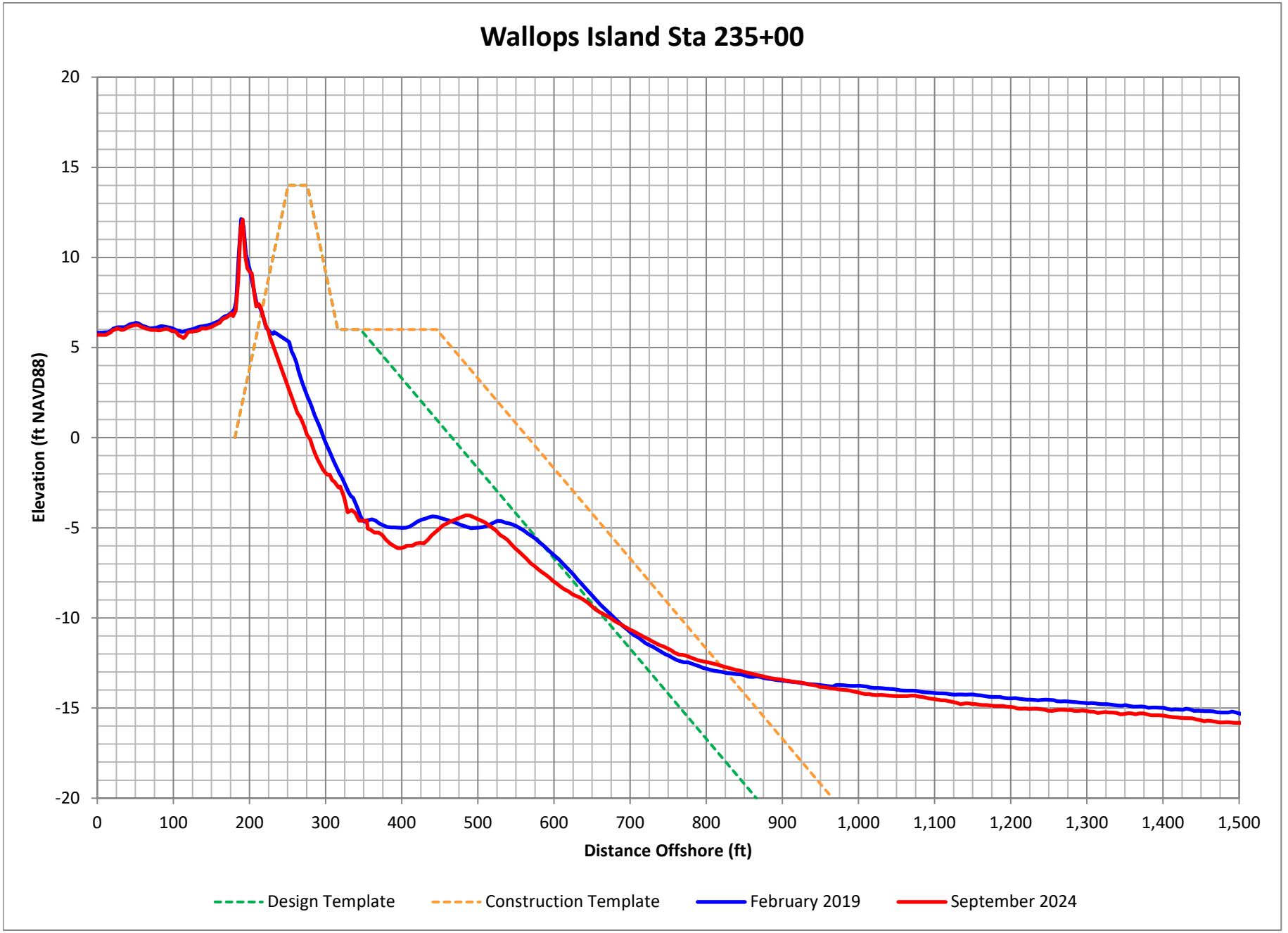


Figure C-38. Wallops Island Profile Comparison Plot

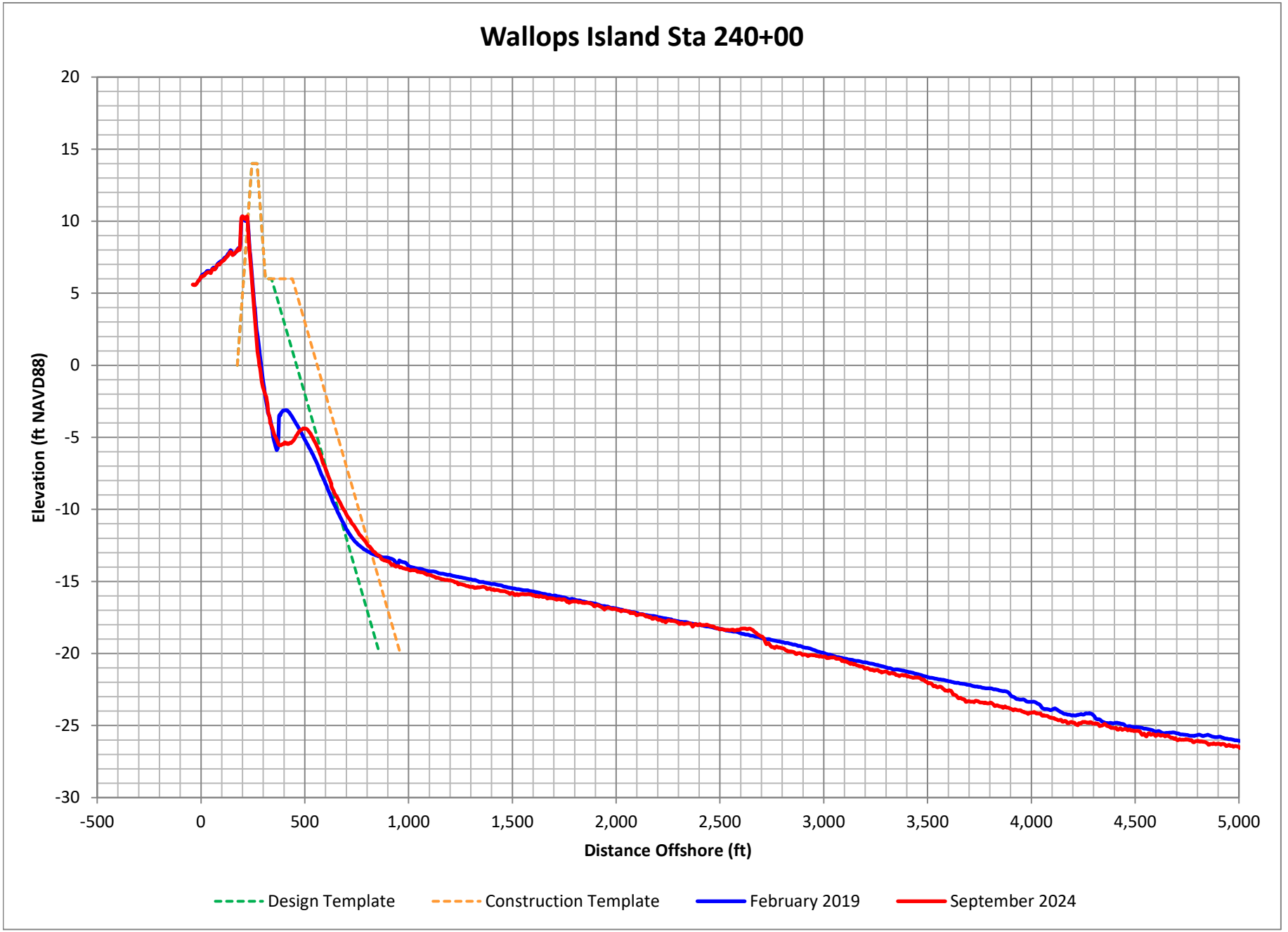


Figure C-39. Wallops Island Profile Comparison Plot

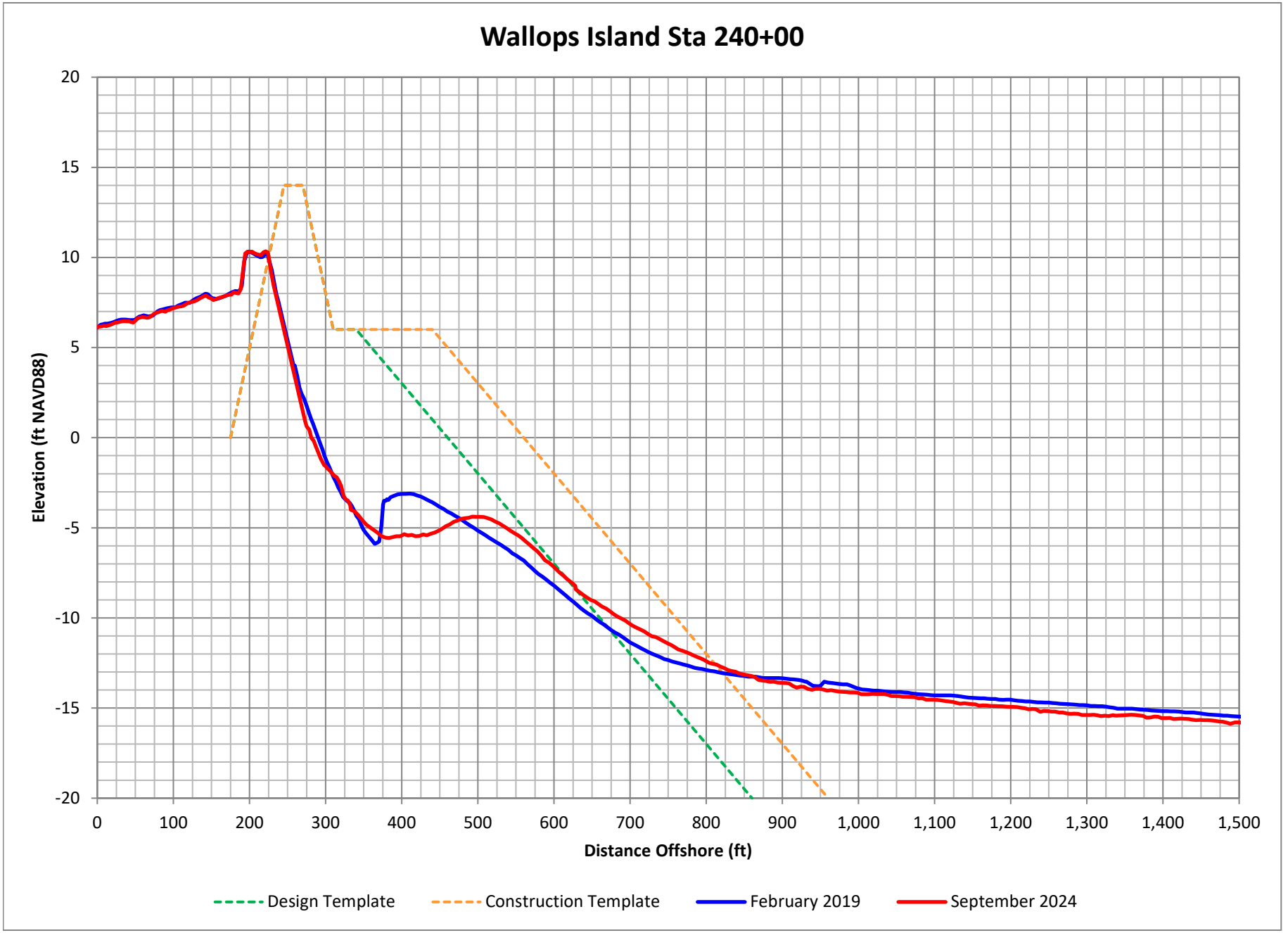


Figure C-40. Wallops Island Profile Comparison Plot

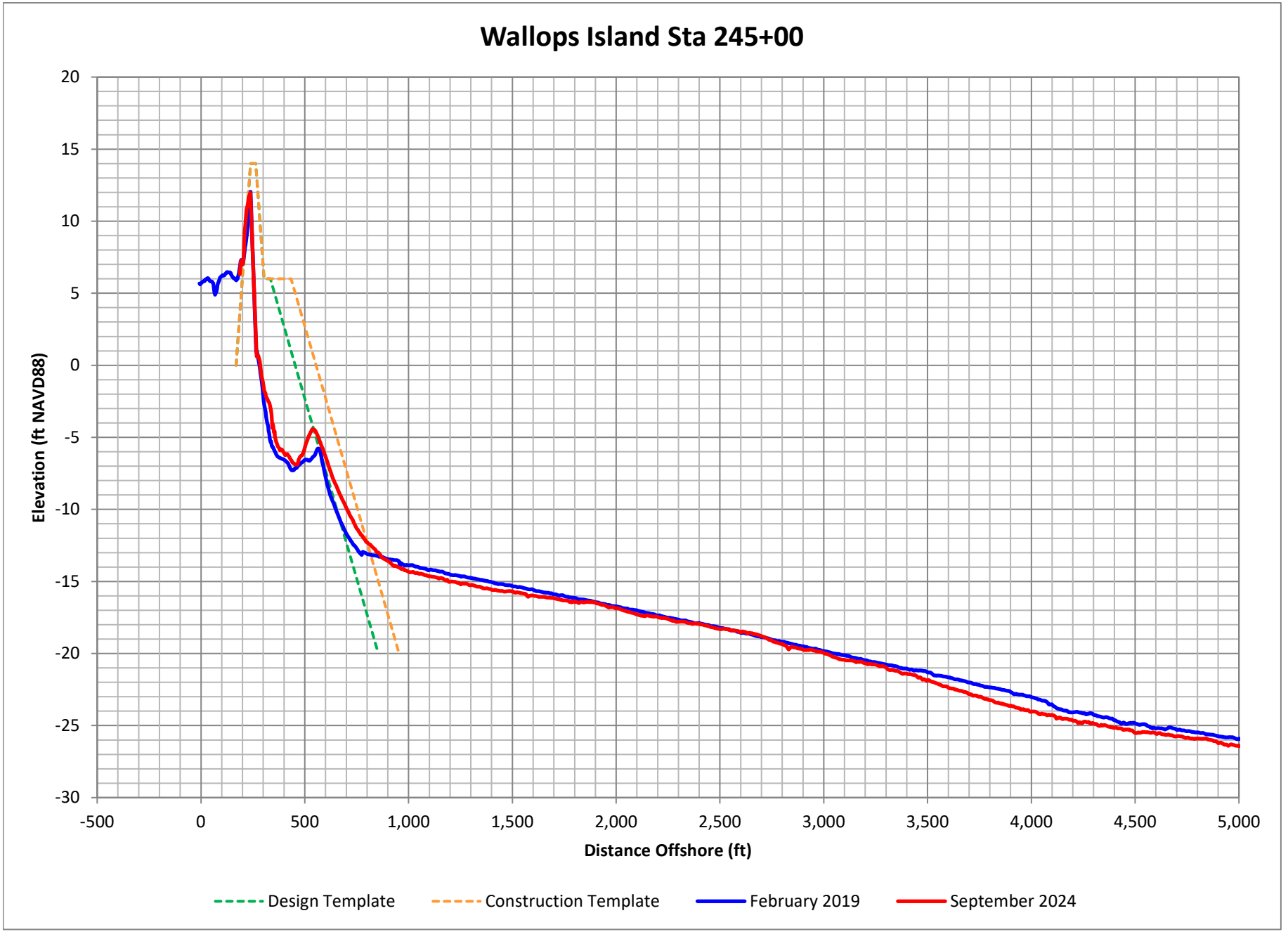


Figure C-41. Wallops Island Profile Comparison Plot

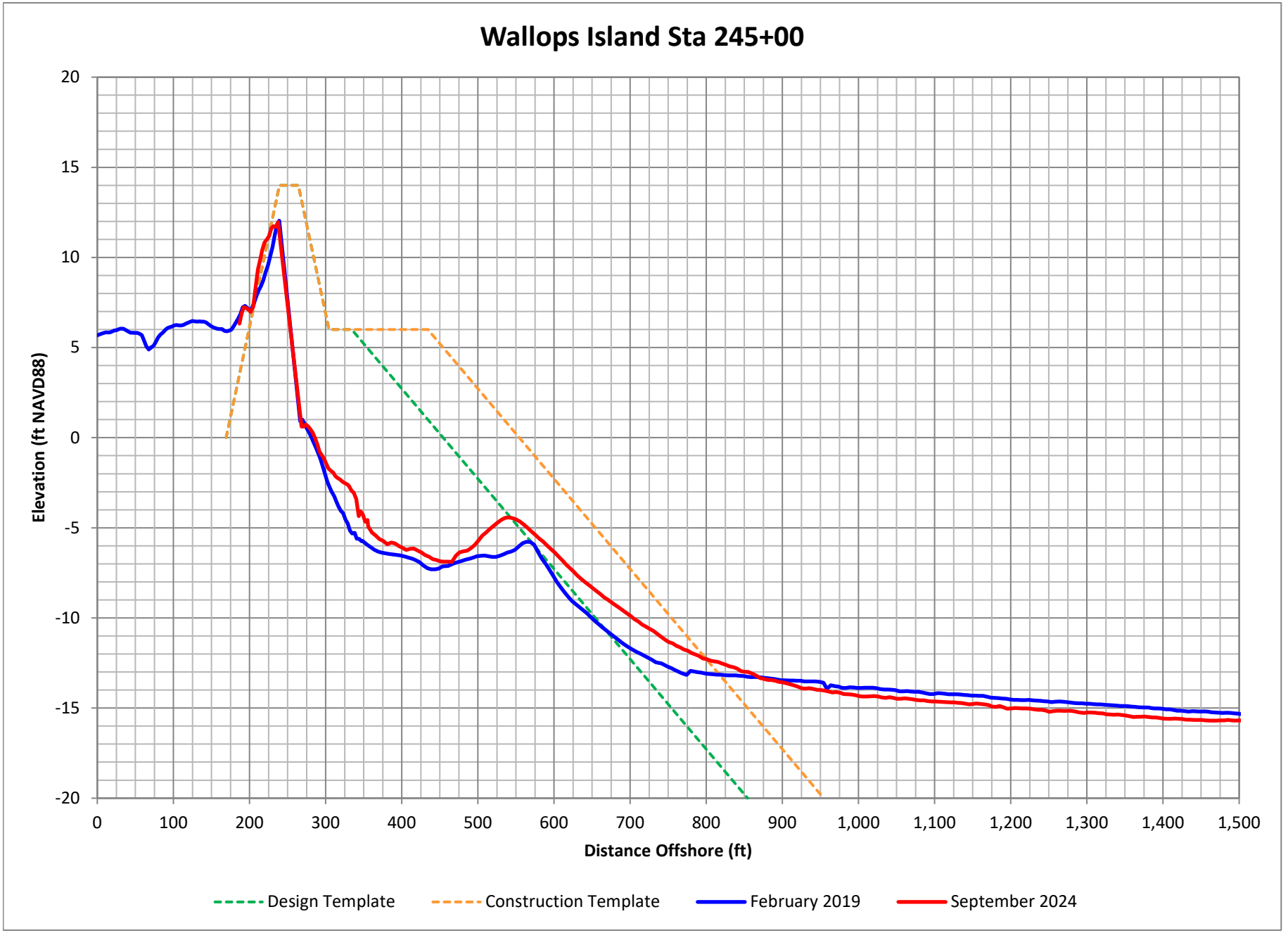


Figure C-42. Wallops Island Profile Comparison Plot

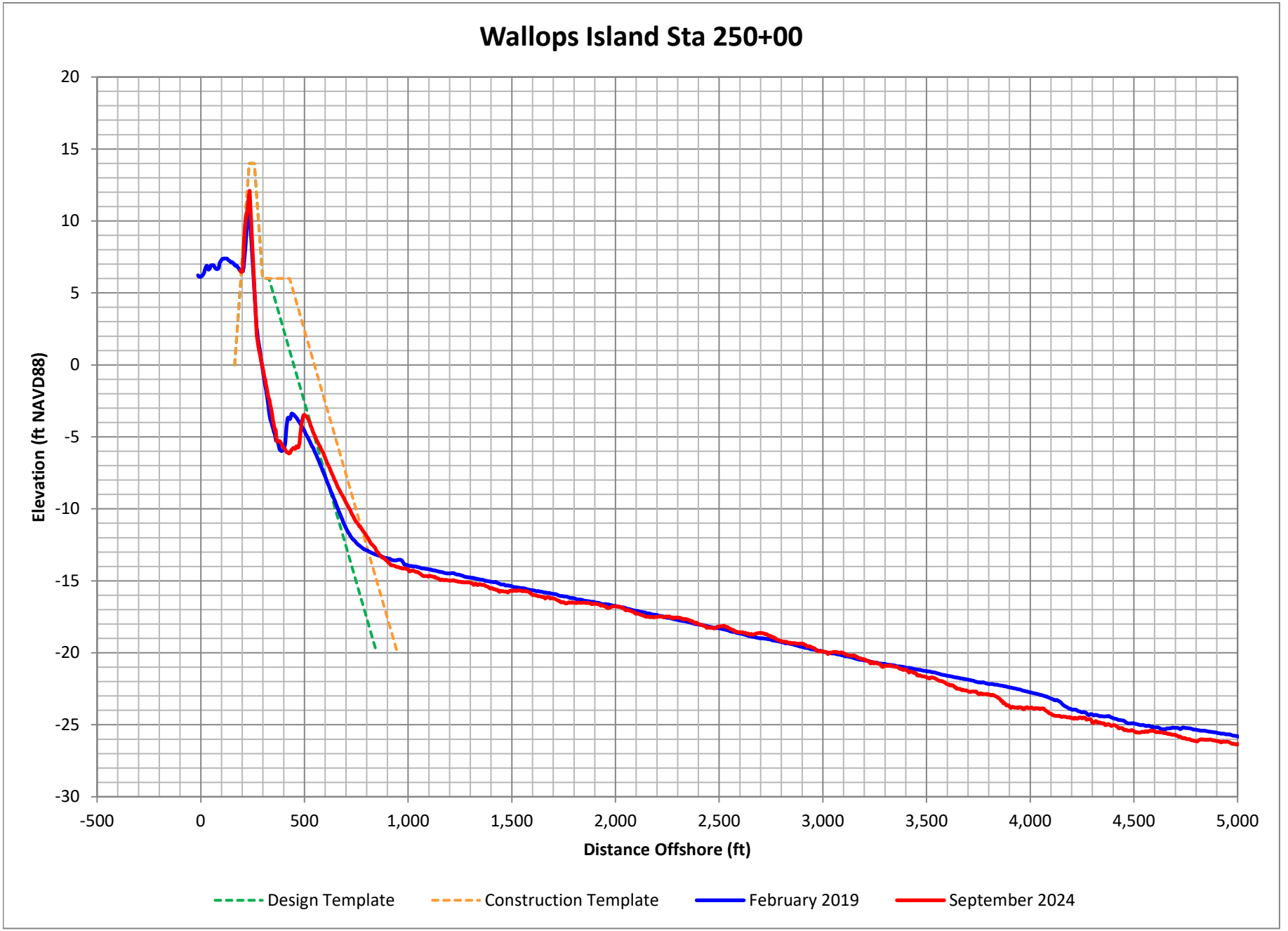


Figure C-43. Wallops Island Profile Comparison Plot

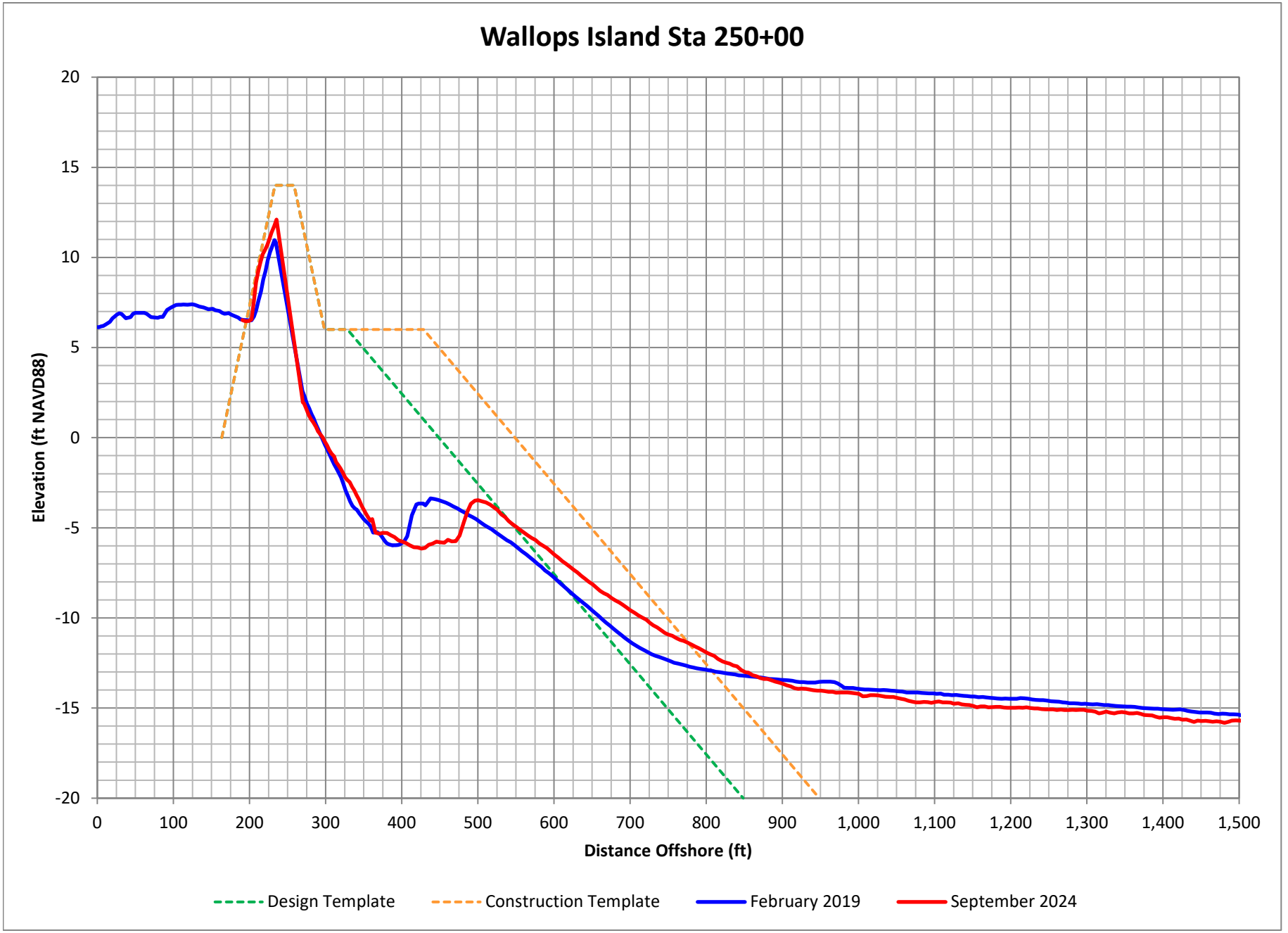


Figure C-44. Wallops Island Profile Comparison Plot

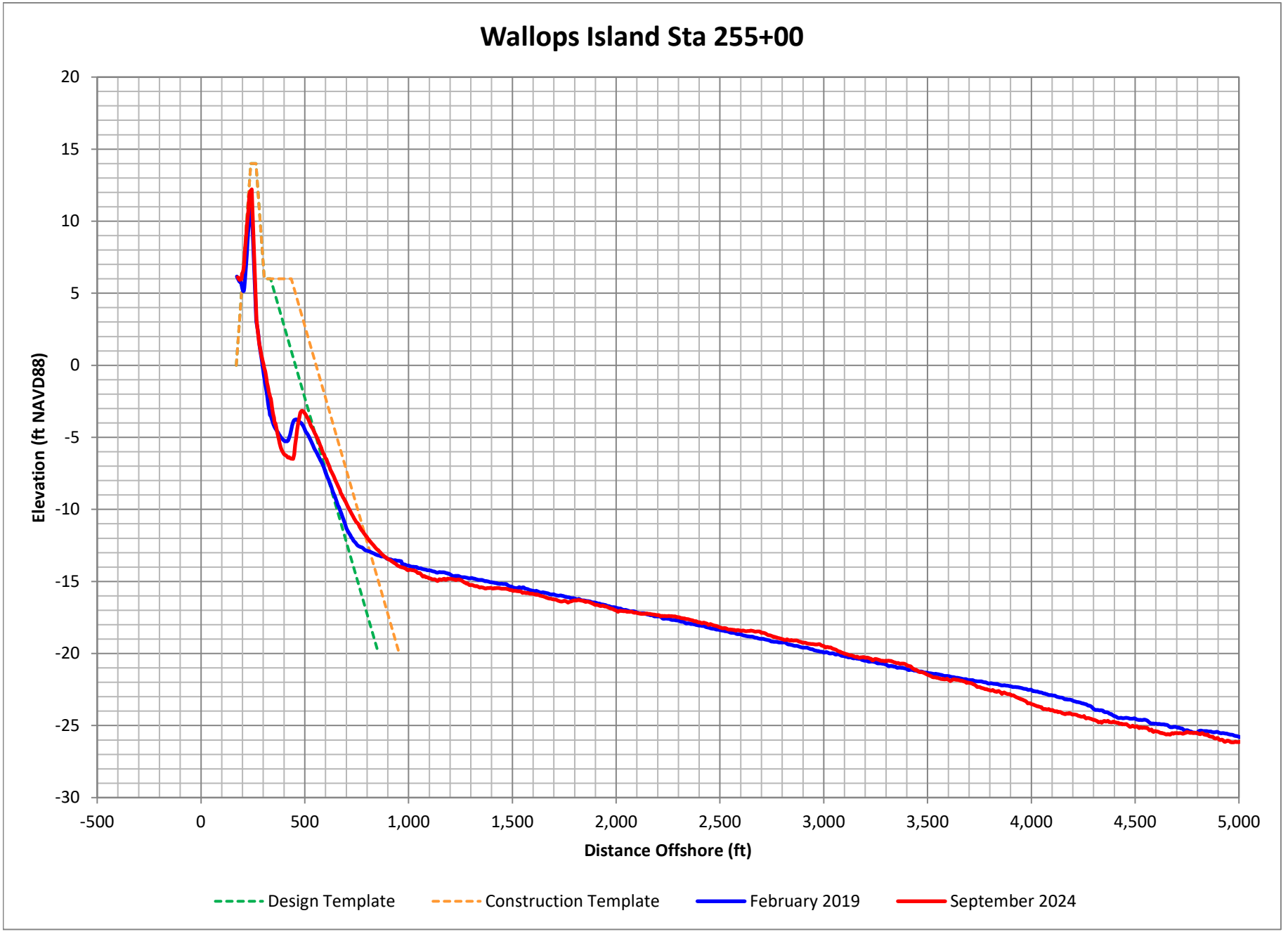


Figure C-45. Wallops Island Profile Comparison Plot

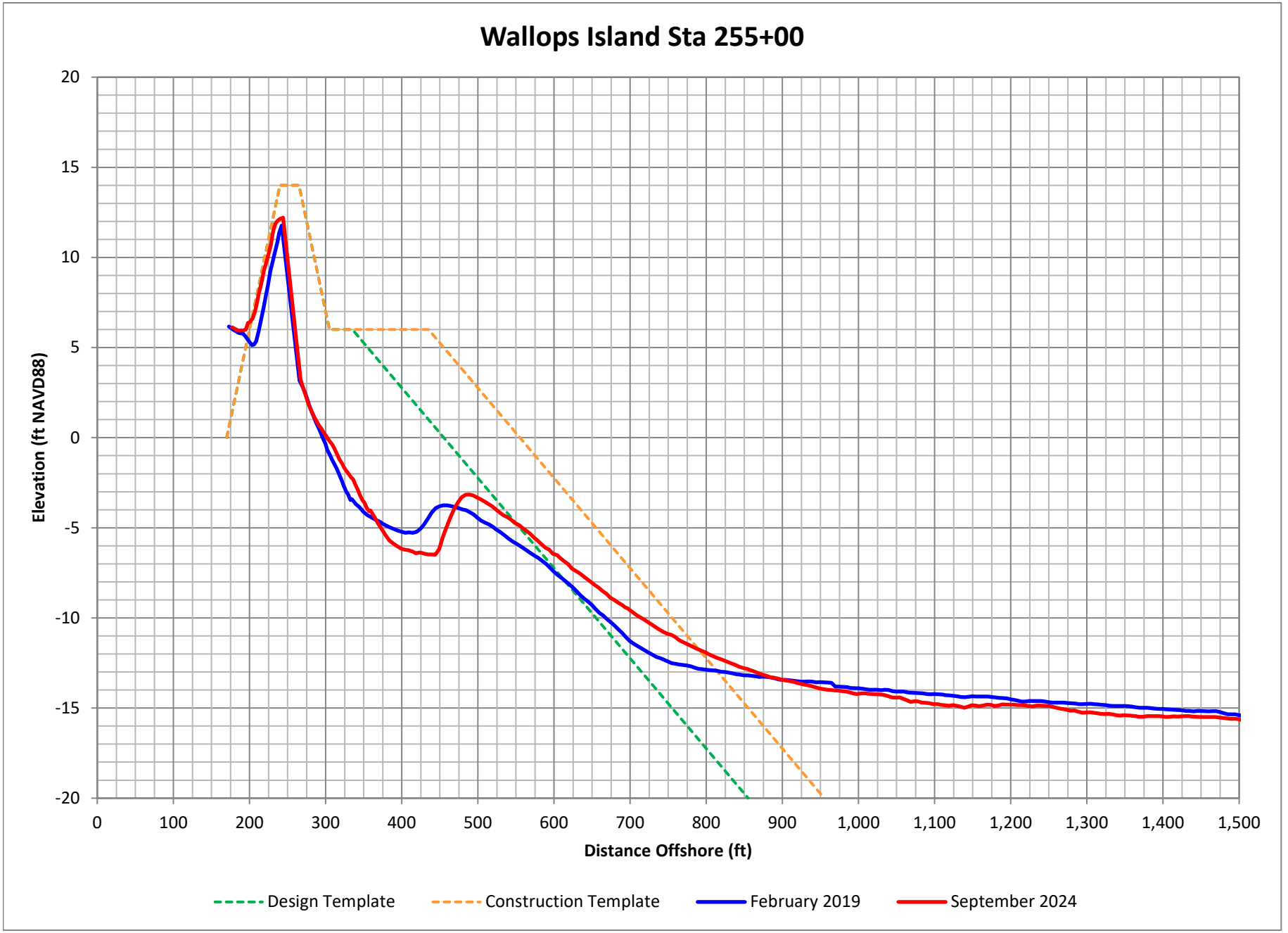


Figure C-46. Wallops Island Profile Comparison Plot

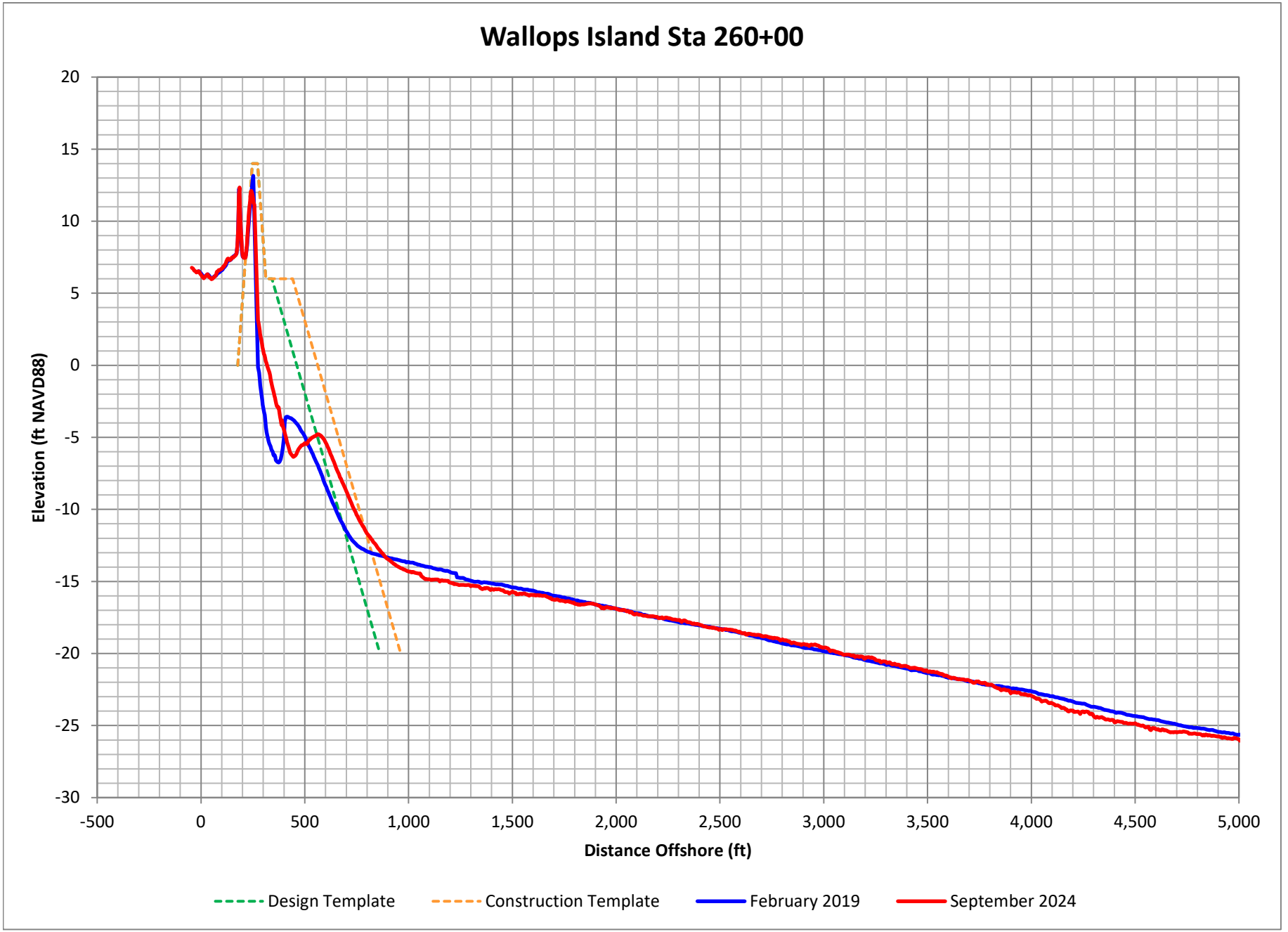


Figure C-47. Wallops Island Profile Comparison Plot

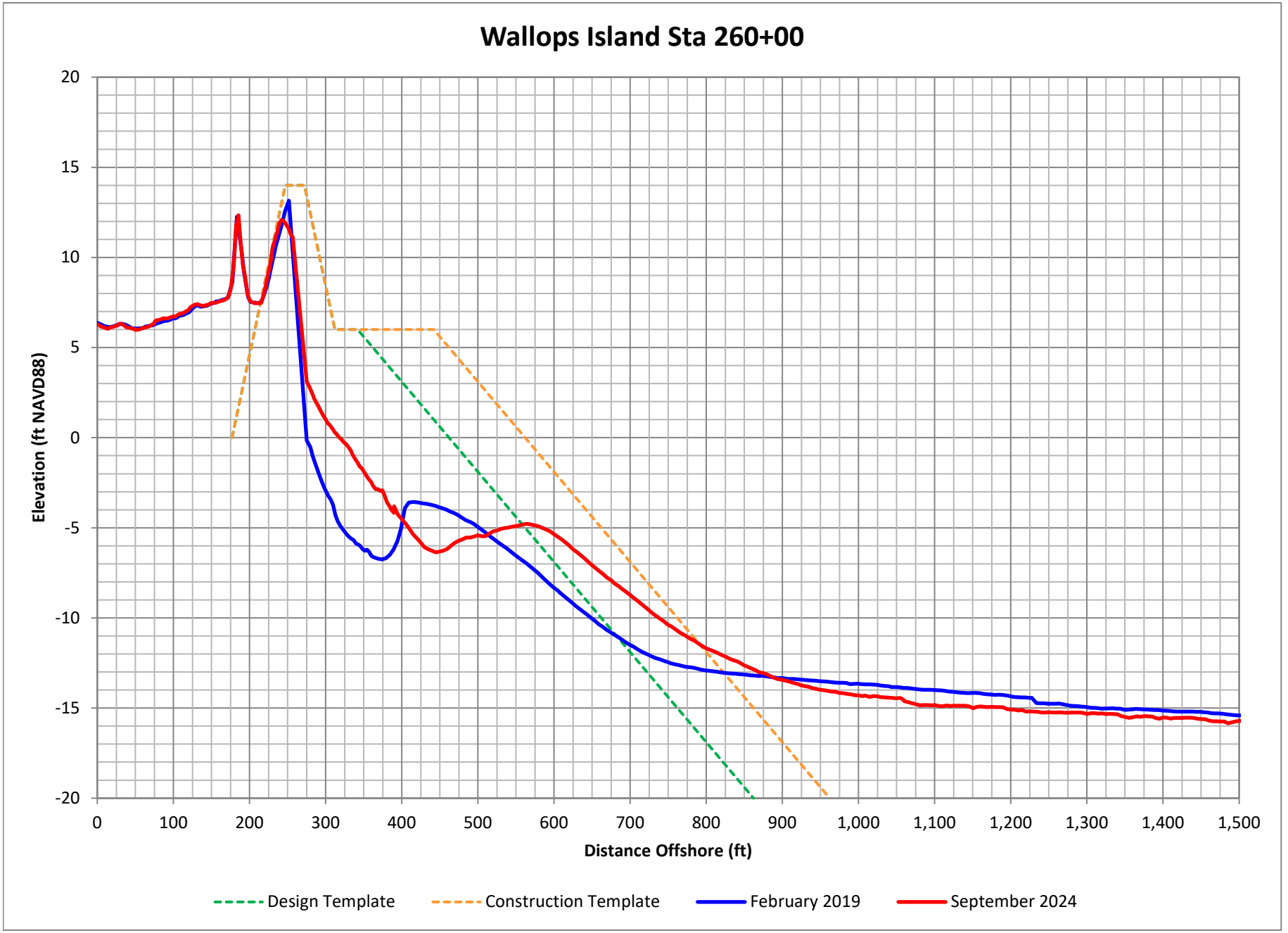


Figure C-48. Wallops Island Profile Comparison Plot

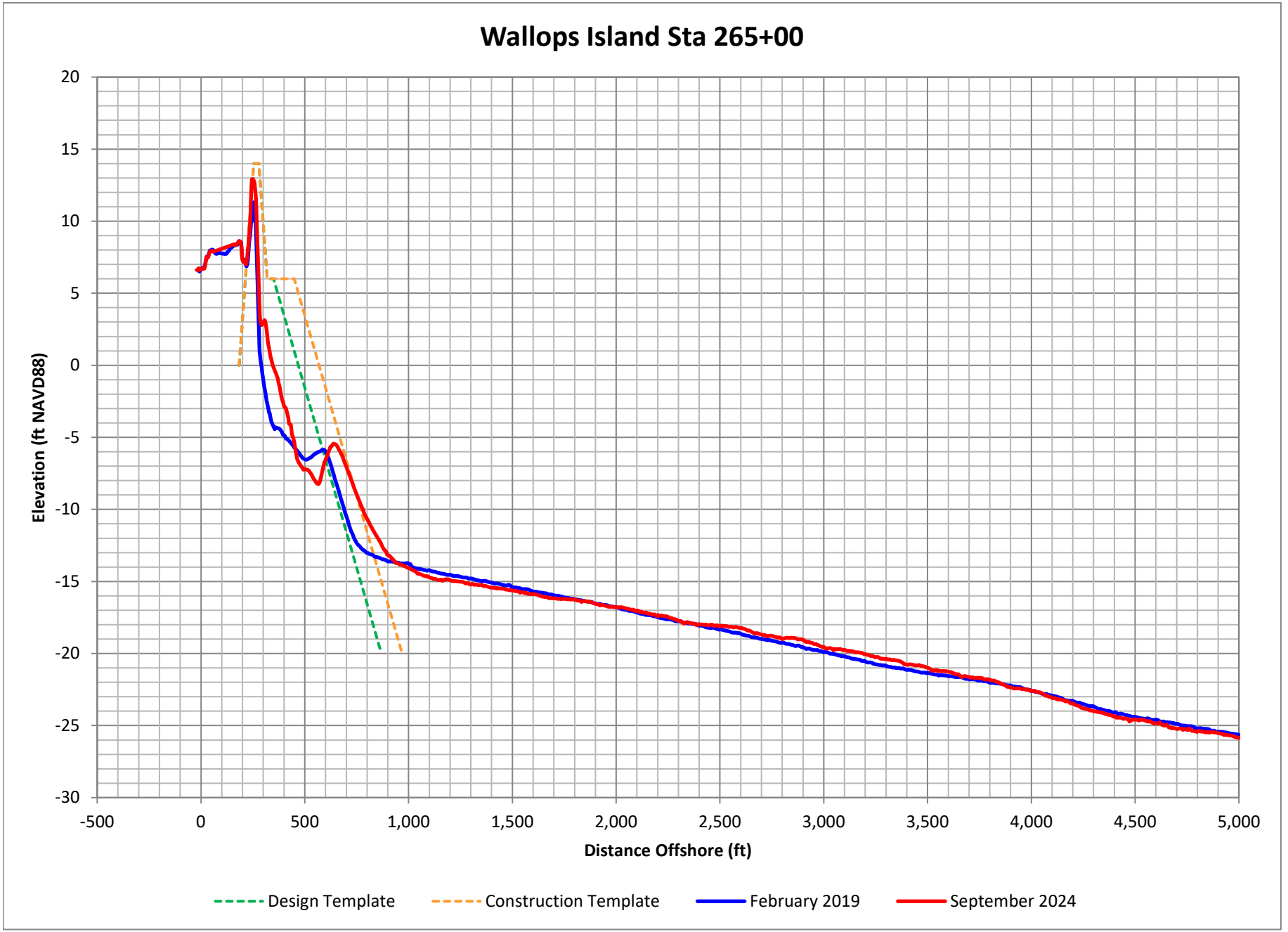


Figure C-49. Wallops Island Profile Comparison Plot

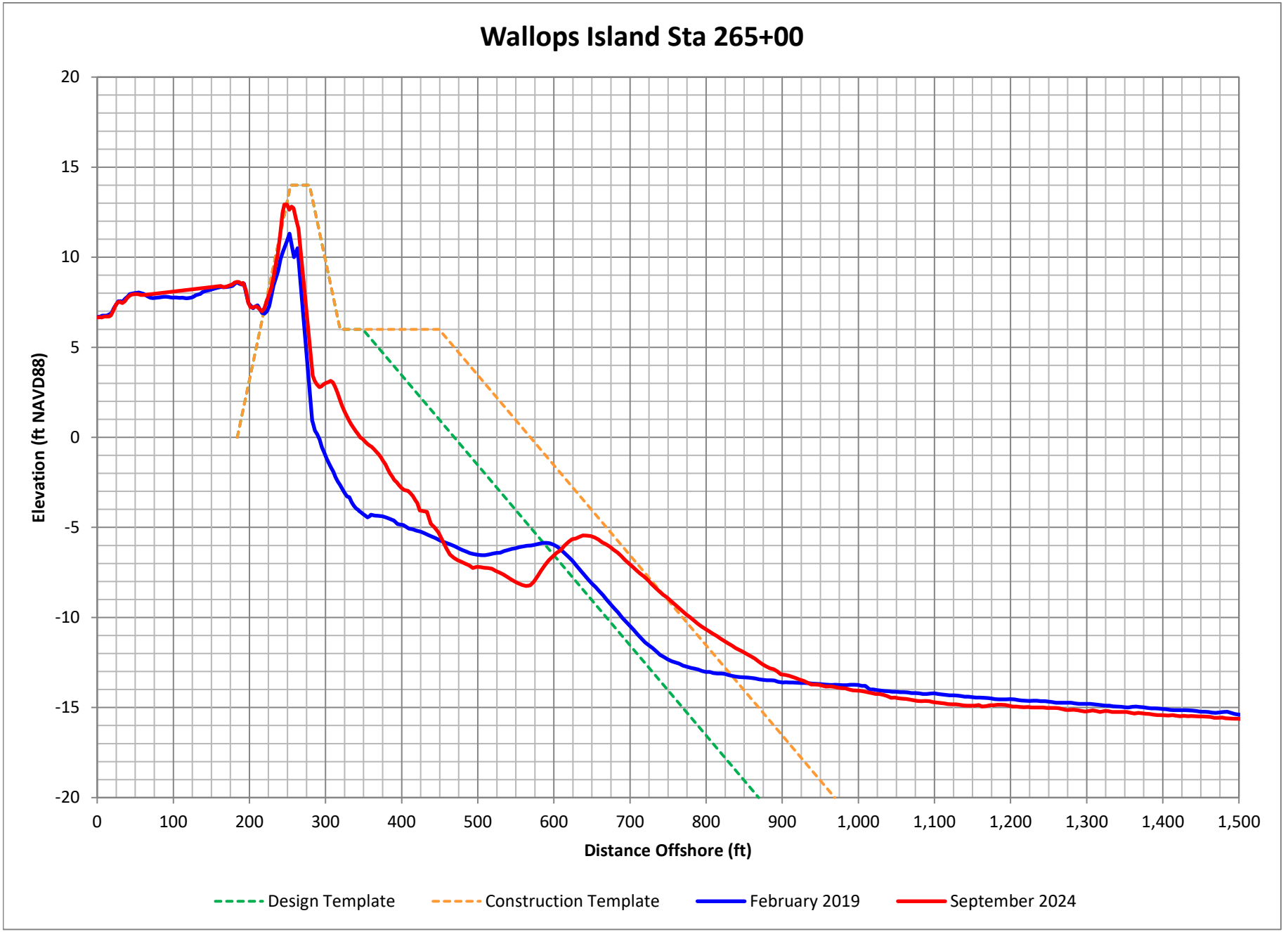


Figure C-50. Wallops Island Profile Comparison Plot

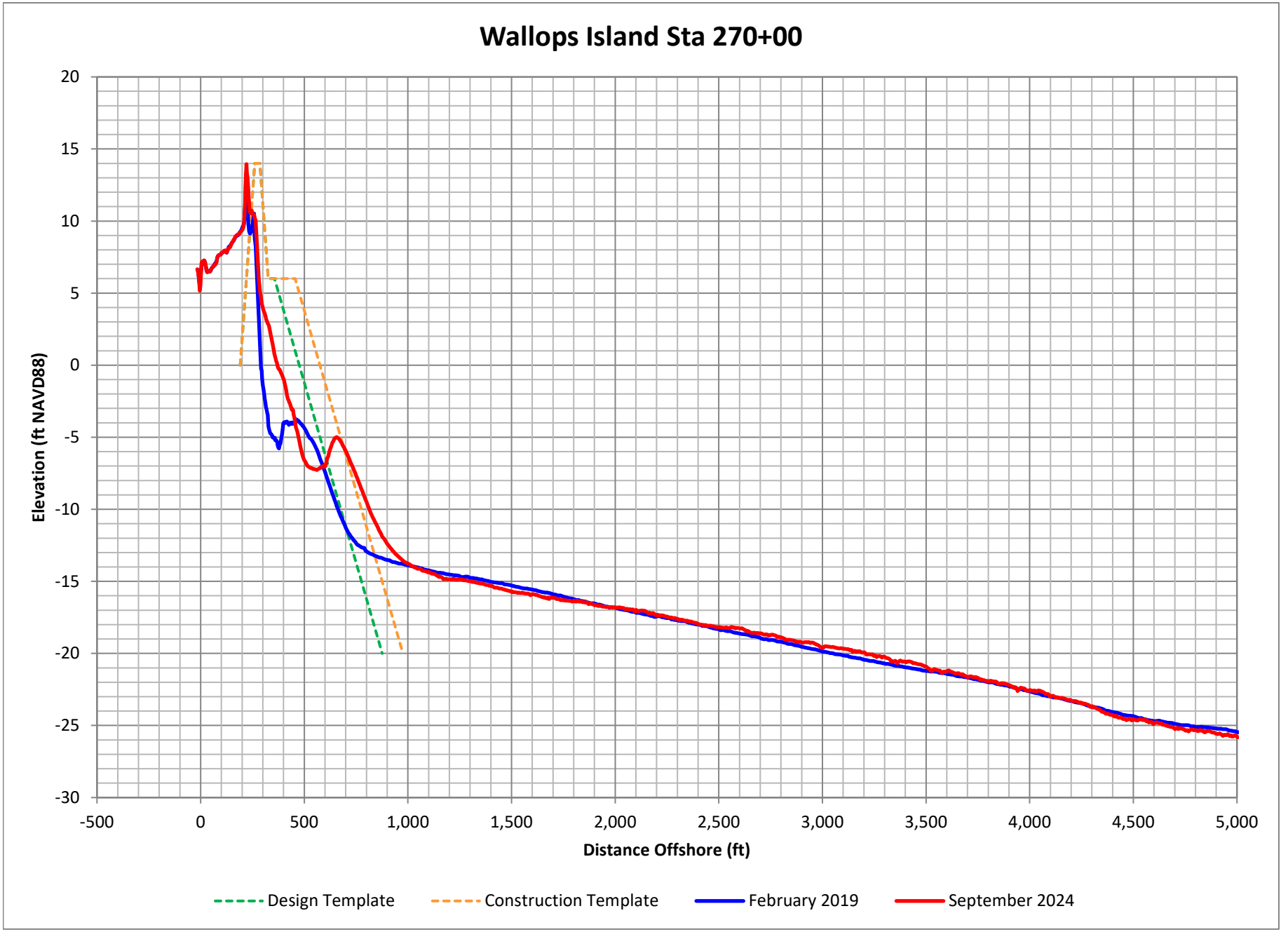


Figure C-51. Wallops Island Profile Comparison Plot

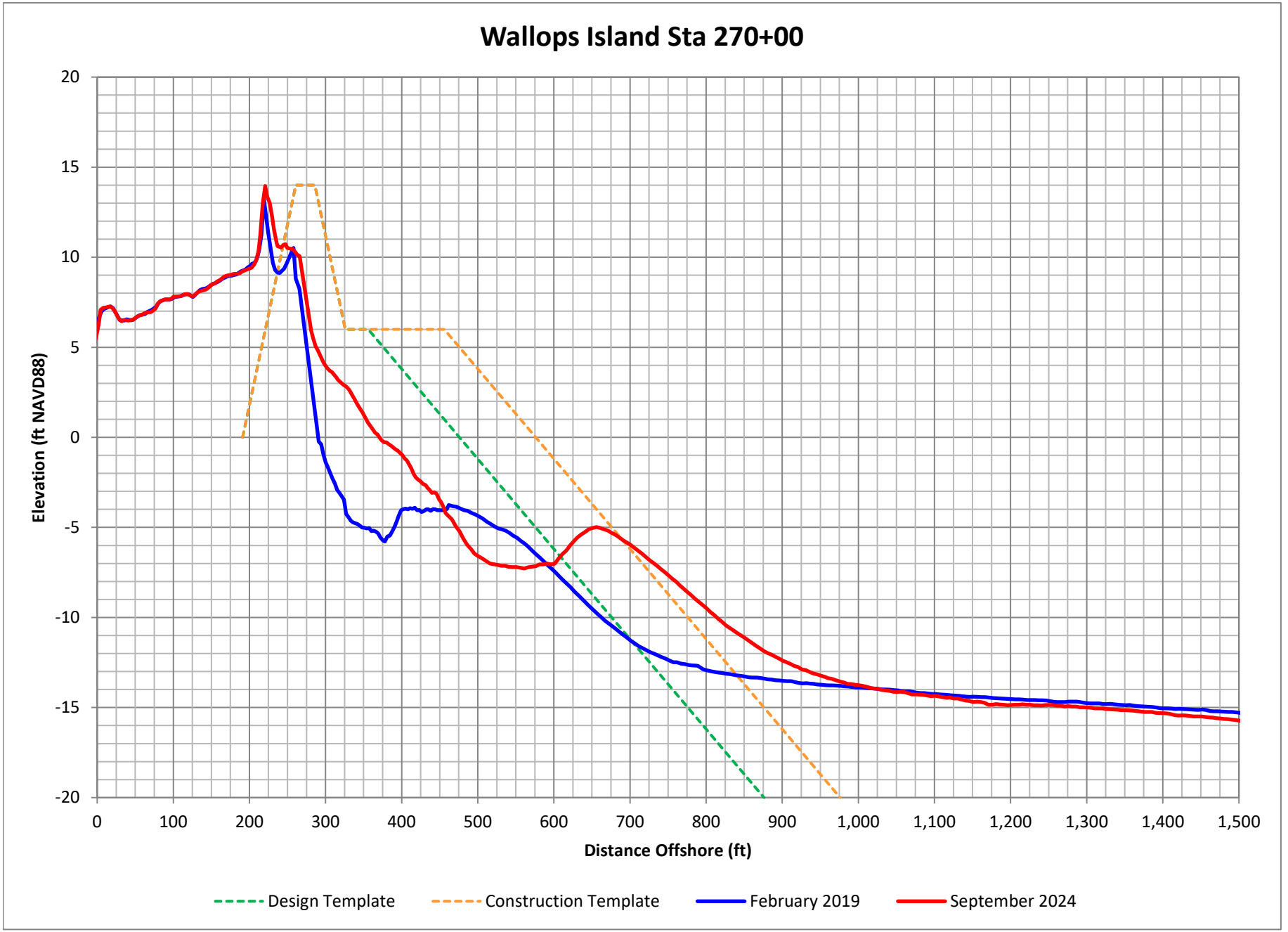


Figure C-52. Wallops Island Profile Comparison Plot

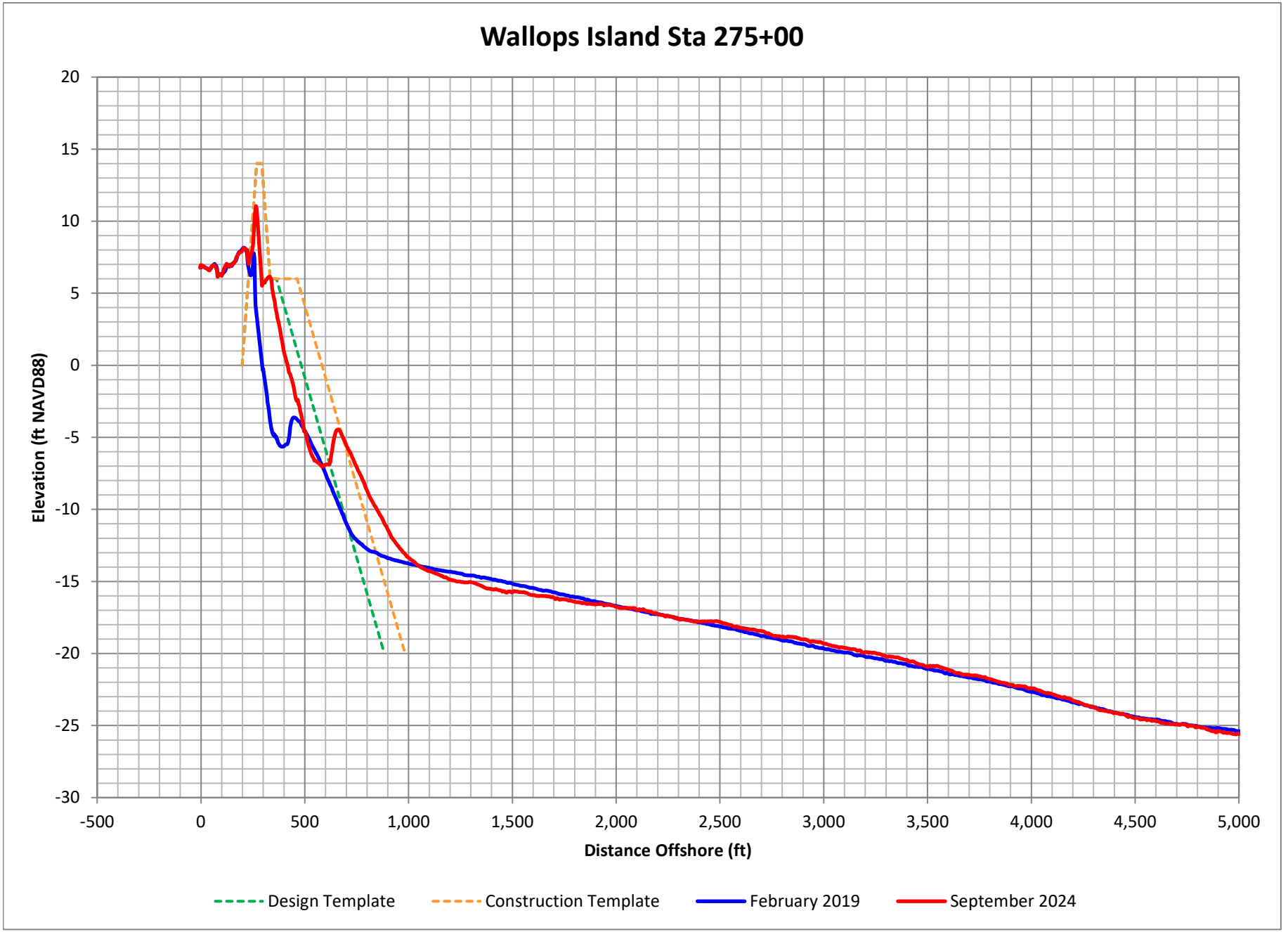


Figure C-53. Wallops Island Profile Comparison Plot

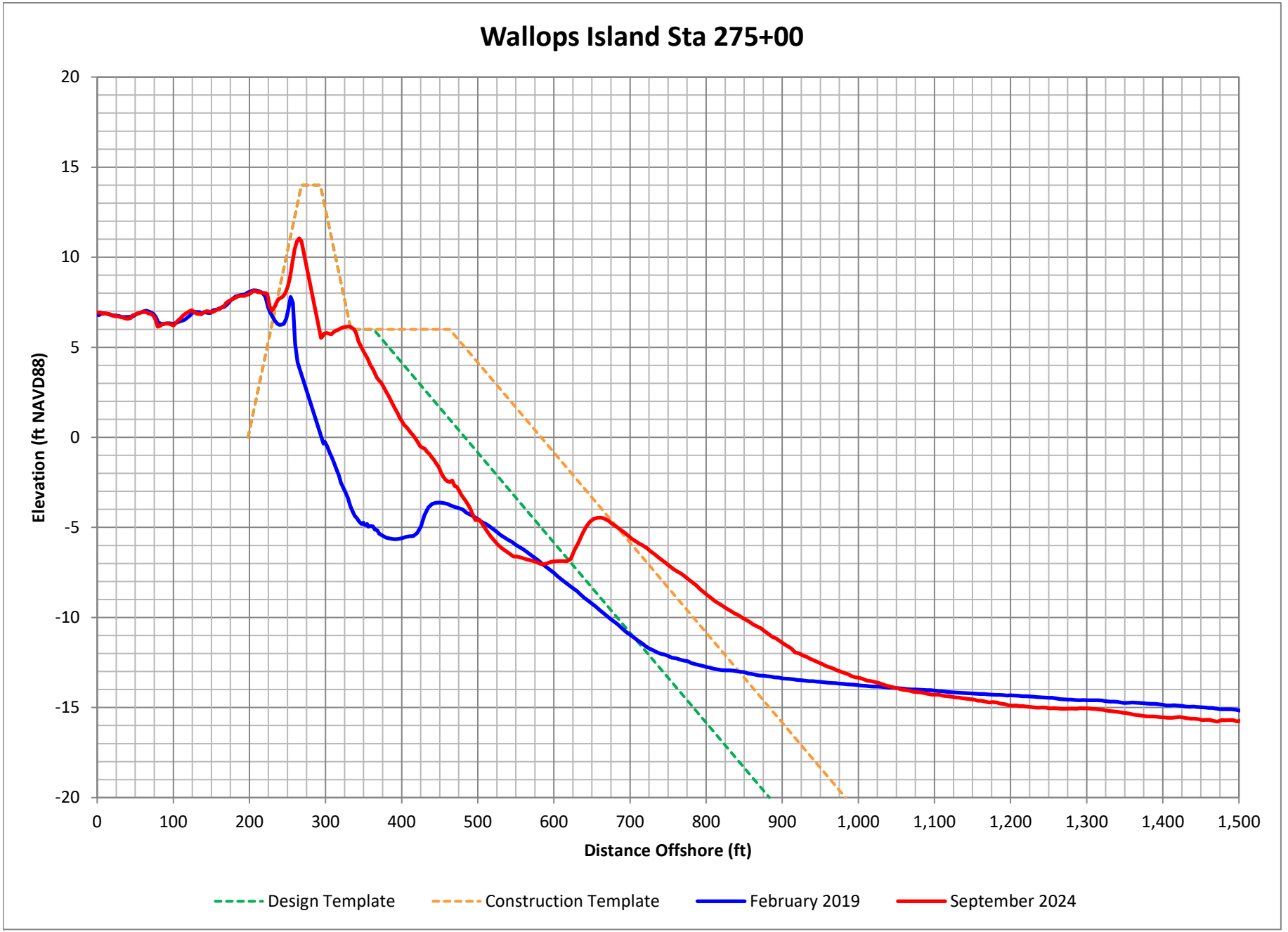


Figure C-54. Wallops Island Profile Comparison Plot

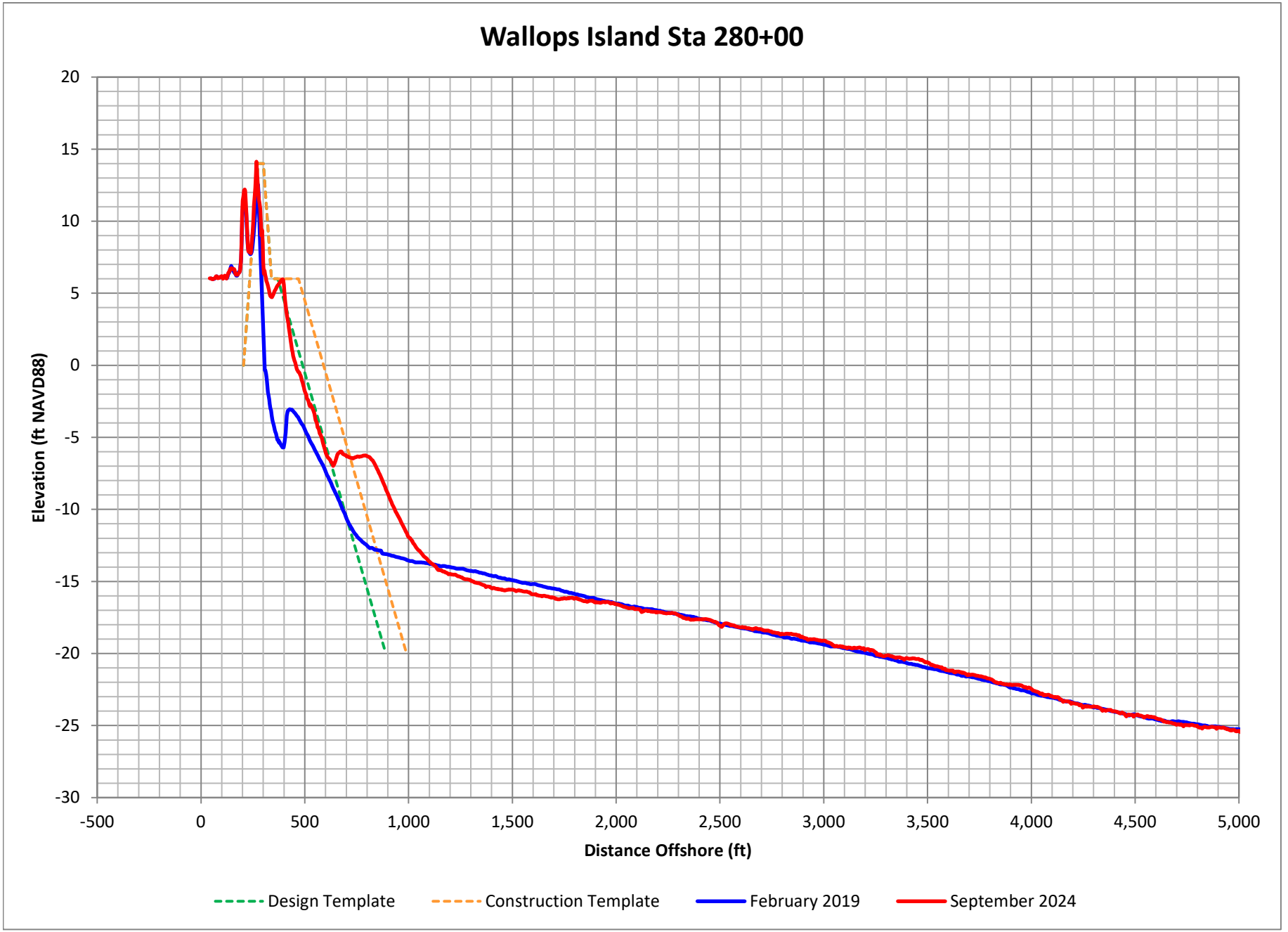


Figure C-55. Wallops Island Profile Comparison Plot

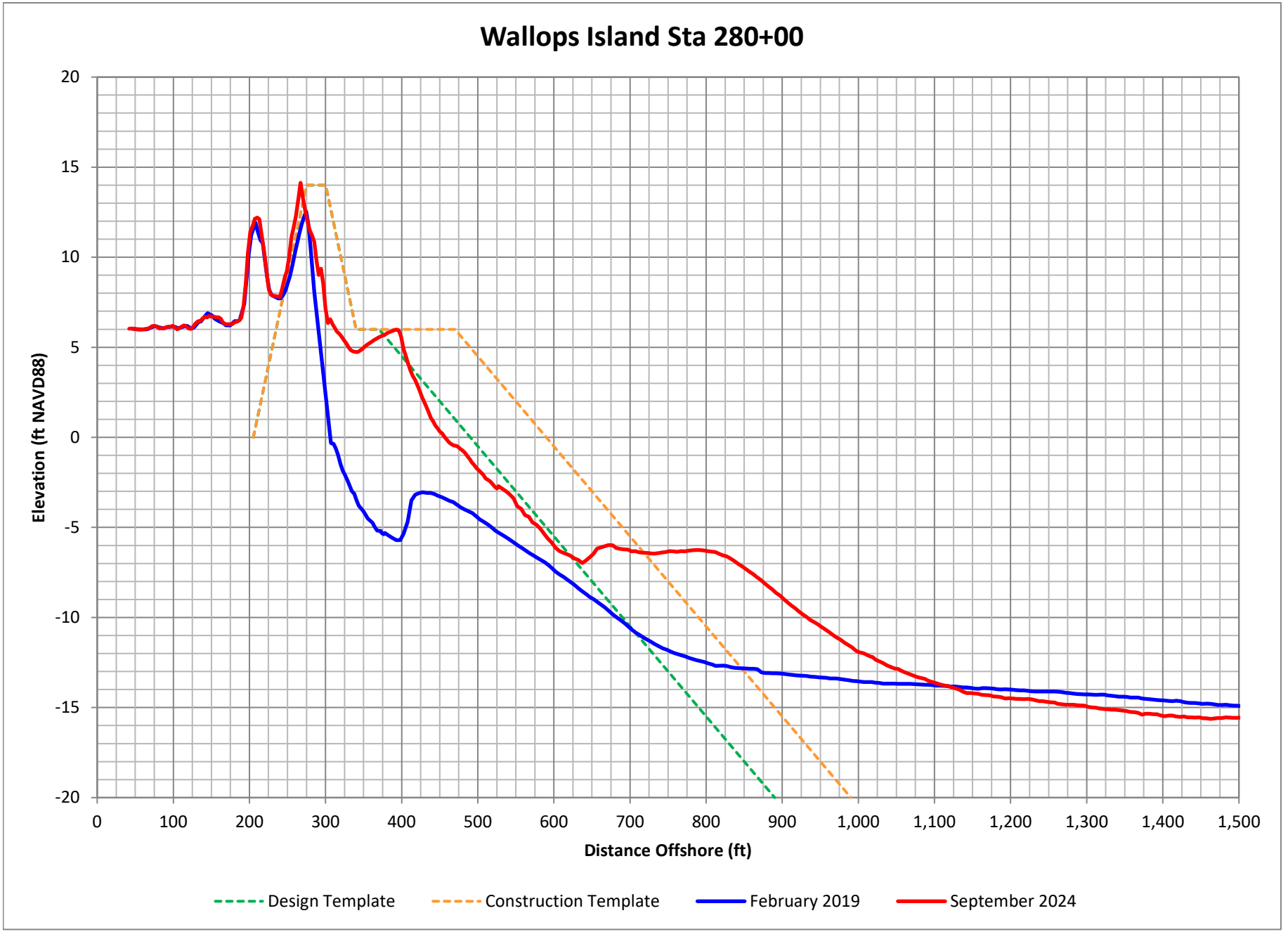


Figure C-56. Wallops Island Profile Comparison Plot

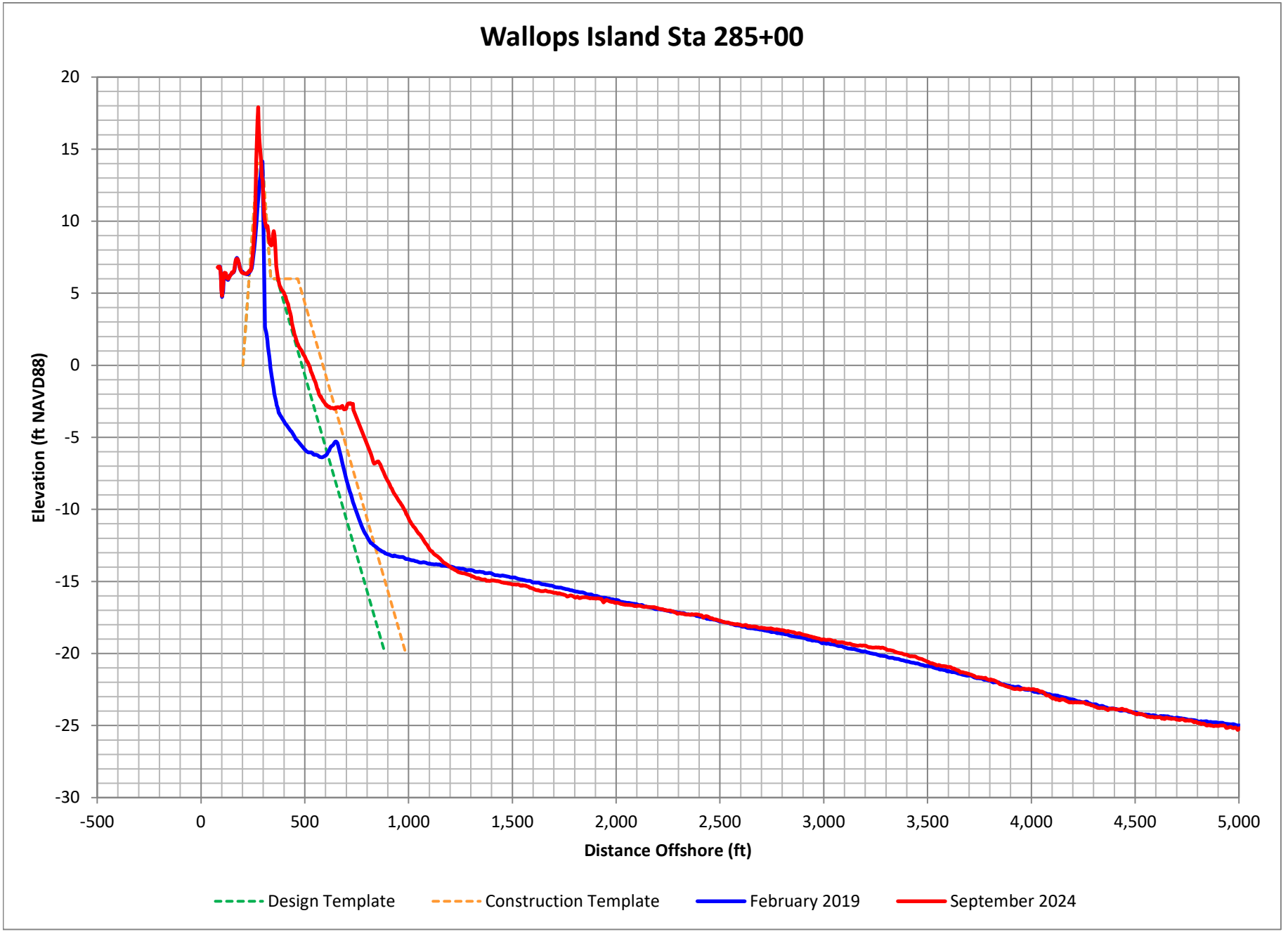


Figure C-57. Wallops Island Profile Comparison Plot

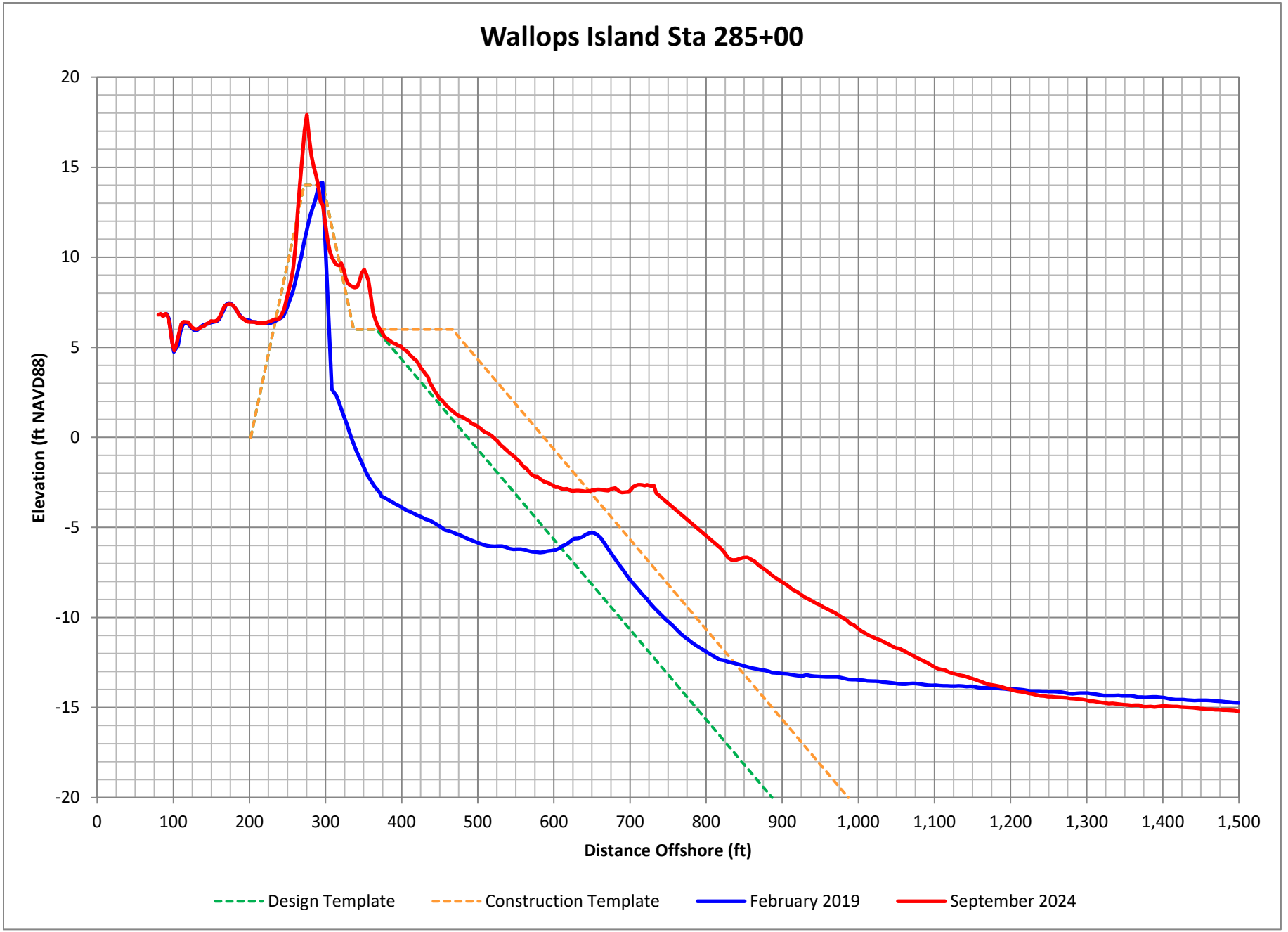


Figure C-58. Wallops Island Profile Comparison Plot

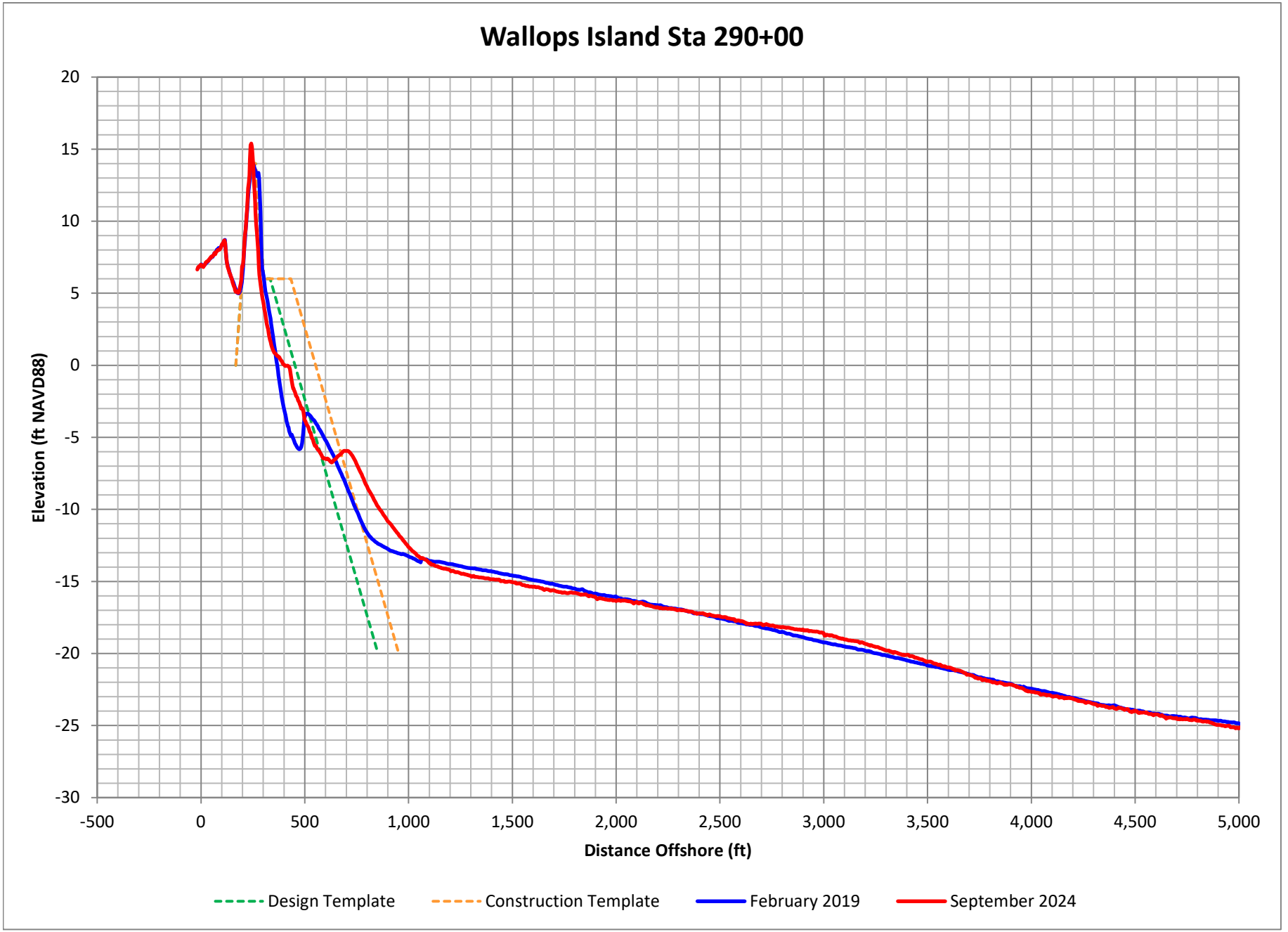


Figure C-59. Wallops Island Profile Comparison Plot

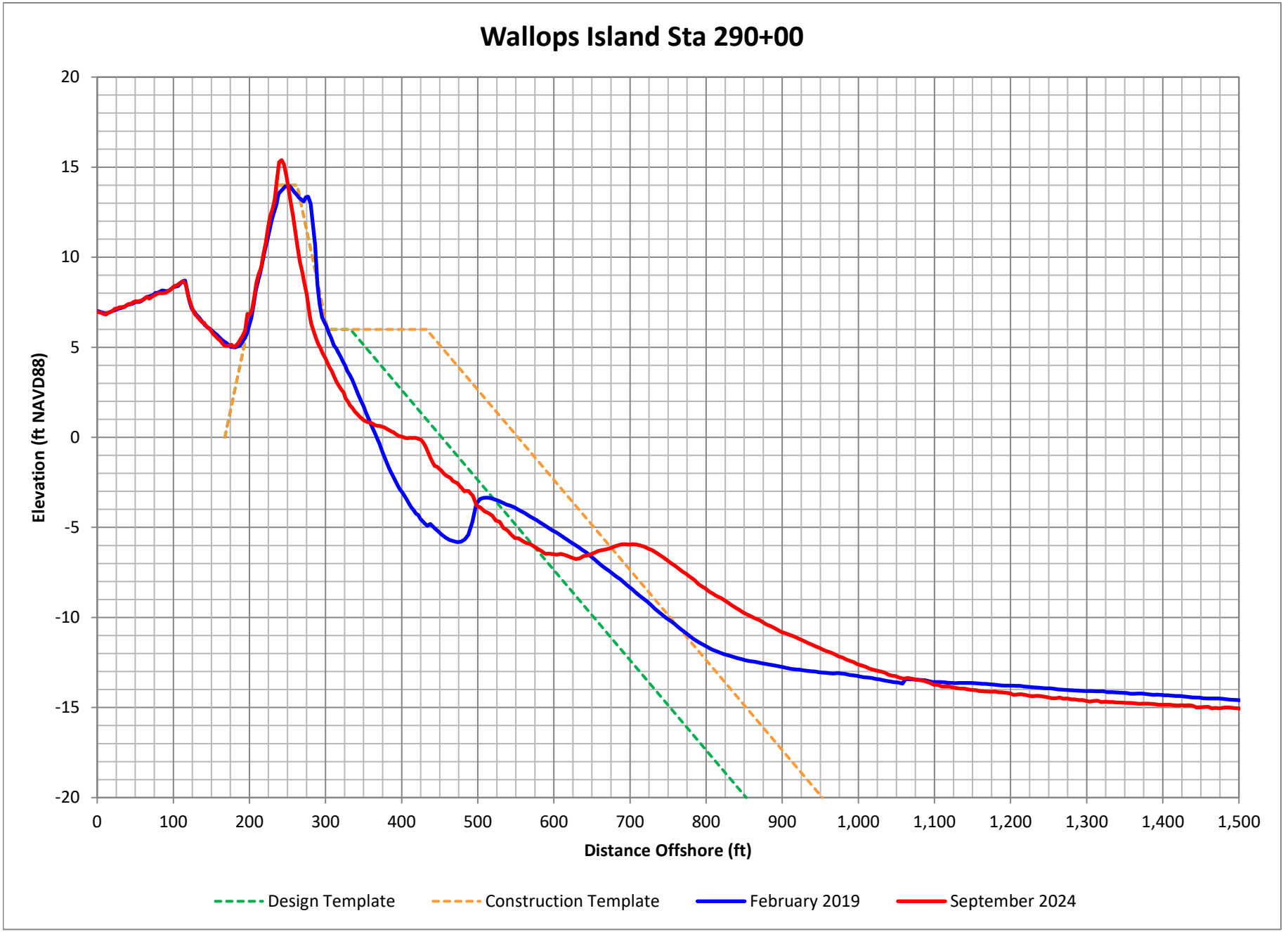


Figure C-60. Wallops Island Profile Comparison Plot

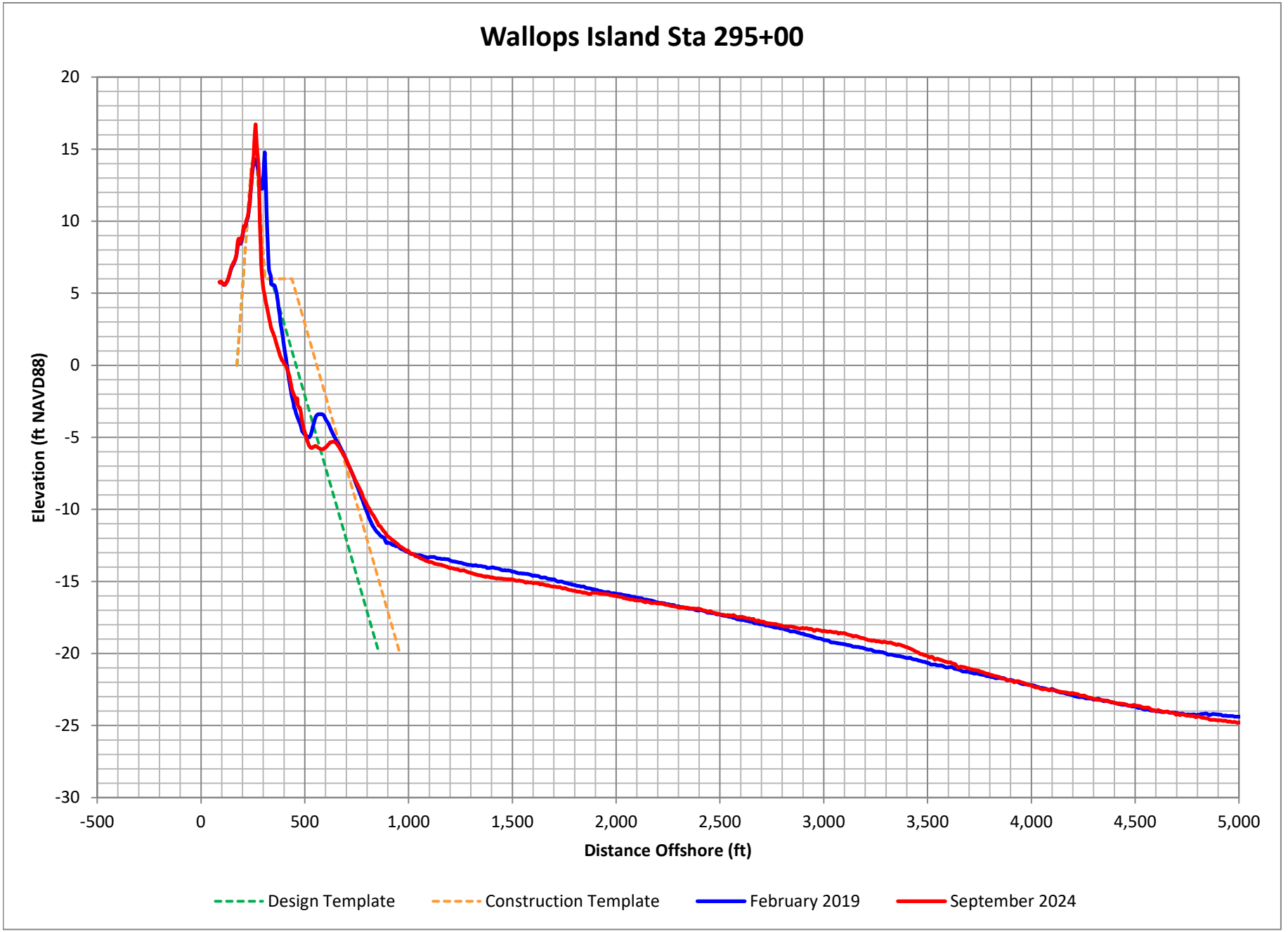


Figure C-61. Wallops Island Profile Comparison Plot

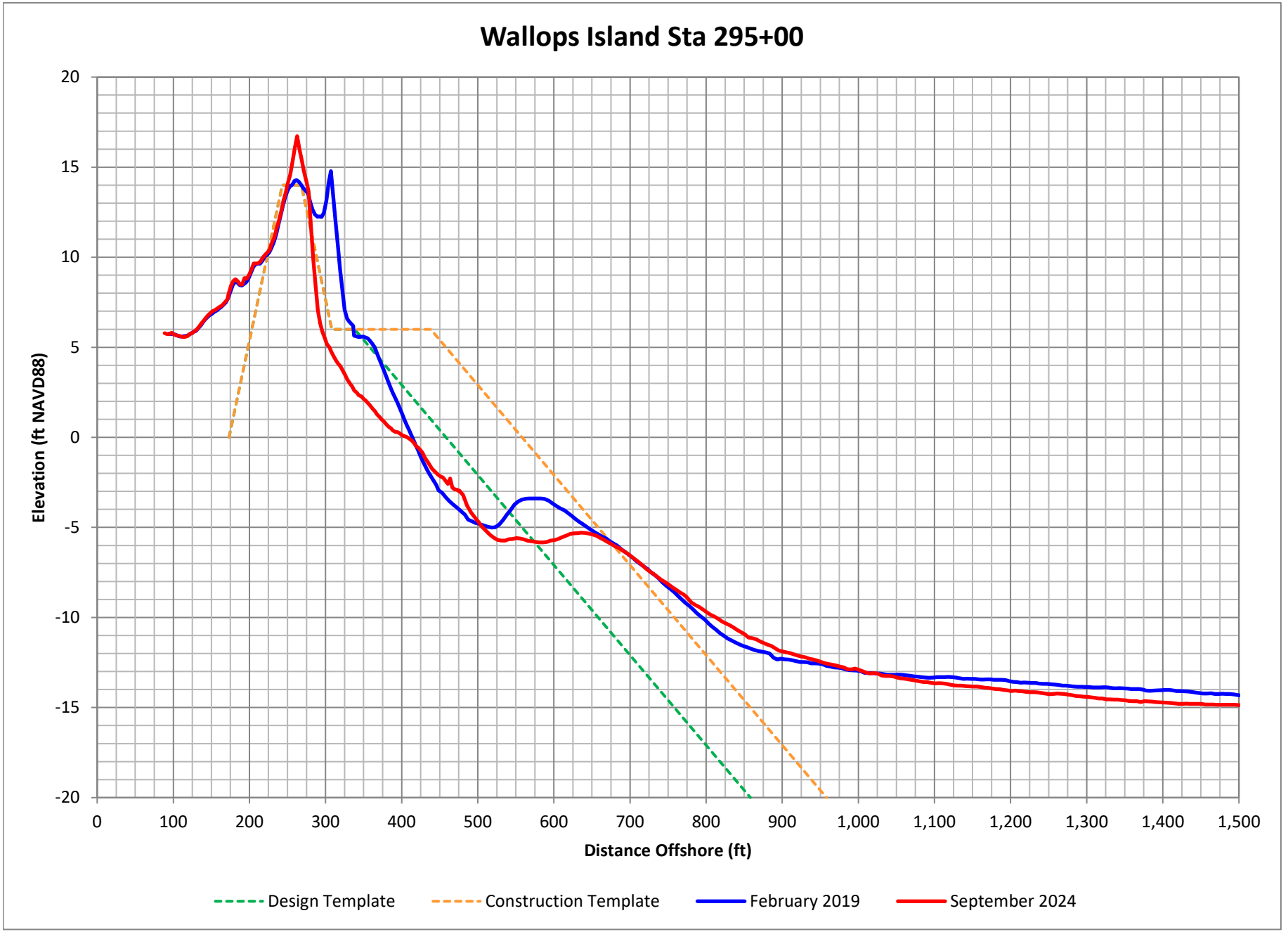


Figure C-62. Wallops Island Profile Comparison Plot

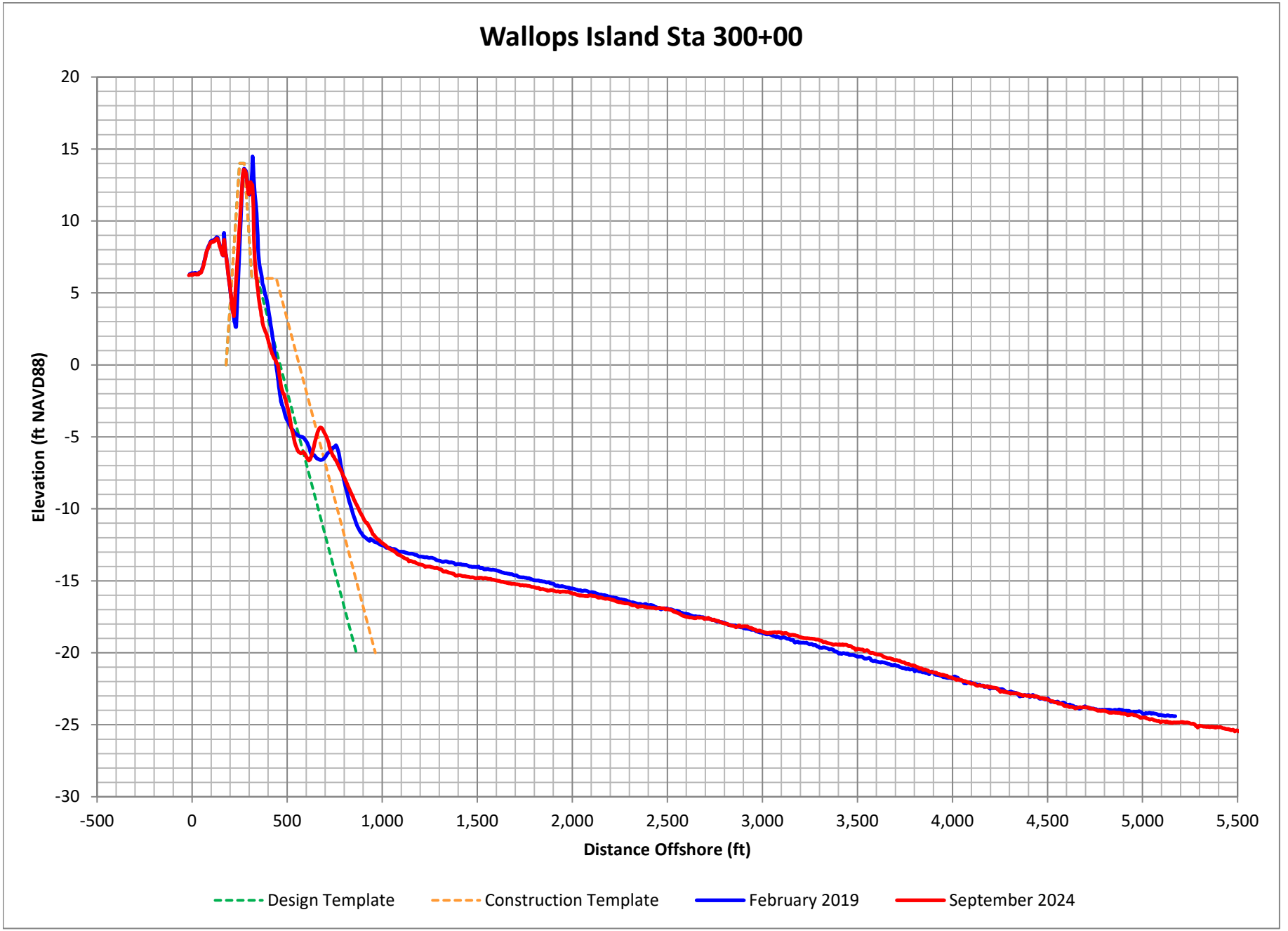


Figure C-63. Wallops Island Profile Comparison Plot

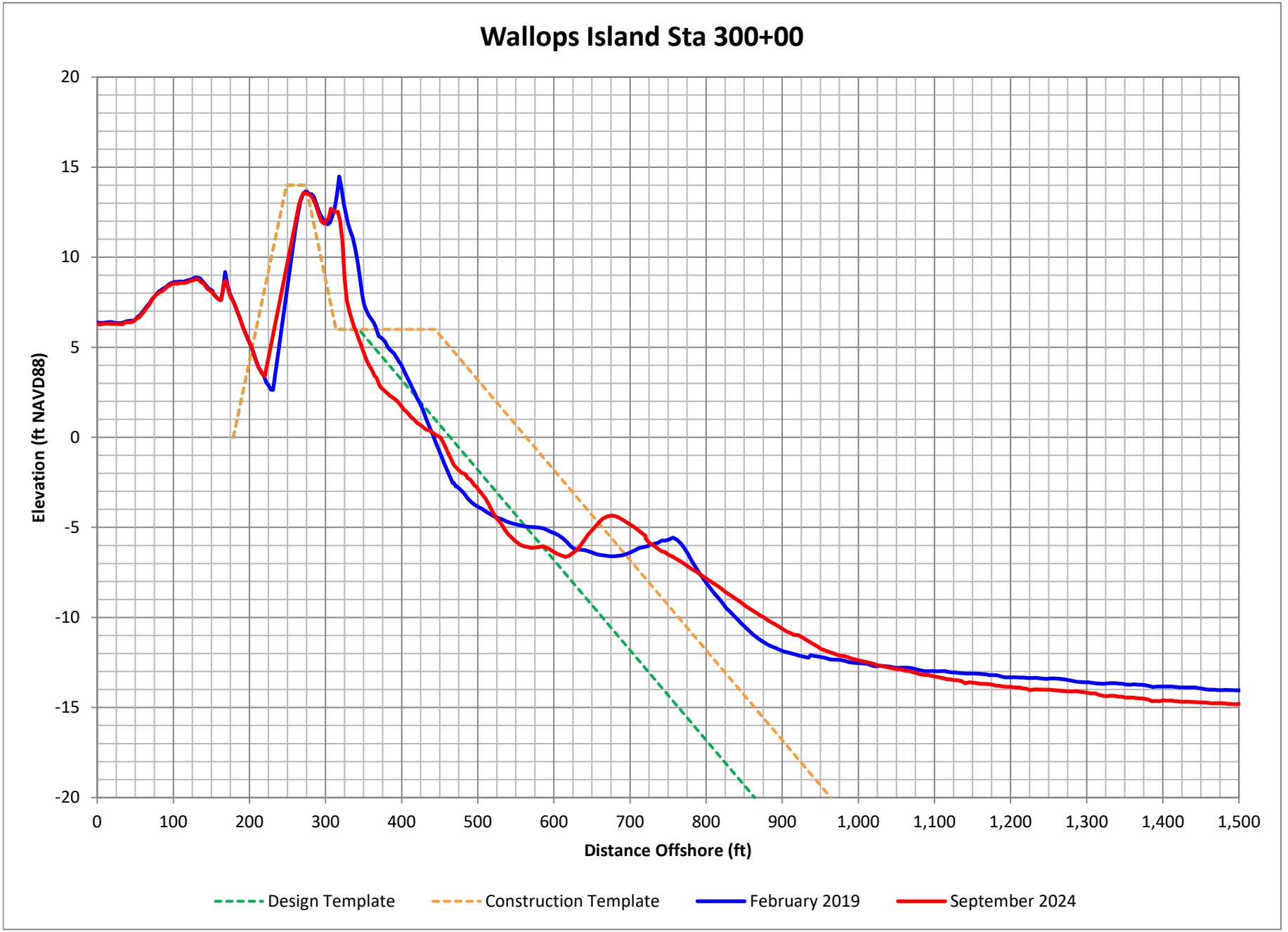


Figure C-64. Wallops Island Profile Comparison Plot

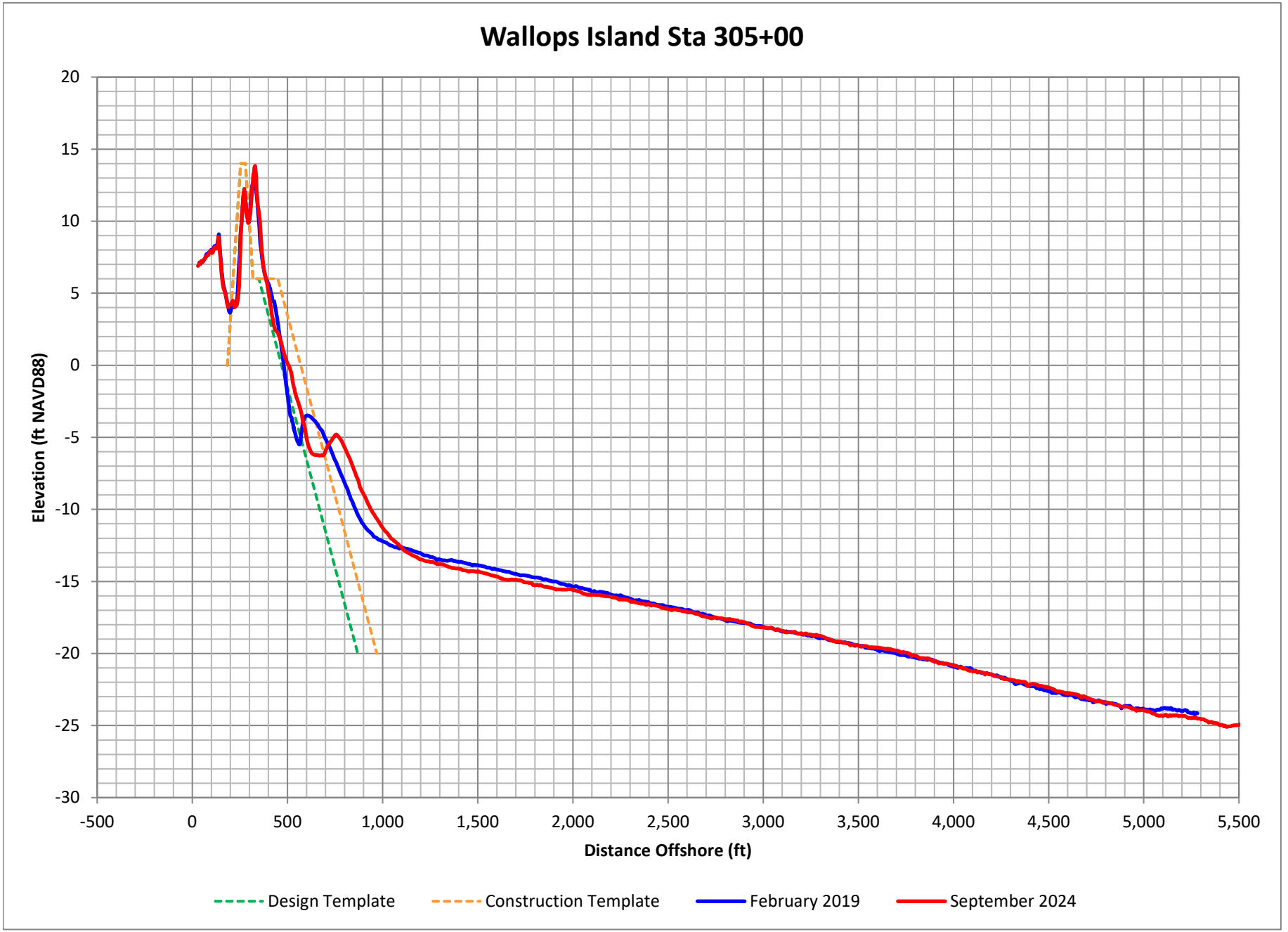


Figure C-65. Wallops Island Profile Comparison Plot

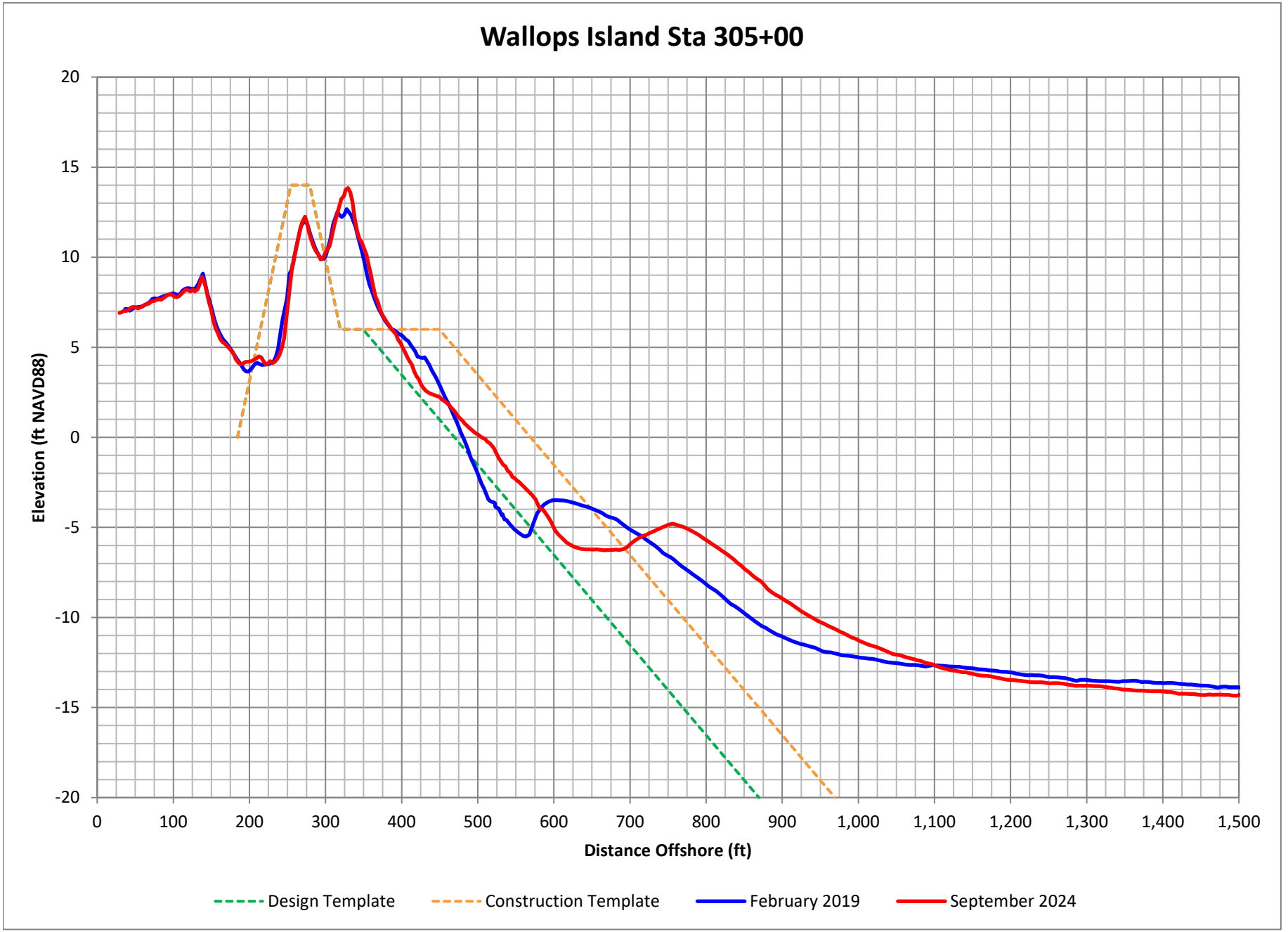


Figure C-66. Wallops Island Profile Comparison Plot

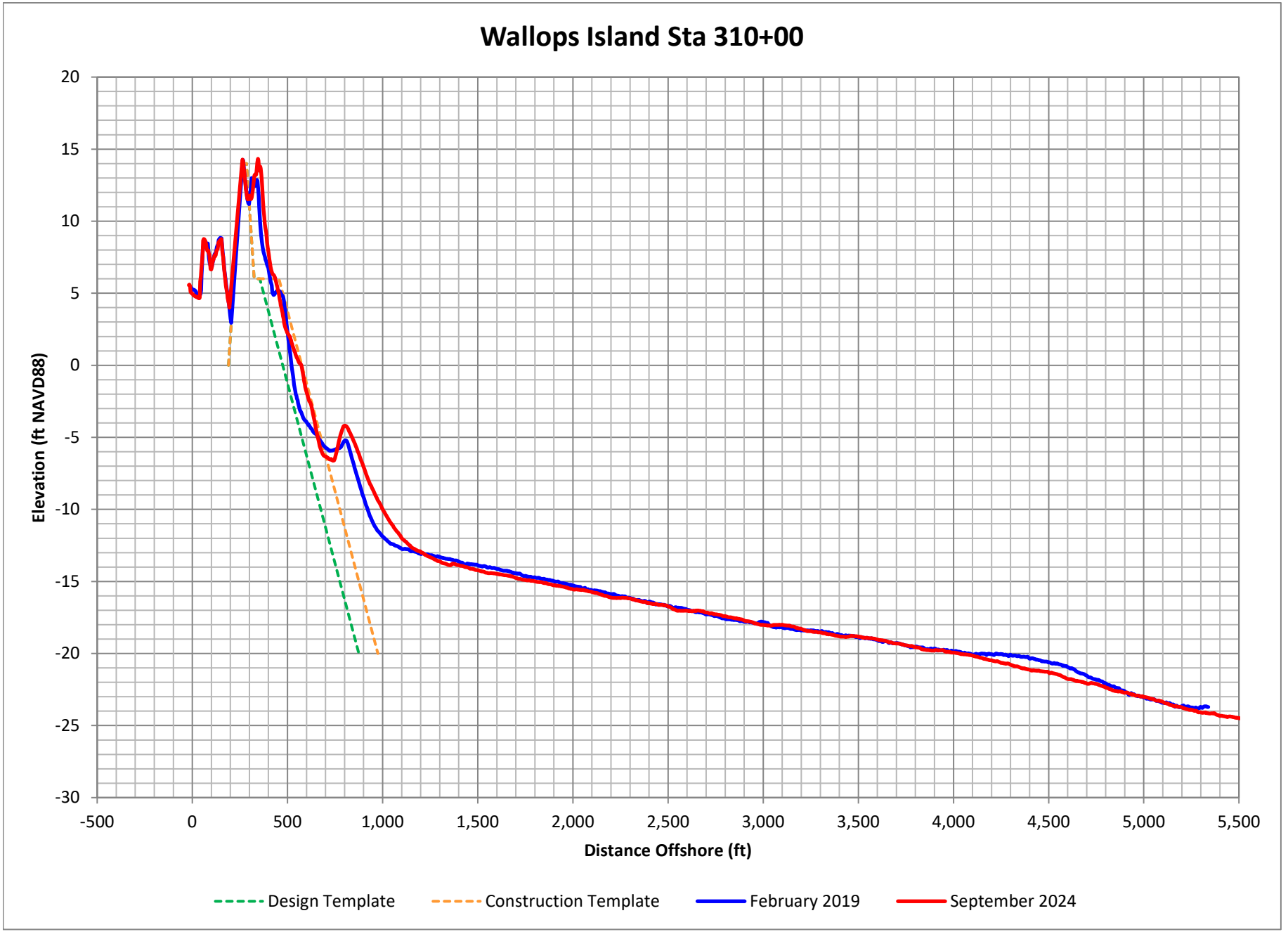


Figure C-67. Wallops Island Profile Comparison Plot

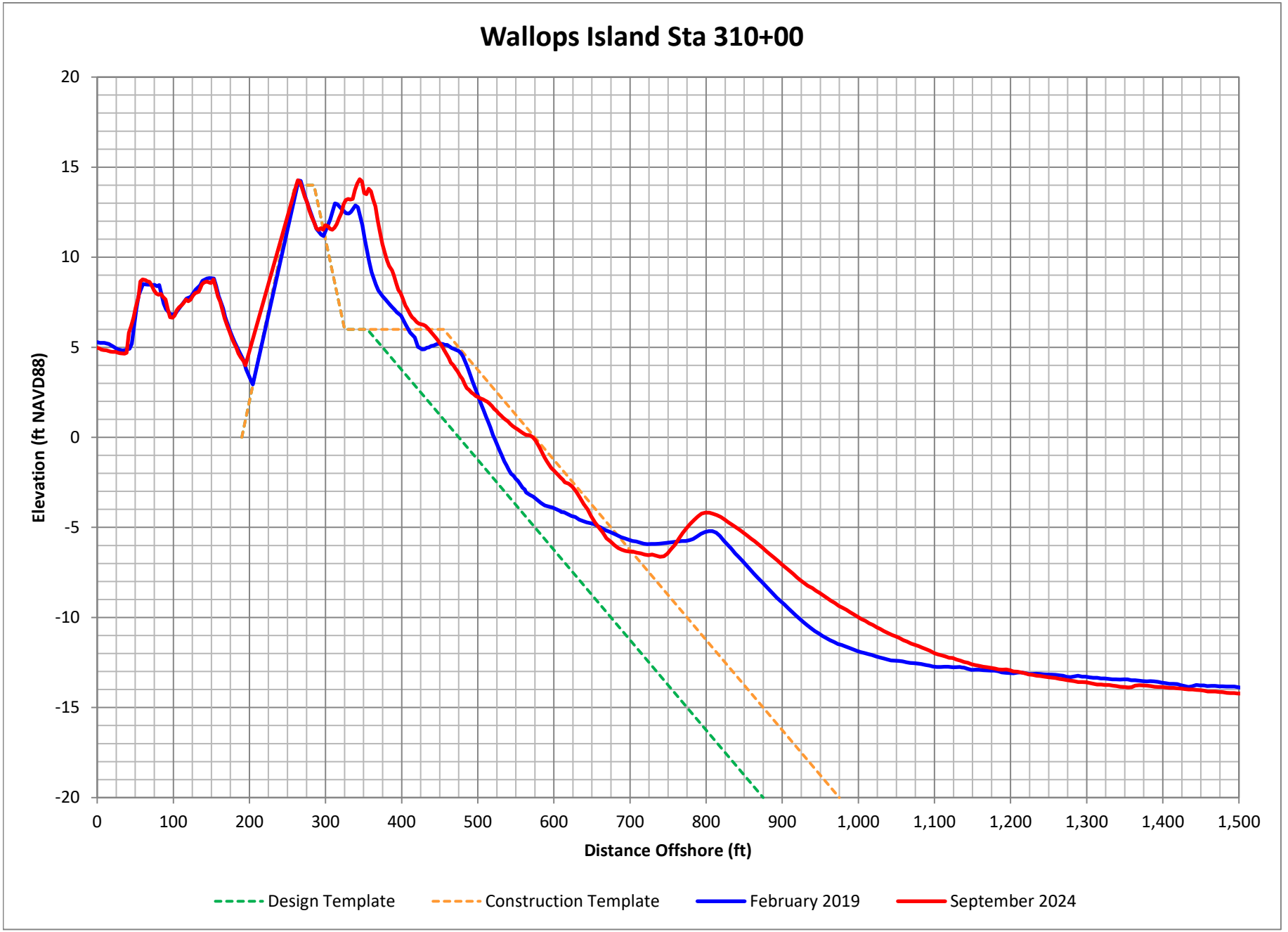


Figure C-68. Wallops Island Profile Comparison Plot

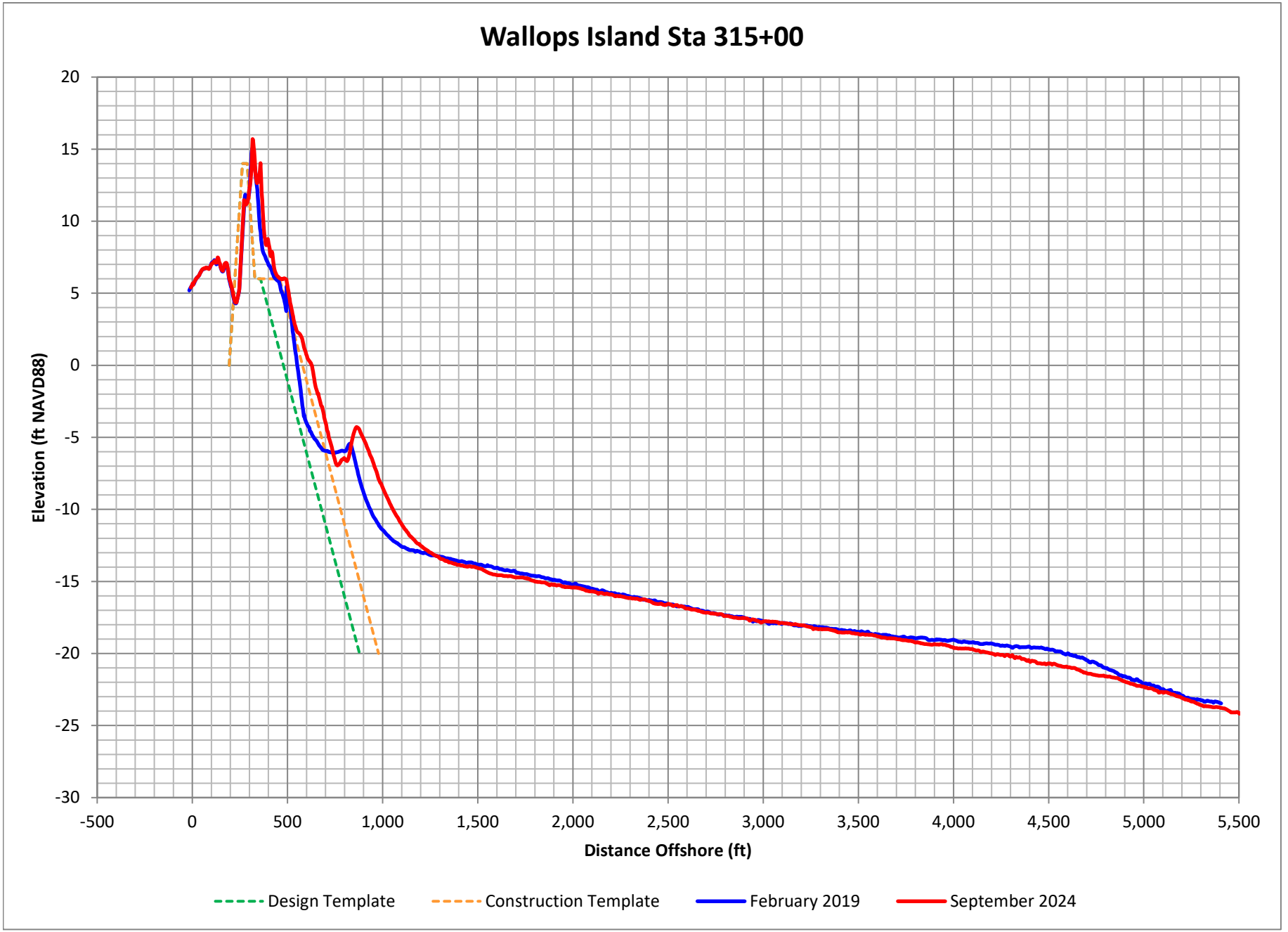


Figure C-69. Wallops Island Profile Comparison Plot

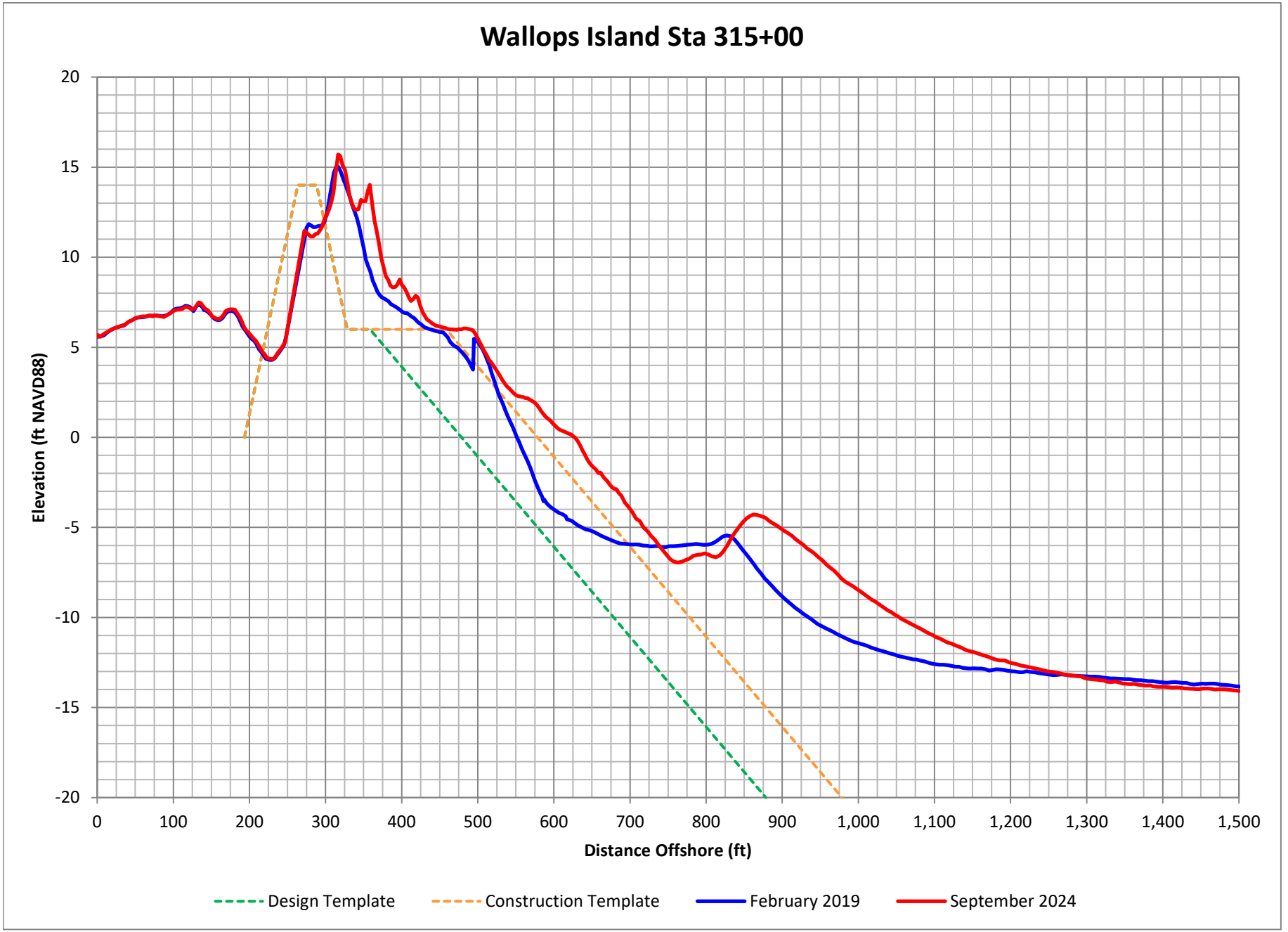


Figure C-70. Wallops Island Profile Comparison Plot

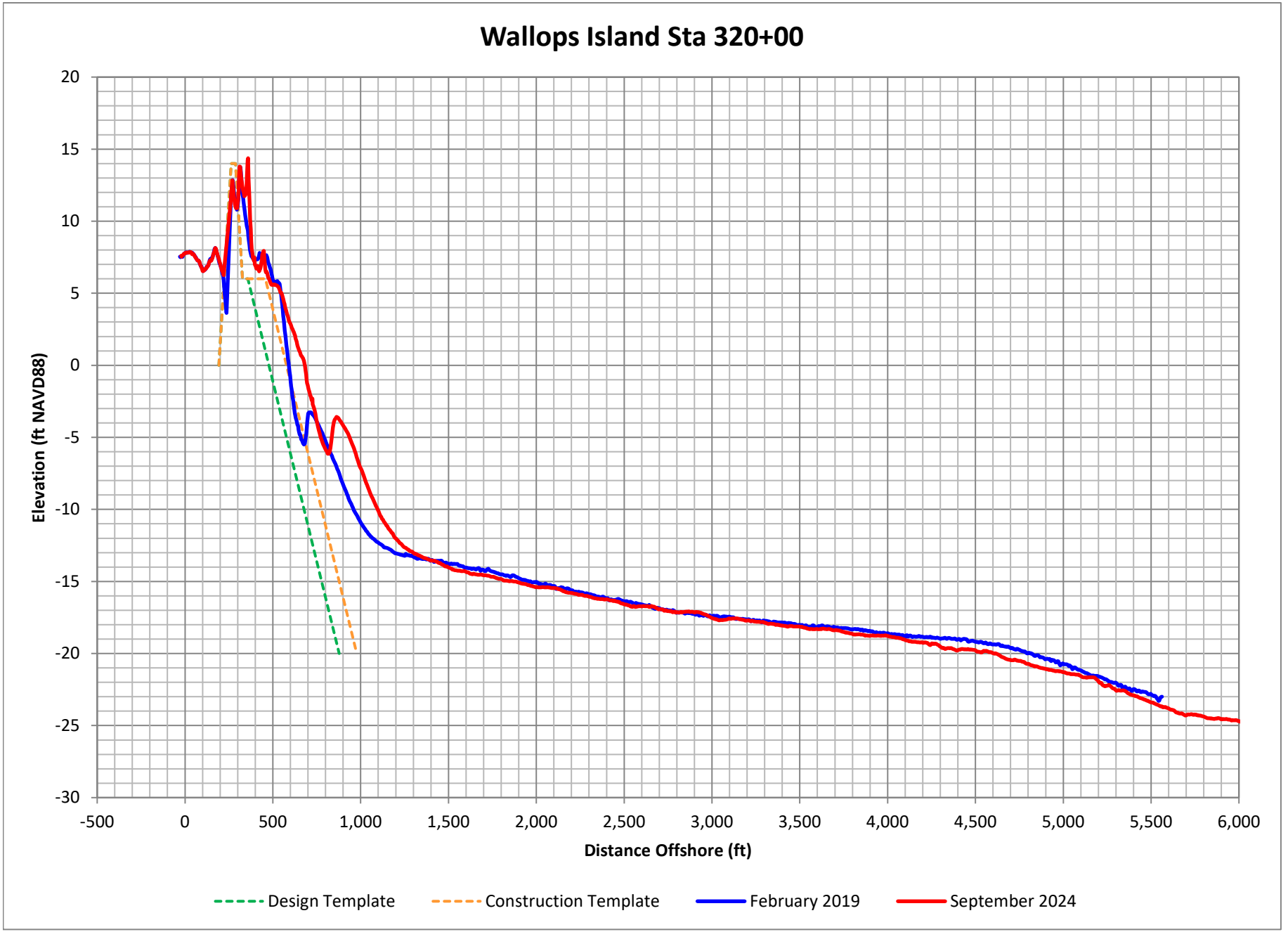


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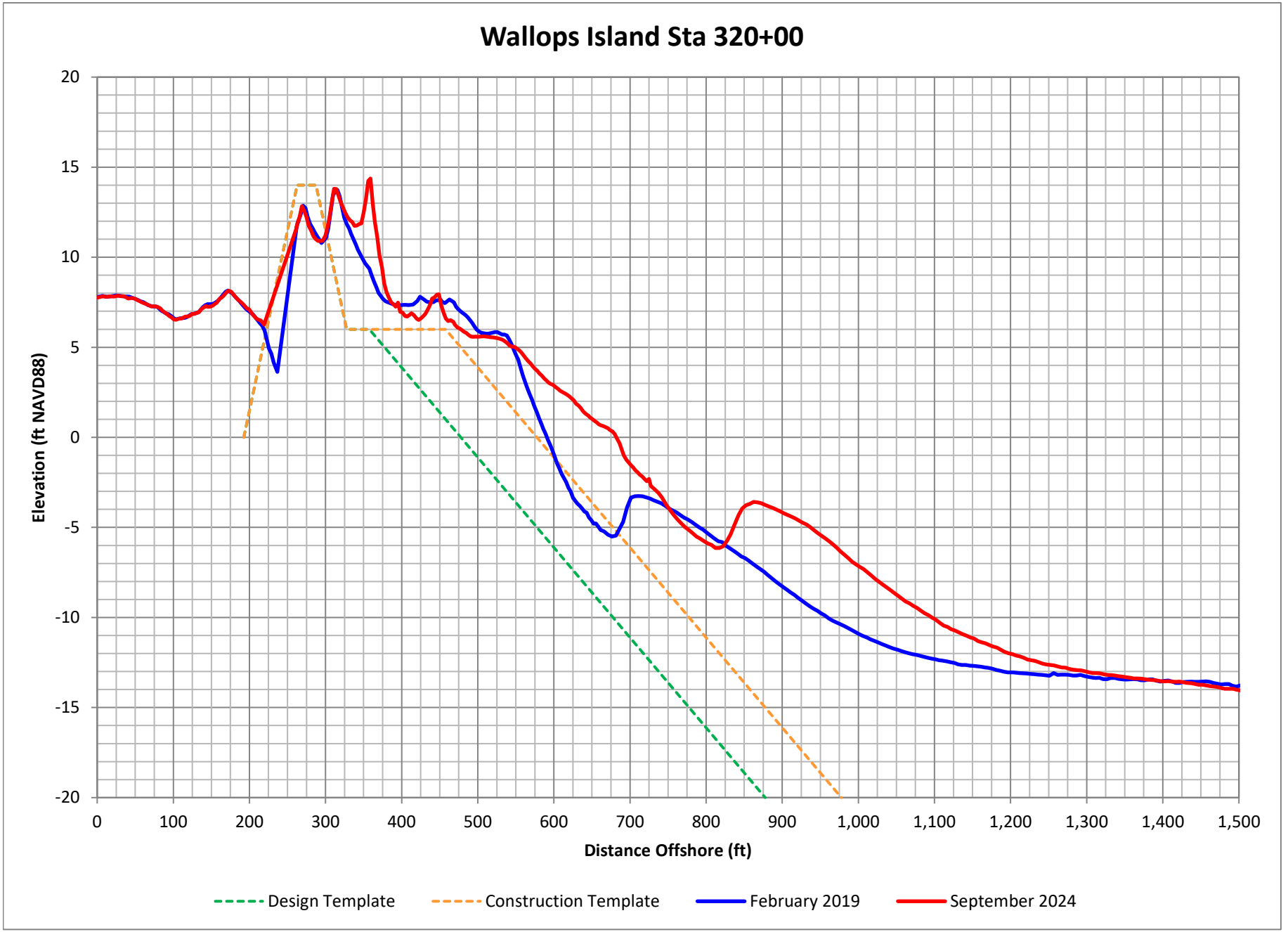


Figure C-72. Wallops Island Profile Comparison Plot

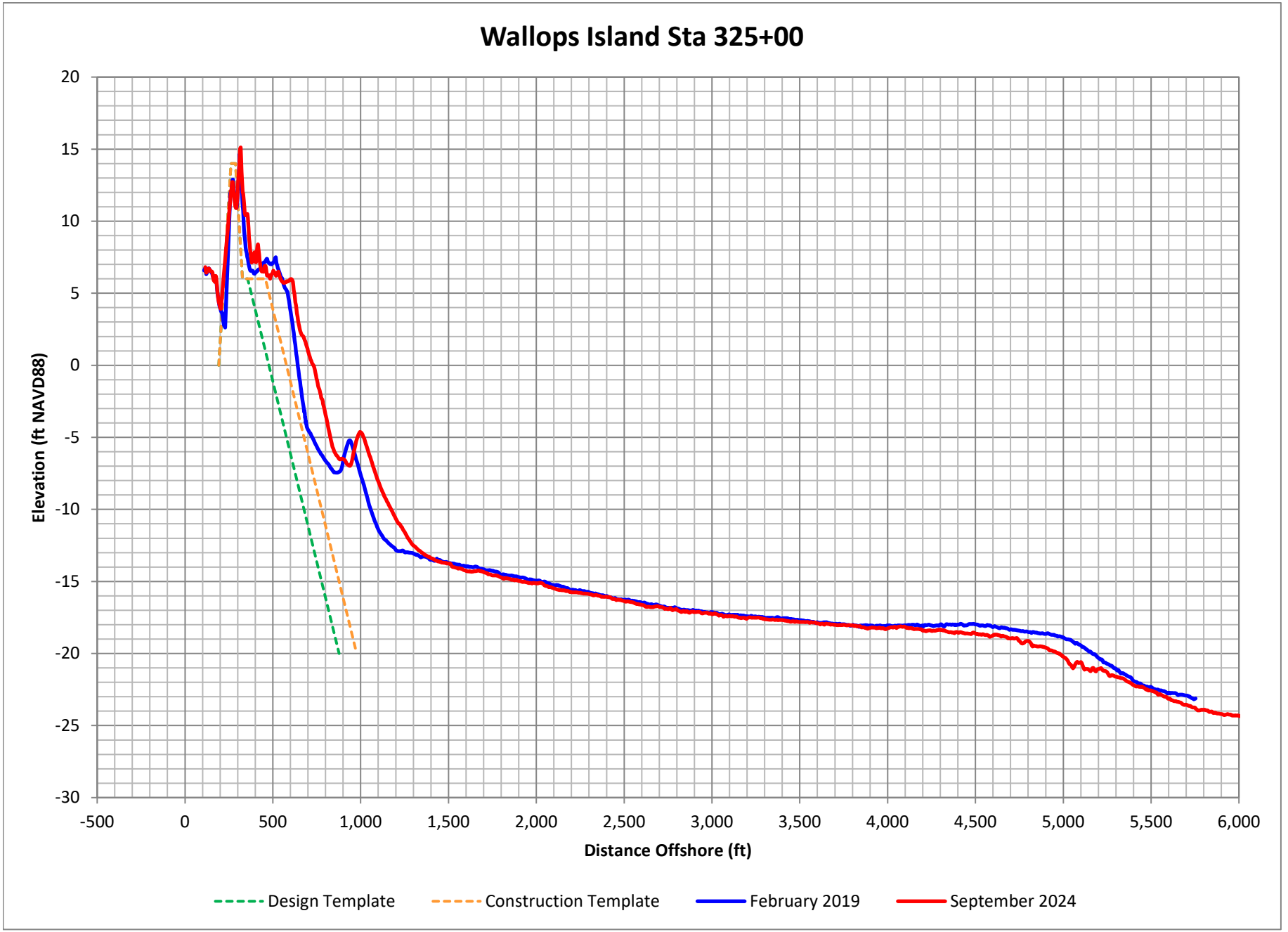


Figure C-73. Wallops Island Profile Comparison Plot

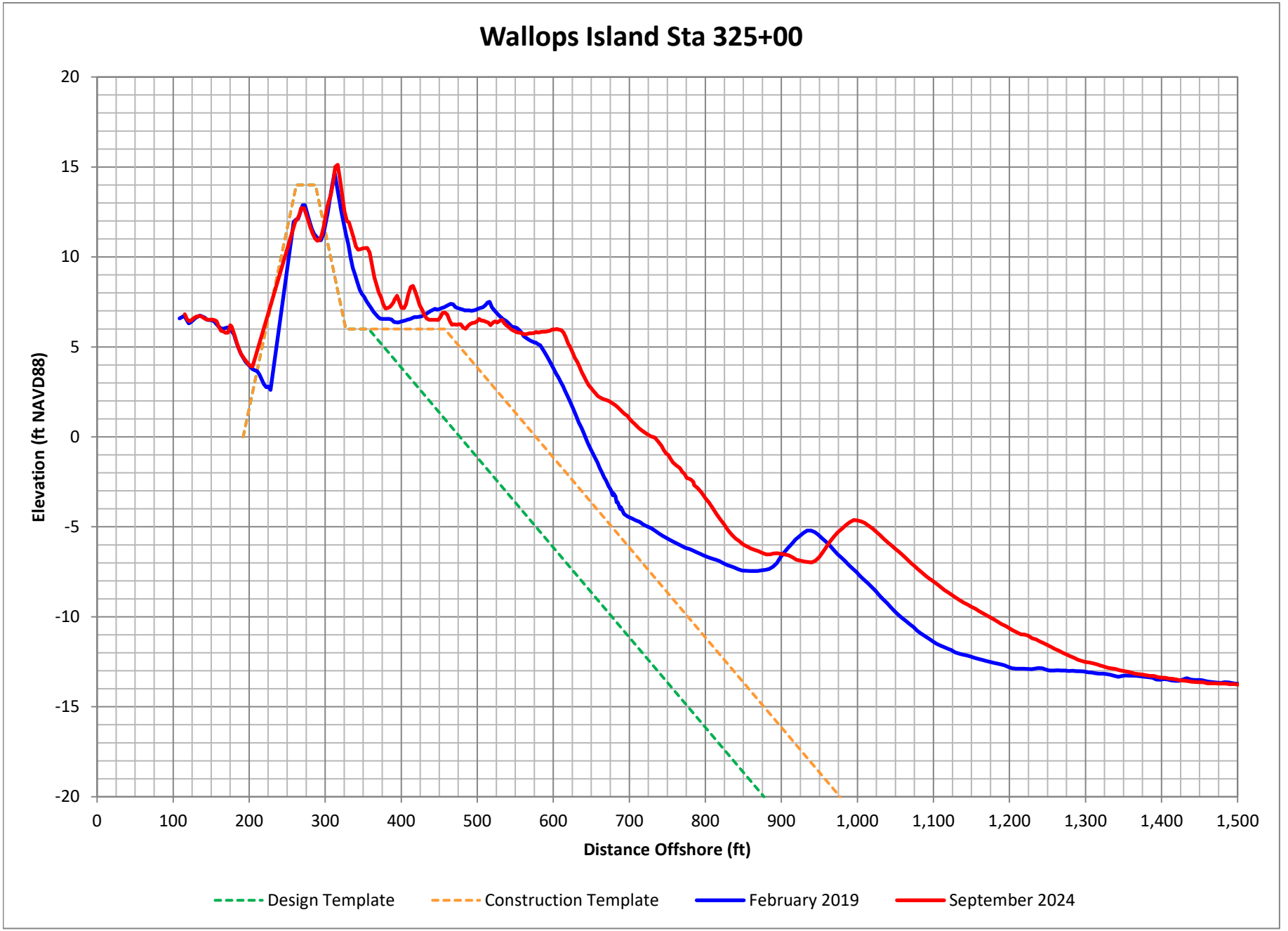


Figure C-74. Wallops Island Profile Comparison Plot

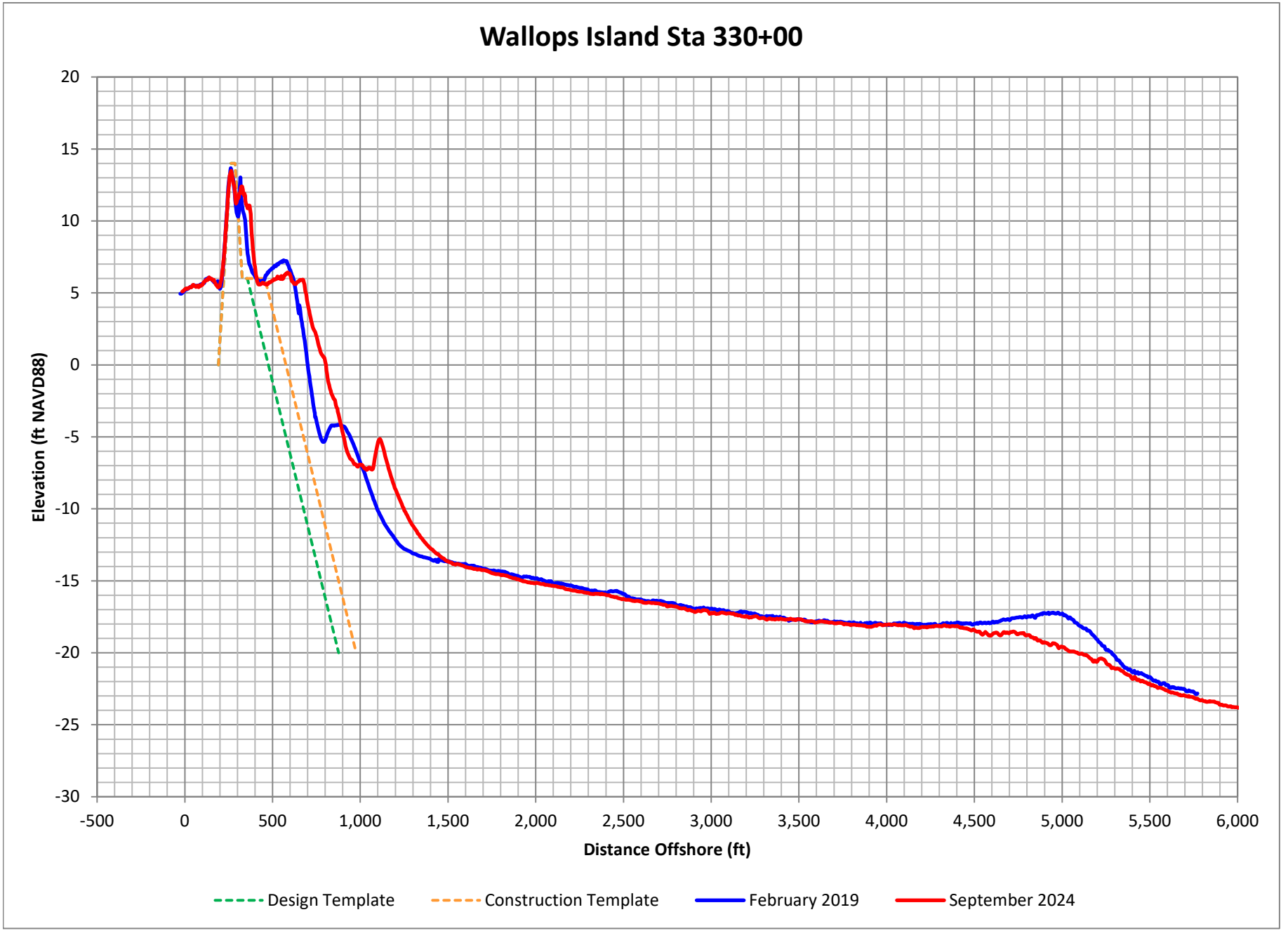


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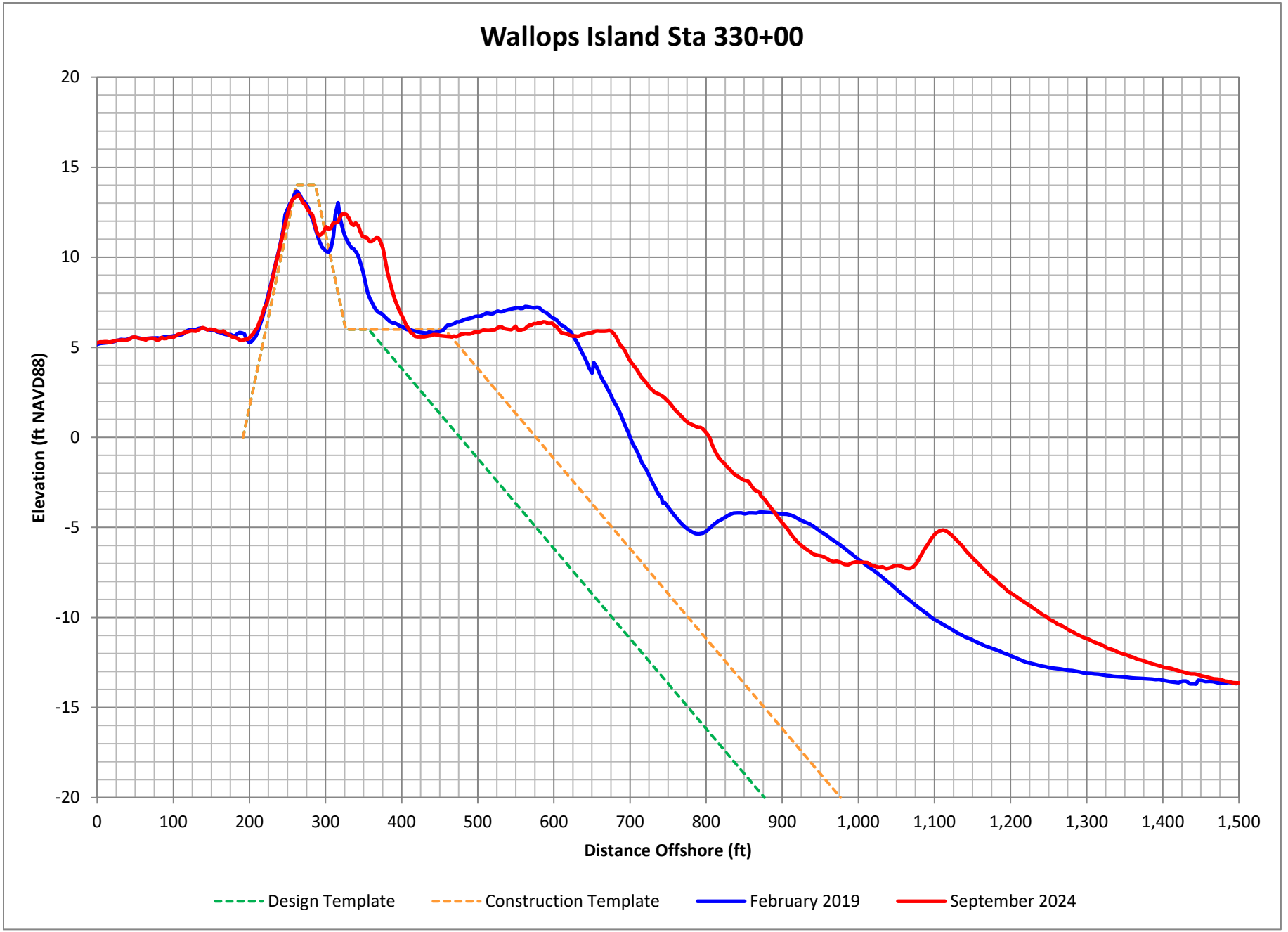


Figure C-76. Wallops Island Profile Comparison Plot

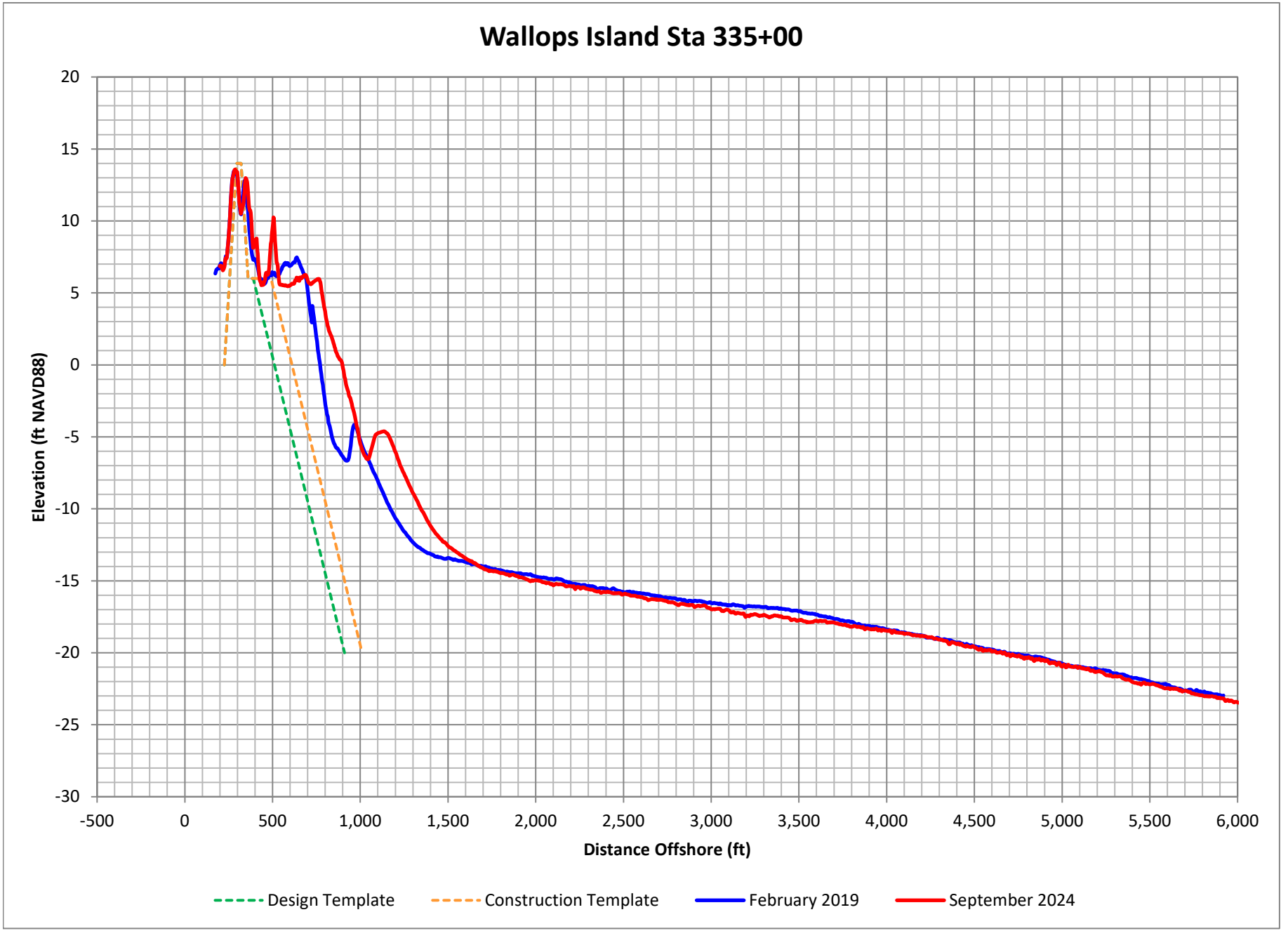


Figure C-77. Wallops Island Profile Comparison Plot

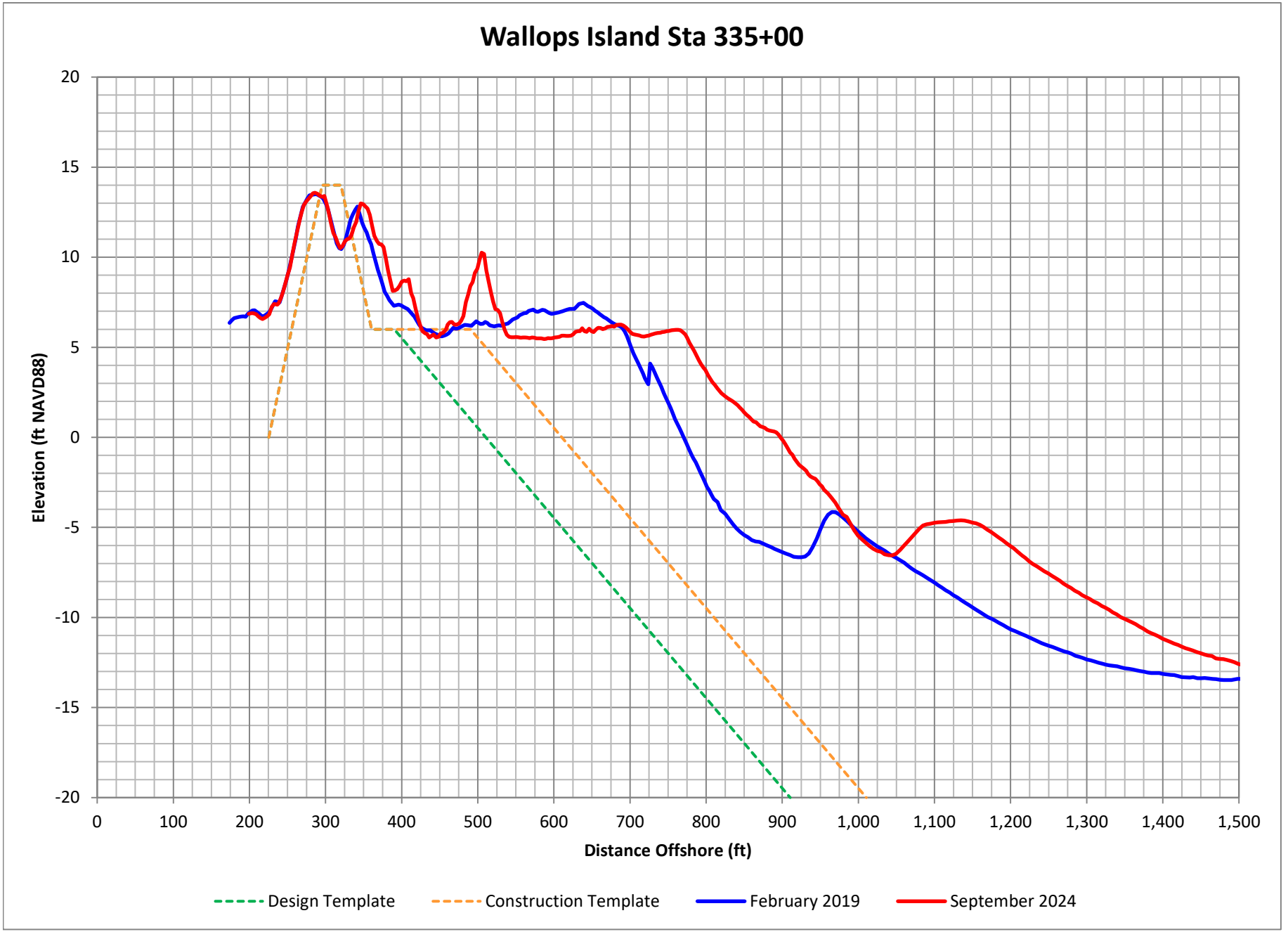


Figure C-78. Wallops Island Profile Comparison Plot

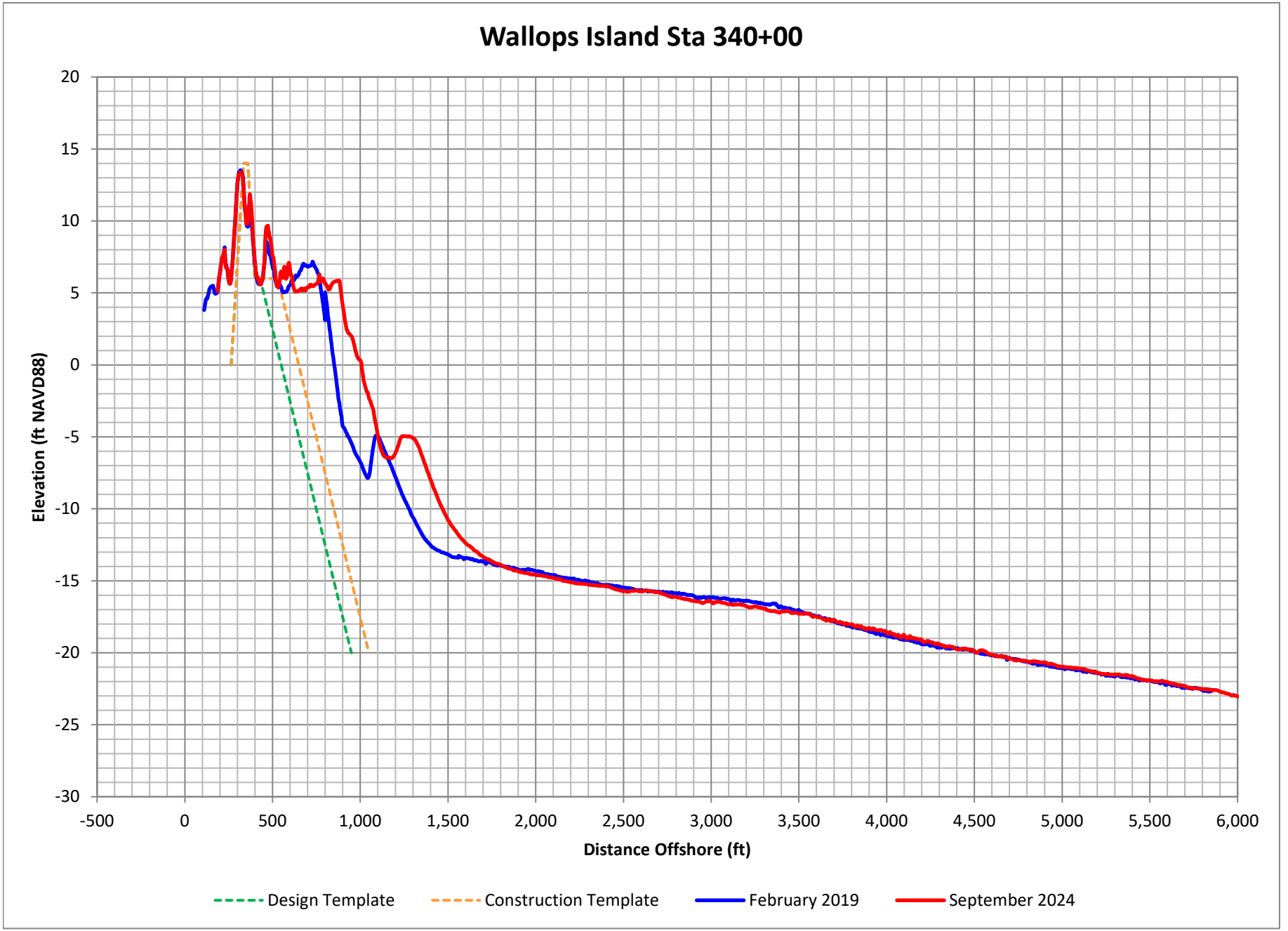


Figure C-79. Wallops Island Profile Comparison Plot

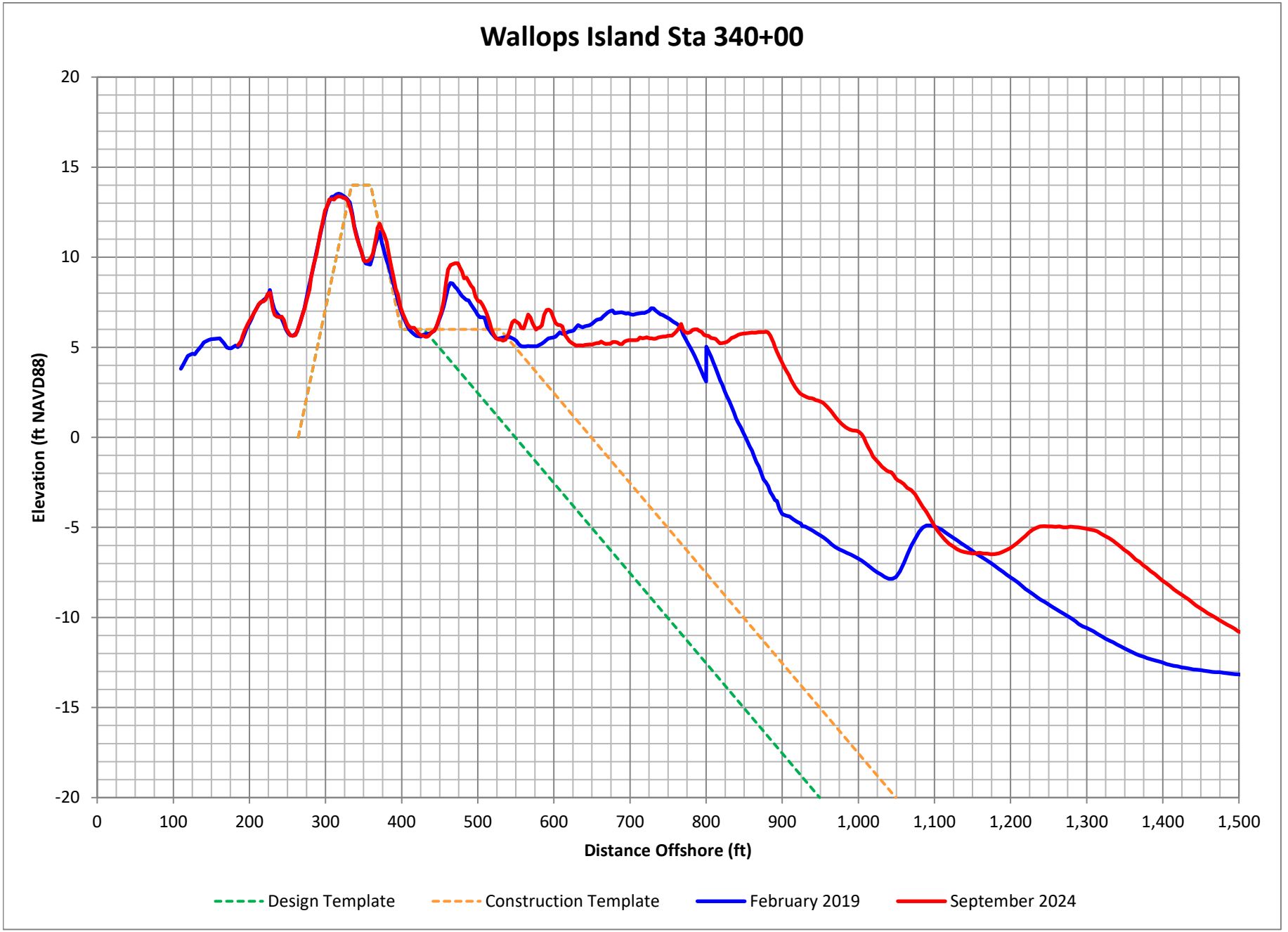


Figure C-80. Wallops Island Profile Comparison Plot

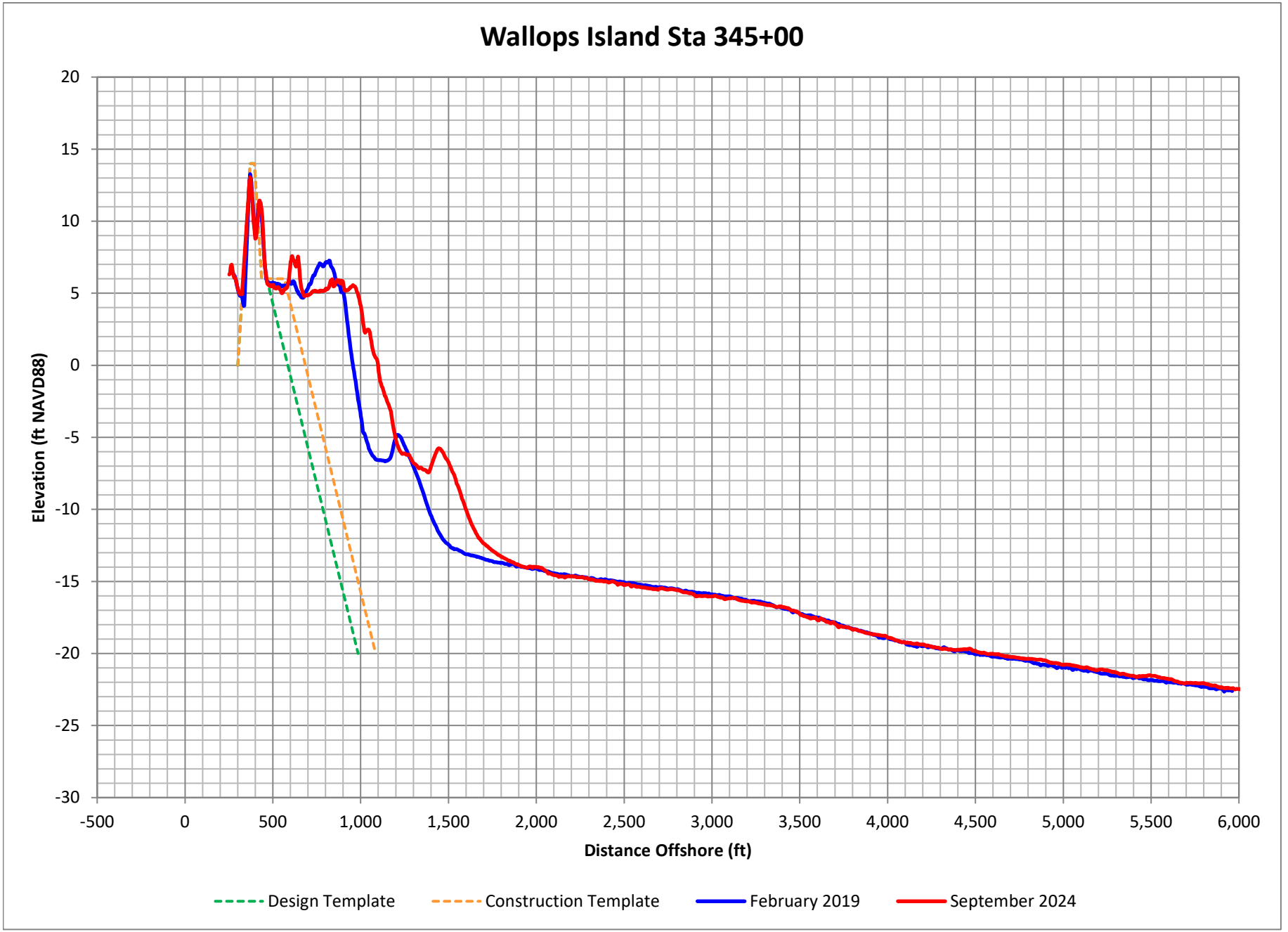


Figure C-81. Wallops Island Profile Comparison Plot

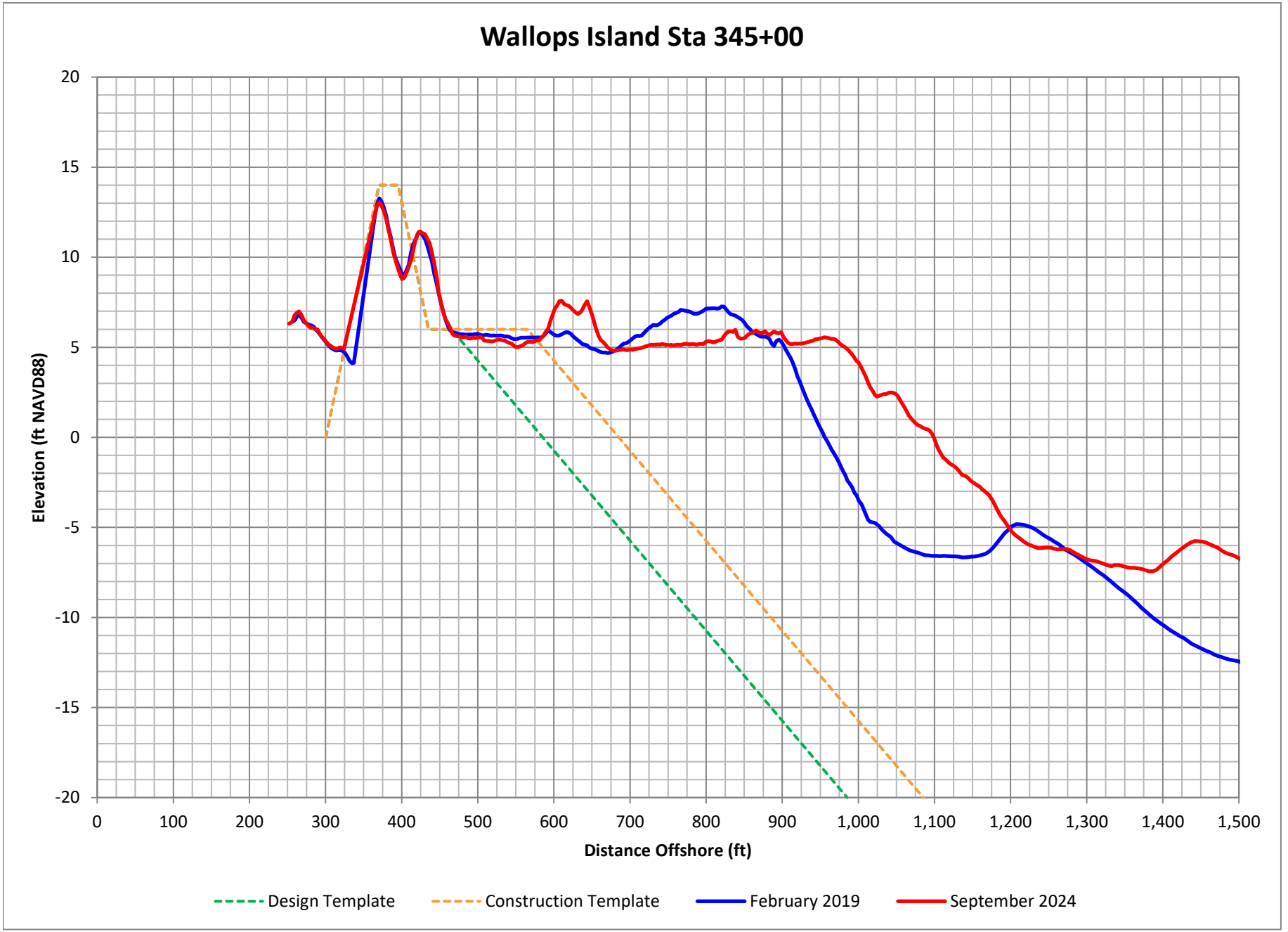


Figure C-82. Wallops Island Profile Comparison Plot

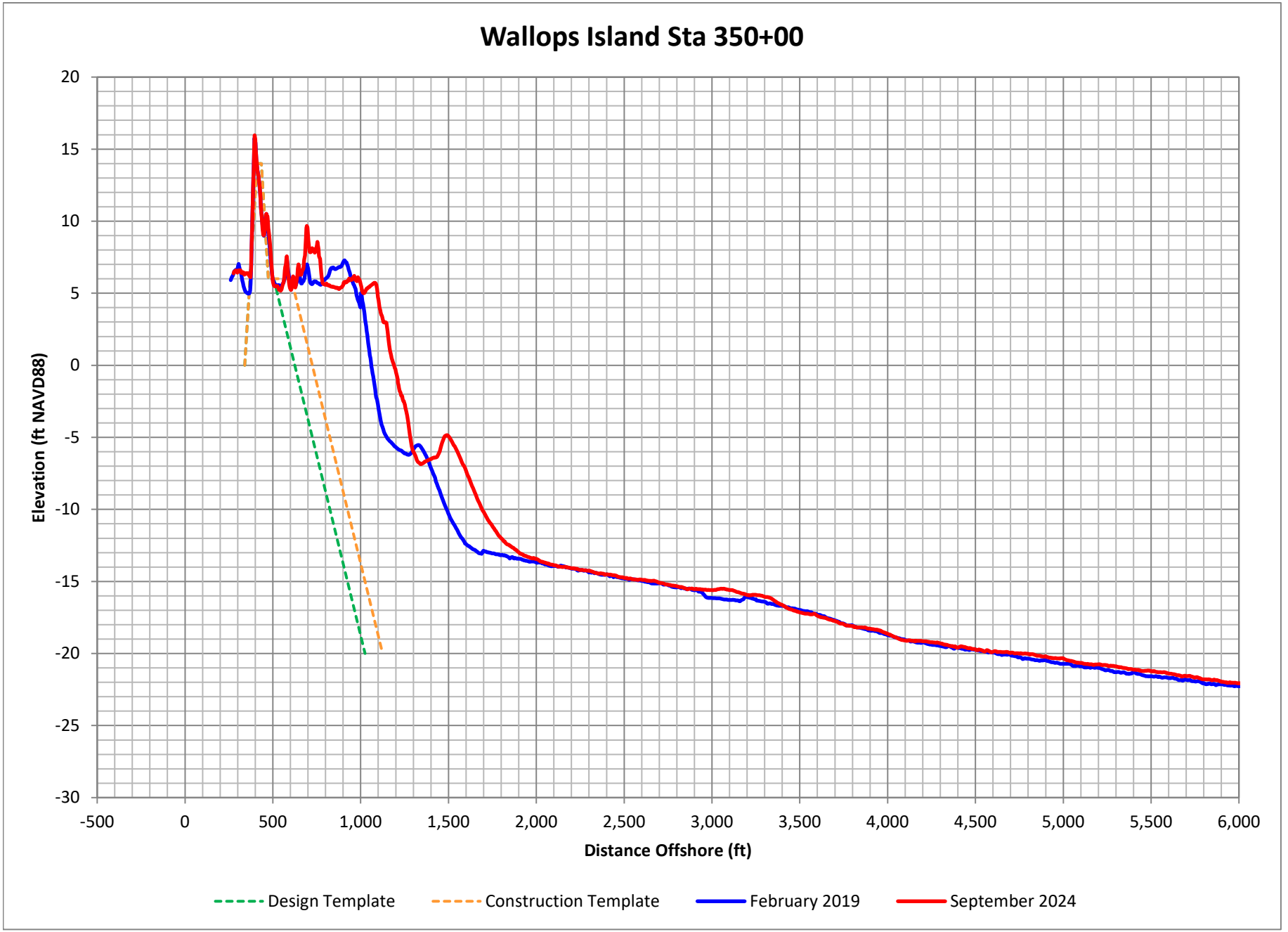


Figure C-83. Wallops Island Profile Comparison Plot

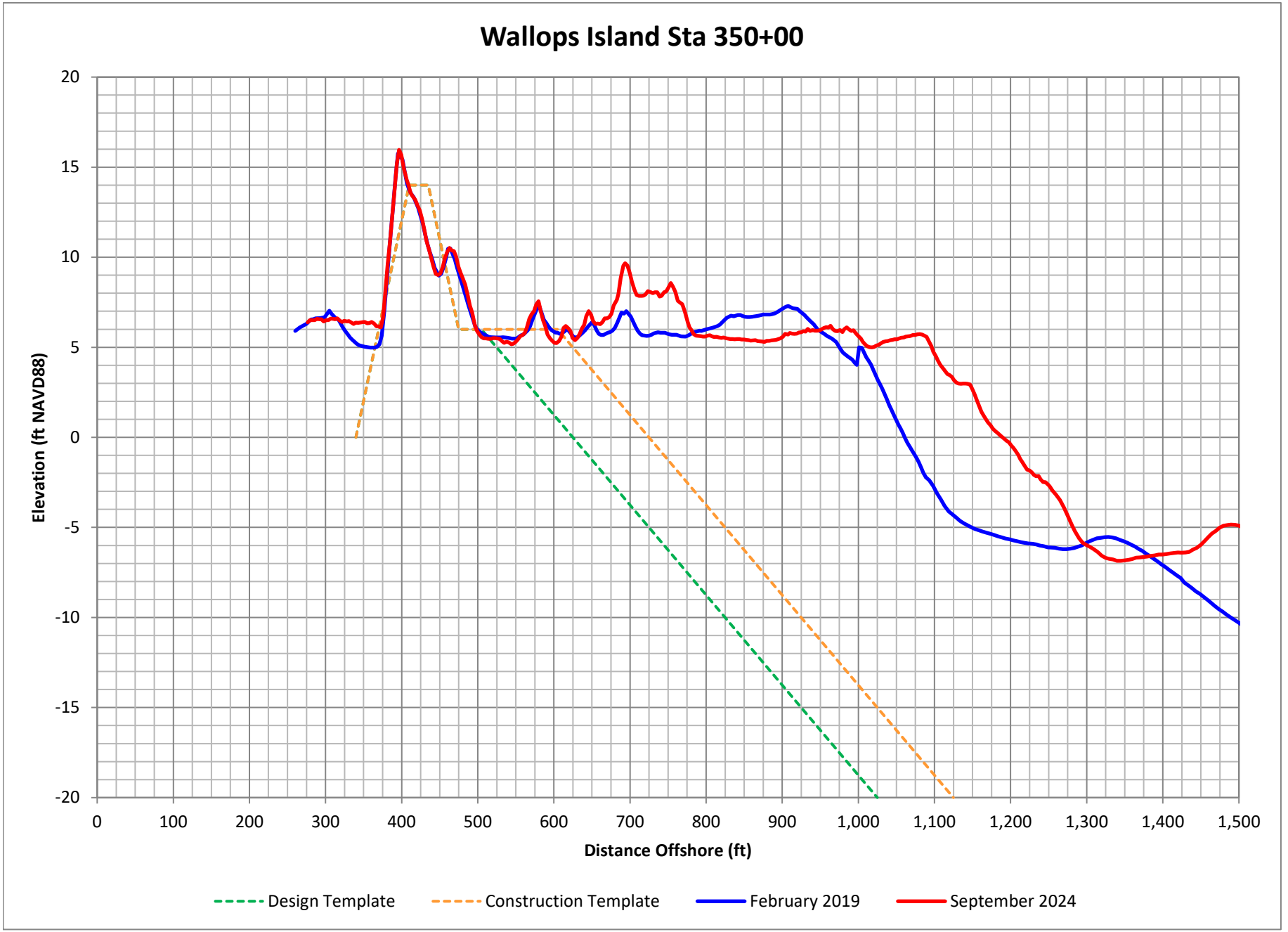


Figure C-84. Wallops Island Profile Comparison Plot

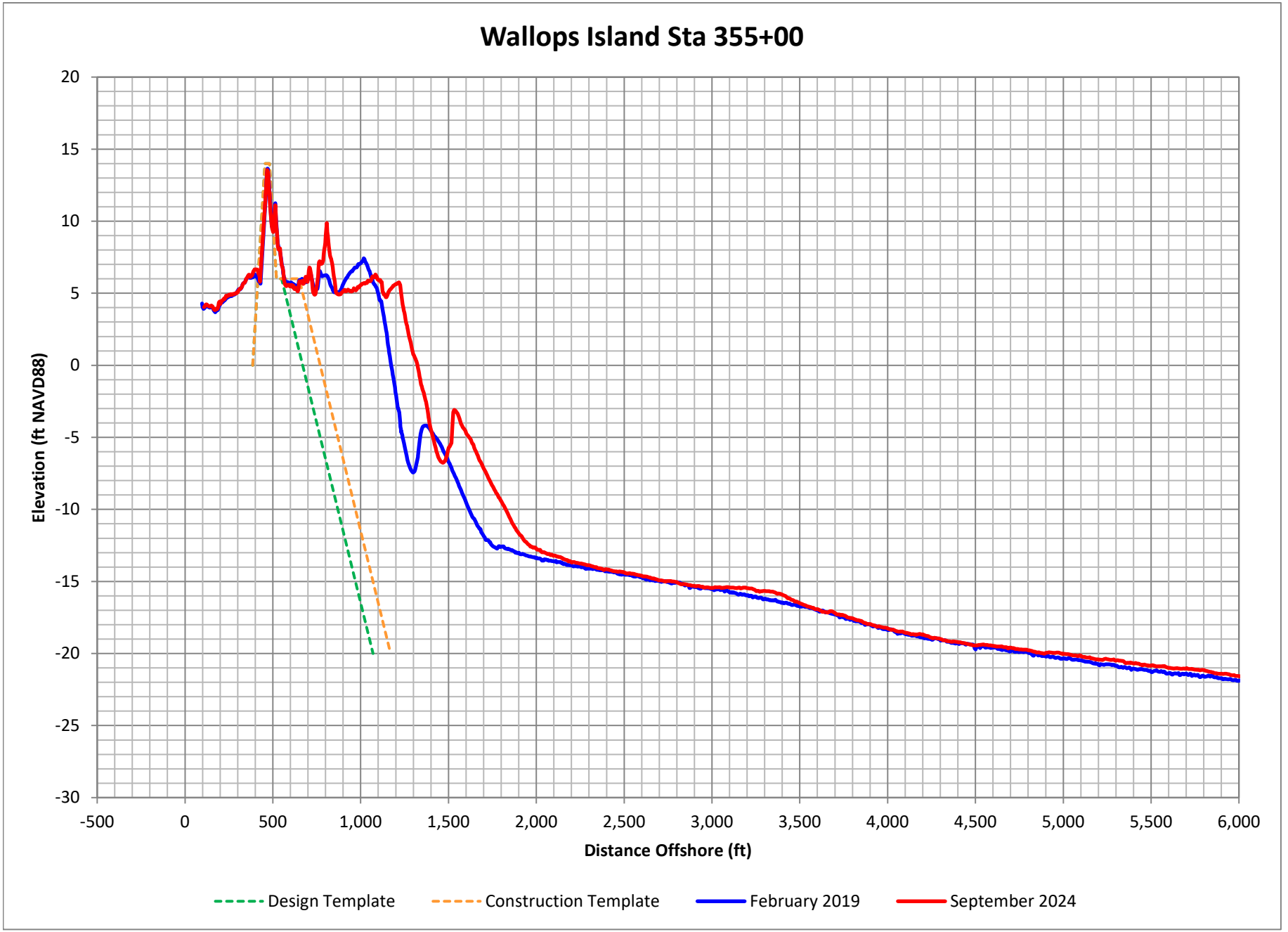


Figure C-85. Wallops Island Profile Comparison Plot

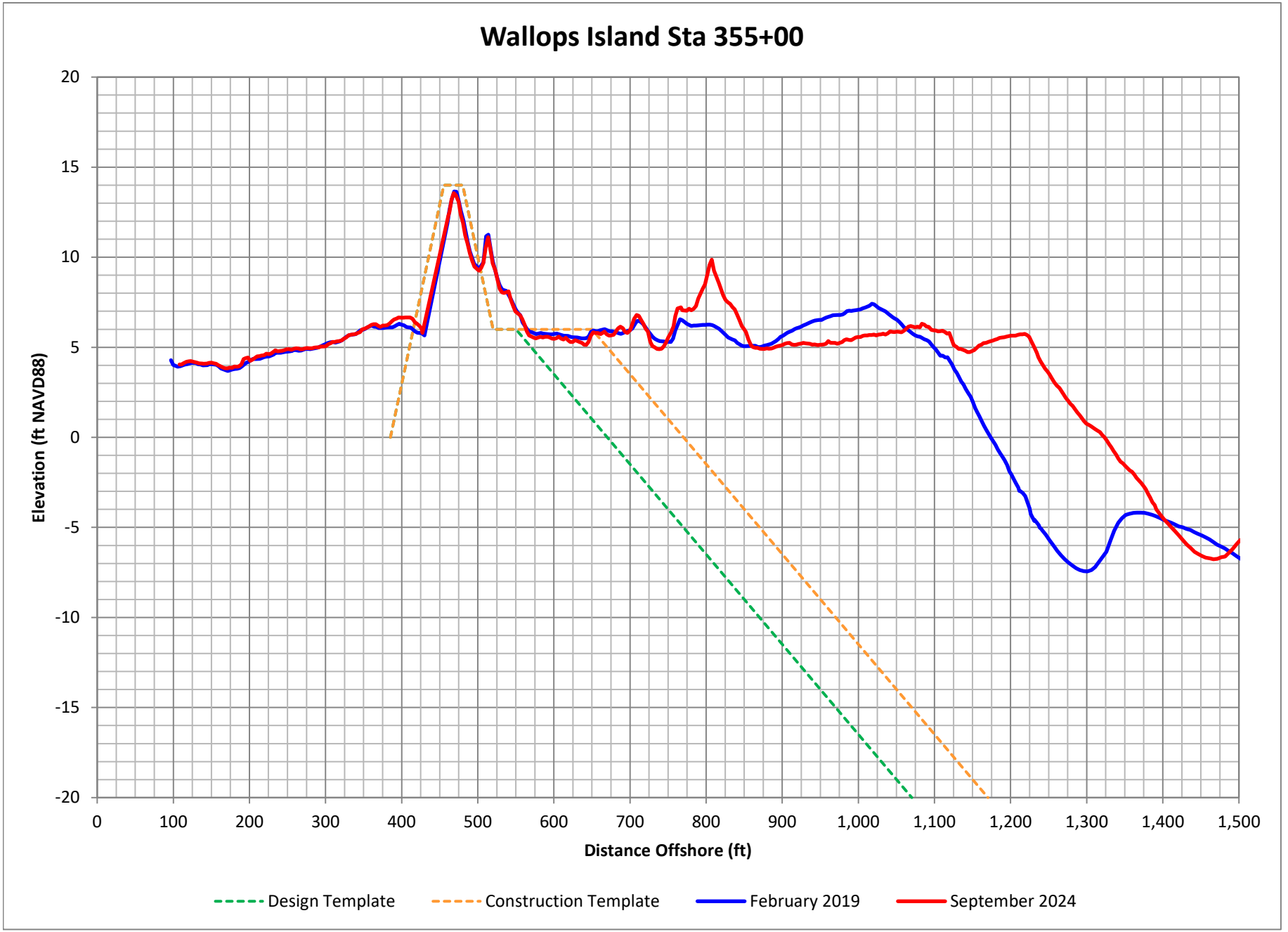


Figure C-86. Wallops Island Profile Comparison Plot

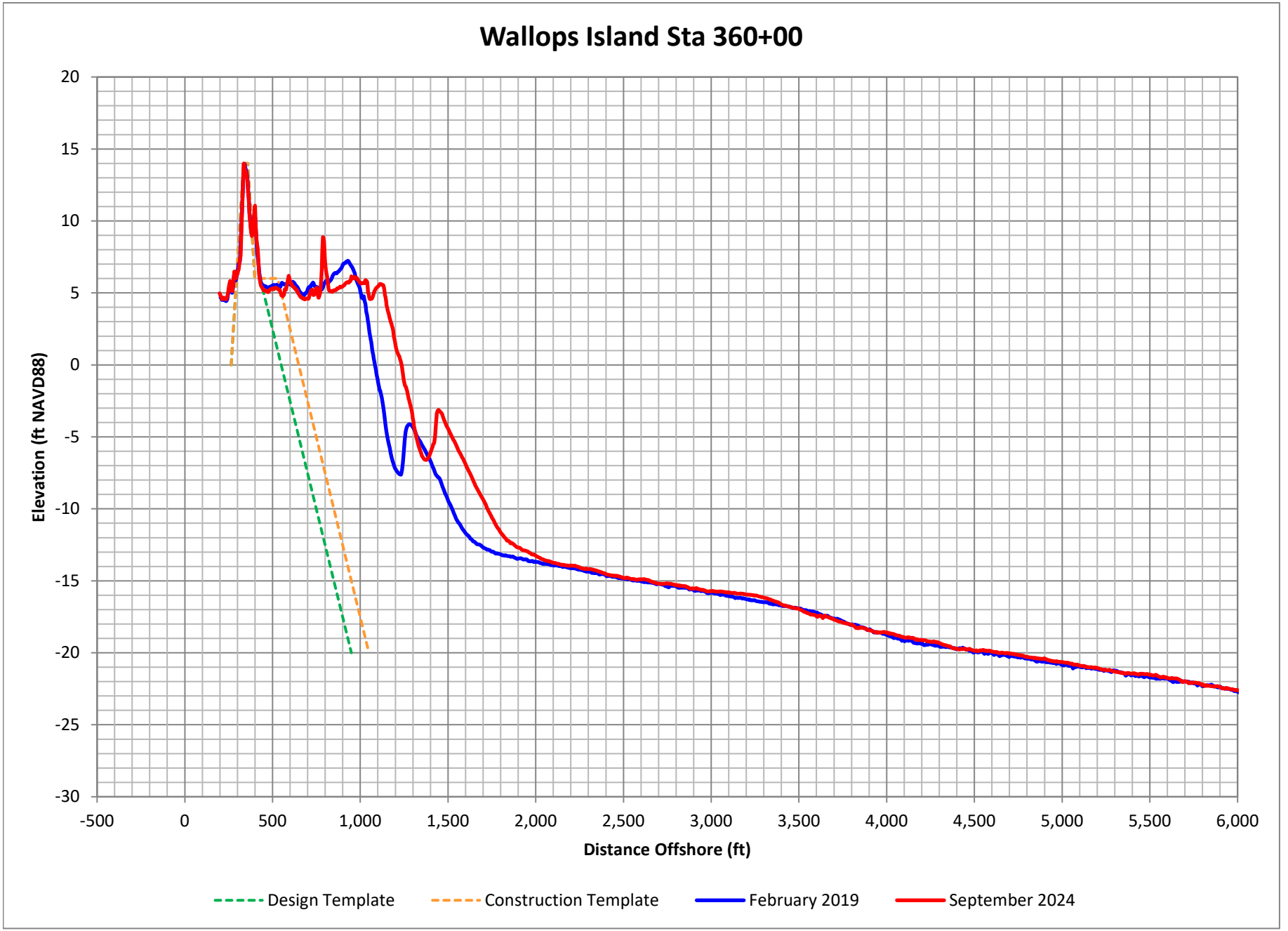


Figure C-87. Wallops Island Profile Comparison Plot

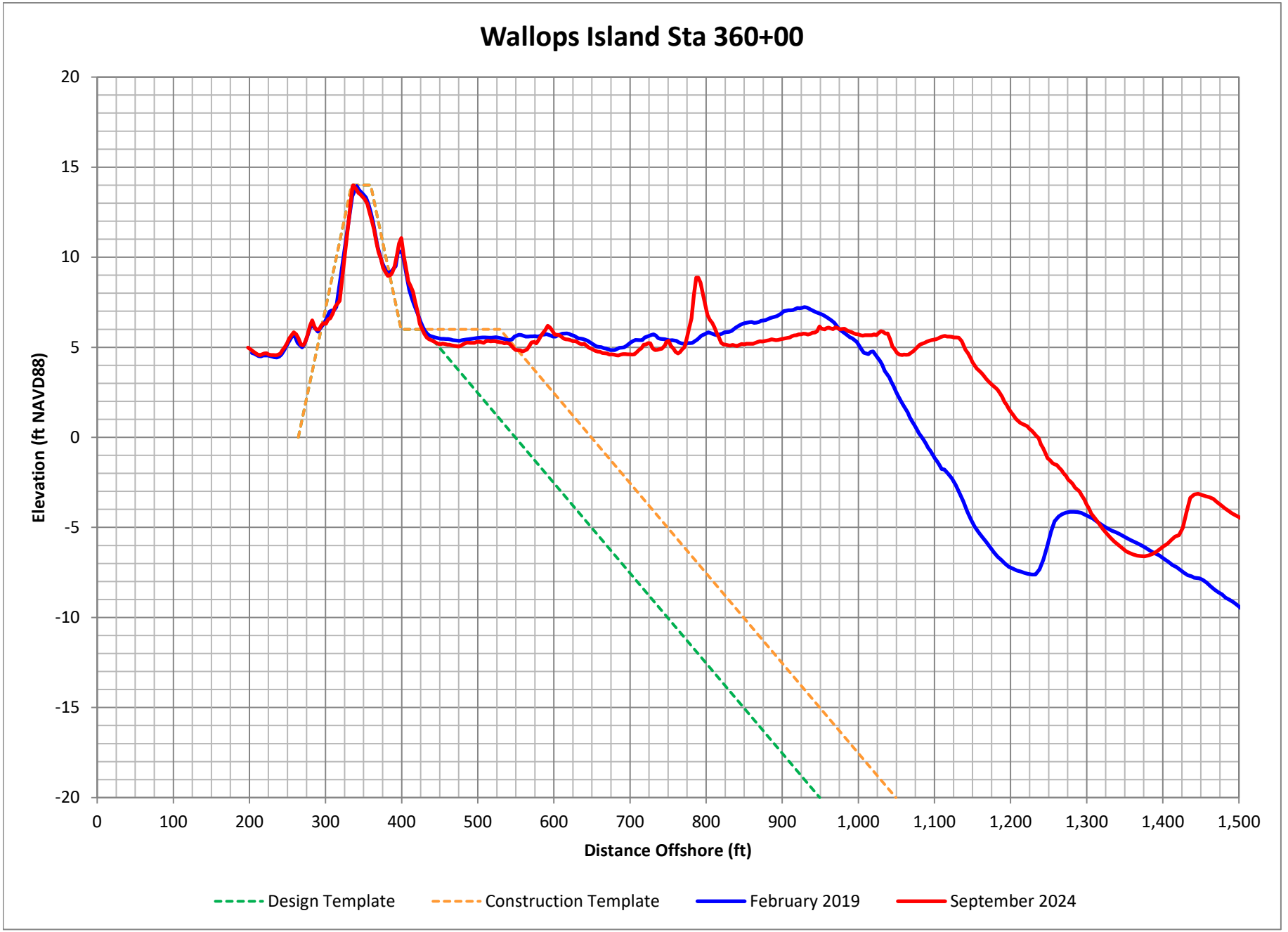


Figure C-88. Wallops Island Profile Comparison Plot

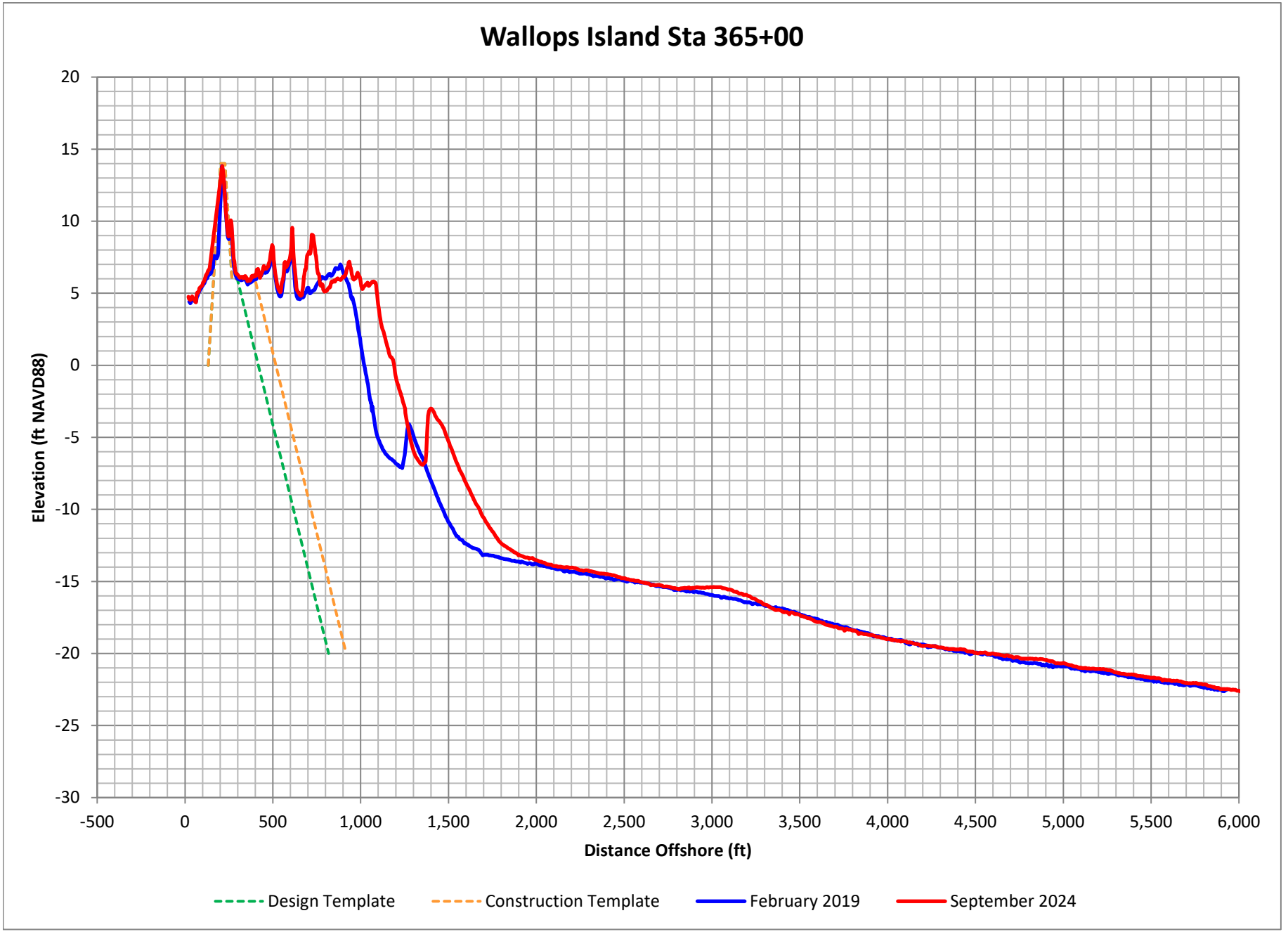


Figure C-89. Wallops Island Profile Comparison Plot

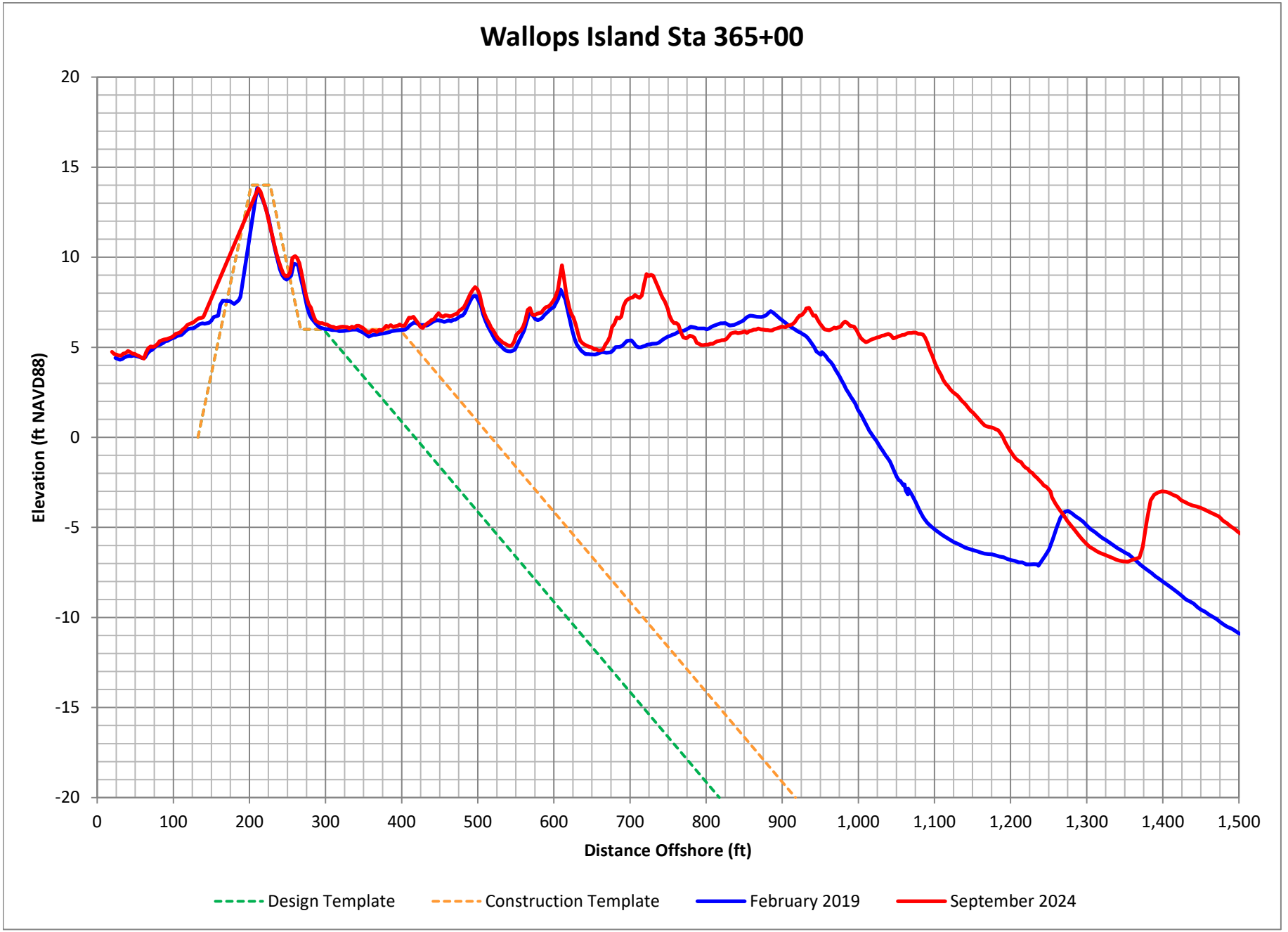


Figure C-90. Wallops Island Profile Comparison Plot

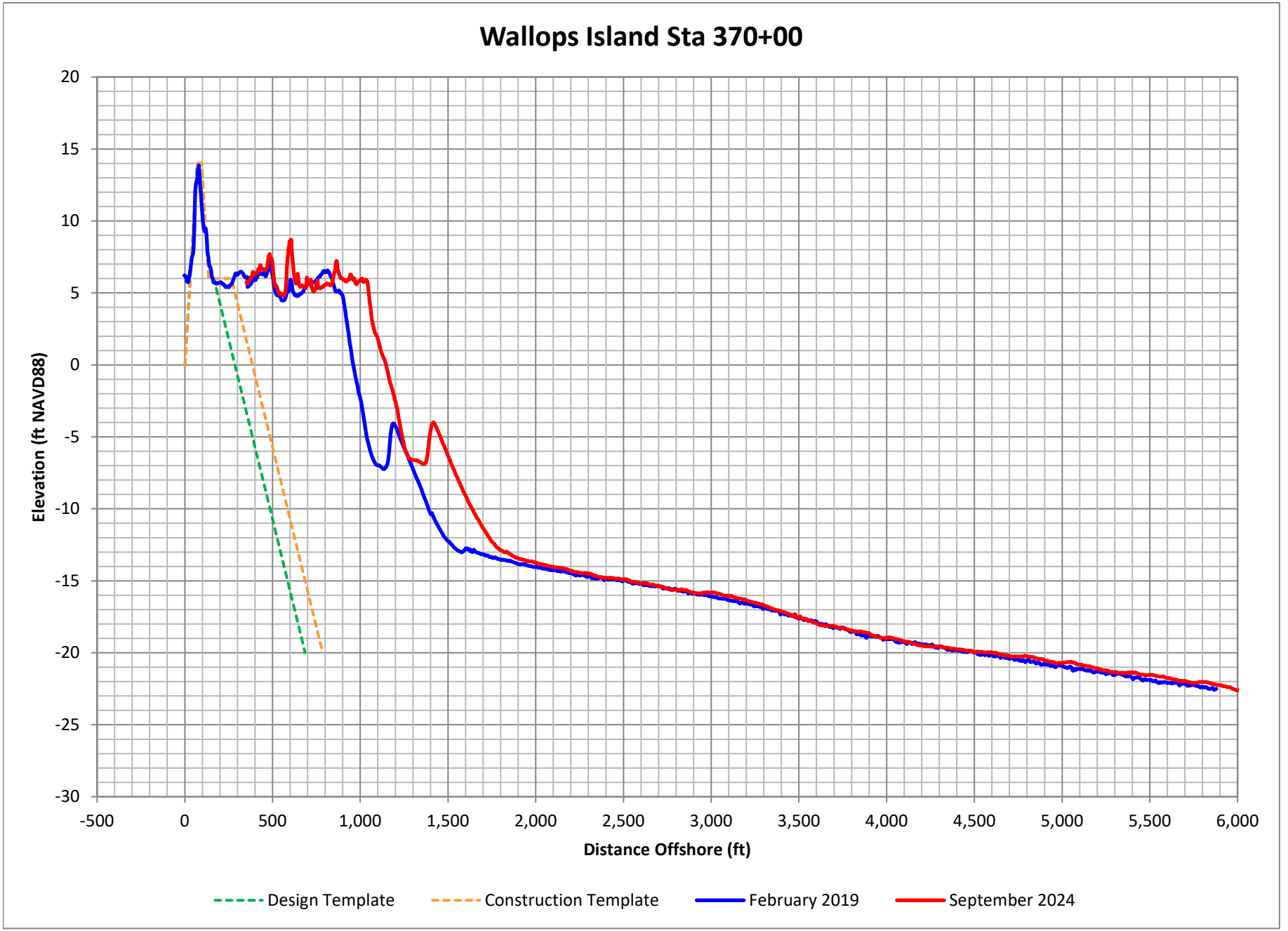


Figure C-91. Wallops Island Profile Comparison Plot

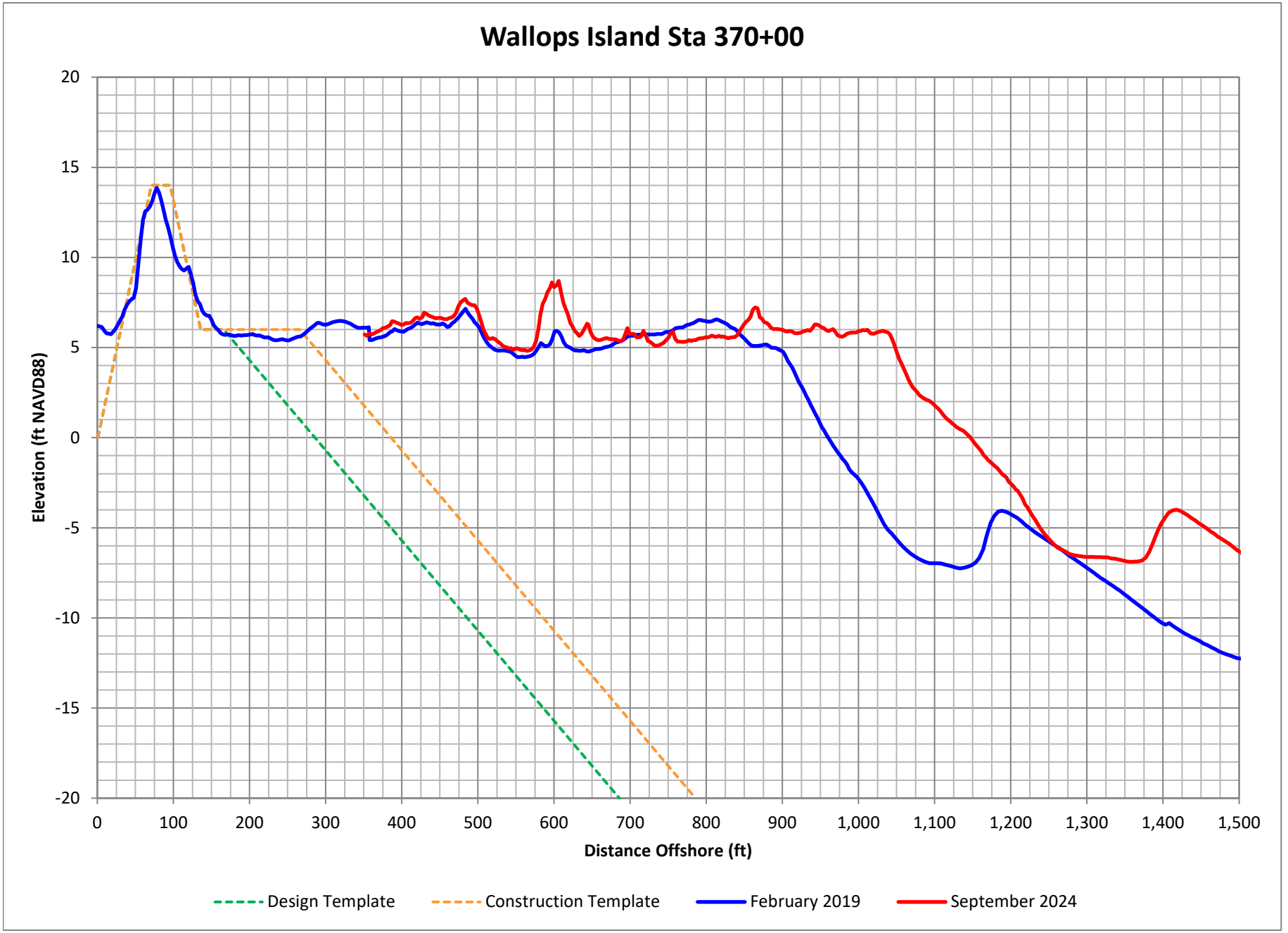


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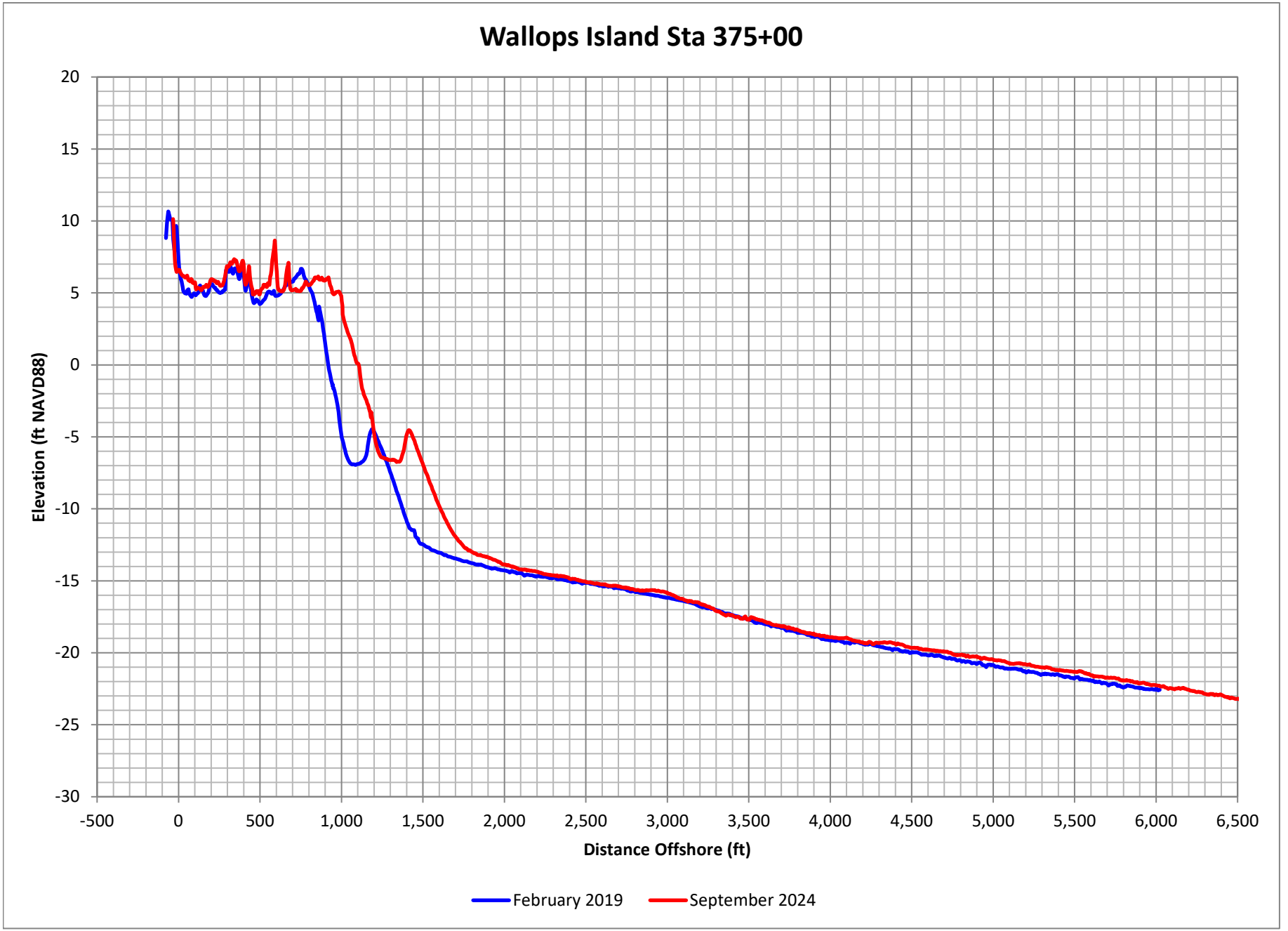


Figure C-93. Wallops Island Profile Comparison Plot

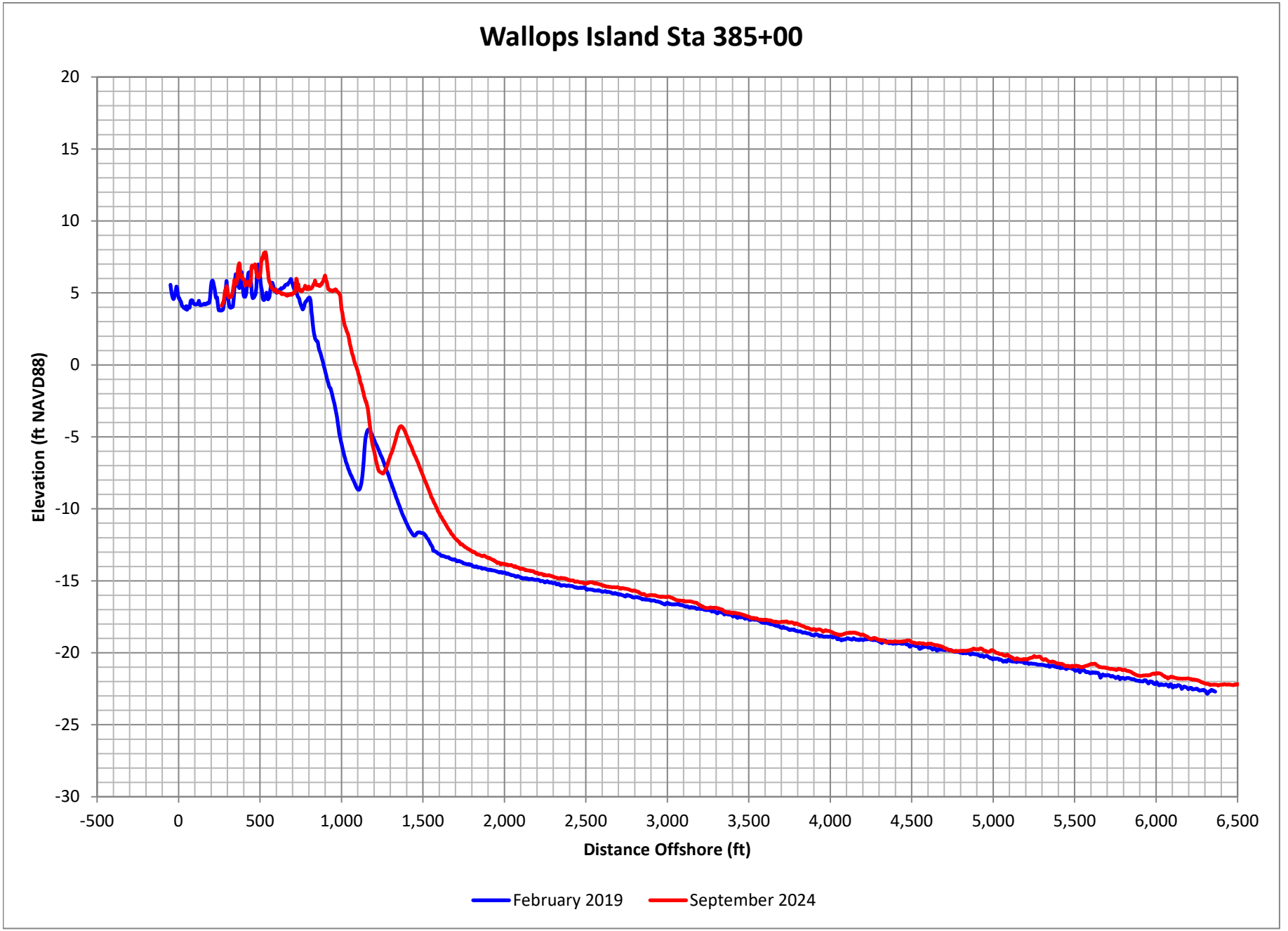


Figure C-94. Wallops Island Profile Comparison Plot

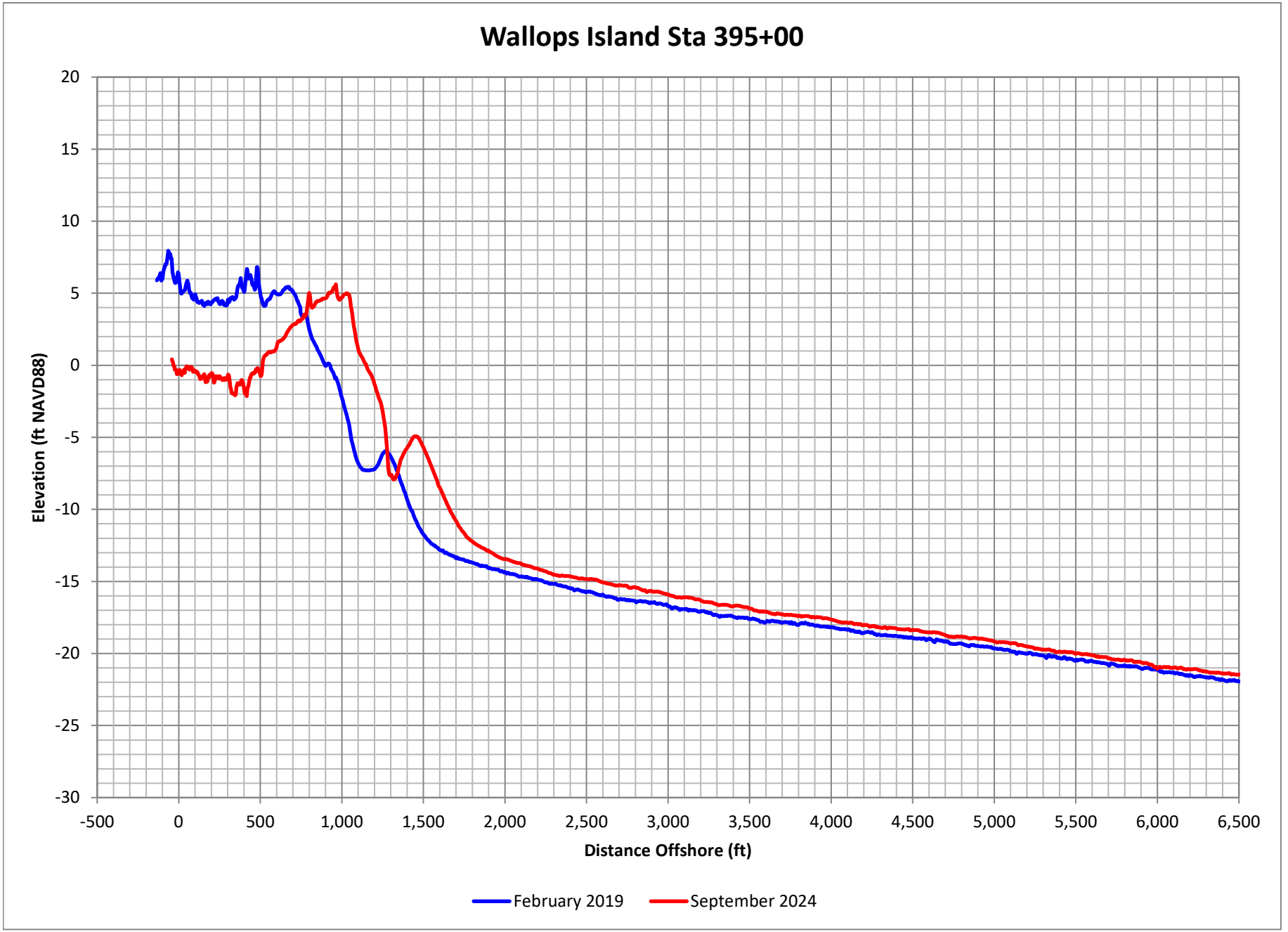


Figure C-95. Wallops Island Profile Comparison Plot

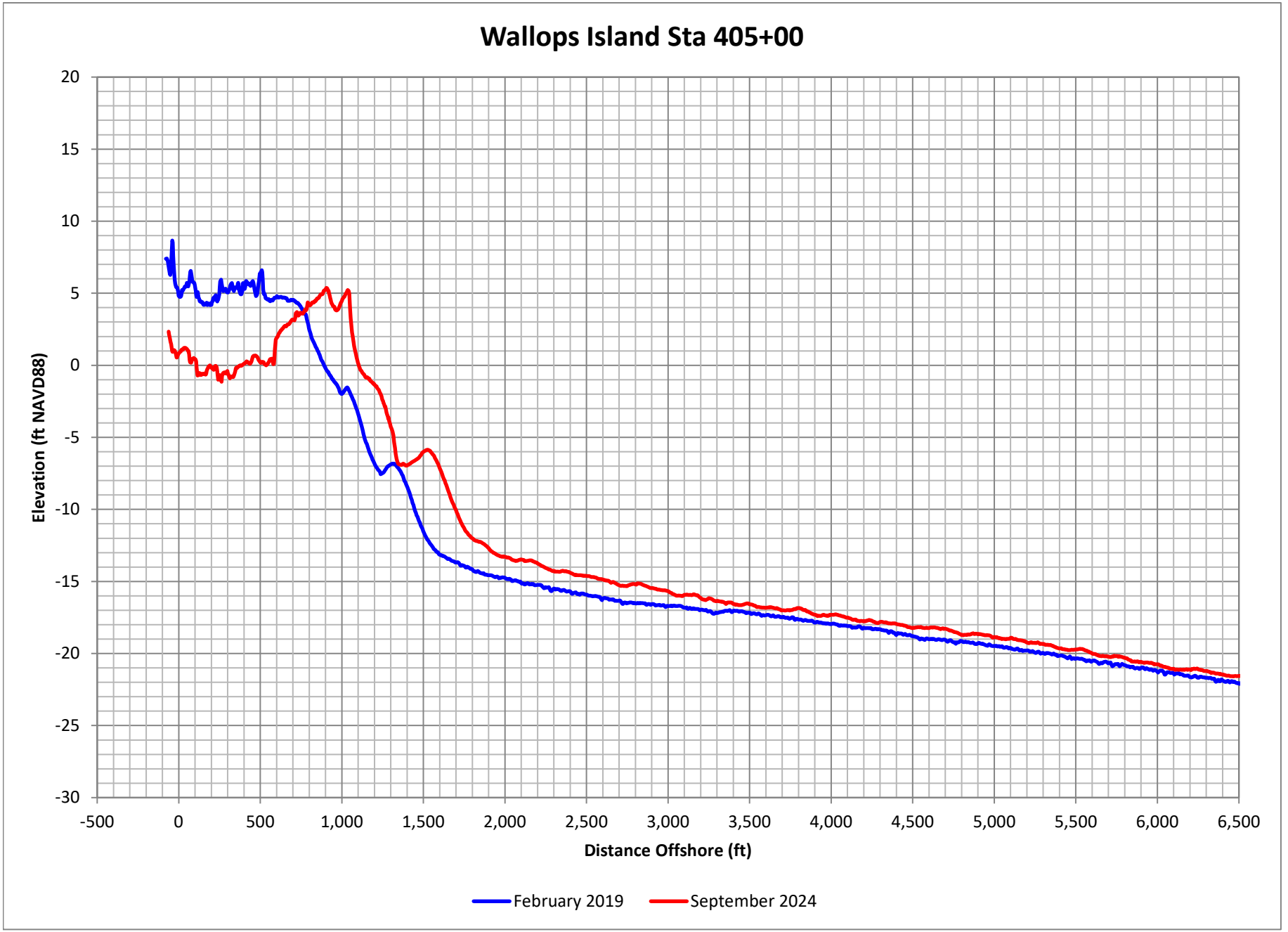


Figure C-96. Wallops Island Profile Comparison Plot

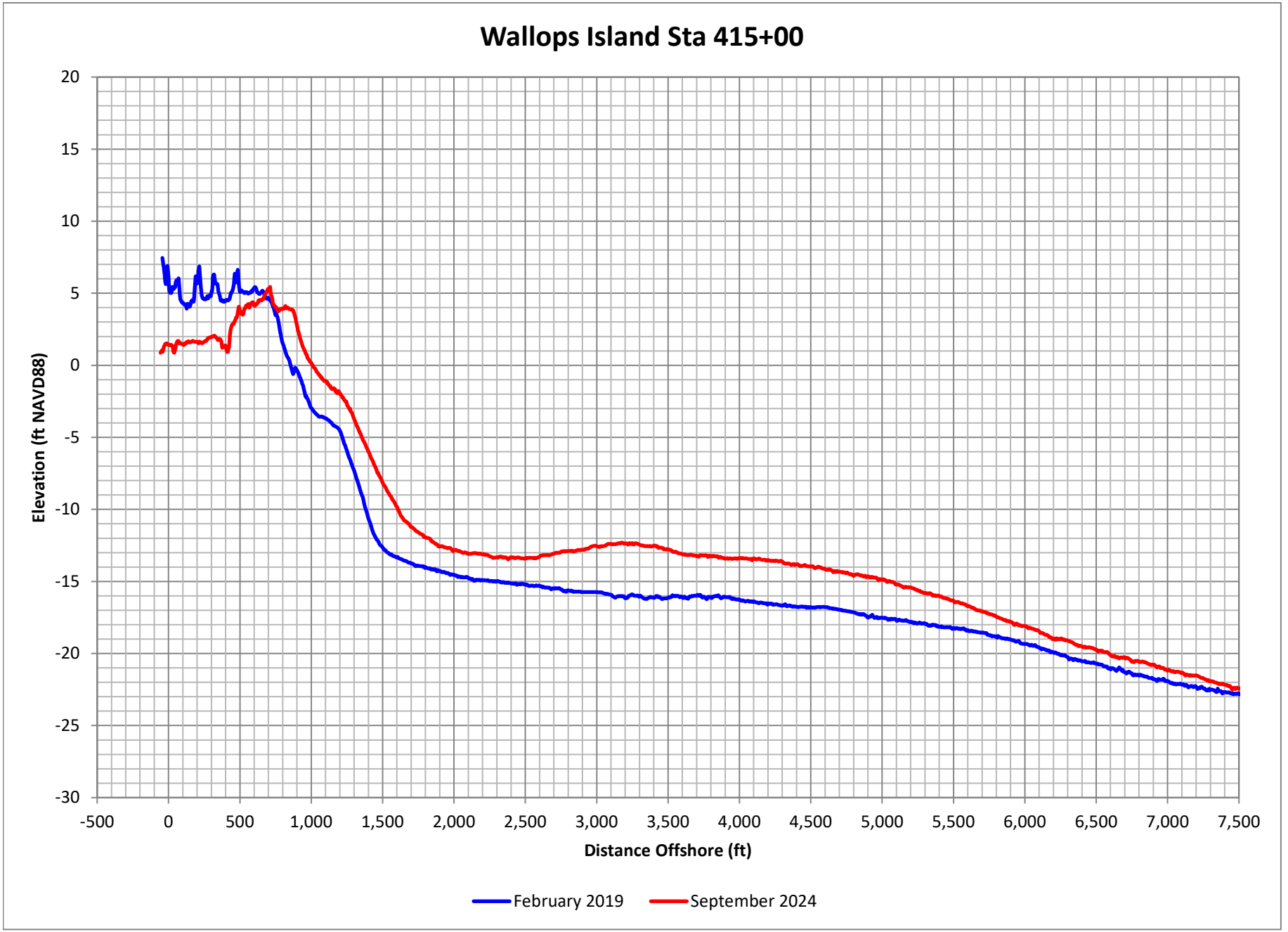


Figure C-97. Wallops Island Profile Comparison Plot

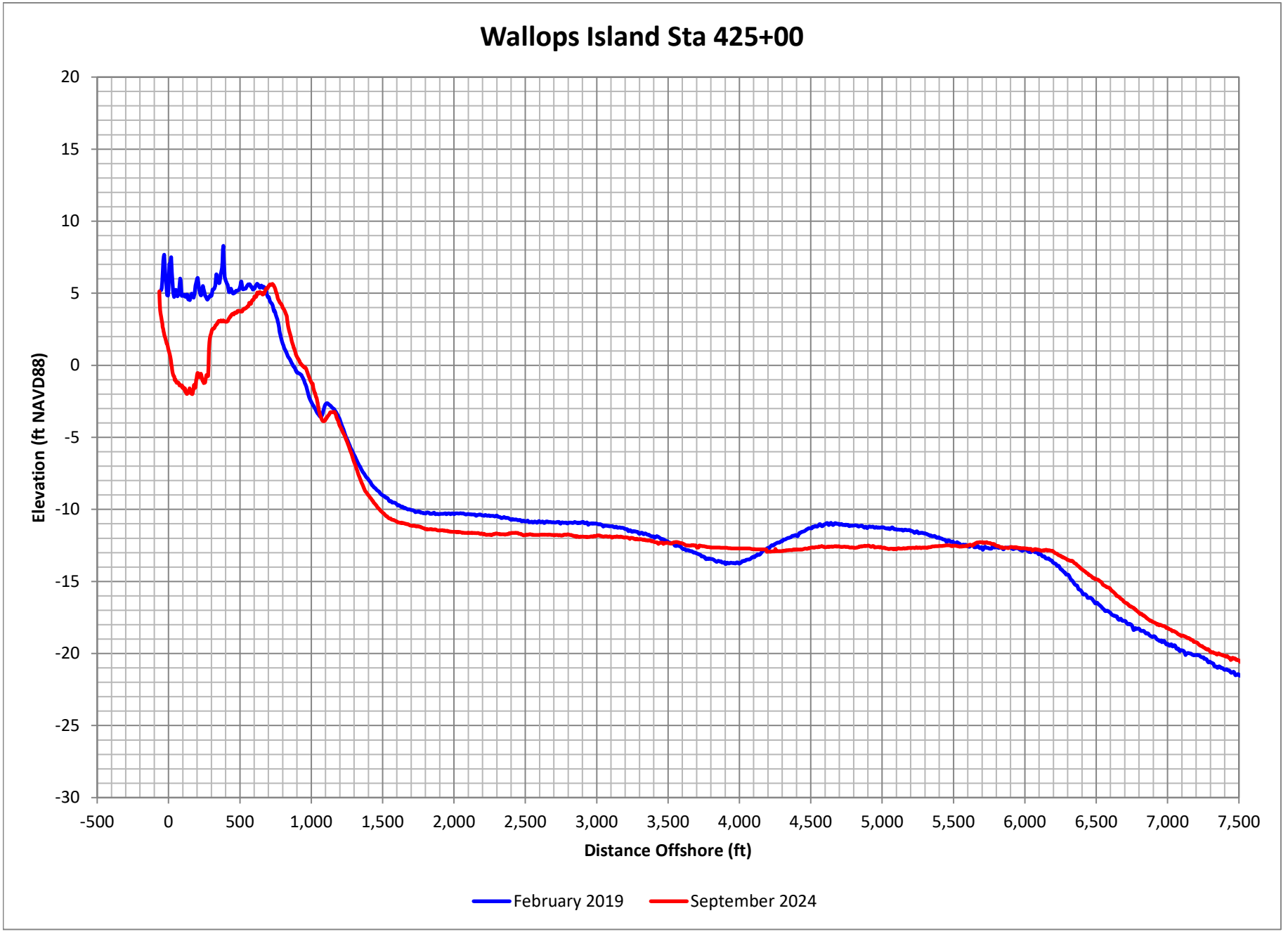


Figure C-98. Wallops Island Profile Comparison Plot

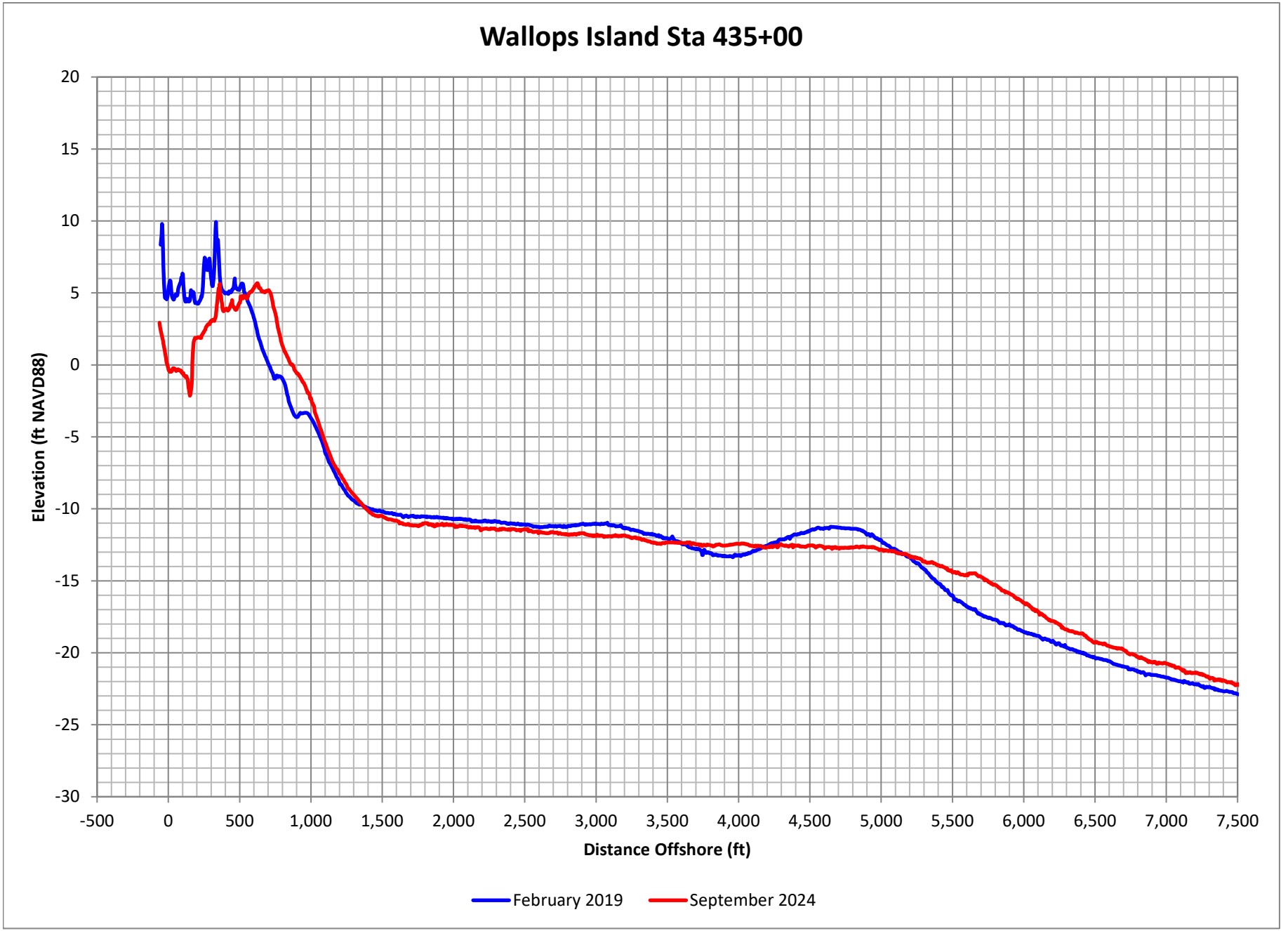


Figure C-99. Wallops Island Profile Comparison Plot

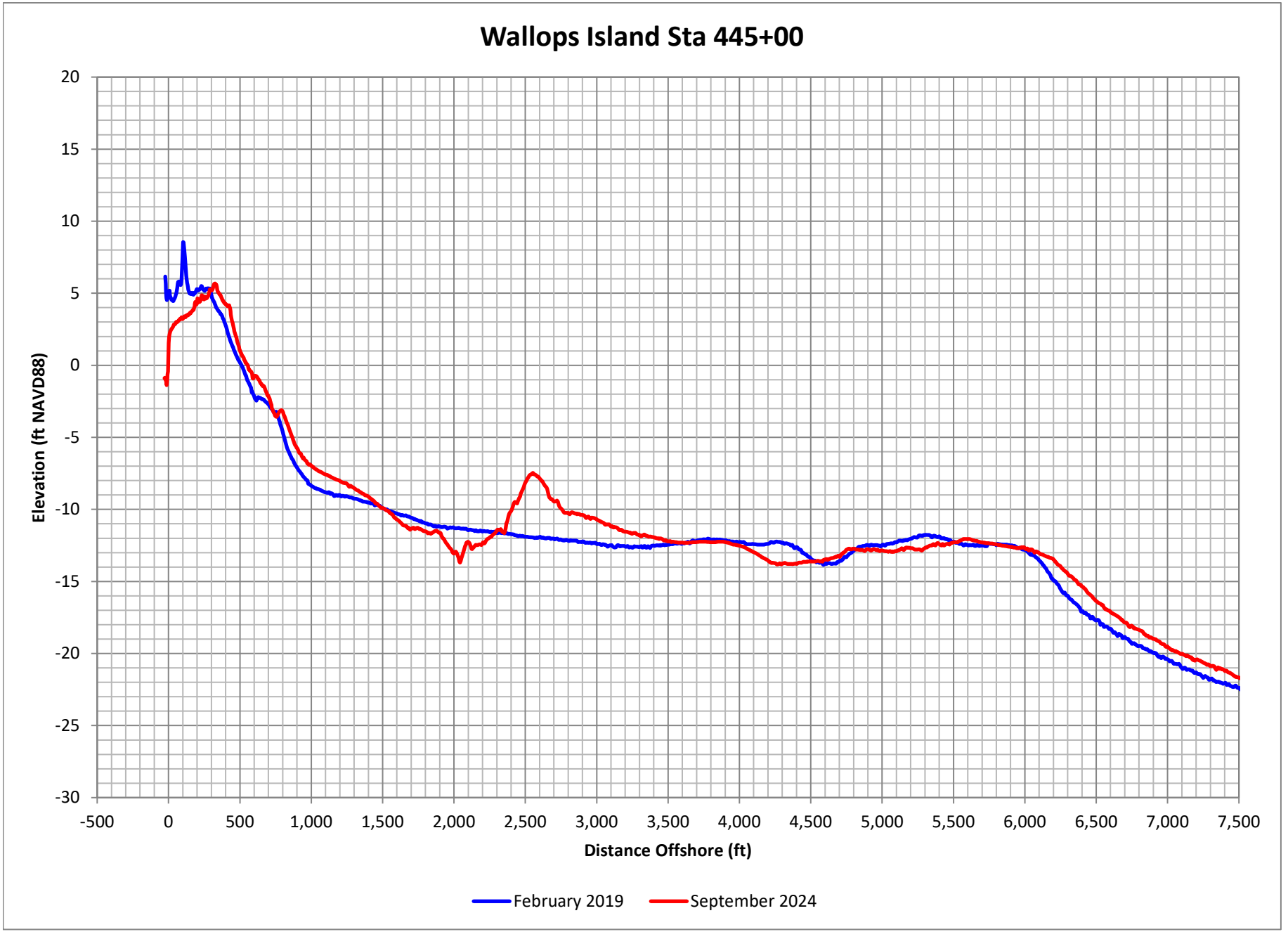


Figure C-100. Wallops Island Profile Comparison Plot

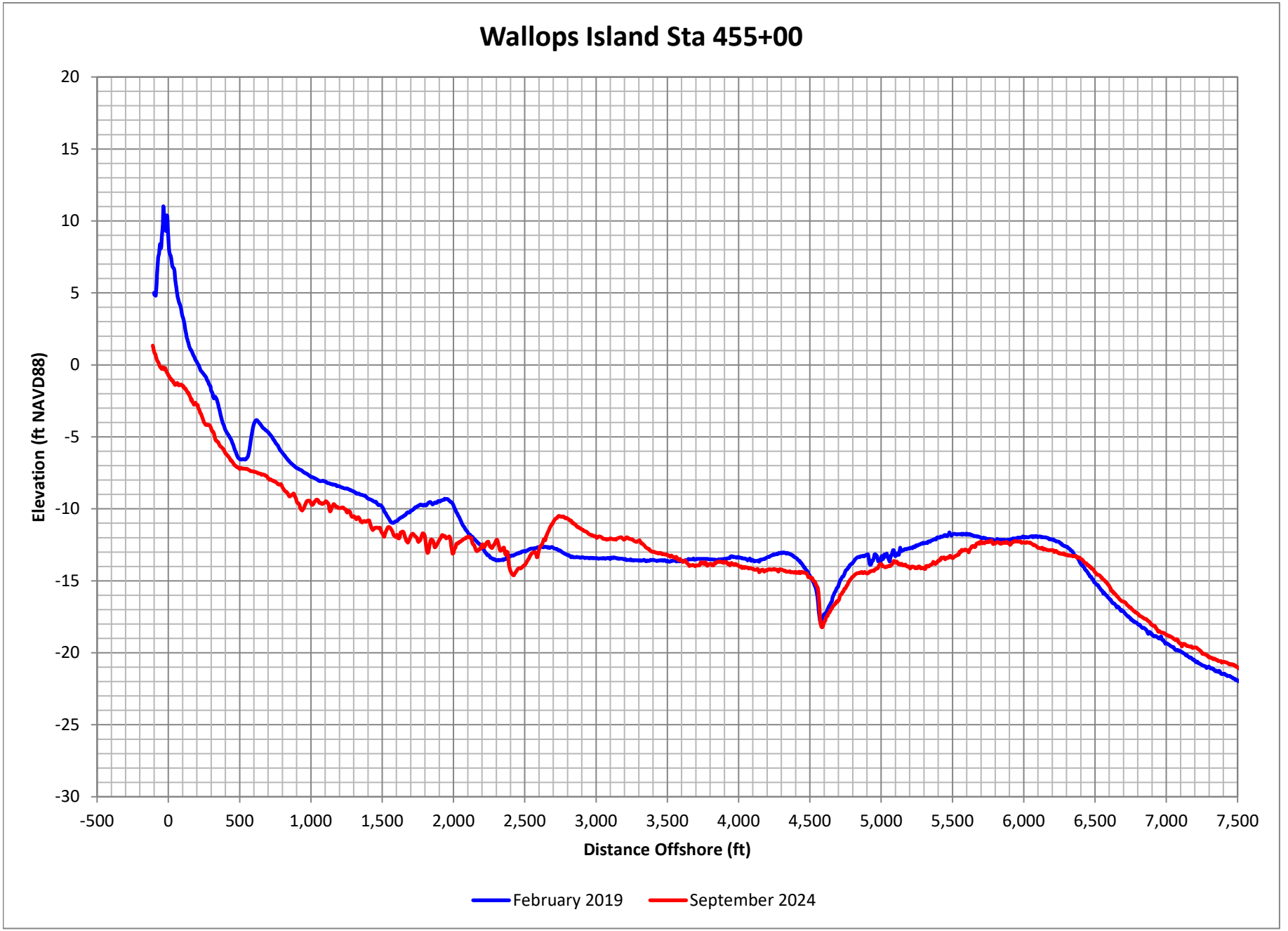


Figure C-101. Wallops Island Profile Comparison Plot

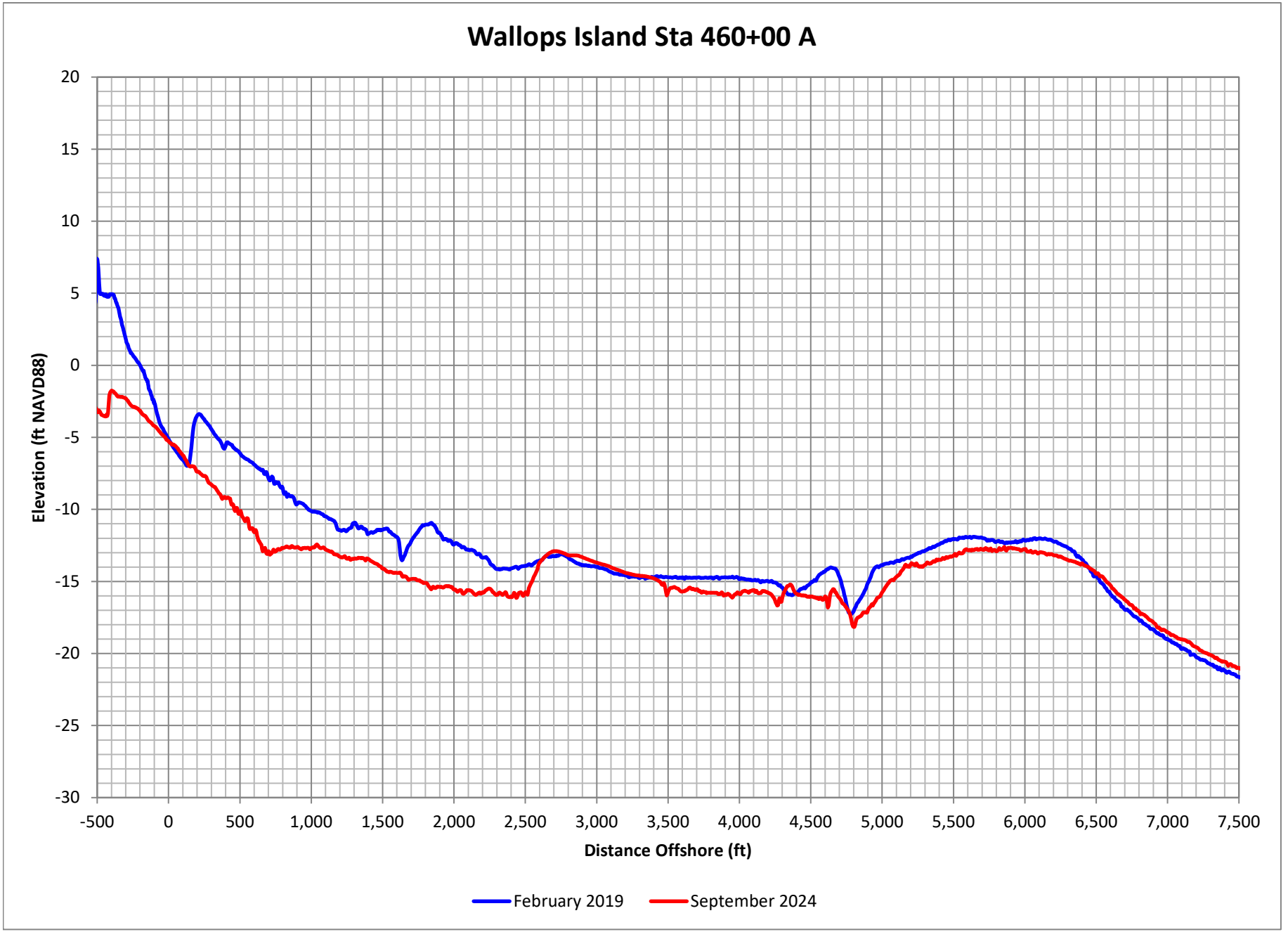


Figure C-102. Wallops Island Profile Comparison Plot

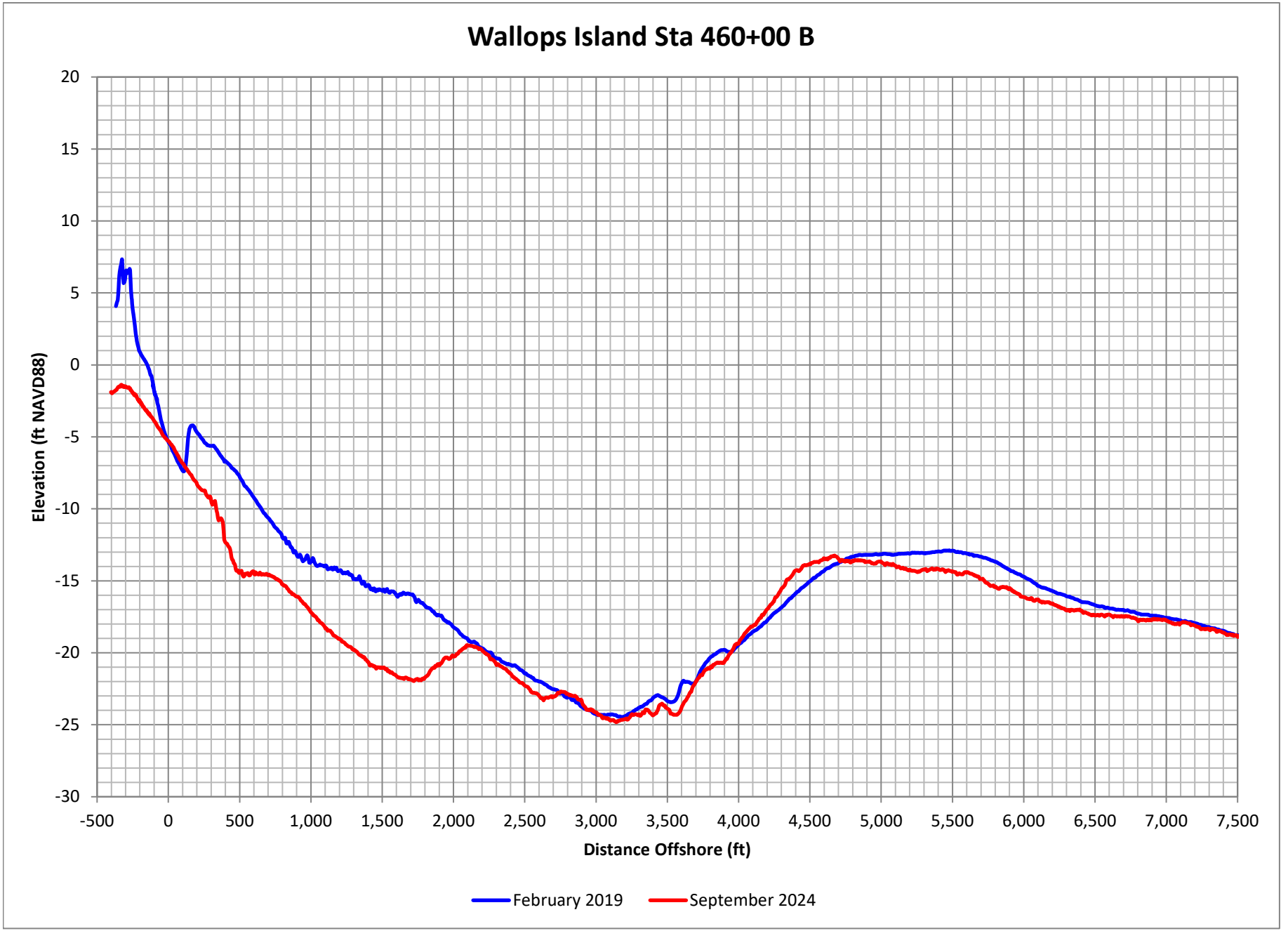


Figure C-103. Wallops Island Profile Comparison Plot

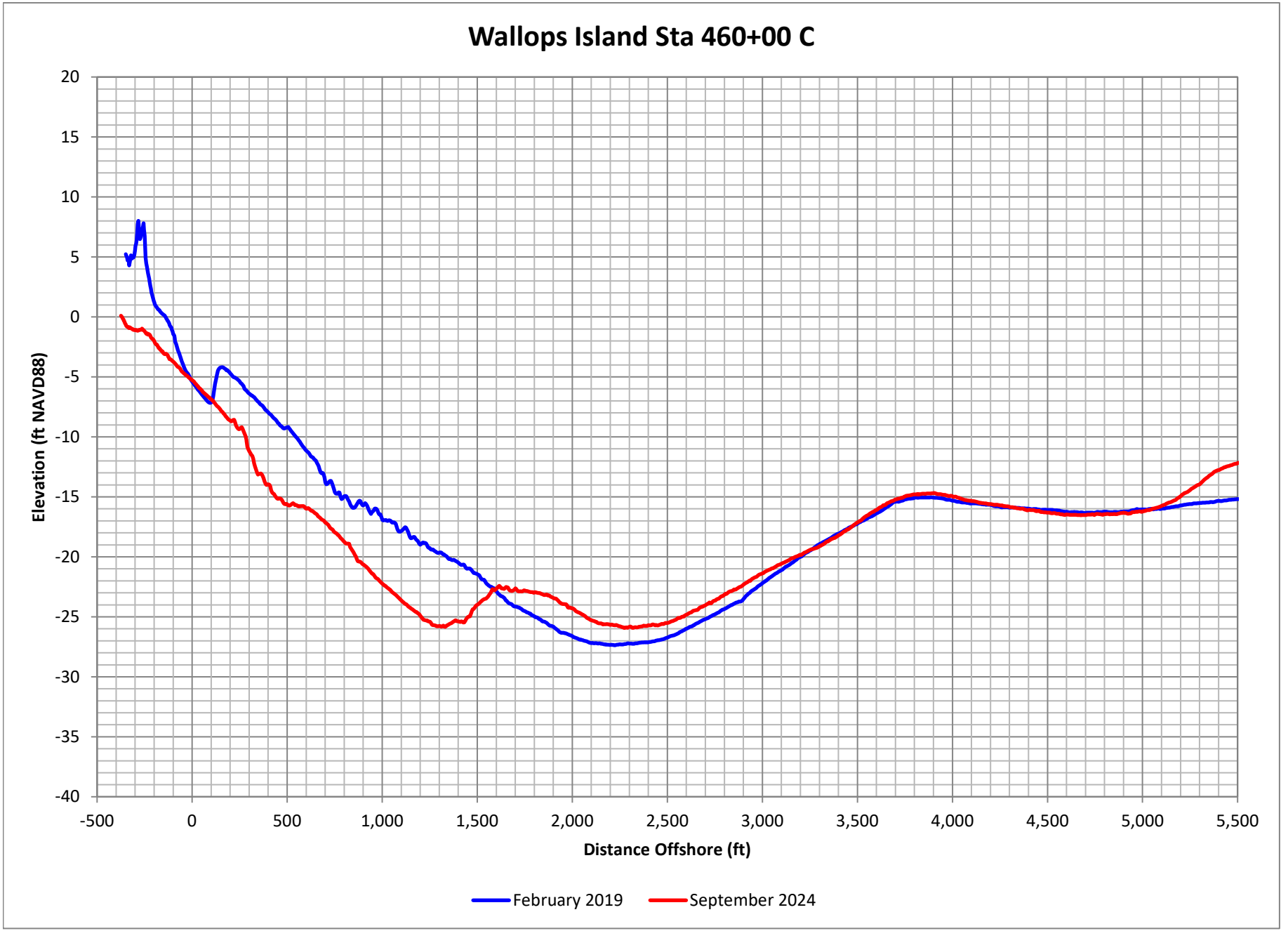


Figure C-104. Wallops Island Profile Comparison Plot

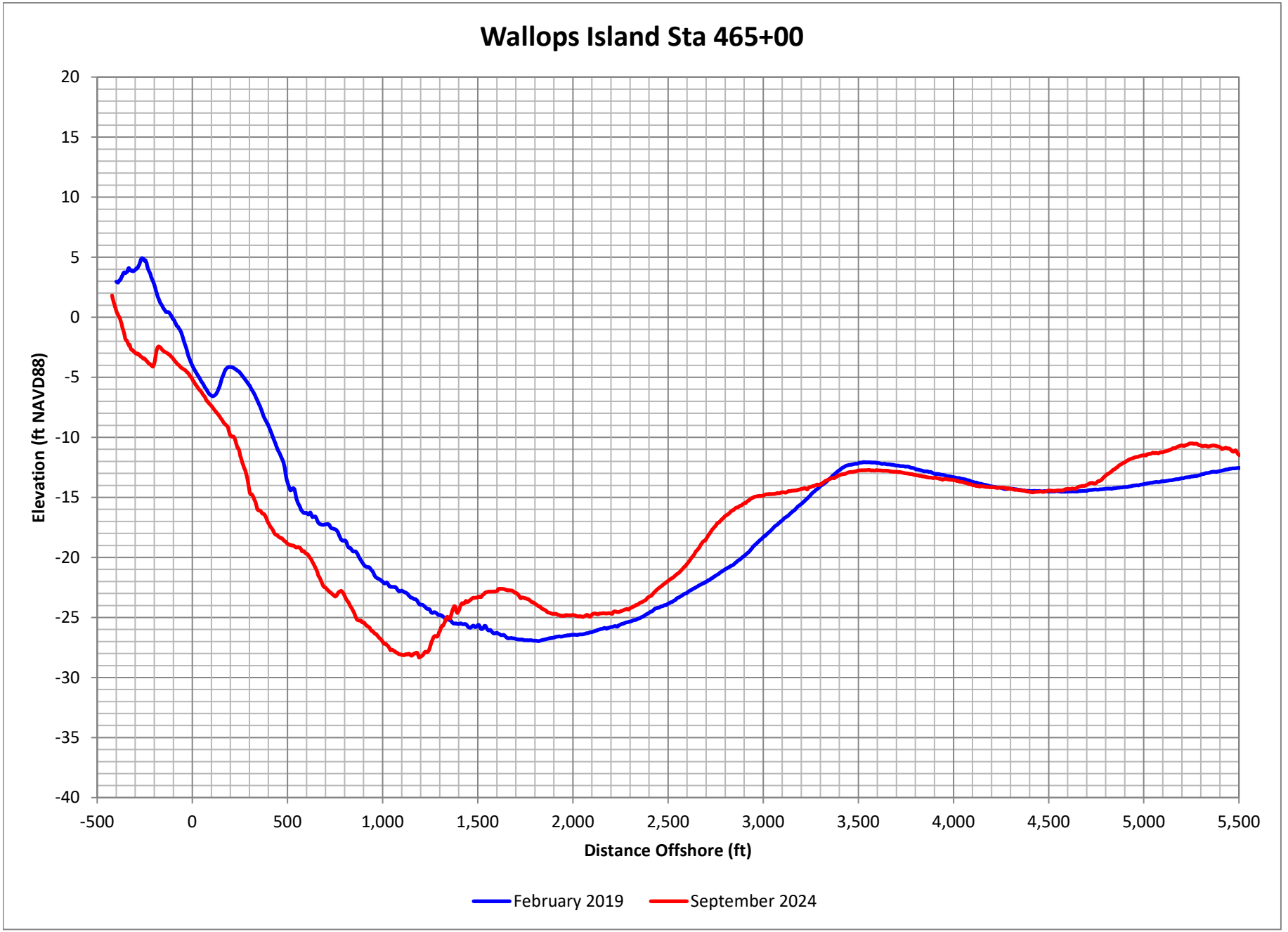


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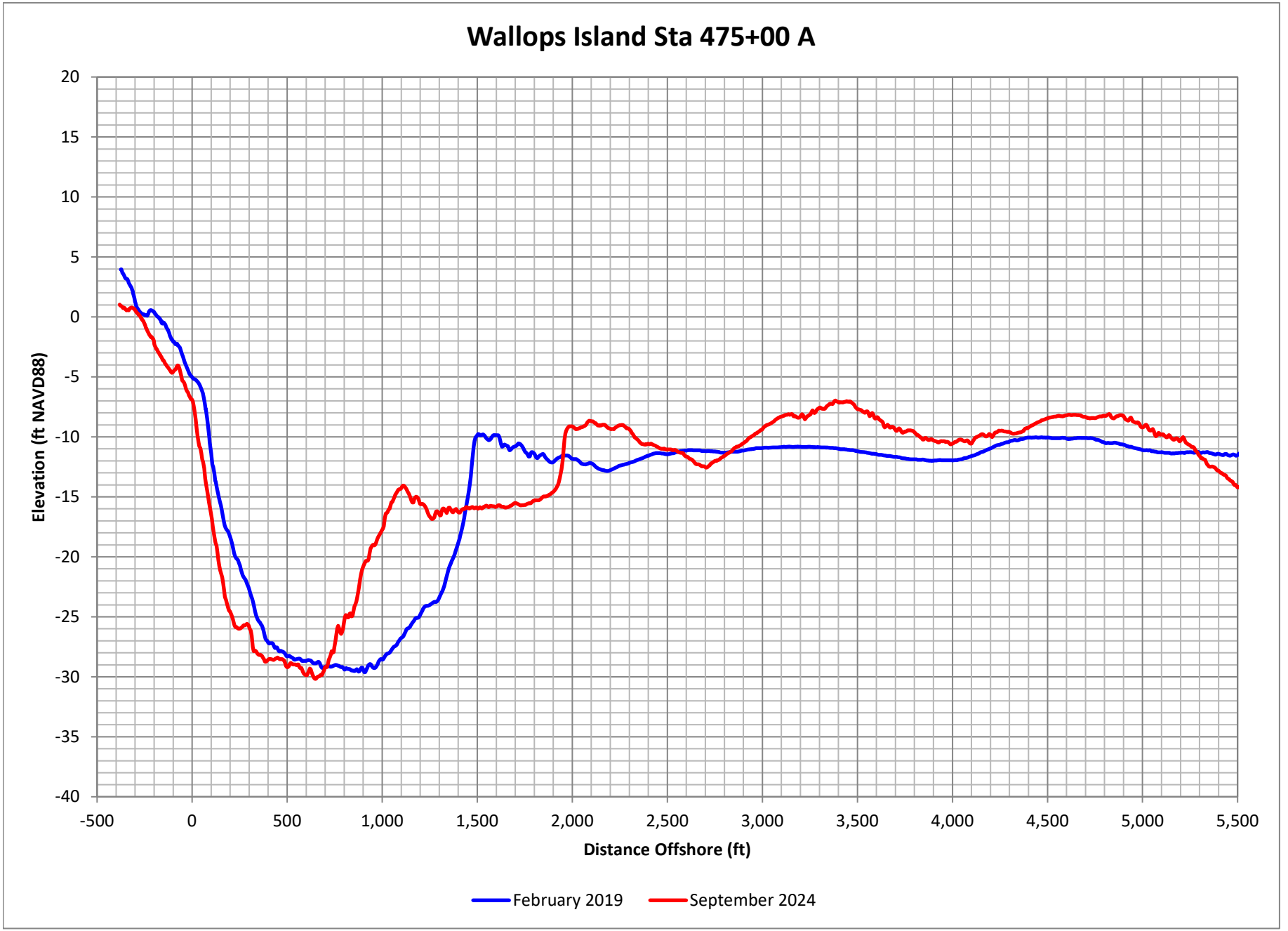


Figure C-106. Wallops Island Profile Comparison Plot

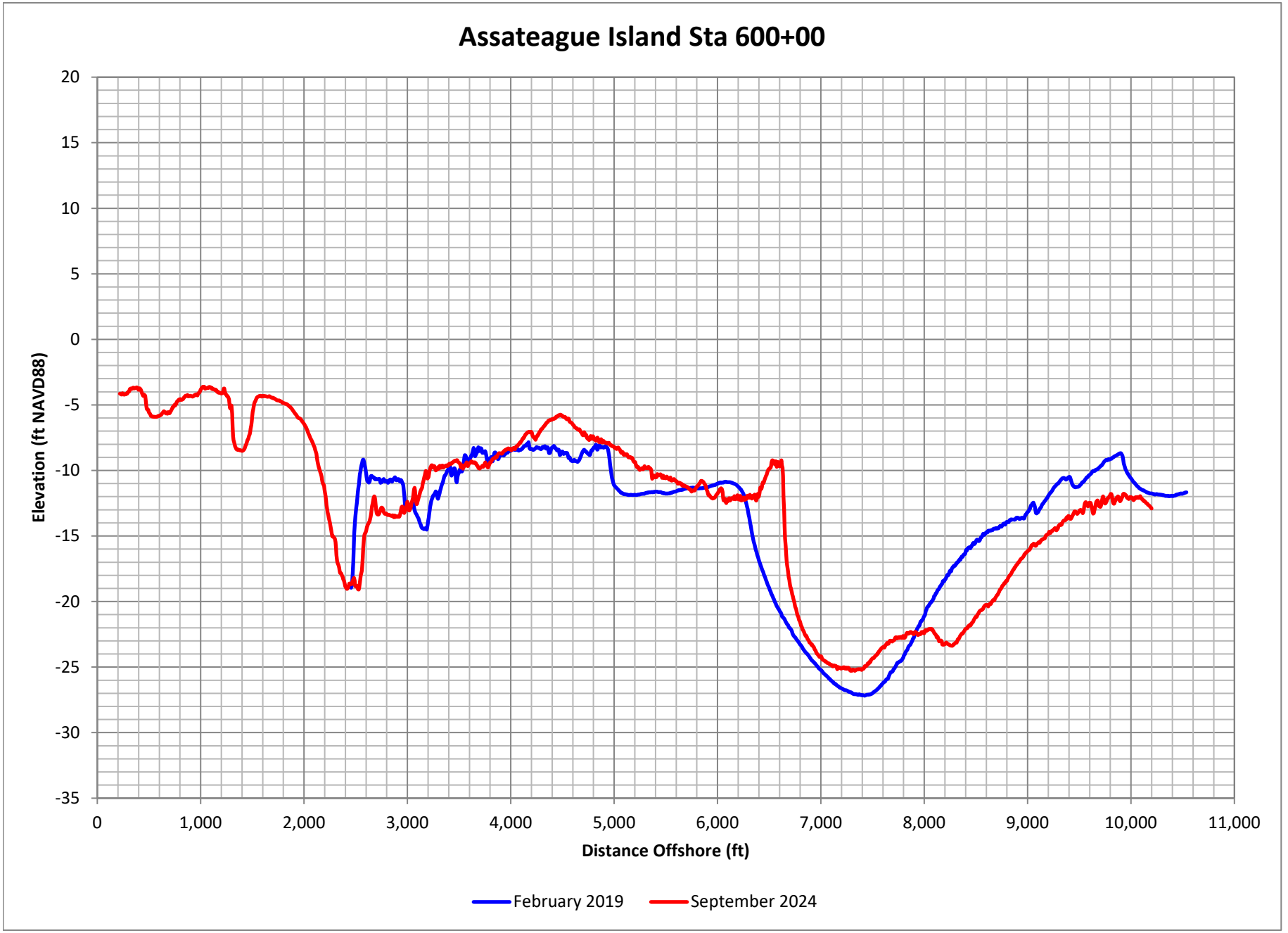


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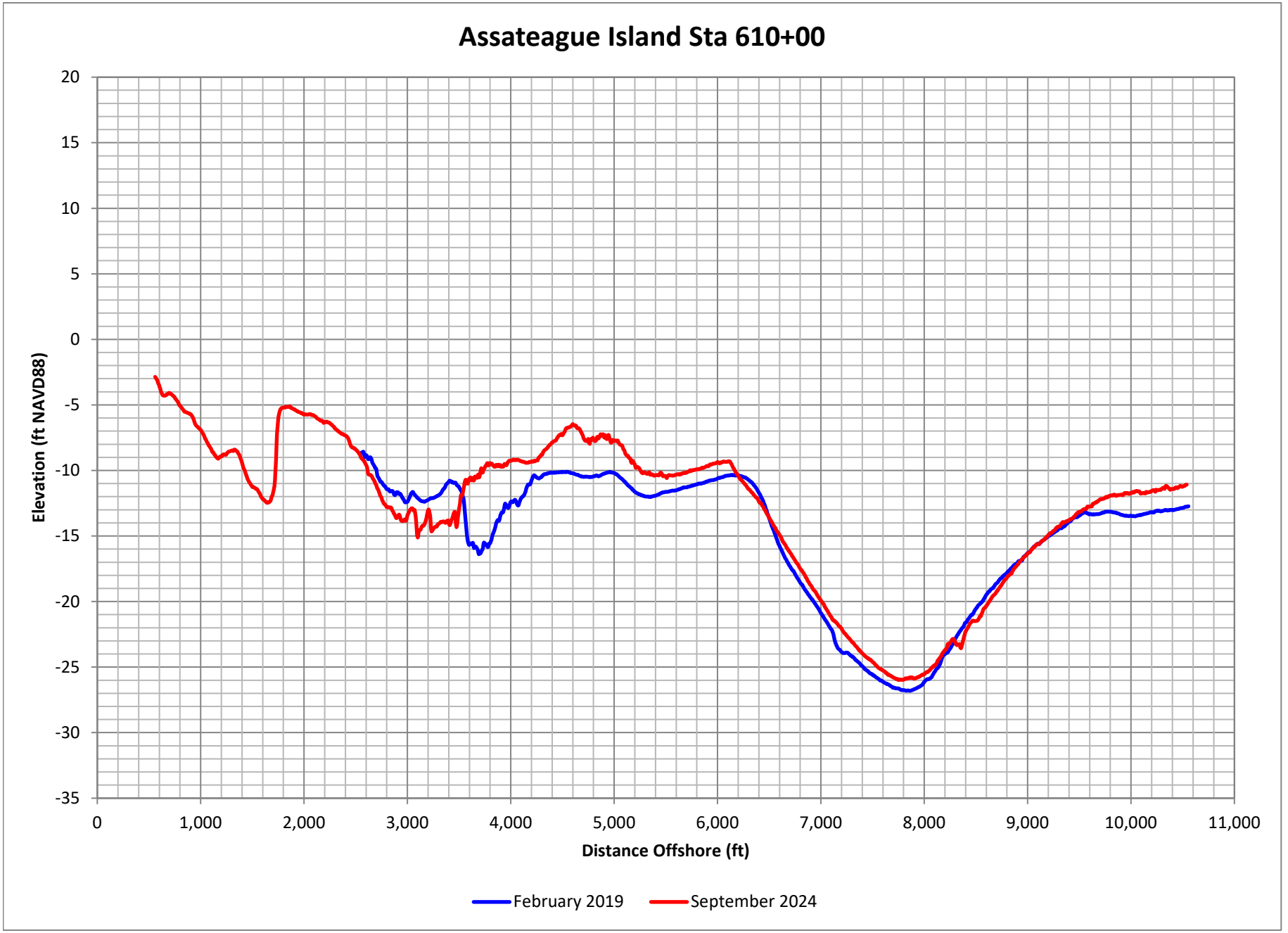


Figure C-108. Wallops Island Profile Comparison Plot

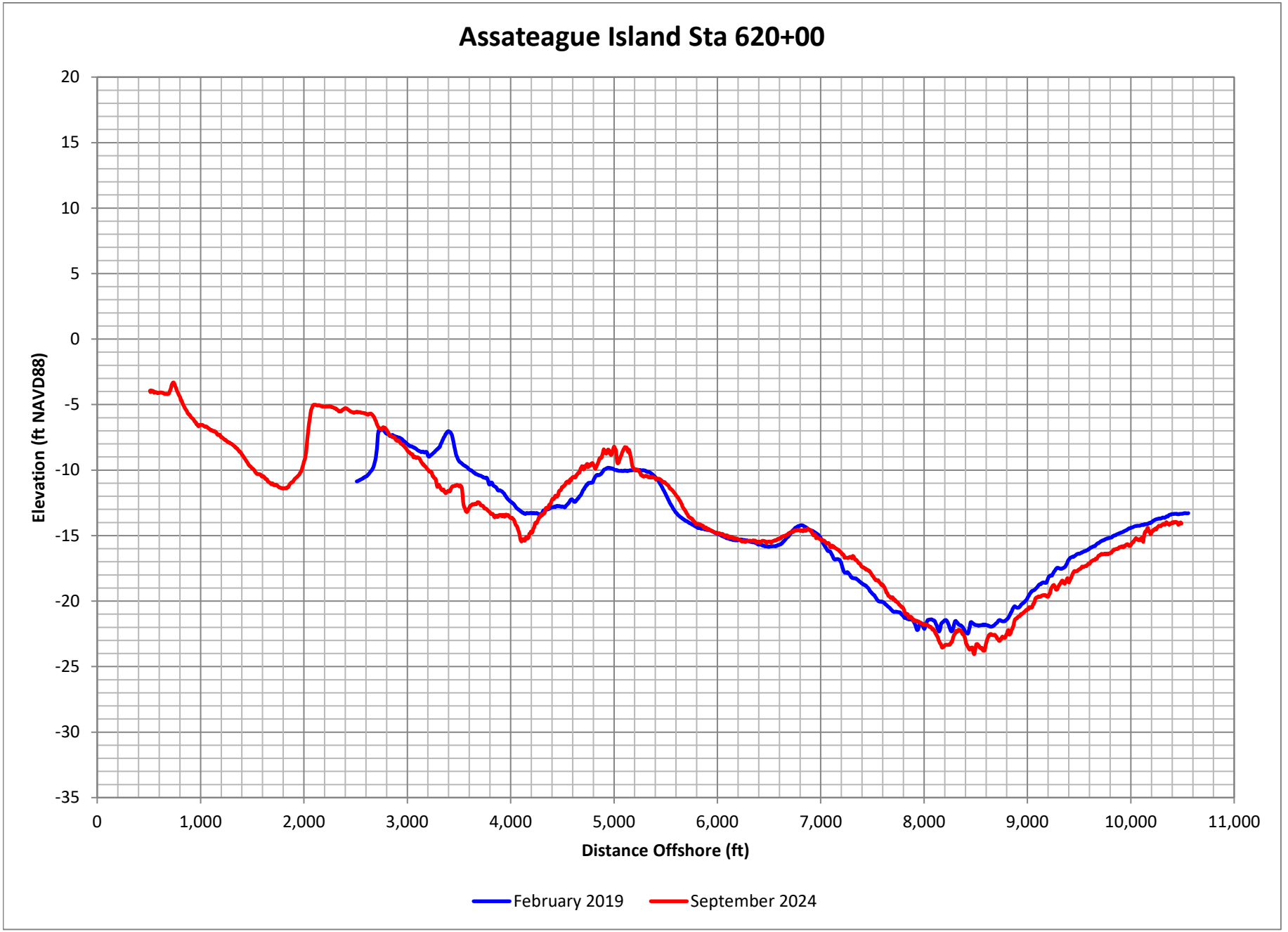


Figure C-109. Wallops Island Profile Comparison Plot

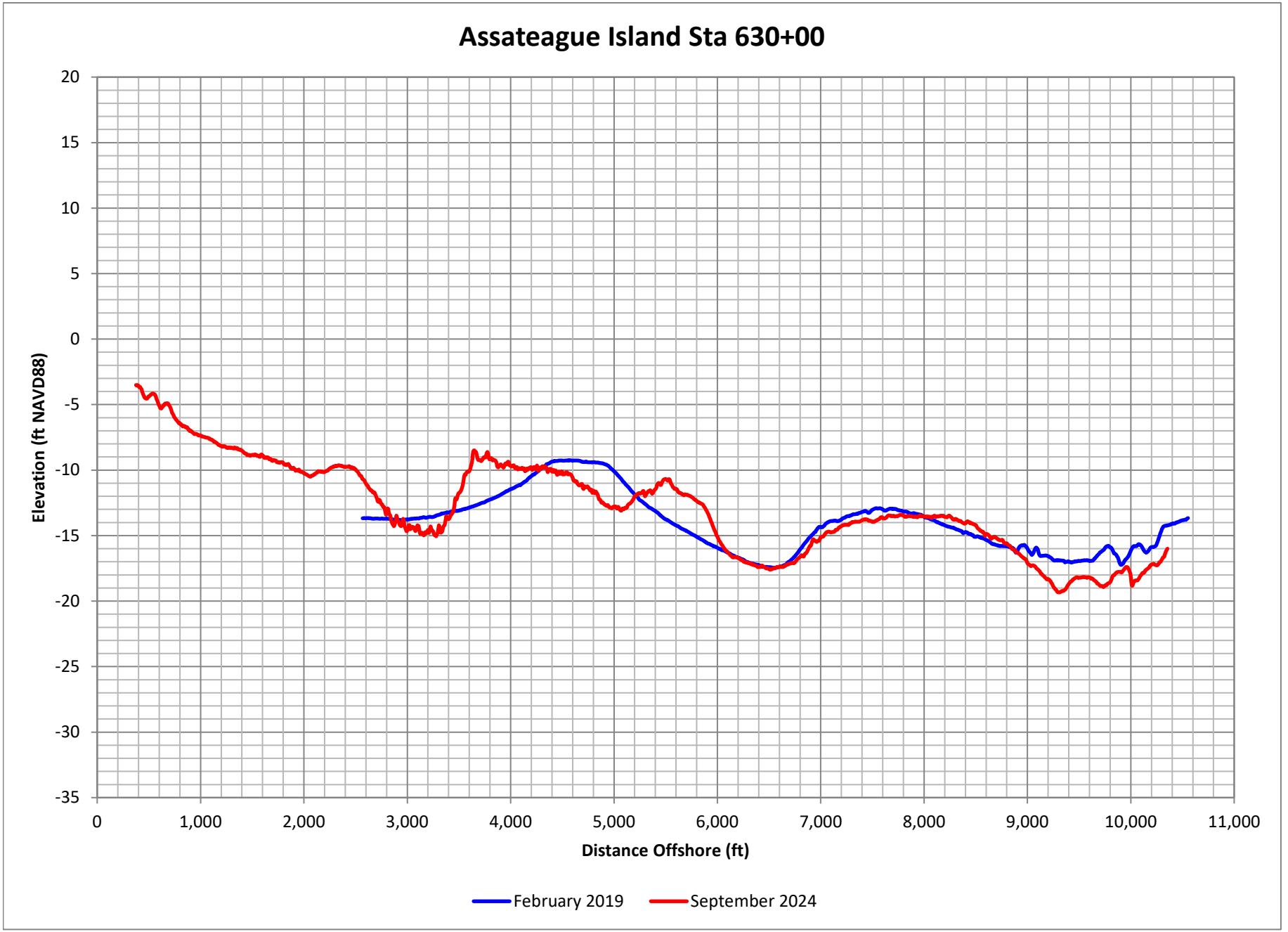


Figure C-110. Wallops Island Profile Comparison Plot

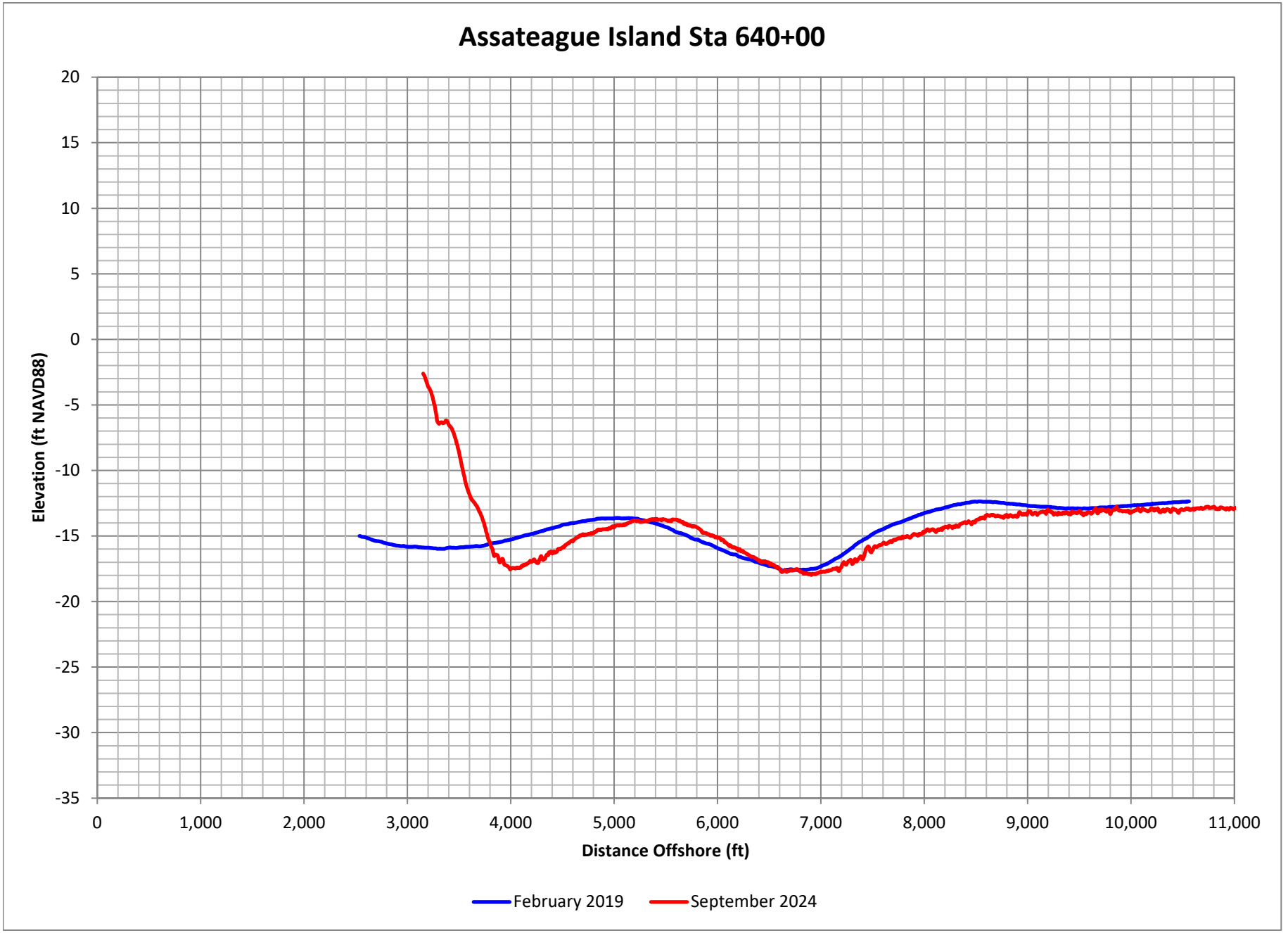


Figure C-111. Wallops Island Profile Comparison Plot

APPENDIX D

Results Tables

Table D-1. Summary of Shoreline Change and Volume Change For Wallops Island Study Area (February 2019 – September 2024)

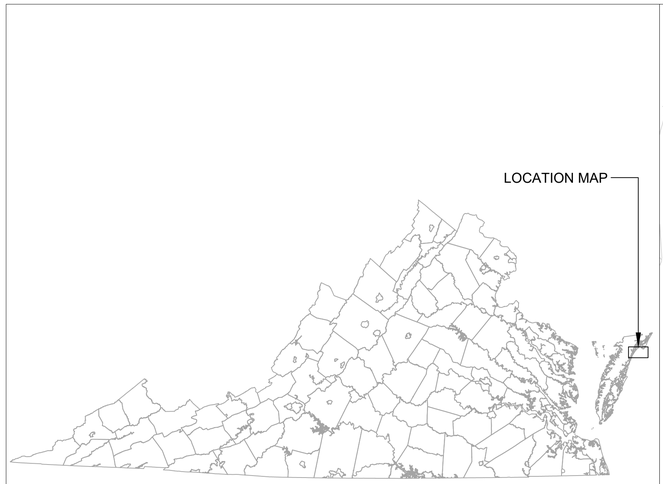
Reach	Transect Number	Station	Shoreline Change @ MHW (+1.5 ft NAVD)	Above MHW (+1.5 ft NAVD)		Above -5 ft NAVD		Above -10 ft NAVD		Above -15 ft NAVD		Above -20 ft NAVD	
				Sept 2024 Measured Volume (cy/ft)	Feb 2019 - Sept 2024 Volume Change (cy/ft)	Sept 2024 Measured Volume (cy/ft)	Feb 2019 - Sept 2024 Volume Change (cy/ft)	Sept 2024 Measured Volume (cy/ft)	Feb 2019 - Sept 2024 Volume Change (cy/ft)	Sept 2024 Measured Volume (cy/ft)	Feb 2019 - Sept 2024 Volume Change (cy/ft)	Sept 2024 Measured Volume (cy/ft)	Feb 2019 - Sept 2024 Volume Change (cy/ft)
Wallops Island - South	3	20+00	-110.38	40.21	-9.57	141.45	-32.97	279.18	-65.23	479.46	-88.75	900.51	-107.98
	5	40+00	-63.18	42.89	1.61	149.87	-21.55	263.71	-16.96	452.34	-39.27	874.85	-66.66
	7	60+00	-30.24	49.53	7.49	133.44	-0.63	235.75	5.71	397.96	0.04	828.24	-19.15
	9	80+00	-43.12	47.50	0.19	160.10	-7.00	299.66	-13.37	482.19	-14.31	917.13	-28.96
	10	90+00	-33.26	38.19	5.22	114.19	-3.78	217.58	-4.92	374.97	-7.25	793.16	-33.54
	11	100+00	-46.35	33.18	-5.47	96.94	-20.20	197.13	-31.31	342.22	-33.83	745.57	-67.66
	12	110+00	-34.07	32.29	-0.88	95.38	-9.39	195.51	-10.61	343.91	-10.31	742.06	-36.15
	13	120+00	-25.10	44.80	4.97	138.44	-1.20	263.65	-6.57	434.60	-7.92	847.10	-22.47
	14	130+00	-44.15	30.48	-4.67	90.84	-16.65	188.33	-21.34	331.16	-19.82	722.61	-35.14
	15	140+00	-38.87	32.97	-4.19	101.54	-14.59	202.92	-22.41	349.00	-23.55	747.43	-35.31
	16	150+00	-48.59	45.39	-1.98	120.91	-10.14	228.36	-15.03	384.19	-19.63	798.72	-39.10
	17	160+00	-47.82	64.24	-1.55	141.89	-8.48	253.46	-13.91	413.90	-12.62	828.14	-21.57
	18	170+00	-47.77	57.16	-3.89	149.10	-9.90	271.39	-15.00	443.77	-15.62	866.25	-27.31
	19	175+00	-64.62	43.79	-10.69	113.23	-23.55	222.02	-33.84	375.91	-37.74	768.34	-48.20
Wallops Island - USACE Project Subreach 1	20	180+00	-45.45	40.23	-19.65	93.43	-24.89	181.04	-21.84	329.95	-26.16	710.41	-33.31
	21	185+00	-68.71	53.21	-22.34	122.38	-38.16	228.84	-55.49	386.58	-69.39	765.84	-75.20
	22	190+00	-51.19	54.45	-26.22	114.36	-34.74	205.27	-38.62	347.65	-44.86	708.81	-77.34
	23	195+00	-73.52	42.63	-26.21	102.65	-43.57	202.44	-56.30	335.83	-59.52	661.38	-75.41
	24	200+00	-16.78	36.32	-15.10	84.35	-13.01	169.31	-5.00	309.84	-9.80	668.55	-58.34
	25	205+00	-5.15	42.94	-10.24	100.60	-11.69	190.64	-8.09	333.84	-3.53	716.72	-41.62
Wallops Island - USACE Project Subreach 2	26	210+00	68.28	40.88	2.13	92.08	26.57	182.95	31.27	326.41	46.01	712.92	21.82
	27	215+00	106.86	41.65	1.72	91.80	44.56	178.03	80.10	320.98	103.41	707.95	81.14
	28	220+00	-73.18	22.63	-8.15	65.67	-18.05	148.56	-18.81	283.97	-16.84	660.39	-28.94
	29	225+00	-51.66	15.24	-6.60	52.46	-17.76	127.15	-23.86	255.60	-30.53	626.79	-39.97
	30	230+00	-27.03	12.10	-2.93	45.14	-8.42	124.00	-16.90	250.24	-24.37	622.15	-37.19
	31	235+00	-21.64	15.41	-4.20	48.01	-9.03	128.00	-17.53	253.58	-21.46	632.31	-37.70
	32	240+00	-7.39	8.99	-0.96	35.97	-6.23	101.56	-1.27	217.79	-1.44	586.39	-12.01
	33	245+00	0.91	6.26	-0.75	21.04	2.62	75.03	14.73	187.55	15.94	559.65	3.23
	34	250+00	-4.06	7.60	-0.47	31.34	-1.36	96.54	3.85	211.60	4.19	579.99	-1.42
	35	255+00	0.00	5.70	0.00	26.74	2.68	92.58	5.54	205.95	7.23	571.72	9.57
	36	260+00	21.06	4.44	1.91	17.51	12.64	74.48	28.77	186.71	30.93	549.42	27.63
	37	265+00	42.85	6.52	5.66	21.70	22.51	86.06	29.45	197.60	38.49	561.04	44.72
	38	270+00	60.75	17.11	7.38	42.44	27.89	112.60	44.33	229.85	60.58	601.67	64.26
	39	275+00	109.12	0.80	18.14	15.49	48.42	75.95	73.13	189.47	90.94	562.36	90.15
	40	280+00	132.12	5.72	22.79	23.09	62.07	83.32	100.55	203.55	126.07	589.66	119.60
	41	285+00	144.34	12.33	27.32	33.20	86.65	104.30	127.16	231.30	155.40	626.72	156.01
	42	290+00	-14.59	26.92	-8.71	65.63	1.96	144.53	13.60	284.13	21.07	695.08	25.51
Wallops Island - USACE Project Subreach 3	43	295+00	-34.92	34.18	-16.97	81.39	-21.11	167.14	-23.70	316.02	-32.50	736.44	-22.67
	44	300+00	-23.98	39.12	-11.49	86.22	-9.27	175.69	-8.12	335.20	-18.94	774.62	-20.66
	45	305+00	2.82	43.98	-0.94	103.00	4.11	196.26	14.28	365.04	10.94	828.62	5.02
	46	310+00	15.90	59.84	6.75	129.56	19.00	236.86	27.60	412.93	30.23	896.84	27.19
	47	315+00	46.30	60.69	12.38	131.61	34.54	236.18	53.77	414.41	60.60	928.25	42.21
	48	320+00	60.80	72.84	6.14	158.70	29.42	270.33	54.02	454.84	63.81	1010.84	39.50
Wallops Island - USACE Project Subreach 4	49	325+00	61.37	77.21	10.79	171.92	35.65	295.06	57.04	490.10	67.90	1106.38	34.87
	50	330+00	74.61	89.07	10.29	203.02	33.88	343.36	49.49	546.40	65.16	1201.88	9.86
	51	335+00	93.21	97.61	14.67	219.70	47.93	361.92	81.17	575.18	100.84	1172.86	74.82
	52	340+00	127.98	105.22	15.28	241.90	55.03	397.42	94.76	626.89	118.17	1220.72	111.16
	53	345+00	123.74	102.70	9.04	249.28	45.92	416.11	77.99	653.22	104.34	1241.00	101.37
	54	350+00	117.26	122.78	18.30	289.13	51.53	471.77	83.02	731.39	110.74	1325.84	120.30
	55	355+00	130.67	121.43	15.98	298.39	55.56	488.89	91.94	759.46	120.98	1366.74	134.21
	56	360+00	135.82	123.35	12.75	310.04	52.82	505.13	91.88	779.12	121.70	1383.66	129.91
	57	365+00	147.32	137.08	32.50	339.32	78.23	548.73	116.99	835.14	148.68	1451.01	154.38
	58	370+00	165.97	140.90	32.64	361.32	78.80	581.30	121.98	878.87	157.02	1509.19	163.49
Wallops Island - North Subreach 1	59	375+00	163.33	143.43	36.09	388.21	80.41	631.26	121.05	945.54	159.89	1596.05	173.95
	61	385+00	195.55	109.17	38.26	345.39	86.17	578.48	129.93	886.59	170.52	1532.94	199.41
Wallops Island - North Subreach 2	63	395+00	258.31	106.24	-64.95	350.25	-59.33	592.44	-13.50	907.79	35.48	1576.84	105.24
	65	405+00	242.03	112.95	-70.95	368.58	-55.72	621.68	-11.25	932.41	55.15	1616.98	142.54
	67	415+00	132.50	107.81	-60.90	352.06	-18.44	601.42	13.22	904.05	249.11	1785.96	452.29
	69	425+00	69.72	116.44	-63.00	371.25	-83.56	639.58	-94.17	1516.12	-186.42	2763.09	-147.57
	71	435+00	149.24	96.96	-40.95	309.99	-26.13	538.87	-20.92	1297.41	-68.65	2382.05	1.84
	73	445+00	44.89	56.10	-12.87	211.07	-2.37	402.07	38.07	1168.73	60.17	2376.89	93.34
Wallops Island - North Subreach 3	75	455+00	-250.28	42.12	-42.12	139.98	-92.01	349.46	-164.83	1055.92	-234.71	2316.41	-221.46
	76	459+00	-359.85	33.56	-33.56	158.69	-109.68	392.31	-184.45	1034.88	-402.93	2397.79	-452.65
	77	460+00	-185.89	20.45	-20.45	84.98	-56.86	231.05	-106.28	466.61	-191.81	881.03	-343.45
	78	461+00	-169.48	19.52	-19.52	80.82	-50.44	208.64	-88.32	396.11	-147.21	659.99	-216.11
	79	465+00	-241.76	17.96	-17.96	101.98	-73.32	237.25	-115.16	400.52	-154.52	605.63	-204.98
	81	475+00	-78.35	3.84	-3.84	64.17	-26.15	145.56	-38.35	235.72	-48.13	338.75	-58.09

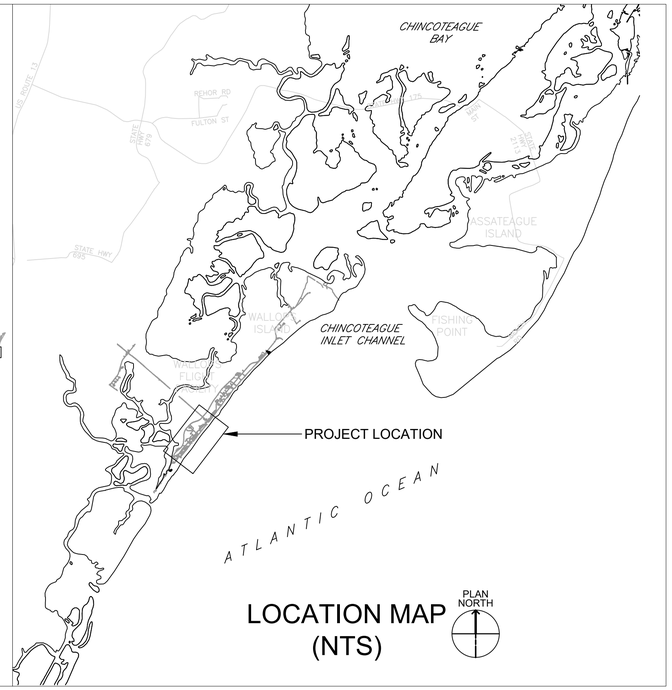
NOTES:
1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from February 21, 2019 to September 12, 2024.

US Army Corps of Engineers®

NORFOLK DISTRICT

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT





SOLICITATION NO.:

CONTRACT NO.:

ISSUE DATE: MAR 2026

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SIGNATURES AFFIXED BELOW INDICATE OFFICIAL RECOMMENDATION AND APPROVAL OF ALL DRAWINGS IN THIS SET AS INDICATED ON INDEX OF DRAWINGS.

RECOMMENDED

DESIGN BRANCH LEAD

APPROVED

CHIEF, DESIGN BRANCH

APPROVED

CHIEF, ENGINEERING DIVISION

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD
DRAWN BY: N. INGOLD
CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
ISSUE DATE: MAR 2026
SOLICITATION NO.:
CONTRACT NO.:
NAO FILE NO.: 1196
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

COVER SHEET

SHEET ID

G-001

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ABBREVIATIONS

L	ANGLE
A/C	AIR CONDITIONING
A/C UNIT	AIR CONDITIONING UNIT
AB	ANCHOR BOLT
ABV	ABOVE
AC	ALTERNATING CURRENT
ACC	ACCESSIBLE
ACI	AMERICAN CONCRETE INSTITUTE
ACR	ACRYLIC PLASTIC
ACS DR	ACCESS DOOR
ACS PNL	ACCESS PANEL
ACSR	ALUMINUM CABLE STEEL REINFORCED
ACST	ACOUSTIC
ACT	ACOUSTICAL CEILING TILE
ADDM	ADDENDUM
ADH	ADHESIVE
ADJ	ADJACENT, ADJOINING, ADJUSTABLE
ADO	AUTOMATIC DOOR OPERATOR
AFF	ABOVE FINISHED FLOOR
AGGR	AGGREGATE
AHR	ANCHOR
AHU	AIR HANDLING UNIT
AI	AREA INLET
AIC	AMPERE INTERRUPTING CAPACITY
AISC	AMERICAN INSTITUTE OF STEEL CONSTRUCTION
A.L.	ACTIVE LEAF
ALT	ALTERNATE
ALUM	ALUMINUM
AMB	AMBIENT
AMP	AMPERE
ANOD	ANODIZE
ANSI	AMERICAN NATIONAL STANDARDS INSTITUTE
APPD	APPROVED
APPROX	APPROXIMATE
ARCH	ARCHITECT
ARI	AMERICAN REFRIGERATION INSTITUTE
ASB	ASBESTOS
ASC	ABOVE SUSPENDED CEILING
ASPH	ASPHALT
ATC	ACOUSTICAL TILE CEILING
AUTO	AUTOMATIC
AVG	AVERAGE
AWG	AMERICAN WIRE GAUGE
AWT	ACOUSTICAL WALL TREATMENT
BB	BULLETIN BOARD
BC	BOOKCASE
BD	BOARD
BDRY	BOUNDARY
BEJ	BRICK EXPANSION JOINT
BEV	BEVEL
BITUMINOUS	BITUMINOUS
BJT	BED JOINT
BL	BUILDING LINE
BLDG	BUILDING
BLW	BELOW
BM	BENCHMARK
BO	BOTTOM OF
BOT	BOTTOM
BP	BACK PLASTER(ED)
BRCG	BRACING
BRDG	BRIDGING
BRG	BEARING
BRG PL	BEARING PLATE
BRK	BRICK
BRKT	BRACKET
BRZ	BRONZE
BS	BOTH SIDES
BSMT	BASEMENT
Btu	BRITISH THERMAL UNIT
BtuH	BTU PER HOUR
BTWN	BETWEEN
BUR	BUILT-UP ROOFING
BW	BOTH WAYS
CAB	CABINET
CAP	CAPACITY
CB	CATCH BASIN
CCT	CUBICLE CURTAIN TRACK
CCTV	CLOSED CIRCUIT TELEVISION
CE	COVER ELEVATION
CEM	CEMENT
CEM PLAS	CEMENT PLASTER
CER	CERAMIC
CFI	CONDUCTIVE FLOORING
CFLG	COUNTERFLASHING
CFM	CUBIC FEET PER MINUTE
CG	CORNER GUARD
CH BD	CHALKBOARD
CHFR	CHAMFER
CHIM	CHIMNEY
CHK	CHECK
CHR PL	CHROME PLATED
CI	CAST IRON
CI	CURB INLET
CIP	CAST-IN-PLACE
CIRC	CIRCULAR
CJ	CONTROL JOINT
CJ	CONSTRUCTION JOINT
CKT	CIRCUIT
CKT BRKR	CIRCUIT BREAKER
CL	CENTER LINE
CLG	CEILING
CLG HT	CEILING HEIGHT
CLGL	CLEAR GLASS
CLL	CONTRACT LIMIT LINE
CLO	CLOSET
CLOS	CLOSURE
CLR	CLEAR(ANCE)
CLWG	CLEAR WIRED GLASS
cm	CENTIMETER(S)
CMP	CORRUGATED METAL PIPE
CMPST	COMPOSITE
CMU	CONCRETE MASONRY UNIT
CND	CONDUIT
CNL	CONDUCTIVE NEOPRENE LATEX
CNR	CORNER
CNTR	COUNTER
CO	CLEANOUT
CO2	CARBON DIOXIDE
COL	COLUMN
COM	COMMON
COMB	COMBUSTION
COMPT	COMPARTMENT
CONC	CONCRETE
CONN	CONNECT
CONSTR	CONSTRUCTION
CONT	CONTINUE
CONTR	CONTRACTOR
CORR	CORRIDOR
COV	COVER
CPRS	COMPRESSIBLE
CPT	CARPET
CRCMF	CIRCUMFERENCE
CRES	CORROSIVE RESISTANT STEEL
CRG	CROSS GRAIN
CRS	COURSE(S)
CS	CAST STONE
CSK	COUNTERSUNK
CSMT	CASEMENT
CT	CERAMIC TILE
CT	CURRENT TRANSFORMER
C TO C	CENTER TO CENTER
CTR	CENTER
CU	CONDENSING UNIT
Cu	COPPER
CU FT	CUBIC FEET
CUH	CABINET UNIT HEATER
CU YD	CUBIC YARDS
CV	CEILING VENT
CVH	CONDUCTIVE VINYL HOMOGENEOUS (SHEET
TYPE)	
CW	COLD WATER
CYL	CYLINDER
d	PENNY (AS IN NAIL - 10D)
DAT	DATUM
DB	DRY BULB
DBL	DOUBLE
DBL ACT DR	DOUBLE ACTING DOOR
DCJ	DOWELED CONTROL JOINT
DCJT	DUMMY CONTROL JOINT
DEG	DEGREE
DEMO	DEMOLITION
DEPR	DEPRESSION
DEPT	DEPARTMENT
DET	DETAIL
DF	DRINKING FOUNTAIN
DH	DOUBLE HUNG
DH	DUCT HEATER
DIA	DIAMETER
DIAG	DIAGONAL
DIM	DIMENSION
DISC	DISCONNECT
DISP	DISPENSER
DISTR PNL	DISTRIBUTION PANEL
DIV	DIVISION
DL	DEAD LOAD
DMPF	DAMPPROOFING
DMPR	DAMPER
DMT	DEMOUNTABLE
DN	DOWN
DR	DOOR
DR	DRAIN
DRB	DRAINBOARD
DR CL	DOOR CLOSER
DS	DOUBLE STRENGTH (GLASS)
DS	DOWNSPOUT
DT	DRAIN TILE
DVTL	DOVETAIL
DWG	DRAWING
DWLS	DOWELS
DWR	DRAWER
DWTR	DUMBWAITER
DX	DIRECT EXPANSION
E	EAST
EA	EACH
EAT	ENTERING AIR TEMPERATURE
EF	EACH FACE
EJ	EXPANSION JOINT
EL	ELEVATION - GRADE OR BUILDING
ELEC	ELECTRIC
EM	EXPANDED METAL
EMD	ESTIMATED MAXIMUM DEMAND
EMER	EMERGENCY
ENCL	ENCLOSE(URE)
ENTR	ENTRANCE, ENTERING
EP	ELECTRICAL PANELBOARD
EPRF	EXPLOSION PROOF
EPY	EPOXY COATING
EQ	EQUAL
EQUIP	EQUIPMENT
ESCAL	ESCALATOR
EST	ESTIMATE(D)
EWC	ELECTRIC WATER COOLER
EWT	ENTERING WATER TEMPERATURE
EXC	EXCAVATE
EXH	EXHAUST
EXH A	EXHAUST AIR
EXST	EXISTING
EXP	EXPANSION
EXP	EXPOSED
EXP BT	EXPANSION BOLT
EXT	EXTERIOR
F	FAHRENHEIT
FA	FIRE ALARM
FA	FRESH AIR
FAC	FIRE APPARATUS CLOSET
FAI	FRESH AIR INTAKE
F BRK	FIRE BRICK
FC	FOOT CANDLE
FC BRK	FACE BRICK
FCG	FACING
FCJ	FLOOR CONSTRUCTION JOINT
FCO	FLOOR CLEANOUT
FCU	FAN COIL UNIT
FD	FLOOR DRAIN
FDMPR	FIRE DAMPER
FDTN	FOUNDATION
FE	FIRE EXTINGUISHER
FEB	FIRE EXTINGUISHER BRACKET
FEC	FIRE EXTINGUISHER CABINET
FF	FACTORY FINISH
FGL	FIBERGLASS
FH	FIRE HYDRANT
FH	FLAT HEAD
FHC	FIRE HOSE CABINET
FHMS	FLAT HEAD MACHINE SCREW
FHR	FIRE HOSE RACK
FHS	FIRE HOSE STATION
FHWS	FLAT HEAD WOOD SCREW
FIG	FIGURE
FIN	FINISH
FIN FLR	FINISH FLOOR
FIXT	FIXTURE
FJT	FLUSH JOINT
FLASH	FLASHING
FLR	FLOOR
FLEX	FLEXIBLE
FLG	FLOORING
FLR PL	FLOOR PLATE
FLUOR	FLUORESCENT
FN	FENCE
FOC	FACE OF CONCRETE
FOF	FACE OF FINISH
FOM	FACE OF MASONRY
FOS	FACE OF STUD
FP	FIRE PARTITION
FP	FIREPROOF
FPM	FEET PER MINUTE
FR	FIRE RESISTANT
FR	FRAME
FRG	FORGED
FRMG	FRAMING
FRT	FIRE-RETARDANT
FS	FULL SIZE
FSTNR	FASTEN(ER)
FT	FEET
FTG	FOOTING
FURG	FURRING
FUT	FUTURE
FW	FIRE WATER
FWC	FABRIC WALL COVERING
G	NATURAL GAS
GA	GAGE
GAL	GALLON(S)
GALV	GALVANIZED
GALV STL	GALVANIZED STEEL
GB	GRAB BAR
GC	GENERAL CONTRACTOR
GEN	GENERAL
GF	GROUND FACE
GFCI	GROUND FAULT CIRCUIT INTERRUPTER
GFE	GOVERNMENT-FURNISHED EQUIPMENT
GFE/CI	GOVERNMENT-FURNISHED EQUIPMENT
CONTRACTOR INSTALLED	
GI	GALVANIZED IRON
GIP	GALVANIZED IRON PIPE
GKT	GASKET(ED)
GL	GLASS
GL BLK	GLASS BLOCK
GLF	GLASS FIBER
GLZ	GLAZING
GLZ CMU	GLAZED CONCRETE MASONRY UNITS
G	GROUND
GOVT	GOVERNMENT
GPM	GALLONS PER MINUTE
GPT	GYPSUM TILE
GRAN	GRANITE
GR LN	GRADE LINE
GRTG	GRATING
GST	GLAZED STRUCTURAL TILE
GSU	GLAZED STRUCTURAL UNITS
GT	GROUT
GWT	GLAZED WALL TILE
GYP	GYPSUM
GYP BD	GYPSUM BOARD
GYP PLAS	GYPSUM PLASTER
HB	HOSE BIBB
HC	HOLLOW CORE
HCD	HALON CONTAINMENT DAMPER
HCP	HANDICAPPED
HD	HEAD
HD	HEAVY DUTY
HDBD	HARDBOARD
HD JT	HEAD JOINT
HDR	HEADER
HDW	HARDWARE
HDWD	HARDWOOD
HES	HIGH EARLY-STRENGTH CEMENT
HEX	HEXAGON
HH	HANDHOLE
HK	HOOK(S)
HM	HOLLOW METAL
HNDRL	HANDRAIL
HORIZ	HORIZONTAL
HP	HIGH PRESSURE
HP	HORSEPOWER
HPT	HIGH POINT
HR	HOUR
HS	HIGH STRENGTH
HSGYP	HIGH-STRENGTH GYPSUM PLASTER
HSKPG	HOUSEKEEPING
HT	HEIGHT
HTG	HEATING
HTR	HEATER
HVAC	HEATING, VENTILATING AND AIR CONDITIONING
HYDR	HYDRAULIC
Hz	HERTZ
IC	INTERCOM
ID	INSIDE DIAMETER
IESNA	ILLUMINATING ENGINEERING SOCIETY OF NORTH
AMERICA	
ILK	INTERLOCK
IN	INCH
INCIN	INCINERATOR
INCL	INCLUDED
INSF	INSULATING FILL
INSUL	INSULATION
INT	INTERIOR
INTM	INTERMEDIATE
INV	INVERT
IP	IRON PIPE
IPS	IRON PIPE SIZE
I.P.S.	INSIDE PIPE SIZE
JAN CLO	JANITOR'S CLOSET
J-BOX	JUNCTION BOX
JCT	JUNCTION
JST	JOIST
JT	JOINT
KIP	KILOPOUND (1000 POUNDS)
KIT	KITCHEN
KOP	KNOCKOUT PANEL
KPL	KICKPLATE
kV	KILOVOLTS
kVA	KILOVOLT AMPERES
kVAR	KILOVOLT AMPERES REACTIVE
kW	KILOWATT
KWY	KEYWAY
LAB	LABORATORY
LAD	LADDER
LAM	LAMINATE
LAT	LEAVING AIR TEMPERATURE
LAU	LAUNDRY
LAV	LAVATORY
LB	LAG BOLT
LB	POUND
LBL	LABEL
LBR	LUMBER
LC	LIGHT CONTROL
LD	LOAD
LDG	LOADING
LG	LENGTH
LH	LEFT HAND(ED)
LIN	LINEAR
LKR	LOCKER
LL	LIVE LOAD
LLD	LEAD-LINED DOOR
LM	LUMEN
LMST	LIMESTONE
LNTL	LINTEL
LONG	LONGITUDINAL
LP	LIGHTPROOF
LPD	LIGHTPROOF DOOR
LPL	LIGHTPROOF LOUVER
LPT	LOW POINT
LR	LIVING ROOM
LS	LAWN SPRINKLER
LT	LIGHT
LT WT	LIGHTWEIGHT
LTG	LIGHTING
LTNG	LIGHTNING
LVR	LOUVER
LWC	LIGHTWEIGHT CONCRETE
LWT	LEAVING WATER TEMPERATURE
m	METER(S)
M&B	MATCHED AND BEADED
MACH	MACHINE
MAS	MASONRY
MATL	MATERIAL(S)
MAX	MAXIMUM
MB	MACHINE BOLTS
MBR	MEMBER
MC	MEDICINE CABINET
MCJ	MASONRY CONTROL JOINT
MCO	METAL-CASED OPENING
MDS	METAL DIVIDER STRIP
MECH	MECHANICAL
MECH RM	MECHANICAL ROOM
MED	MEDIUM
MEMB	MEMBRANE
MES	METAL EDGE STRIP
MFD	METAL FLOOR DECKING
MFG	MANUFACTURING
MFR	MANUFACTURER
MG	MOTOR GENERATOR
MGT	MATTE-GLAZED TILE
MH	MANHOLE
MI	MALLEABLE IRON
MIN	MINIMUM
MIRR	MIRROR
MISC	MISCELLANEOUS
ML	METAL LATH
MLDG	MOULDING
MLWK	MILLWORK
mm	MILLIMETER(S)
MNIC	MATERIAL NOT IN CONTRACT (INSTALLATION BY
CONTRACTOR)	
MO	MASONRY OPENING
MOD	MODULAR
MOD.	MODIFIED
MOT	MOTOR
MP	MOVABLE PARTITION
MR	MOP RECEIVOR
MRB	MARBLE BASE
MRD	METAL ROOF DECKING
MS	MACHINE SCREWS
MT	METAL THRESHOLD
MT	MOUNT
MTD	MOUNTED
MTFR	METAL FURRING
MTL	METAL
MVBL	MOVABLE
MULL	MULLION
N	NORTH
NAT	NATURAL
NC	NORMALLY CLOSED
NEC	NATIONAL ELECTRICAL CODE
NEMA	NATIONAL ELECTRICAL MANUFACTURERS
ASSOCIATION	
NFPA	NATIONAL FIRE PROTECTION ASSOCIATION
Ni	NICKEL
NIC	NOT IN CONTRACT
NL	NAILABLE
N.L.	NEOPRENE LATEX
NM	NONMETALLIC
NO	NORMALLY OPEN
NO	NUMBER
NOM	NOMINAL
NR	NOISE REDUCTION
NRC	NOISE REDUCTION COEFFICIENT
N"REQD	NOT REQUIRED
NTS	NOT TO SCALE
OA	OUTSIDE AIR
OBSC	OBSCURE
OBW	OBSERVATION WINDOW
OC	ON CENTER
OCEW	ON CENTER EACH WAY
OD	OUTSIDE DIAMETER
OFC	OFFICE
OGL	OBSCURE GLASS
OH	OVERHEAD
OHMS	OVALHEAD MACHINE SCREW
OHWS	OVALHEAD WOOD SCREW
OPH	OPPOSITE HAND
OPNG	OPENING
OPP	OPPOSITE
OPQ	OPAQUE
OPS	OPERATIONS
OS & Y	OUTSIDE SCREW AND YOKE
OWGL	OBSCURE WIRED GLASS
P	POLE
PA	PUBLIC ADDRESS
PAR	PARALLEL
PB	PANIC BAR
PBD	PARTICLE BOARD
PBS	PUSH BUTTON STATION
PC	PIECE
PCC	PRECAST CONCRETE
PCF	POUNDS PER CUBIC FOOT
PCP	CEMENT PLASTER (PORTLAND)
PD	PAVEMENT DRAIN
PED	PEDESTAL
PERF	PERFORATE(D)
PERIM	PERIMETER
PH	PHASE
PHAR	PHARMACY
PI	POINT OF INTERSECTION
PIPU	PREFAB ISOLATION POWER UNIT
PIV	POST INDICATING VALVE
PL	PLATE
PL	PROPERTY LINE
PLAM	PLASTIC LAMINATE
PLAS	PLASTER
PLAT	PLATFORM
PLBG	PLUMBING
PLF	POUNDS PER LINEAR FOOT
PLG	PILING
PL GL	PLATE GLASS
PLYWD	PLYWOOD
PNL	PANEL
PT	PAINT(ED)
POL	POLISHED
PORC	PORCELAIN
PORT	PORTABLE
PPGL	POLISHED PLATE GLASS
PPM	PARTS PER MILLION
PR	PAIR
PREFAB	PREFABRICATE(D)
PREFIN	PREFINISHED
PREFMD	PREFORMED
PRKG	PARKING
PROJ	PROJECT
PRV	PRESSURE-REGULATING VALVE
PS	PIPE SPACE
P.S.	PRESSED STEEL
PS CONC	PRESTRESSED CONCRETE
PSF	POUNDS PER SQUARE FOOT
PSI	POUNDS PER SQUARE INCH
PT	PNEUMATIC TUBE
PT.	POINT
PT CONC	POST-TENSIONED CONCRETE
PTD	PAPER TOWEL DISPENSER
PTN	PARTITION
PTR	PAPER TOWEL RECEPTACLE
PV	PAVED
PVC	POLYVINYL CHLORIDE
PVG	PAVING
PW	PASS WINDOW
QT	QUARRY TILE
QT.	QUART
QTR	QUARTER
1/4 RND	QUARTER ROUND
QTY	QUANTITY
R	RADIUS
R	RANGE
R	RISER
RA	RETURN AIR
RAB	RABBETED
RA GR	RETURN AIR GRILLE
RAR	RETURN AIR REGISTER
RB	RUBBER BASE, RESILIENT BASE
RBL	RUBBLE STONE
RBR	RUBBER
RC	REMOTE CONTROL
RCP	REINFORCED CONCRETE PIPE
RCVR	RECEIVER
RD	ROOF DRAIN
RDG INS	RIGID INSULATION
RECPT	RECEPTACLE
REC ROOM	RECREATION ROOM
RECT	RECTIFIER
REF	REFERENCE
REFL	REFLECT
REFR	REFRIGERATION
REG	REGISTER
REG	REGLET
REINF	REINFORCE
REM	REMOVE(ABLE)
REQD	REQUIRED
RESIL	RESILIENT
RET	RETURN
REV	REVISION
RFG	ROOFING
RH	RELATIVE HUMIDITY
RH	RIGHT HAND
RH	ROOF HATCH
RK	RACK
RLG	RAILING
RM	ROOM
RND	ROUND
RO	ROUGH OPENING
ROW	RIGHT OF WAY
RP	RETRACTABLE PARTITION
RPM	REVOLUTIONS PER MINUTE
RPRT	RAISED PATTERN RUBBER TILE
RTF	RUBBER TILE FLOOR
RVS	REVERSE
RVT	RIVET
RWC	RAINWATER CONDUCTOR
S	SOUTH
SA	SUPPLY AIR
SB	SPLASH BLOCK
S.B.	SECURITY BARS
SC	SOLID CORE
SCHED	SCHEDULE
SCRN	SCREEN
SCT	STRUCTURAL CLAY TILE
SD	STORM DRAIN
SDI	STEEL DOOR INSTITUTE
SECT	SECTION
SEQ	SEQUENCE
SFGL	SAFETY GLASS
SFTU	STRUCTURAL FACING TILE UNIT
SFU	STRUCTURAL FACING UNIT
SG	SHEET GLASS
SHLDR	SHOULDER
SHT	SHEET
SHTHG	SHEATHING
SHV	SHELVING
SIM	SIMILAR
SJI	STEEL JOIST INSTITUTE
SKLT	SKYLIGHT
SLNT	SEALANT
SLV	SLEEVE
SM	SHEET METAL
SMS	SHEET METAL SCREWS
SOV	SHUT OFF VALVE
SPC	SPACER
SPCL	SPECIAL
SPD	SOUNDPROOF DOOR
SPEC	SPECIFICATION
SPF	SOUNDPROOF
SP FIN	SPECIAL FINISH
SPH	SPACE HEATER
SPKR	SPEAKER
SQ	SQUARE
SQHD	SQUARE HEAD
S&R	SHELF AND ROD
SS	SERVICE SINK
SS	STANDING SEAM (ROOF)
SST	STAINLESS STEEL
STA	STATION
STD	STANDARD
STG	SEATING
STL	STEEL
STOR	STORAGE
ST PR	STATIC PRESSURE
STR	STRINGER
STRUCT	STRUCTURAL
STWY	STAIRWAY
SUB FL	SUBFLOOR
SUSP	SUSPENDED
SV	SHEET VINYL
SW	SWITCH
SWBD	SWITCHBOARD
SYMM	SYMMETRICAL
SYNTH	SYNTHETIC
SYS	SYSTEM
T	TREAD
TAN	TANGENT
TB	TOWEL BAR
TC	TERRA COTTA
TEL	TELEPHONE
TEMP	TEMPERATURE
TEMP	TEMPORARY
TER	TERRAZZO
TERM	TERMINAL
T&G	TONGUE AND GROOVE
TGL	TOGGLE
TH	TRUSS HEAD
THK	THICK(NESS)
THRES	THRESHOLD
TK BD	TACKBOARD
TKS	TACK STRIP
TO	TOP OF
TOL	TOLERANCE
TOPO	TOPOGRAPHY
TOS	TOP OF SLAB
TOS	TOP OF STEEL
TOW	TOP OF WALL
TPD	TOILET PAPER DISPENSER
TPTN	TOILET PARTITION
TRANS	TRANSOM
TRANS	TRANSVERSE
TSTAT	THERMOSTAT
TV	TELEVISION
TYP	TYPICAL
UC	UNIT COOLER
UGND	UNDERGROUND
UH	UNIT HEATER
UL	UNDERWRITERS LABORATORIES
UNEX	UNEXCAVATED
UNFIN	UNFINISHED
UPS	UNINTERRUPTABLE POWER SUPPLY
URINAL	URINAL
UTIL	UTILITY
UV	UNIT VENTILATOR
V	VOLT
VAR	VARNISH
VB	VINYL BASE
VCT	VINYL COMPOSITION TILE
VCT	VITRIFIED CLAY TILE
VD	VAULT DOOR
VENT	VENTILATOR(TION)
VERT	VERTICAL
VEST	VESTIBULE
VF	VINYL FABRIC
VG	VERTICAL GRAIN
VH	VINYL HOMOGENEOUS
VJ	V-JOINT(ED)
VNR	VENEER
VOL	VOLUME
VR	VAPOR RETARDER
VRM	VERMICULITE
VS	VENT STACK
V.T.	VOLTAGE TRANSFORMER
VTR	VENT THRU ROOF
VWC	VINYL WALL COVERING
W	WEST
W/	WITH
WB	WET BULB
WBL	WOOD BLOCKING
WC	WATER CLOSET
WC	WHEELCHAIR
WCO	WOOD-CASED OPENING
WD	WOOD
WD	WOOD DOOR
WDSP	WASTE DISPOSER
WDW	WINDOW
WF	WIDE FLANGE
WGL	WIRED GLASS
WH	WALL HUNG
WH	WATER HEATER
WHB	WHEEL BUMPER
WHM	WATT-HOUR METER
WI	WROUGHT IRON
WKSH	WORK SHOP
WM	WIRE MESH
W/O	WITHOUT
WP	WATERPROOF(ING)
WP	WEATHERPROOF
WP	WORKING POINT
WR	WASTE RECEPTACLE
WRB	WARDROBE
WS	WATERSTOP
W.S.	WASTE STACK
WSCT	WAINSCOT
WT	WEIGHT
WTH	WIDTH
WW	WALL TO WALL
WWF	WELDED WIRE FABRIC
WWM	WELDED WIRE MESH
WWR	WELDED WIRE REINFORCEMENT
XFMR	TRANSFORMER
YD	YARD
YD	YARD DRAIN

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MARK	DESCRIPTION	DATE

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DESIGNED BY:	N. INGOLD
DRAWN BY:	N. INGOLD
CHECKED BY:	K. THEVERAPPERUMA
SUBMITTED BY:	N.INGOLD
SIZE:	ANSI D

ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN SOLICNUM
CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

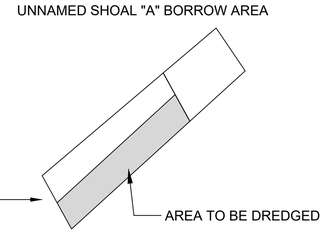
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

ABBREVIATIONS

SHEET ID
G-002





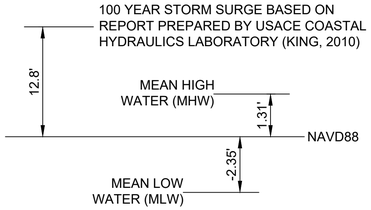
APPROXIMATELY 11 MILES OFFSHORE

E7 GENERAL OVERVIEW
1" = 5,000'

PLAN NORTH

GENERAL NOTES:

1. THE EXISTING UTILITIES AND OBSTRUCTIONS SHOWN ARE FROM THE BEST AVAILABLE RECORDS AND SHALL BE VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION.
2. NECESSARY PRECAUTIONS SHALL BE TAKEN BY THE CONTRACTOR TO PROTECT EXISTING SERVICES AND STRUCTURES. ANY DAMAGE TO THEM SHALL BE REPAIRED IMMEDIATELY AT THE CONTRACTOR'S EXPENSE.
3. TIDAL DATUM BASED ON USACE PROJECT *NASA-WALLOPS ISLAND BREAKWATER AND BEACHFILL PROJECT, 2018*
4. PUBLISHED MEAN TIDAL RANGE IS 3.66 FEET.
5. HORIZONTAL CONTROL: NORTH ATLANTIC DATUM OF 1983 (NAD83), VIRGINIA STATE PLANE, SOUTH
6. VERTICAL CONTROL: NORTH ATLANTIC VERTICAL DATUM OF 1988 (NAVD88)
7. PROPERTY LINES SHOWN ARE APPROXIMATE ONLY. THIS PLAN IS NOT INTENDED TO BE A PROPERTY LINE SURVEY.
8. DISTURBED AREAS WILL BE RESTORED TO A CONDITION EQUAL TO OR BETTER THAN FOUND. THIS INCLUDES THE TEMPORARY STAGING AREAS.
9. A LOW PROBABILITY EXISTS THAT MUNITIONS AND EXPLOSIVES OF CONCERN (MEC) COULD BE ENCOUNTERED AND AWARENESS TRAINING (PERFORMED BY NASA) IS REQUIRED PRIOR TO GRADING ACTIVITIES. IF ANY MEC IS ENCOUNTERED, STOP WORK, CLEAR THE AREA, AND CONTACT WALLOPS FLIGHT FACILITY PROTECTION SERVICES DIVISION AT 757-824-1333. SEE SPECIFICATIONS FOR DETAILS.
10. PROJECT AND BEACH AREA IS DYNAMIC IN NATURE DUE TO EROSIVE FORCES AND MAY NOT REPRESENT CURRENT CONDITIONS AT THE TIME OF CONSTRUCTION. SEE SPECIFICATIONS FOR PRE- AND POST-SURVEY REQUIREMENTS.



1983-2001 NTDE

TIDAL DATUM DIAGRAM

DATE: 06/12/2024
SCALE: NTS

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DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
DRAWN BY: N. INGOLD	SOLICITATION NO.: +AEC_MAN_SOLICNUM
CHECKED BY: K. THEVERAPPERUMA	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
	SIZE: ANSI D

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NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

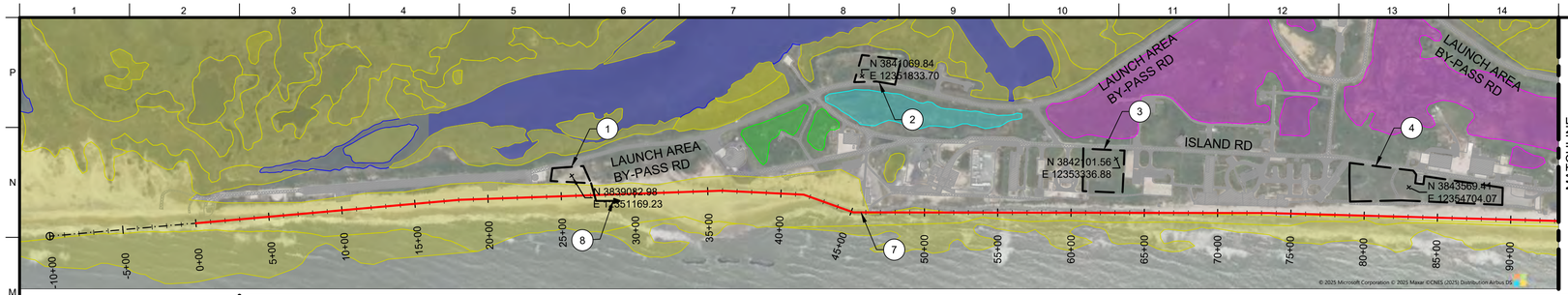
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WALLOPS ISLAND
SHORELINE PROJECTION PROJECT
BEACH RENOURISHMENT

GENERAL OVERVIEW

SHEET ID
G-003

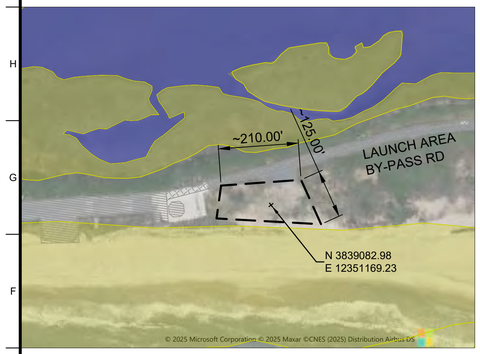
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L6 LAYDOWN AND STAGING AREA OVERVIEW
1" = 800'

PLAN NORTH



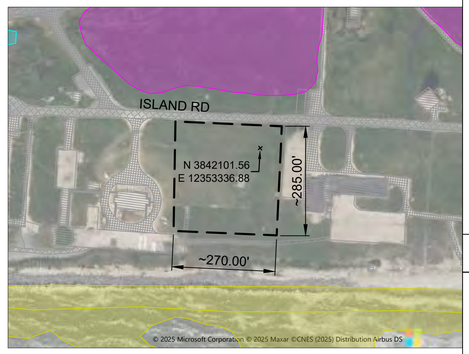
E1 LAYDOWN AREA 1
1" = 200'-0"

PLAN NORTH



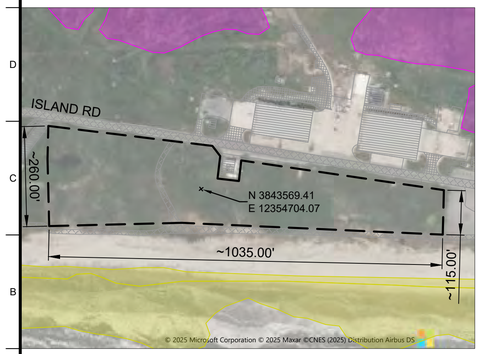
E7 LAYDOWN AREA 2
1" = 200'-0"

PLAN NORTH



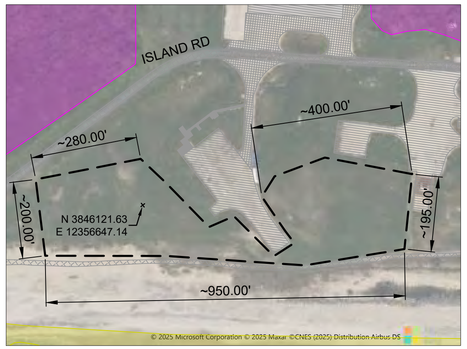
E13 LAYDOWN AREA 3
1" = 200'-0"

PLAN NORTH



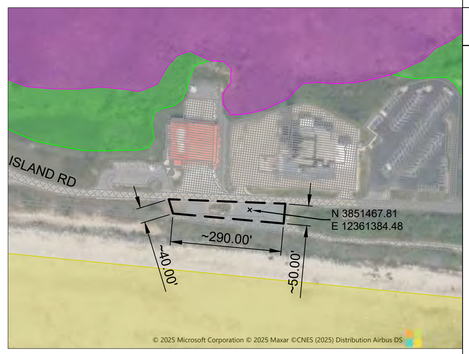
A1 LAYDOWN AREA 4
1" = 200'-0"

PLAN NORTH



A7 LAYDOWN AREA 5
1" = 200'-0"

PLAN NORTH



A13 LAYDOWN AREA 6
1" = 200'-0"

PLAN NORTH

GENERAL NOTES:

1. AREAS SHOWN ARE POTENTIAL LAYDOWN AND STAGING AREAS FOR THE CONTRACTOR TO USE. AREAS WILL BE DETERMINED AFTER CONTRACT AWARD AND APPROVED BY THE COR.
2. ALL AREA BOUNDARIES ARE APPROXIMATE.
3. LAYDOWN AND STAGING AREAS SHALL NOT IMPACT ANY WETLANDS.
4. OTHER NON-OCCUPIED UPLAND AREAS NOT IDENTIFIED ON THE PLANS MAY BE REQUESTED FOR LAYDOWN OR STAGING BY THE CONTRACTOR AND MUST BE APPROVED BY THE COR.
5. NO ADDITIONAL CLEARING OR EARTHWORK IS PERMITTED IN LAYDOWN OR STAGING AREAS.
6. LAYDOWN AND STAGING AREAS ARE TO HAVE THE APPROPRIATE EROSION AND SEDIMENT CONTROL MEASURES, PER THE LATEST EDITION OF THE VIRGINIA STORMWATER MANAGEMENT HANDBOOK.
7. INSTALL SAFETY FENCE (A2/C-501) AROUND THE PERIMETER OF ALL DESIGNATED LAYDOWN AND STAGING AREAS. INSTALL SILT FENCE (A17/C-501) AND STABILIZED CONSTRUCTION ENTRANCE (A9/C-501) AS A PRECAUTIONARY MEASURE.
8. LAYDOWN AND STAGING AREAS MUST BE RESTORED TO ORIGINAL CONDITION PRIOR TO COMPLETION OF CONSTRUCTION.
9. CONTRACTOR IS RESPONSIBLE FOR THE SAFETY AND SECURITY OF THEIR EQUIPMENT AND MATERIALS.
10. ALL EQUIPMENT AND MATERIALS MAY BE LEFT IN LAYDOWN AND STAGING AREAS DURING PRE-LAUNCH AND LAUNCH ACTIVITIES.
11. NASA HAZARDOUS OPERATIONS (HAZ OPS) MAY IMPACT ACCESS TO ALL LAYDOWN AREAS. DURING HAZ OPS, PORTIONS OF OR ENTIRE LAYDOWN AREAS MAY BE IMPACTED. DURING HAZ OPS, ALL MATERIALS AND EQUIPMENT MAY REMAIN IN AN AREA, HOWEVER PERSONNEL WILL BE REQUIRED TO LEAVE. LAYDOWN AREAS 1, 3, AND 4 WILL BE IMPACTED AT A HIGHER RATE THAN OTHER LAYDOWN AREAS.
12. SITE ACCESS TO THE PROJECT SITE IS SHOWN. OTHER ACCESS POINTS MAY OCCUR BETWEEN STA 0+00 AND STA 150+00 WITH APPROVAL FROM THE COR AND OWNER.
13. WETLAND AREAS SHOWN WERE OBTAINED FROM THE NATIONAL WETLAND INVENTORY ON NOVEMBER 2025.
14. SEE V-SHEETS FOR DETAILS OF EXISTING CONDITIONS AND SITE FEATURES.

KEYNOTES:

1. LAYDOWN AREA 1
2. LAYDOWN AREA 2
3. LAYDOWN AREA 3
4. LAYDOWN AREA 4
5. LAYDOWN AREA 5
6. LAYDOWN AREA 6
7. POTENTIAL SITE ACCESS BETWEEN STA 0+00 TO STA 150+00
8. SITE ACCESS POINTS

LEGEND

- ESTUARINE AND MARINE DEEPWATER
- ESTUARINE AND MARINE WETLAND
- FRESHWATER AND EMERGENT WETLAND
- FRESHWATER FORESTED AND SHRUB WETLAND
- FRESHWATER POND
- OTHER
- PROJECT ALIGNMENT BETWEEN STA 0+00 TO STA 150+00

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MARK	DESCRIPTION	DATE

ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN_SOLICNUM
CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 11196
DESIGNED BY: N. INGOLD
DRAWN BY: N. INGOLD
CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
SIZE: ANSI D

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NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

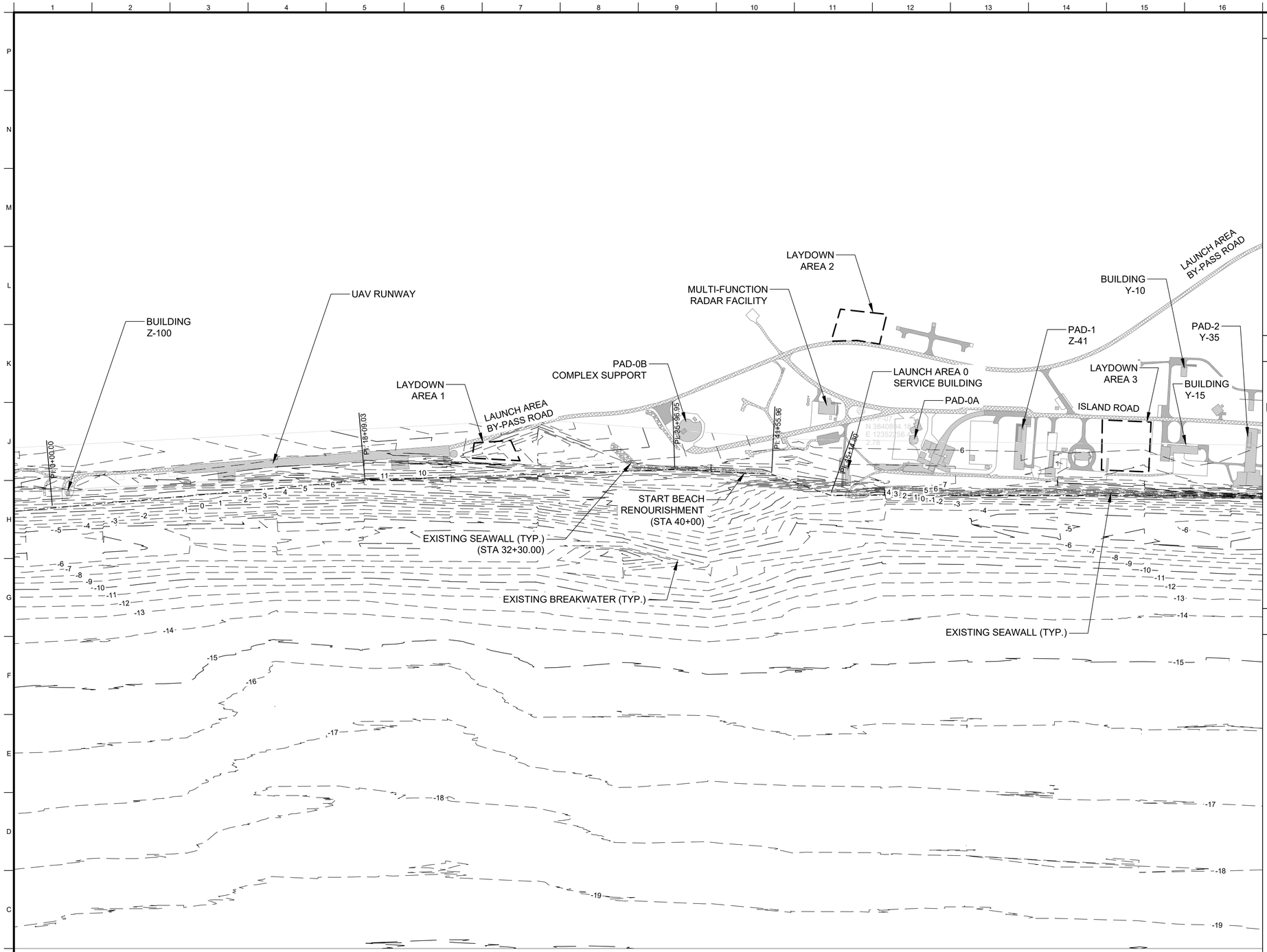
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

LAYDOWN AND STAGING AREAS

SHEET ID
G-004

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E4ECENWI



B7 EXISTING CONDITIONS
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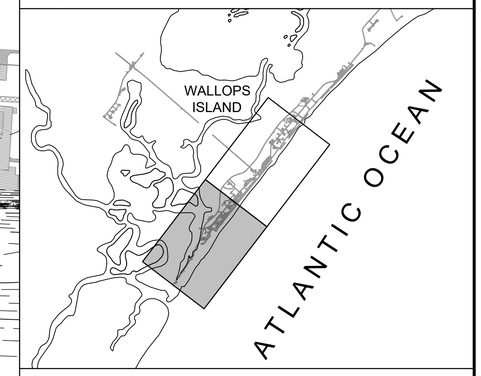
PLAN NORTH

300 0 300 600
SCALE IN FEET

GENERAL NOTES:

1. SURVEY NOTES:
   1.1. SURVEY PERFORMED BY GEODYNAMICS ON SEPTEMBER 9 TO 12, 2024 VIA SINGLEBEAM BATHYMETRIC AND TOPOGRAPHIC.
   1.2. HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
   1.3. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88), US FEET
   1.4. ADDITIONAL SURVEY WAS CONDUCTED BY NORFOLK DISTRICT IDENTIFY EXISTING SITE FEATURES AND EXISTING BREAKWATER ELEVATIONS. RTK TS SURVEY PERFORMED JUNE 2 TO 10, 2025 AND PROCESSED ON JUNE 26, 2025. CONTROL MONUMENT: WFF-09.
2. SITE ACCESS TO THE PROJECT SITE MAY OCCUR BETWEEN STA 0+00 AND STA 150+00 WITH APPROVAL FROM COR AND OWNER. SEE SHEET G-004 FOR ADDITIONAL DETAILS REGARDING PROJECT SITE ACCESS AND LAYDOWN AND STAGING AREAS.

KEY PLAN



LEGEND:

- 5 — EXISTING CONTOUR (MAJOR)
- 1 — EXISTING CONTOUR (MINOR)
- MHW — MEAN HIGH WATER (MHW) ELEVATION
- MLW — MEAN LOW WATER (MLW) ELEVATION
- LAYDOWN AREAS

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CHECKED BY: K. THEVERAPPERUMA	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
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NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

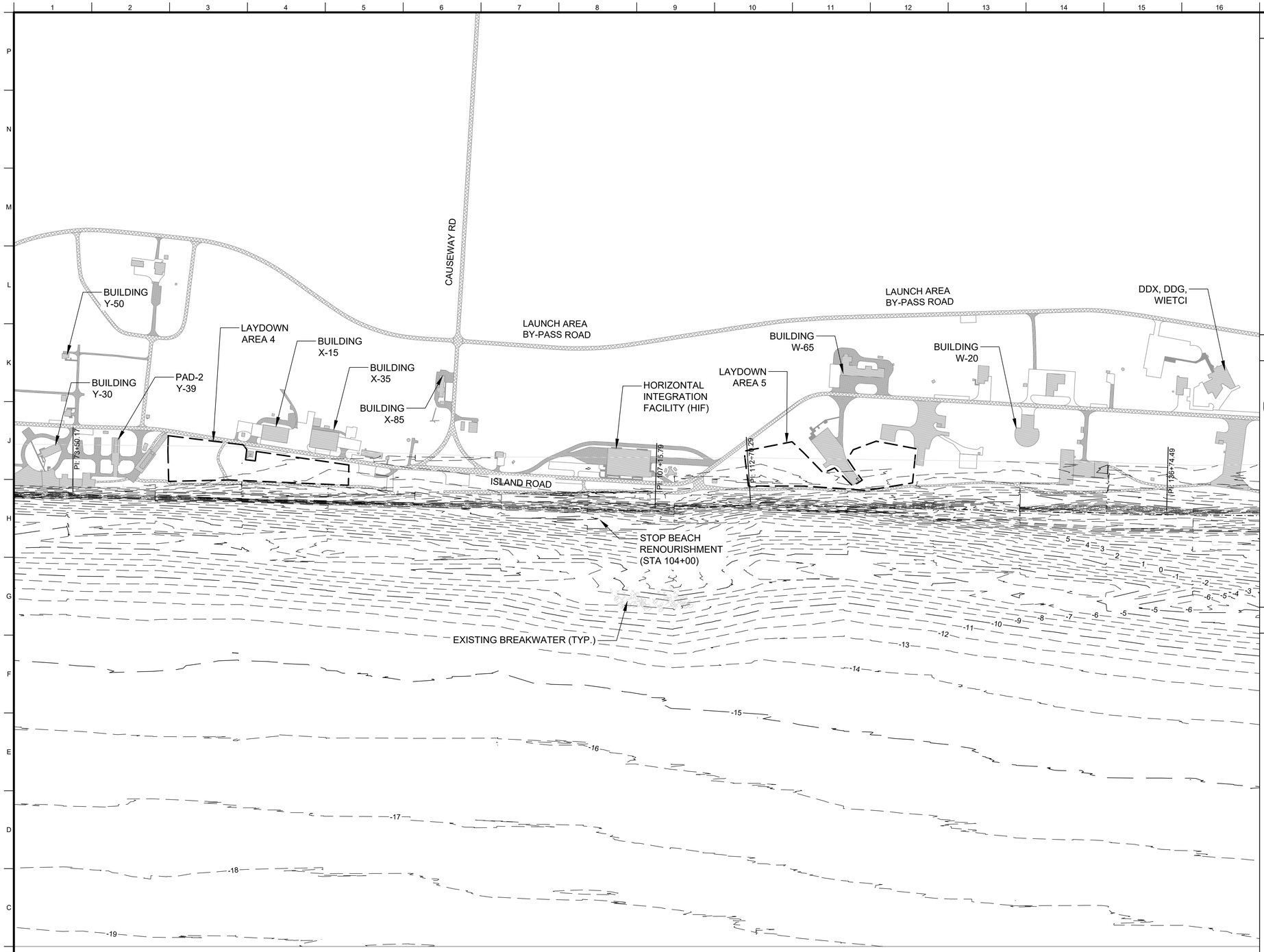
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

EXISTING CONDITIONS

SHEET ID
V-101

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AEC_B&W.STB
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B7 EXISTING CONDITIONS
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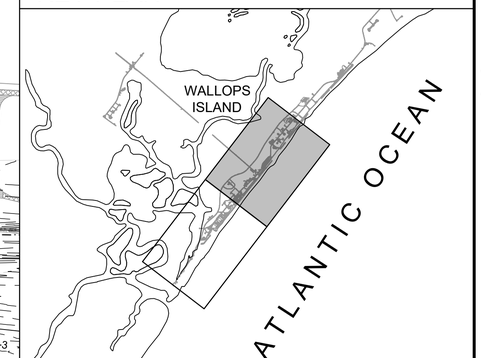
PLAN NORTH

300 0 300 600
SCALE IN FEET

GENERAL NOTES:

1. SURVEY NOTES:
   - 1.1. SURVEY PERFORMED BY GEODYNAMICS ON SEPTEMBER 9 TO 12, 2024 VIA SINGLEBEAM BATHYMETRIC AND TOPOGRAPHIC.
   - 1.2. HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
   - 1.3. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88), US FEET
   - 1.4. ADDITIONAL SURVEY WAS CONDUCTED BY NORFOLK DISTRICT IDENTIFY EXISTING SITE FEATURES AND EXISTING BREAKWATER ELEVATIONS. RTK TS SURVEY PERFORMED JUNE 2 TO 10, 2025 AND PROCESSED ON JUNE 26, 2025. CONTROL MONUMENT: WFF-09.
2. SITE ACCESS TO THE PROJECT SITE MAY OCCUR BETWEEN STA 0+00 AND STA 150+00 WITH APPROVAL FROM COR AND OWNER. SEE SHEET G-004 FOR ADDITIONAL DETAILS REGARDING PROJECT SITE ACCESS AND LAYDOWN AND STAGING AREAS.
3. LAYDOWN AREA 6 NOT SHOWN. SEE G-004 FOR MORE INFORMATION.

KEY PLAN



LEGEND:

- 5 — EXISTING CONTOUR (MAJOR)
- 1 — EXISTING CONTOUR (MINOR)
- MHW — MEAN HIGH WATER (MHW) ELEVATION
- MLW — MEAN LOW WATER (MLW) ELEVATION
- LAYDOWN AREAS

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
DRAWN BY: N. INGOLD	SOLICITATION NO.: +AEC_MAN_SOLICNUM
CHECKED BY: K. THEVERAPPERUMA	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
	SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

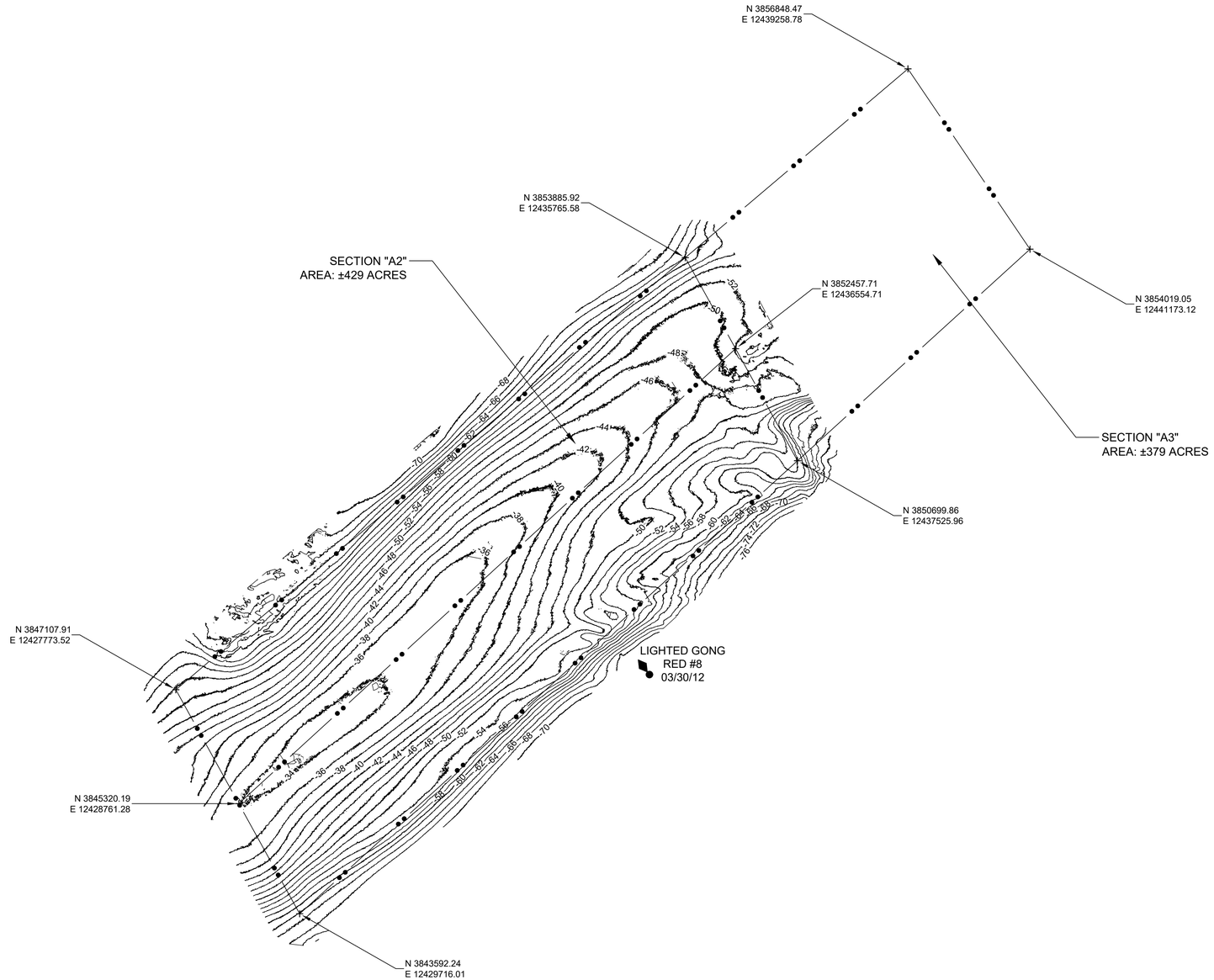
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

EXISTING CONDITIONS

SHEET ID
V-102

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B7 EXISTING CONDITIONS
SCALE: 1"=1,000'-0"

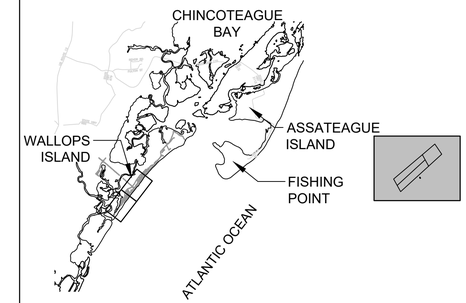
PLAN NORTH

1000 0 1000 2000
SCALE IN FEET

GENERAL NOTES:

1. SURVEY NOTES:
   - 1.1. SURVEY PERFORMED BY GEODYNAMICS ON OCTOBER 15 AND 23, 2024, VIA MULTIBEAM BATHYMETRIC (0.5 METER GRIDDED SURFACE)
   - 1.2. HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
   - 1.3. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88), US FEET
2. SURVEY WAS NOT CONDUCTED WITHIN SECTION "A3"

KEY PLAN



LEGEND:

- 10 — EXISTING CONTOUR (MAJOR)
- 2 — EXISTING CONTOUR (MINOR)
- •• — BORROW AREA BOUNDARY

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
DRAWN BY: N. INGOLD	SOLICITATION NO.: +AEC_MAN_SOLICNUM
CHECKED BY: K. THEVERAPPERUMA	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

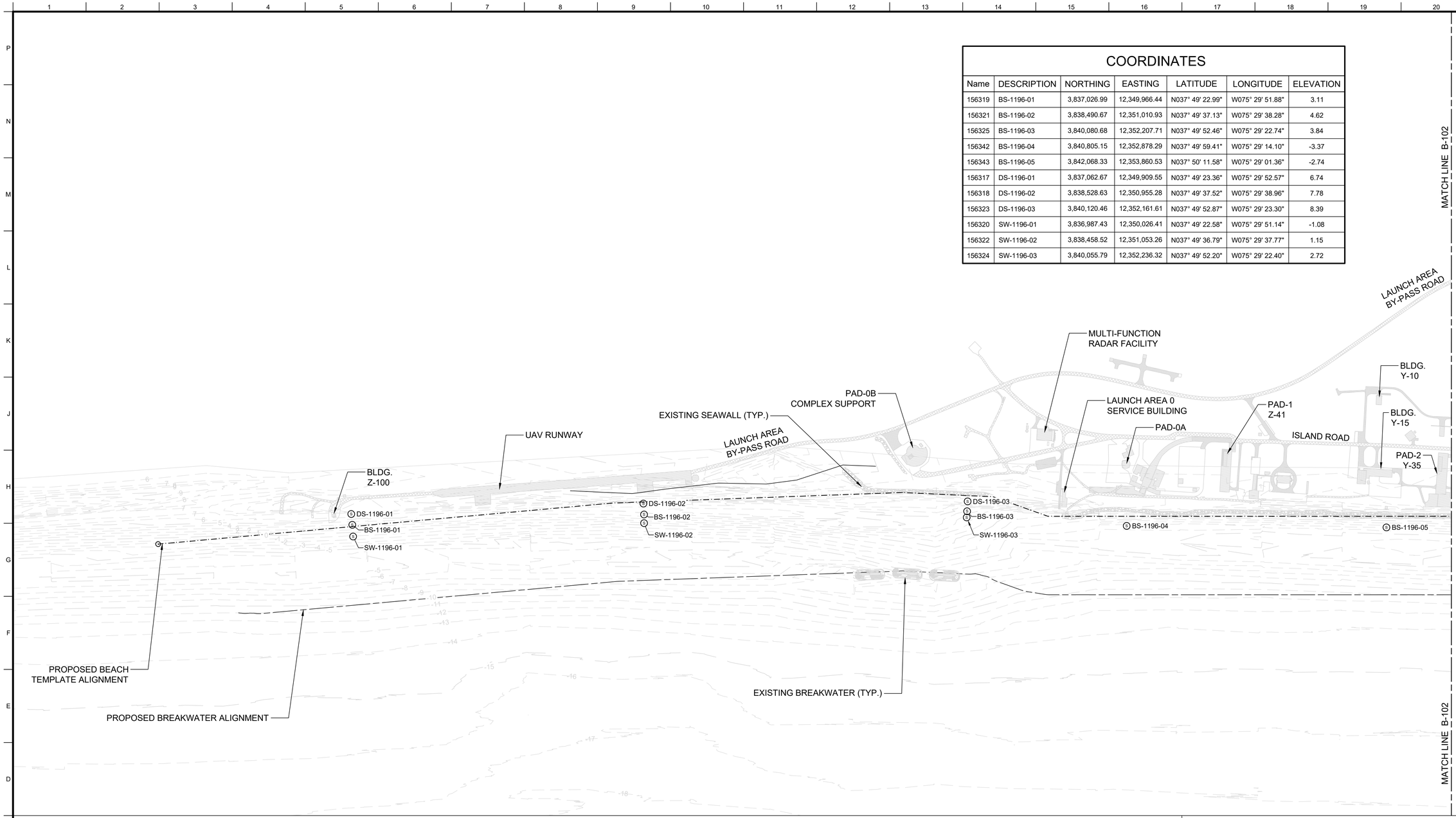
EXISTING CONDITIONS
BORROW AREA

SHEET ID
V-103

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COORDINATES

Name	DESCRIPTION	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEVATION
156319	BS-1196-01	3,837,026.99	12,349,966.44	N037° 49' 22.99"	W075° 29' 51.88"	3.11
156321	BS-1196-02	3,838,490.67	12,351,010.93	N037° 49' 37.13"	W075° 29' 38.28"	4.62
156325	BS-1196-03	3,840,080.68	12,352,207.71	N037° 49' 52.46"	W075° 29' 22.74"	3.84
156342	BS-1196-04	3,840,805.15	12,352,878.29	N037° 49' 59.41"	W075° 29' 14.10"	-3.37
156343	BS-1196-05	3,842,068.33	12,353,860.53	N037° 50' 11.58"	W075° 29' 01.36"	-2.74
156317	DS-1196-01	3,837,062.67	12,349,909.55	N037° 49' 23.36"	W075° 29' 52.57"	6.74
156318	DS-1196-02	3,838,528.63	12,350,955.28	N037° 49' 37.52"	W075° 29' 38.96"	7.78
156323	DS-1196-03	3,840,120.46	12,352,161.61	N037° 49' 52.87"	W075° 29' 23.30"	8.39
156320	SW-1196-01	3,836,987.43	12,350,026.41	N037° 49' 22.58"	W075° 29' 51.14"	-1.08
156322	SW-1196-02	3,838,458.52	12,351,053.26	N037° 49' 36.79"	W075° 29' 37.77"	1.15
156324	SW-1196-03	3,840,055.79	12,352,236.32	N037° 49' 52.20"	W075° 29' 22.40"	2.72



C9 GEOTECHNICAL EXPLORATIONS

1" = 300'

0 300' 600'

PLAN NORTH

LEGEND:

⊙ GRAB SAMPLE

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: J. SPITZ	ISSUE DATE: MAR 2026
DRAWN BY: N. INGOLD	SOLICITATION NO.: +AEC_MAN_SOLICNUM
CHECKED BY: K. THEVERAPPERUMA	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
	SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

GEOTECHNICAL EXPLORATIONS

SHEET ID
B-101

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COORDINATES

Name	DESCRIPTION	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEVATION
156328	BS-1196-06	3,843,174.42	12,354,723.68	N037° 50' 22.24"	W075° 28' 50.16"	-0.95
156330	BS-1196-07	3,844,731.80	12,355,975.19	N037° 50' 37.23"	W075° 28' 33.95"	5.03
156333	BS-1196-08	3,846,299.41	12,357,220.66	N037° 50' 52.32"	W075° 28' 17.80"	3.32
156336	BS-1196-09	3,847,412.68	12,358,225.24	N037° 51' 03.00"	W075° 28' 04.84"	5.08
156339	BS-1196-10	3,848,579.48	12,359,173.16	N037° 51' 14.23"	W075° 27' 52.56"	6.11
156332	DS-1196-08	3,846,321.24	12,357,190.02	N037° 50' 52.55"	W075° 28' 18.18"	5.86
156335	DS-1196-09	3,847,480.63	12,358,142.29	N037° 51' 03.70"	W075° 28' 05.85"	13.43
156338	DS-1196-10	3,848,658.01	12,359,071.45	N037° 51' 15.04"	W075° 27' 53.80"	10.67
156331	SW-1196-07	3,844,684.44	12,356,037.03	N037° 50' 36.74"	W075° 28' 33.20"	0.78
156334	SW-1196-08	3,846,273.38	12,357,254.35	N037° 50' 52.06"	W075° 28' 17.39"	0.76
156337	SW-1196-09	3,847,374.06	12,358,272.41	N037° 51' 02.61"	W075° 28' 04.27"	2.65
156340	SW-1196-10	3,848,469.39	12,359,313.60	N037° 51' 13.10"	W075° 27' 50.85"	3.68

MATCHLINE B-101

LAUNCH AREA BY-PASS ROAD

CAUSEWAY RD

LAUNCH AREA BY-PASS ROAD

LAUNCH AREA BY-PASS ROAD

BLDG. Y-50

BLDG. Y-30

PAD-2 Y-39

BLDG. X-15

BLDG. X-35

BLDG. X-85

HORIZONTAL INTEGRATION FACILITY (HIF)

BLDG. W-65

BLDG. W-20

DDX, DDG, WIETCI

AEGIS ENGINEERING AND TRAINING COMPLEX

ISLAND ROAD

ISLAND ROAD

BS-1196-06

BS-1196-07

SW-1196-07

DS-1196-08

BS-1196-08

SW-1196-08

DS-1196-09

BS-1196-09

SW-1196-09

DS-1196-10

BS-1196-10

SW-1196-10

PROPOSED BEACH TEMPLATE ALIGNMENT

EXISTING BREAKWATER (TYP.)

PROPOSED BREAKWATER ALIGNMENT

MATCHLINE B-101

C9 GEOTECHNICAL EXPLORATIONS

1" = 300'

0 300' 600'

PLAN NORTH

LEGEND:

GRAB SAMPLE

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

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ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN_SOLICNUM
CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196

DESIGNED BY: J. SPITZ
DRAWN BY: N. INGOLD
CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

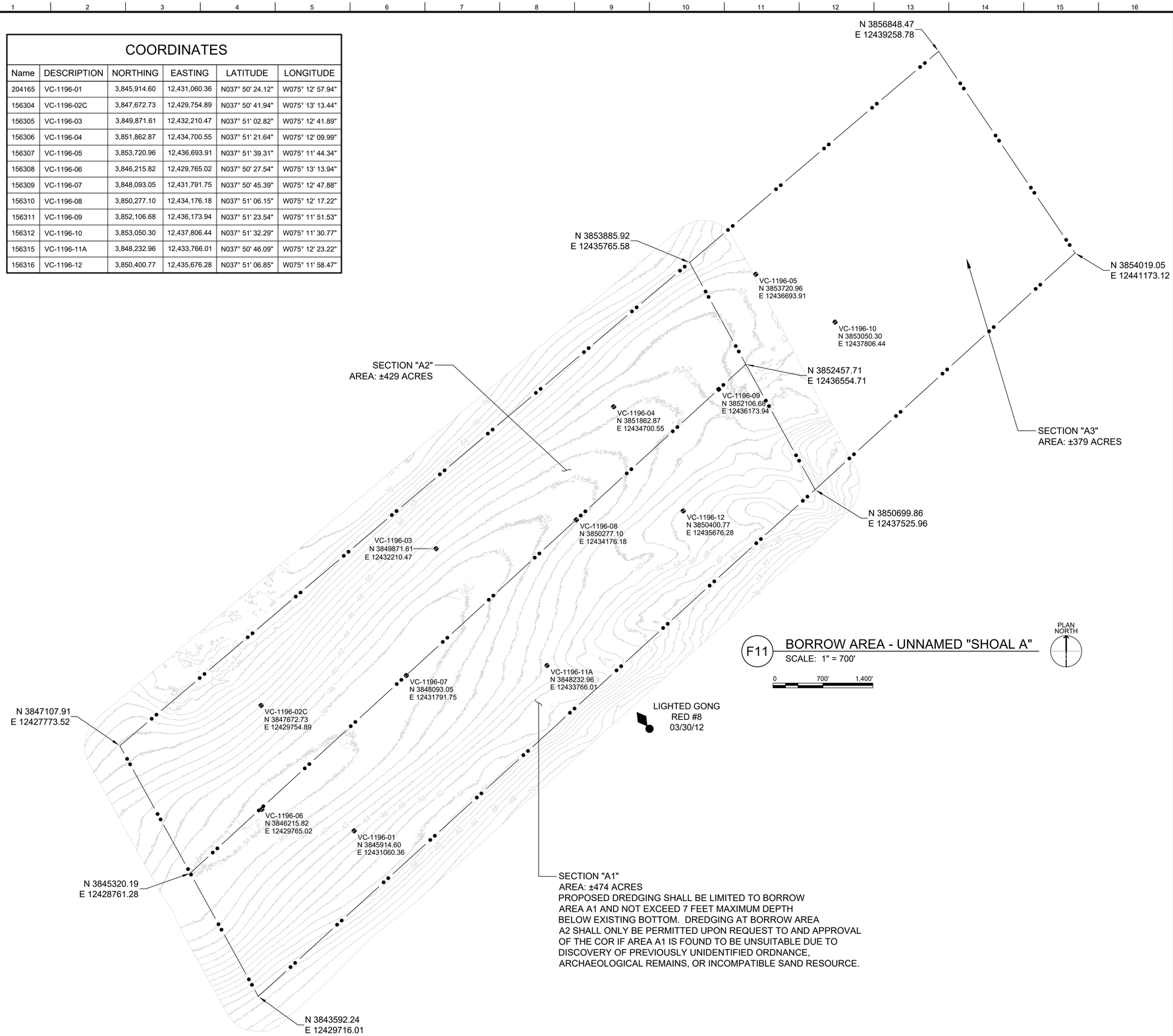
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

GEOTECHNICAL EXPLORATIONS

SHEET ID
B-102

COORDINATES

Name	DESCRIPTION	NORTHING	EASTING	LATITUDE	LONGITUDE
204165	VC-1196-01	3,845,914.60	12,431,060.36	N037° 50' 24.12"	W075° 12' 57.94"
156304	VC-1196-02C	3,847,672.73	12,429,754.89	N037° 50' 41.94"	W075° 13' 13.44"
156305	VC-1196-03	3,849,871.61	12,432,210.47	N037° 51' 02.82"	W075° 12' 41.89"
156306	VC-1196-04	3,851,862.87	12,434,700.55	N037° 51' 21.64"	W075° 12' 09.99"
156307	VC-1196-05	3,853,720.96	12,436,693.91	N037° 51' 39.31"	W075° 11' 44.34"
156308	VC-1196-06	3,846,215.82	12,429,765.02	N037° 50' 27.54"	W075° 13' 13.94"
156309	VC-1196-07	3,848,093.05	12,431,791.75	N037° 50' 45.39"	W075° 12' 47.88"
156310	VC-1196-08	3,850,277.10	12,434,176.18	N037° 51' 06.15"	W075° 12' 17.22"
156311	VC-1196-09	3,852,106.68	12,436,173.94	N037° 51' 23.54"	W075° 11' 51.53"
156312	VC-1196-10	3,853,050.30	12,437,806.44	N037° 51' 32.29"	W075° 11' 30.77"
156315	VC-1196-11A	3,848,232.96	12,433,766.01	N037° 50' 46.09"	W075° 12' 23.22"
156316	VC-1196-12	3,850,400.77	12,435,676.28	N037° 51' 06.85"	W075° 11' 58.47"



GENERAL NOTES:

1. VIBRACORE BORING SAMPLES WERE OBTAINED BY SCHNABEL ENGINEERING FROM AUGUST 17 TO 27, 2025.
2. SURVEY NOTES:
   - 2.1 SURVEY PERFORMED BY GEODYNAMIC ON OCTOBER 15 AND 23, 2024, VIA MULTIBEAM BATHYMETRIC (0.5 METER GRIDDED SURFACE)
   - 2.2 HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
   - 2.3 VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88), US FEET
   - 2.4 SURVEY WAS NOT CONDUCTED WITHIN SECTION "A3"

LEGEND:

- VIBRACORE SAMPLE LOCATION
- BORROW AREA BOUNDARY

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: J. SPITZ
DRAWN BY: N. INGOLD
CHECKED BY: R. WILLIAMS
SUBMITTED BY: N. INGOLD
SIZE: ANSI D

ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN_SOLICNUM
CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

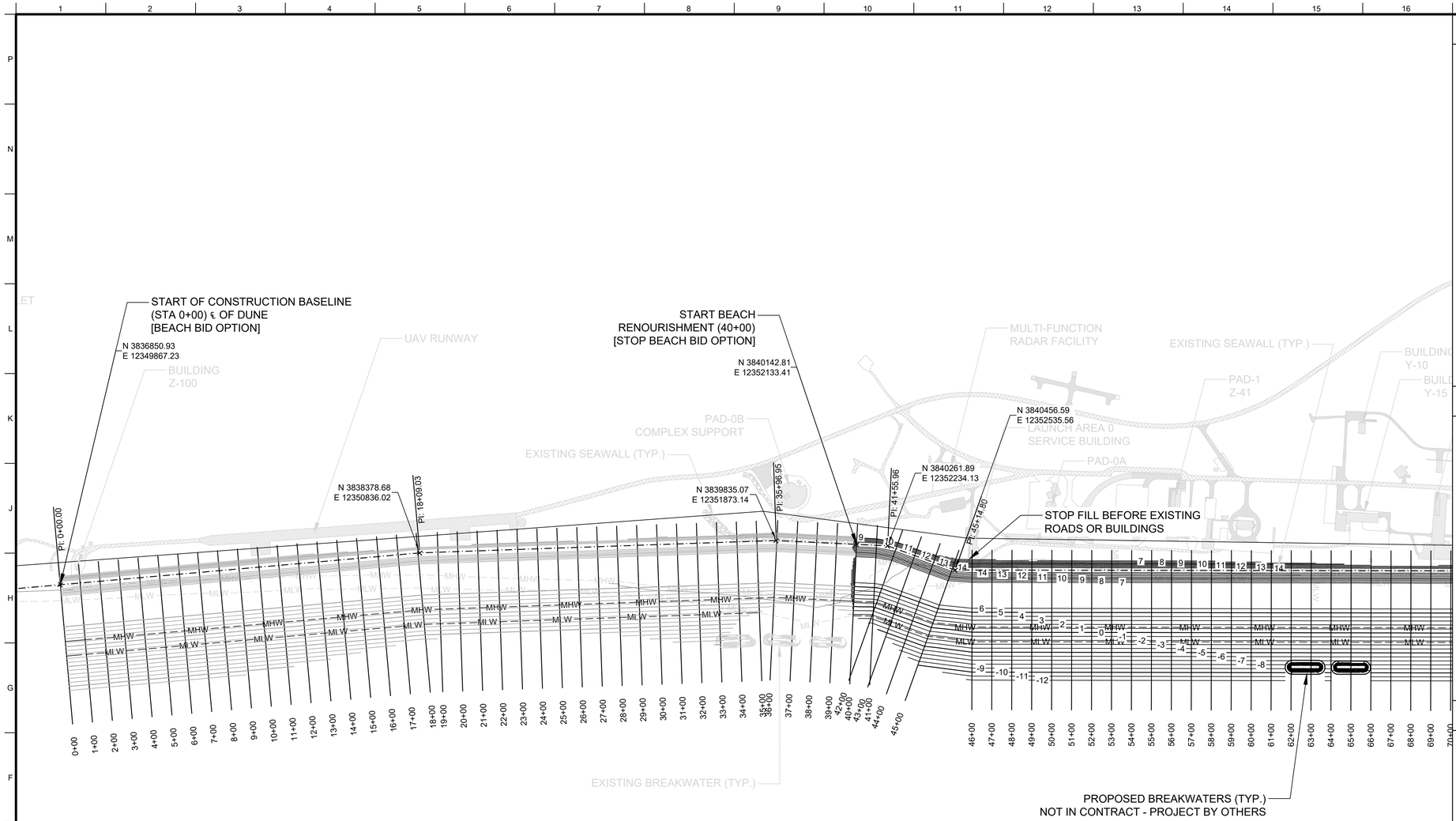
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

GEOTECHNICAL EXPLORATIONS
BORROW AREA

SHEET ID
B-103

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B7 SHORE PROTECTION
SCALE: 1"=300'-0"

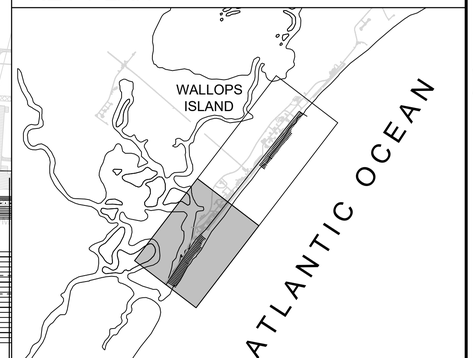
PLAN NORTH

300 0 300 600
SCALE IN FEET

GENERAL NOTES:

1. BEACH FILL TO BE PLACED BETWEEN STA 40+00 TO STA 104+00. SOUTH END BID OPTION IS PLACED BETWEEN STA 0+00 TO STA 40+00. NORTH END BEACH OPTION IS PLACED BETWEEN STA 104+00 TO STA 150+00.
2. GRADE 5H:1V ON SOUTH AND NORTH LIMITS FROM NEW BEACH FILL TO EXISTING GRADE
3. CONTRACTOR TO WORK AROUND EXISTING AND PROPOSED BREAKWATER CONSTRUCTION DURING BEACH FILL
4. STOP FILL AT LEAST 5 FEET BEFORE ALL EXISTING ROADS AND BUILDINGS, OR AS INDICATED BY THE CONTRACTING OFFICER.
5. CONTRACTOR WORK LIMITS BOUNDED BY PROPOSED WORK SHOWN AND CAN BE INDICATED BY THE CONTRACTING OFFICER.

KEY PLAN



LEGEND:

- EXISTING CONTOUR (MAJOR)
- EXISTING CONTOUR (MINOR)
- PROPOSED CONTOUR (MAJOR)
- PROPOSED CONTOUR (MINOR)
- MEAN HIGH WATER (MHW) ELEVATION
- MEAN LOW WATER (MLW) ELEVATION
- CONSTRUCTION BASELINE

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:	ISSUE DATE:
N. INGOLD	MAR 2026
DRAWN BY:	SOLICITATION NO.:
N. INGOLD	+AEC_MAN_SOLICNUM
CHECKED BY:	CONTRACT NO.:
R. WILLIAMS	+AEC_MAN_CONTRNUM
SUBMITTED BY:	NAO FILE NO.:
N. INGOLD	1196
SIZE:	ANSI D

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NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

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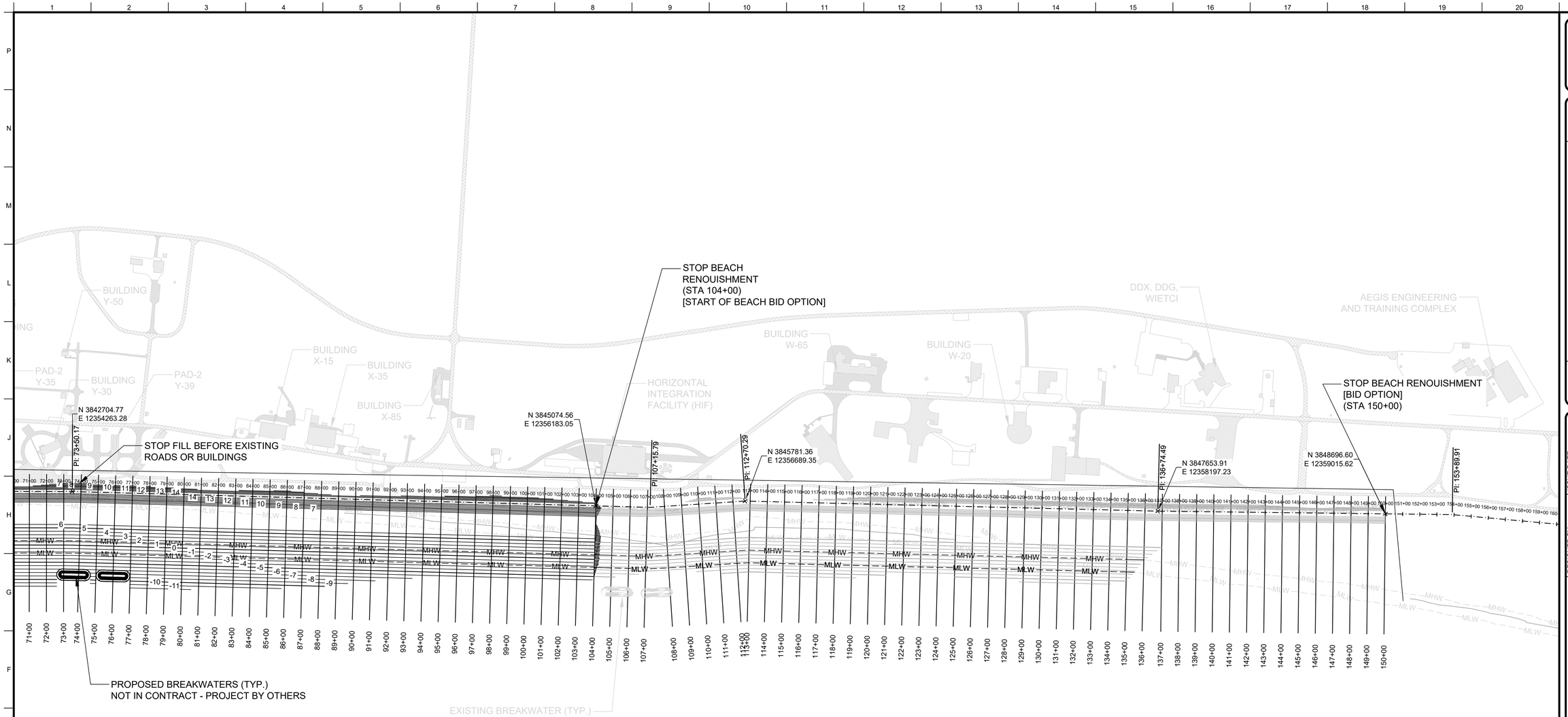
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

BEACH RENOURISHMENT
STA 0+00 TO STA 70+00

SHEET ID

CB101

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GENERAL NOTES:

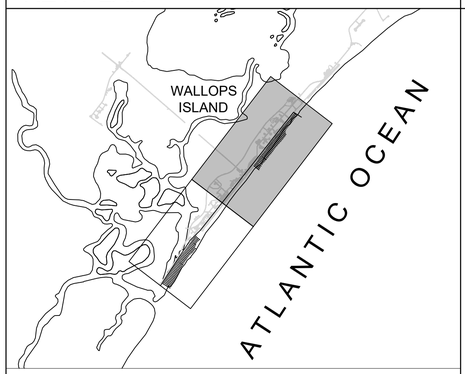
1. BEACH FILL TO BE PLACED BETWEEN STA 40+00 TO STA 104+00. SOUTH END BID OPTION IS PLACED BETWEEN STA 0+00 TO STA 40+00. NORTH END BEACH OPTION IS PLACED BETWEEN STA 104+00 TO STA 150+00.
2. GRADE 5H:1V ON SOUTH AND NORTH LIMITS FROM NEW BEACH FILL TO EXISTING GRADE
3. CONTRACTOR TO WORK AROUND EXISTING AND PROPOSED BREAKWATER CONSTRUCTION DURING BEACH FILL
4. STOP FILL AT LEAST 5 FEET BEFORE ALL EXISTING ROADS AND BUILDINGS, OR AS INDICATED BY THE CONTRACTING OFFICER.
5. CONTRACTOR WORK LIMITS BOUNDED BY PROPOSED WORK SHOWN AND CAN BE INDICATED BY THE CONTRACTING OFFICER.

D7 SHORE PROTECTION
SCALE: 1"=300'-0"

300 0 300 600
SCALE IN FEET

PLAN NORTH

KEY PLAN



LEGEND:

- EXISTING CONTOUR (MAJOR)
- EXISTING CONTOUR (MINOR)
- PROPOSED CONTOUR (MAJOR)
- PROPOSED CONTOUR (MINOR)
- MEAN HIGH WATER (MHW) ELEVATION
- MEAN LOW WATER (MLW) ELEVATION
- CONSTRUCTION BASELINE

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD
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CHECKED BY: R. WILLIAMS
ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN_SOLICNUM
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SUBMITTED BY: N INGOLD
NAO FILE NO.: 1196
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

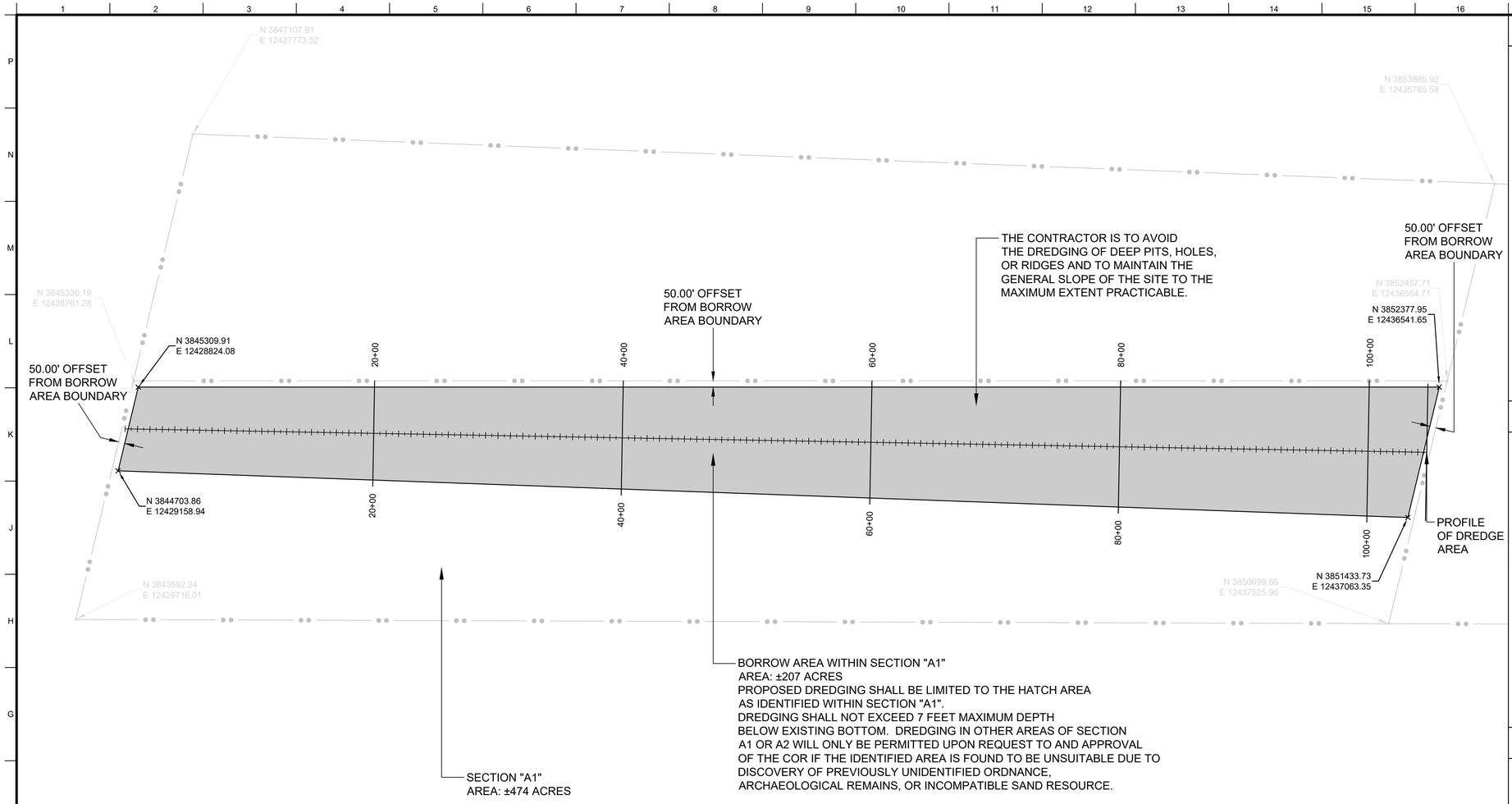
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

BEACH RENOURISHMENT
STA 70+00 TO STA 150+00

SHEET ID
CB102

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E4ECENWI



E7 EXISTING CONDITIONS
SCALE: 1"=1,000'-0"

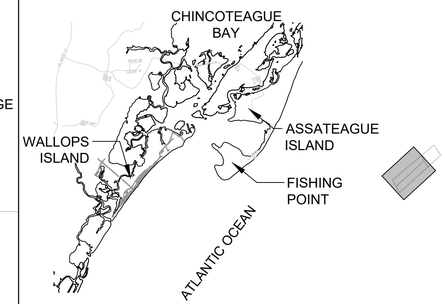
PLAN NORTH

500 0 500 1000
SCALE IN FEET

GENERAL NOTES:

1. DREDGE AREA BOUNDED BY COORDINATES SHOWN.
2. DREDGE AREA OFFSET 50 FEET FROM BOUNDARY.
3. DREDGING SHALL BE NO DEEPER THAN 7 FEET BELOW EXISTING GRADE.
4. SEE SHEET CN301 FOR PROFILE AND CROSS SECTIONS.
5. SURVEY NOTES:
   - 5.1. SURVEY PERFORMED BY GEODYNAMICS ON OCTOBER 15 AND 23, 2024, VIA MULTIBEAM BATHYMETRIC (0.5 METER GRIDDED SURFACE)
   - 5.2. HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
   - 5.3. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88), US FEET
6. SURVEY WAS NOT CONDUCTED WITHIN SECTION "A3"

KEY PLAN



LEGEND:

- EXISTING CONTOUR (MAJOR)
- EXISTING CONTOUR (MINOR)
- BORROW AREA BOUNDARY
- DREDGE AREA BOUNDARY
- DREDGE LIMITS OF BORROW AREA

MATERIAL VOLUME: DREDGE

STATION	AREA	VOLUME	CUMULATIVE VOLUME
0+00.00	1160.84	0.00	0.00
0+25.00	1965.78	1447.51	1447.51
0+50.00	2755.67	2185.86	3633.36
1+17.00	4609.67	9138.63	12771.99
5+00.00	4704.12	66058.71	78830.71
10+00.00	4835.14	88326.44	167157.15
15+00.00	4961.73	90711.75	257868.90
20+00.00	5089.09	93063.17	350932.07
25+00.00	5215.37	95411.63	446343.70
30+00.00	5341.59	97749.60	544093.30
35+00.00	5467.41	100083.31	644176.61
40+00.00	5591.64	102398.56	746575.17
45+00.00	5718.09	104719.69	851294.86
50+00.00	5845.53	107070.59	958365.46

MATERIAL VOLUME: DREDGE

STATION	AREA	VOLUME	CUMULATIVE VOLUME
55+00.00	5971.82	109419.92	1067785.38
60+00.00	6097.80	111755.72	1179541.10
65+00.00	6222.22	114074.25	1293615.35
70+00.00	6351.50	116423.27	1410038.62
75+00.00	6475.32	118766.80	1528805.42
80+00.00	6602.47	121090.62	1649896.04
85+00.00	6732.57	123472.56	1773368.60
90+00.00	6859.58	125853.20	1899221.80
95+00.00	6984.36	128184.65	2027406.45
100+00.00	7125.79	130649.53	2158055.98
103+12.05	7202.64	82799.63	2240855.61
104+46.47	3266.65	26061.78	2266917.39
104+71.36	2484.78	2650.70	2269568.09
104+71.47	2481.36	10.04	2269578.13

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
DRAWN BY: N. INGOLD	SOLICITATION NO.: +AEC_MAN_SOLICNUM
CHECKED BY: K. THEVERAPPERUMA	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
	SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

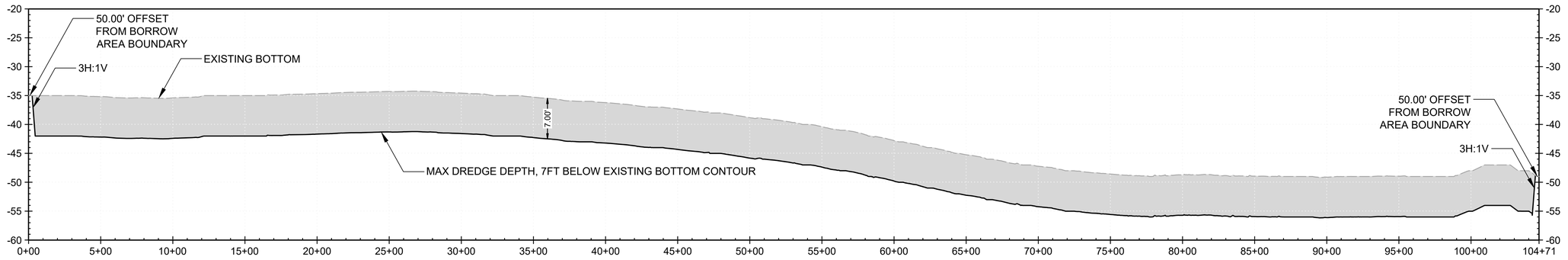
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

DREDGE AREA
BORROW AREA - SECTION A1

SHEET ID
CN101

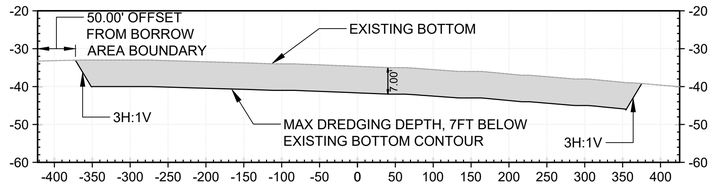
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AEC_B&W.STB
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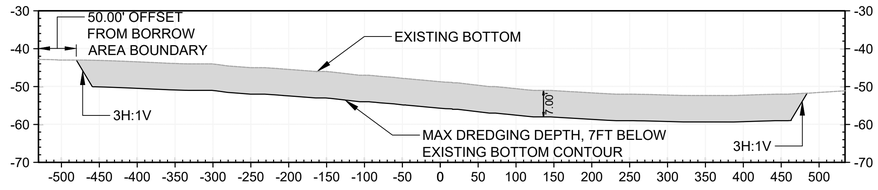
B9 PROFILE - DREDGE AREA

HORIZONTAL: 1" = 400'
400 0 400 800
SCALE IN FEET

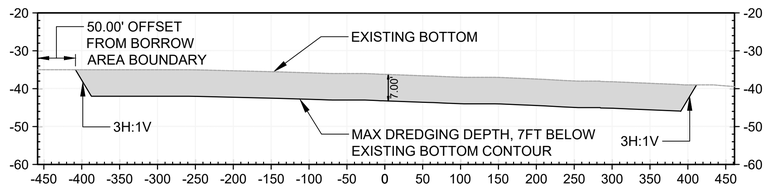
VERTICAL: 1" = 10'
10 0 10 20
SCALE IN FEET



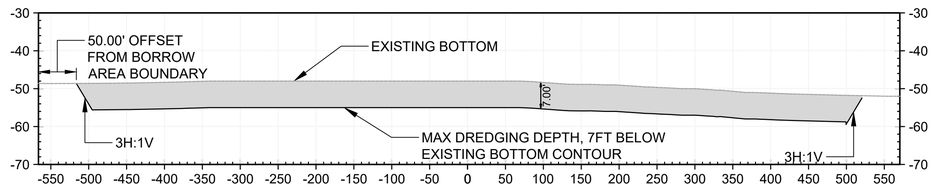
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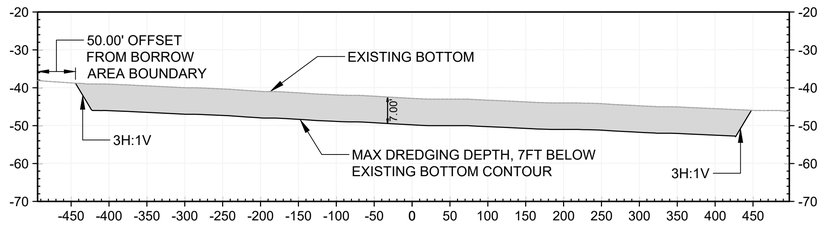
STA. 80+00



STA. 40+00



STA. 100+00



STA. 60+00

D12 CROSS SECTIONS - DREDGE AREA

HORIZONTAL: 1" = 100'
100 0 100 200
SCALE IN FEET

VERTICAL: 1" = 20'
20 0 20 40
SCALE IN FEET

NOTES:
1. SURVEY NOTES:
   - 1.1. SURVEY PERFORMED BY GEODYNAMICS ON OCTOBER 15 AND 23, 2024, VIA MULTIBEAM BATHYMETRIC (0.5 METER GRIDDED SURFACE)
   - 1.2. HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
   - 1.3. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88), US FEET
2. DREDGING SHALL NOT EXCEED 7 FEET MAXIMUM DEPTH BELOW EXISTING BOTTOM.

LEGEND:

- DREDGE AREA
- EXISTING BOTTOM
- MAXIMUM DREDGING DEPTH

US Army Corps of Engineers®

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ISSUE DATE: MAR 2026
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CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

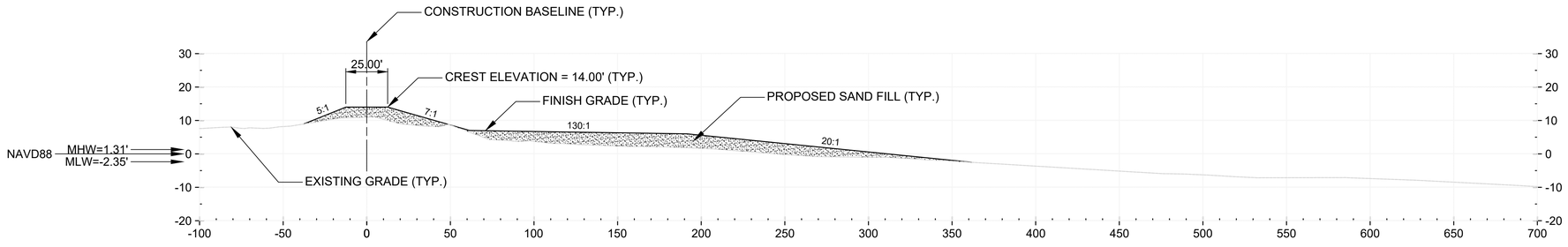
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

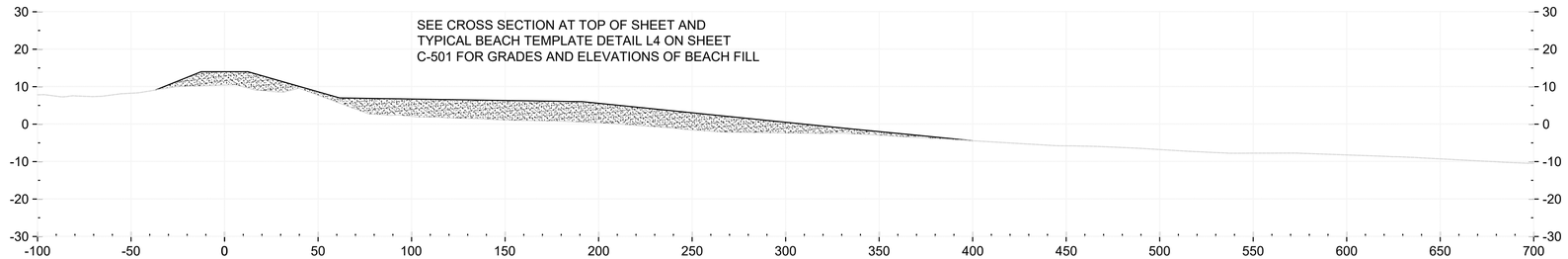
DREDGE AREA
PROFILE & CROSS SECTIONS

SHEET ID
CN301

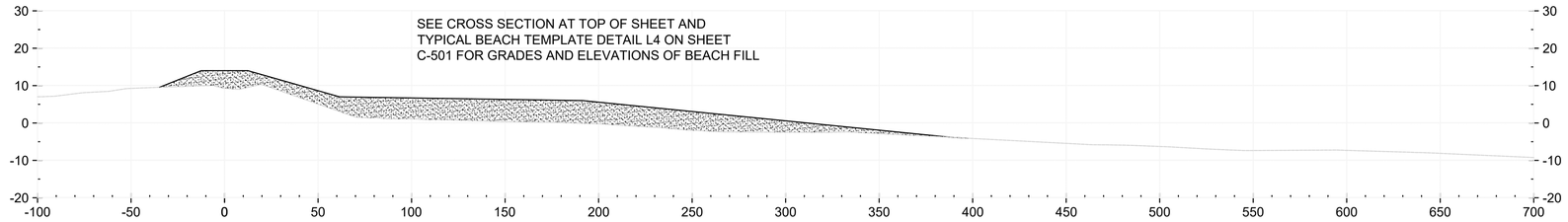
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E4ECENWI



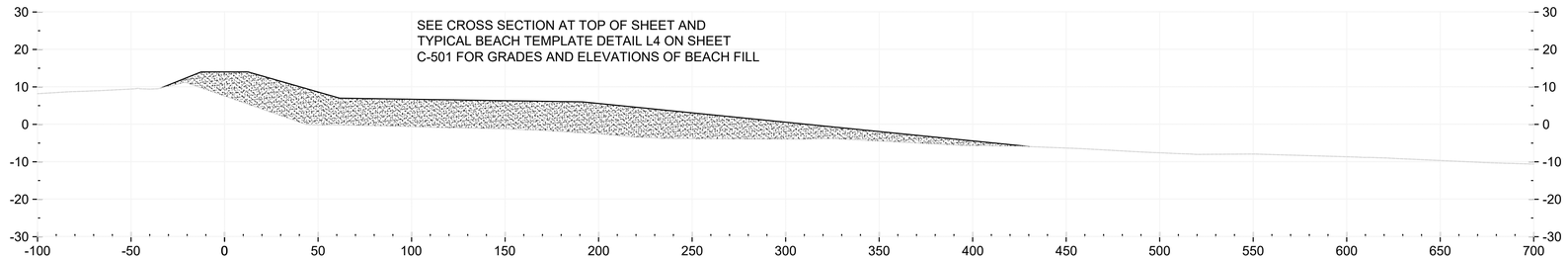
STA. 40+00



STA. 41+00



STA. 42+00



STA. 43+00

US Army Corps of Engineers®

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
	SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

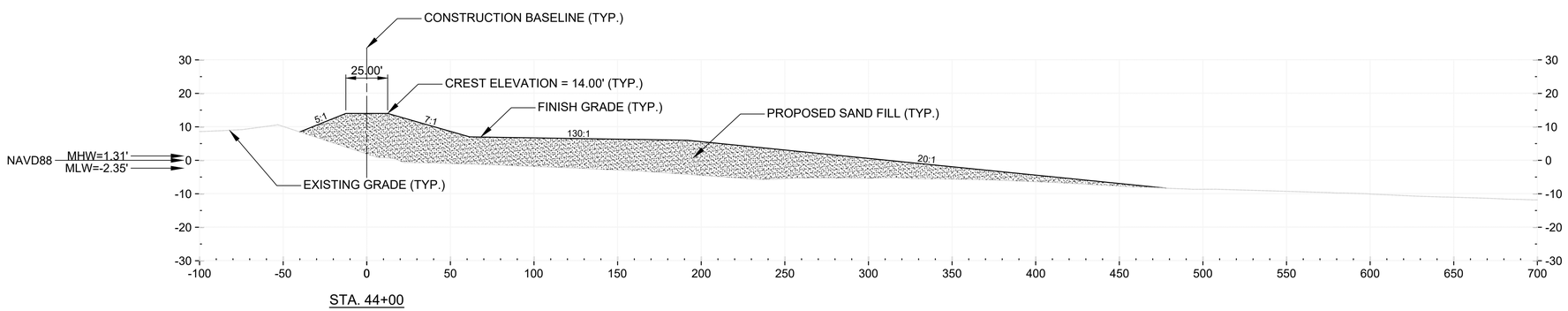
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

CROSS SECTIONS
STA 40+00 TO STA 43+00

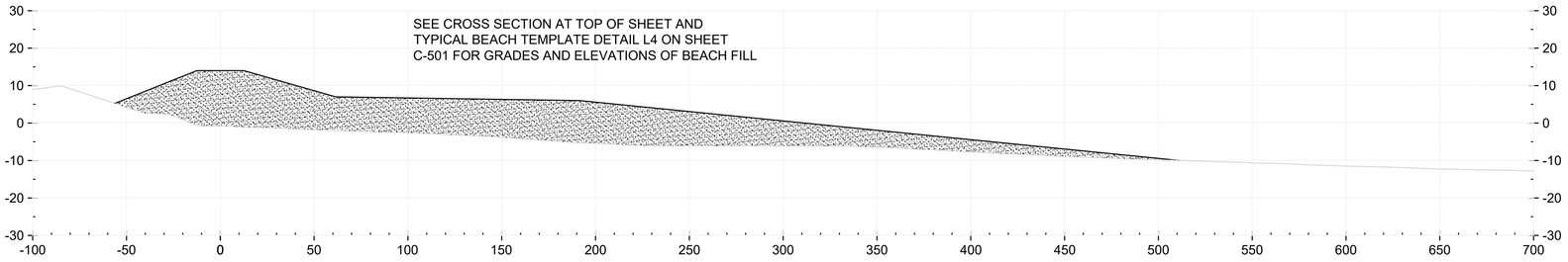
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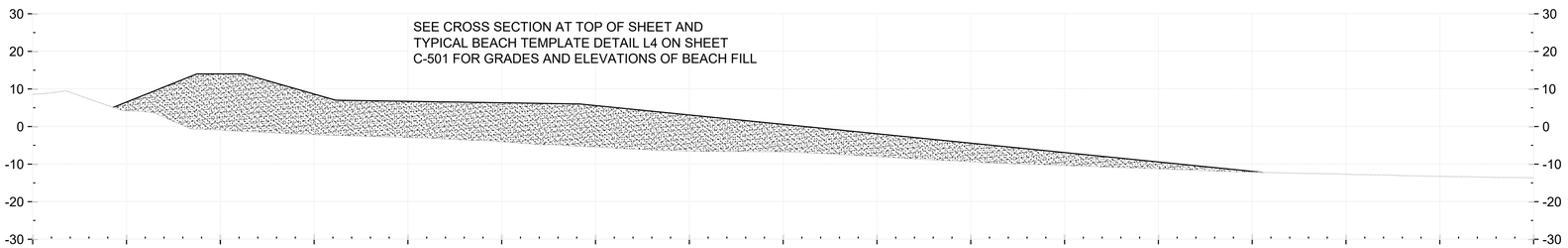
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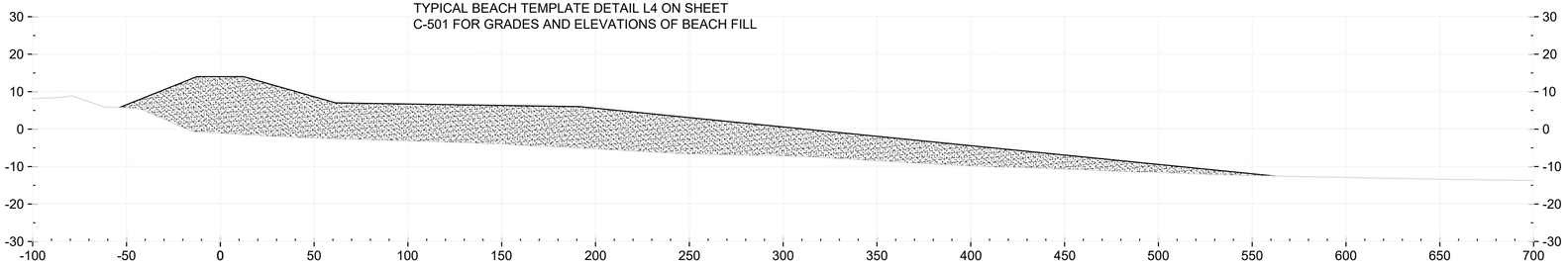
STA. 44+00



STA. 45+00



STA. 46+00



STA. 47+00

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

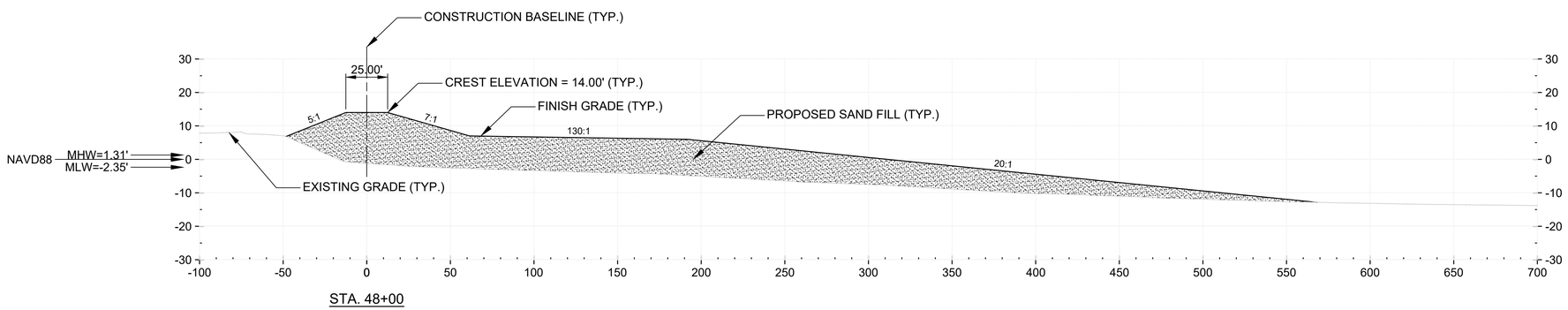
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

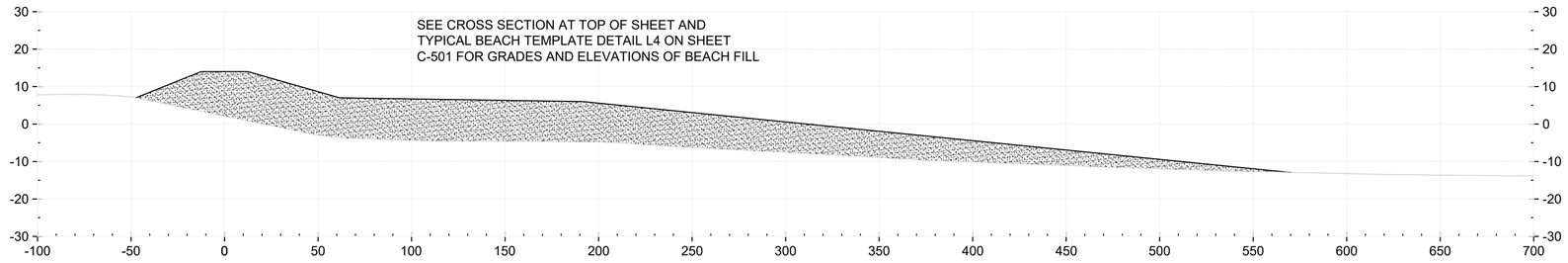
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SHEET ID
C-302

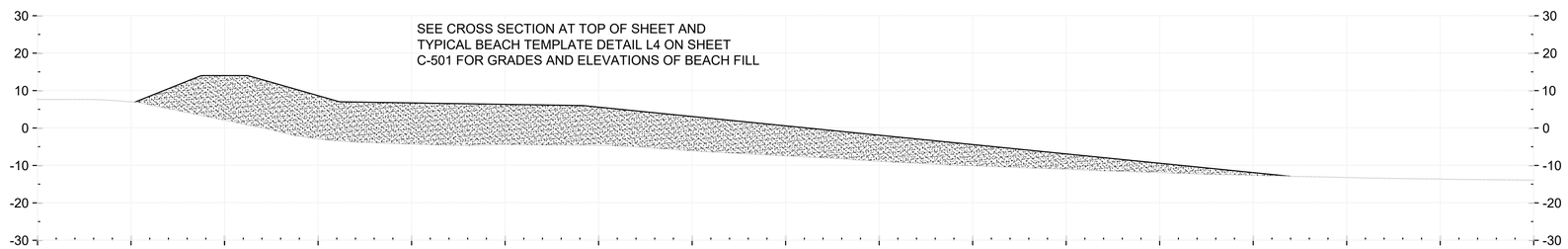
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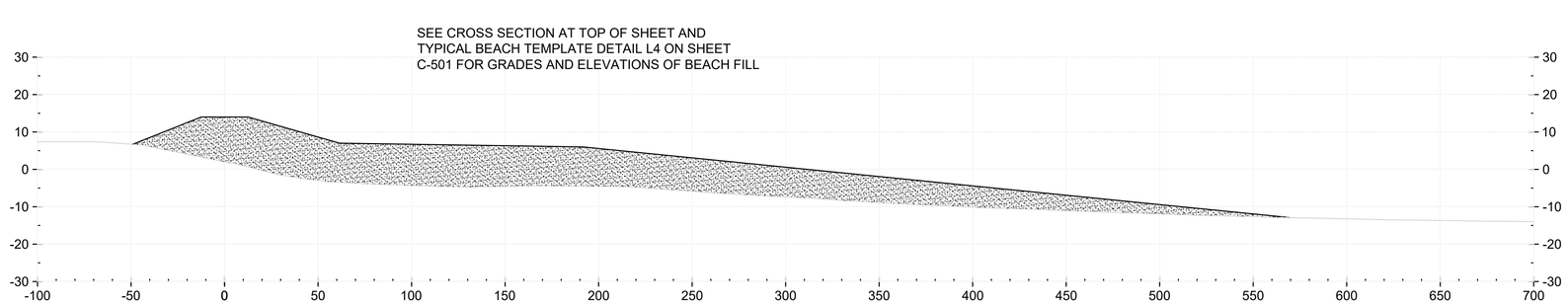
STA. 48+00



STA. 49+00



STA. 50+00



STA. 51+00

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE:	ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

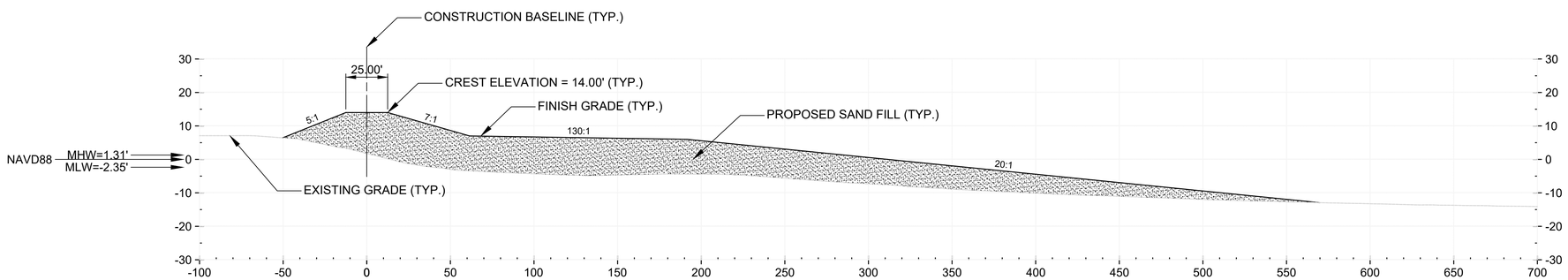
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

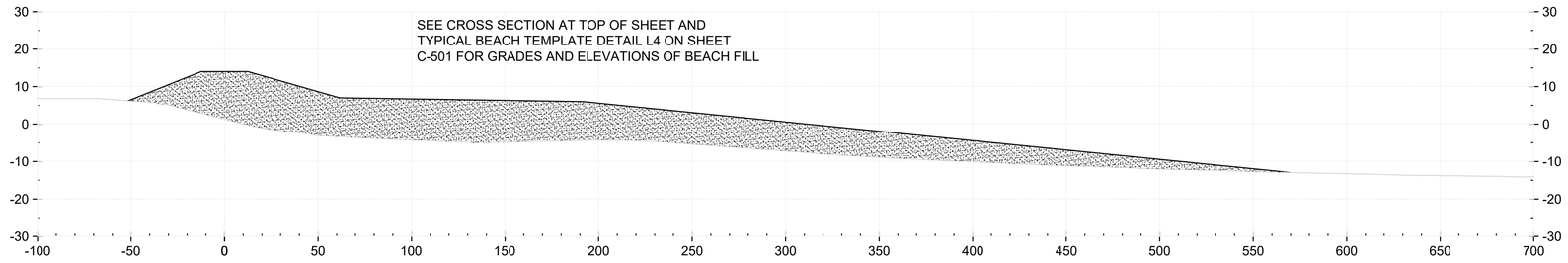
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SHEET ID
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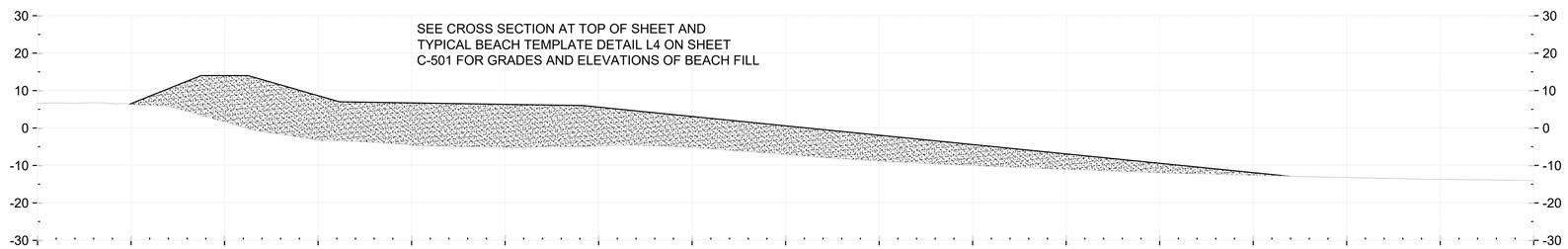
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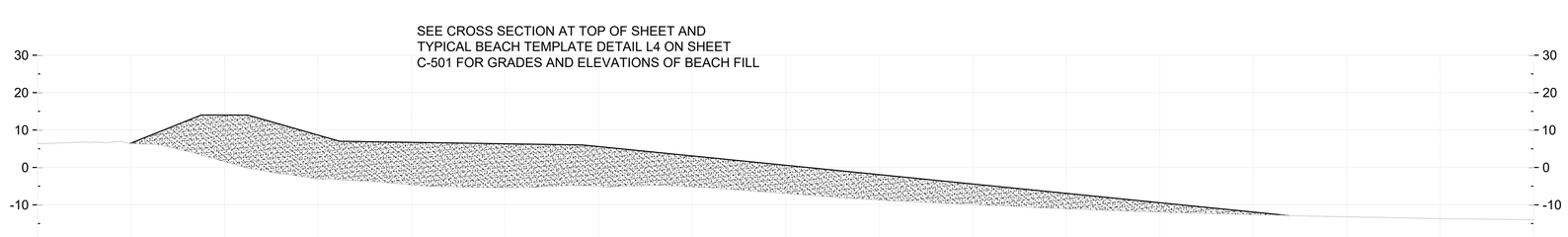
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STA. 53+00



STA. 54+00



STA. 55+00

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
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U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

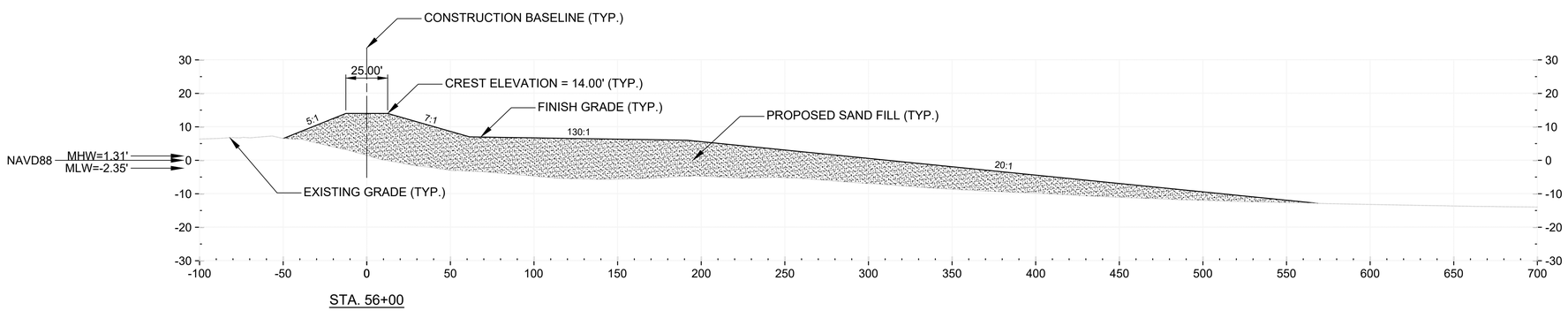
BCOES SUBMITTAL
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

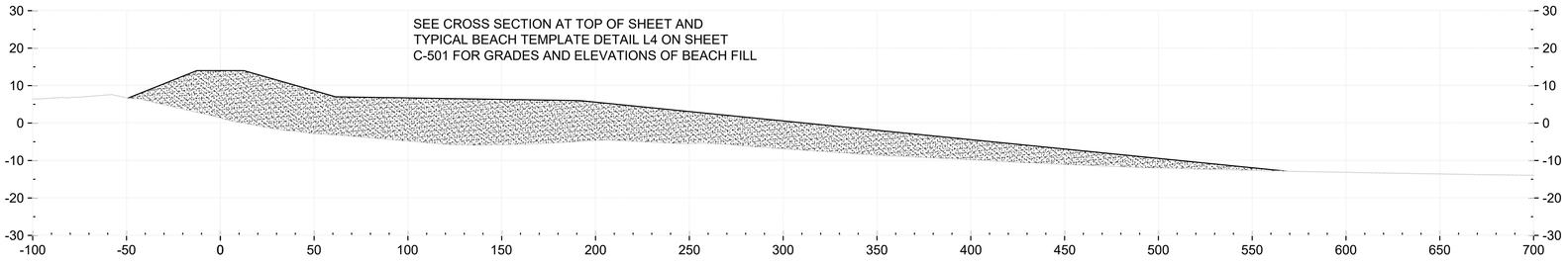
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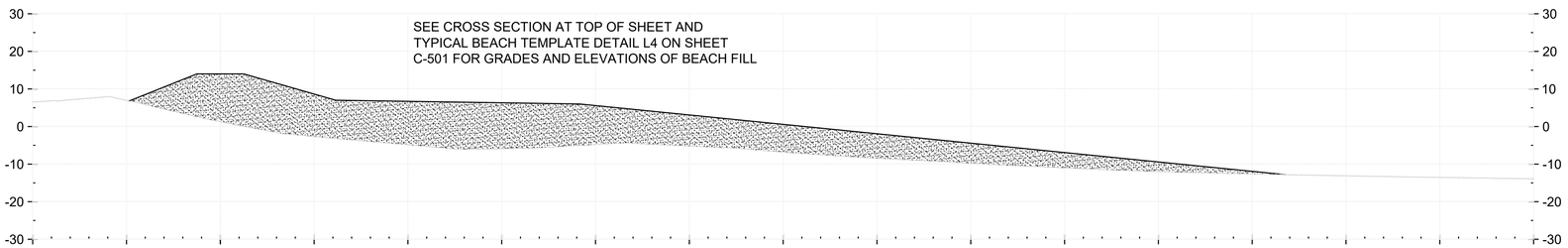
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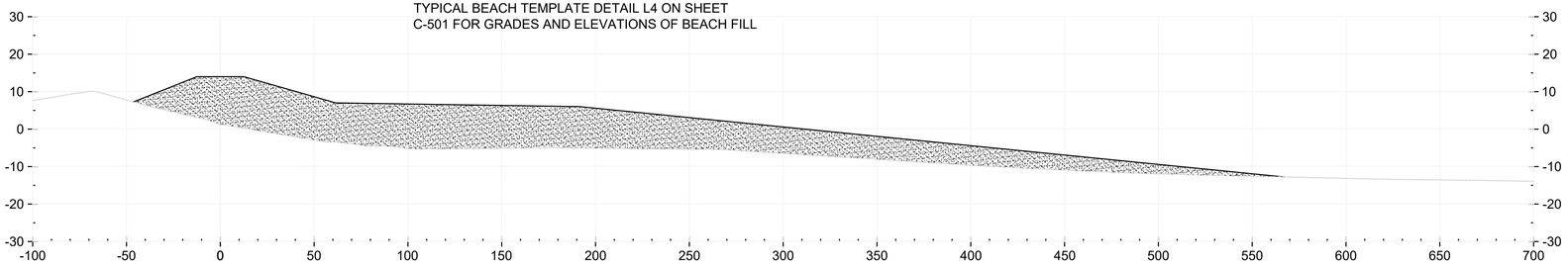
STA. 56+00



STA. 57+00



STA. 58+00



STA. 59+00

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

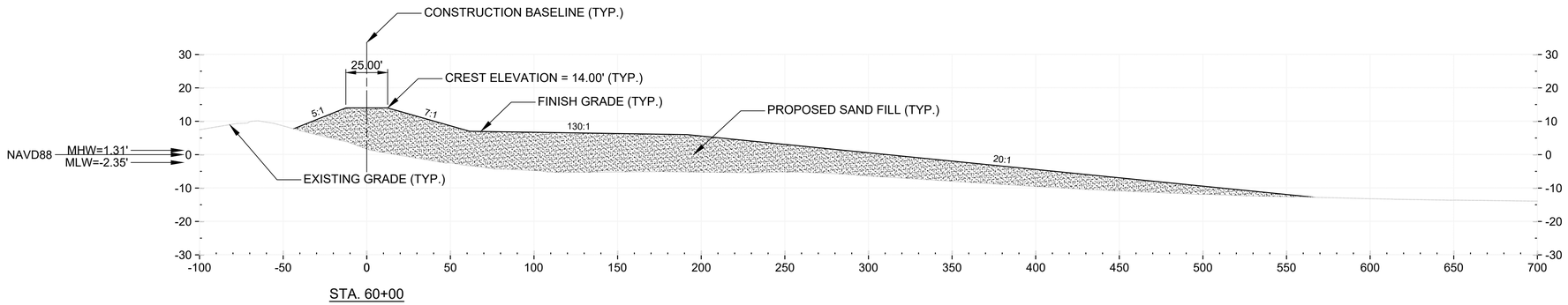
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

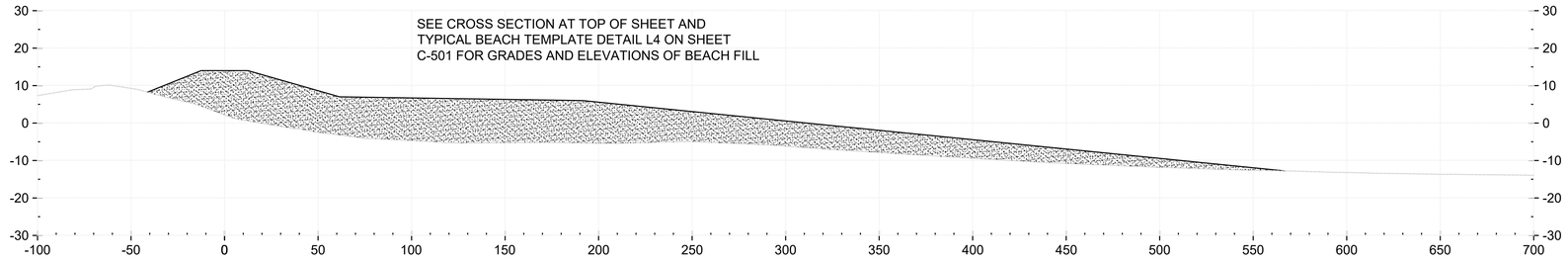
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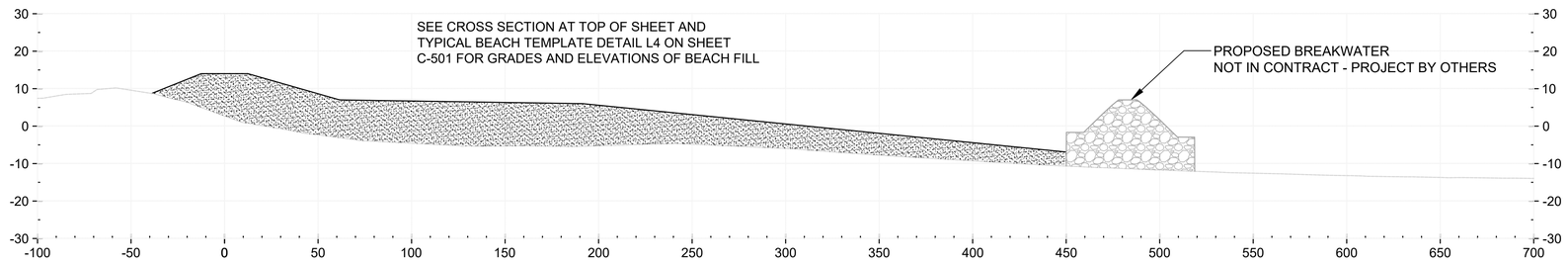
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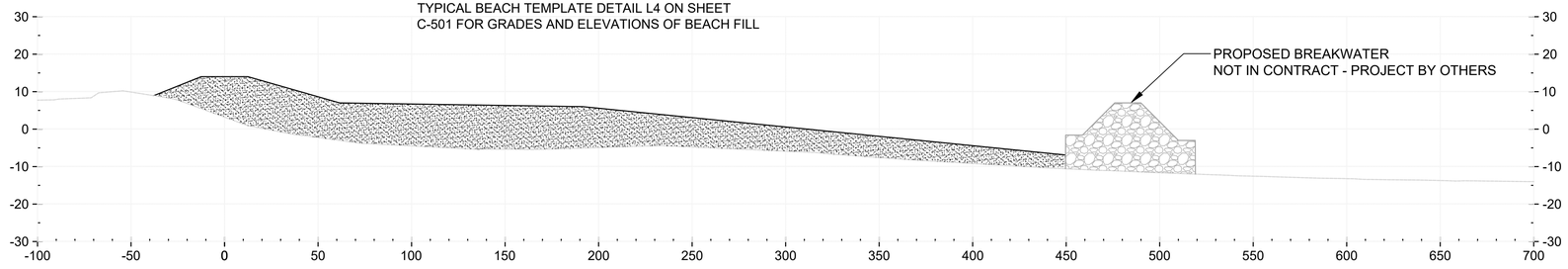
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STA. 61+00



STA. 62+00



STA. 63+00

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SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

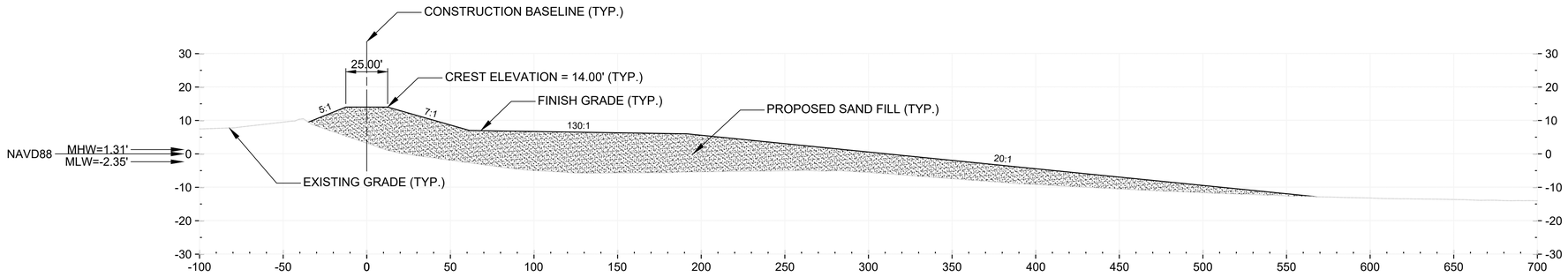
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

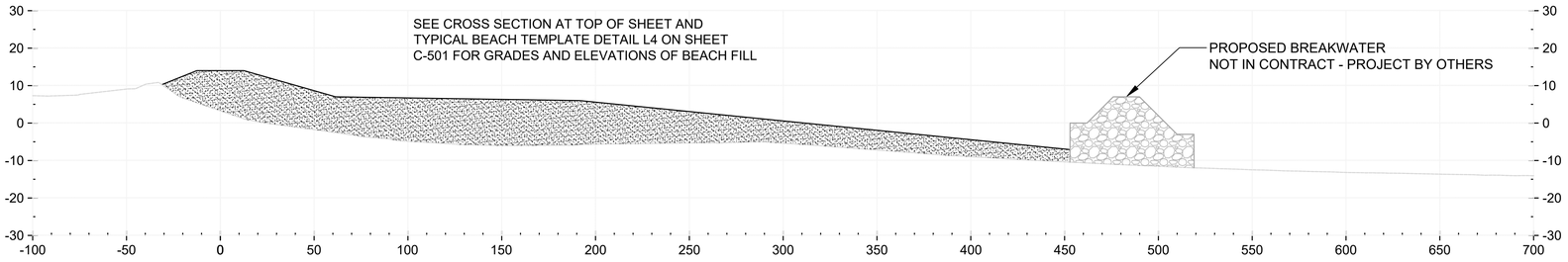
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SHEET ID
C-306

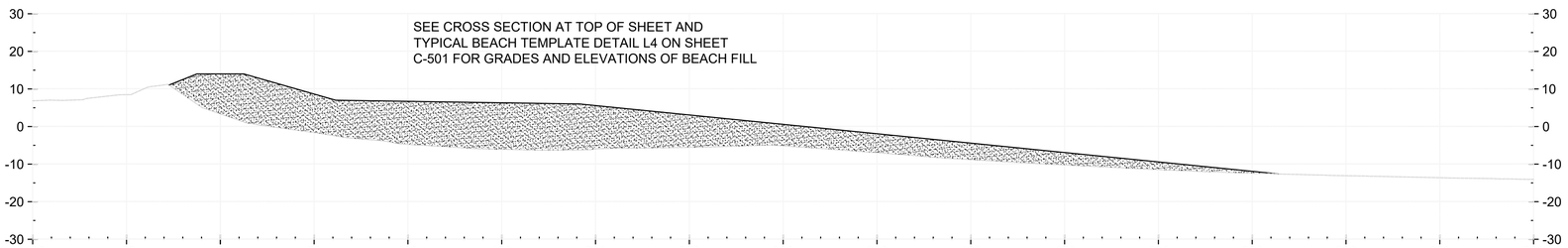
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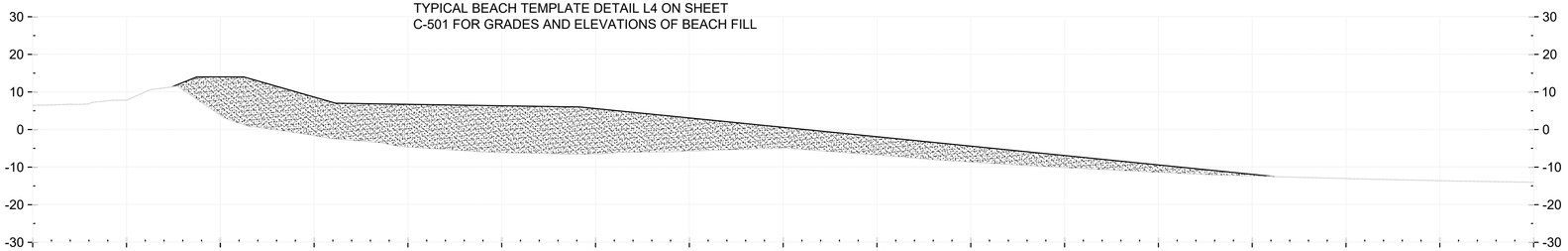
STA. 64+00



STA. 65+00



STA. 66+00



STA. 67+00

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
DRAWN BY: N. INGOLD	SOLICITATION NO.: +AEC_MAN_SOLICNUM
CHECKED BY: R. WILLIAMS	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

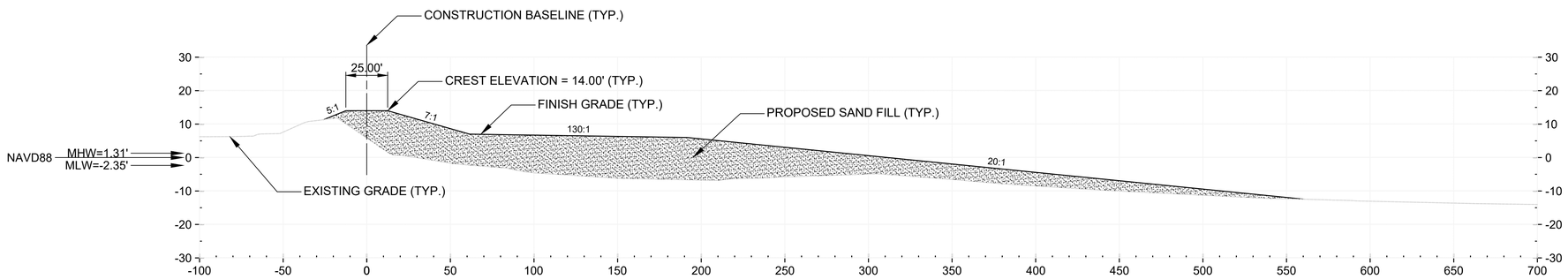
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

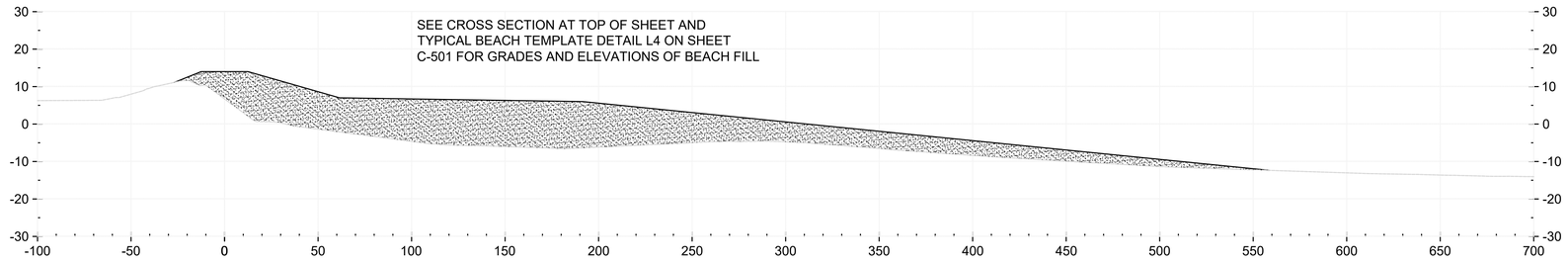
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SHEET ID
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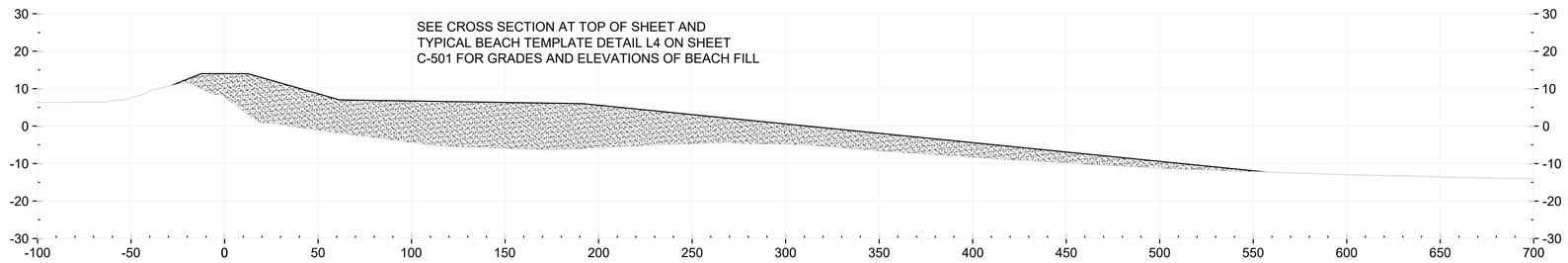
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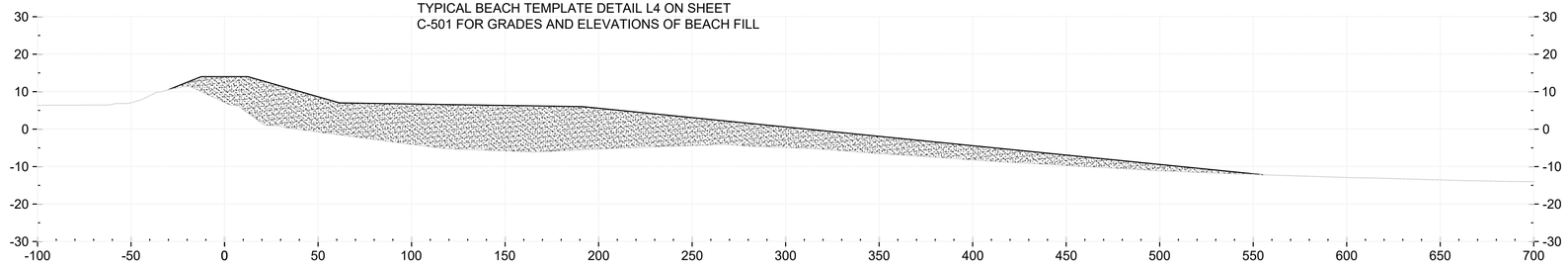
STA. 68+00



STA. 69+00



STA. 70+00



STA. 71+00

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE:	ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

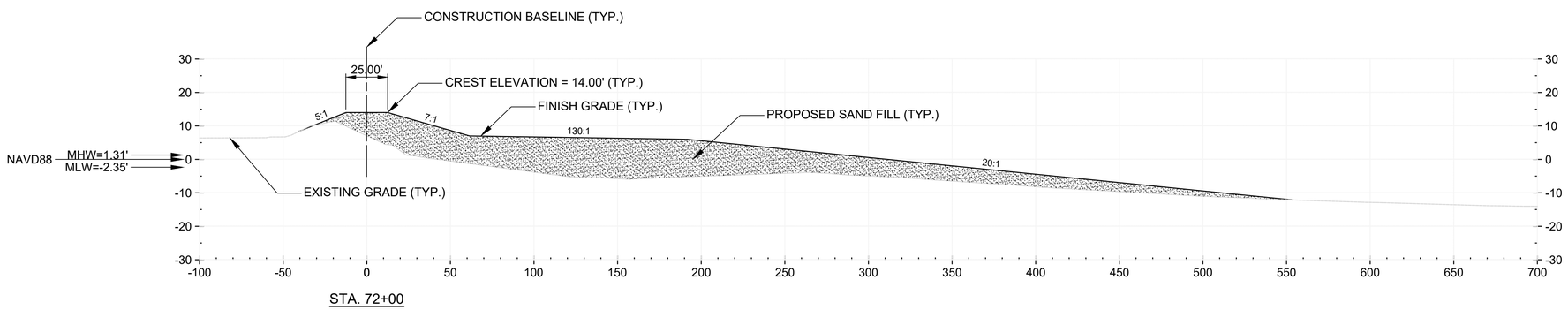
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

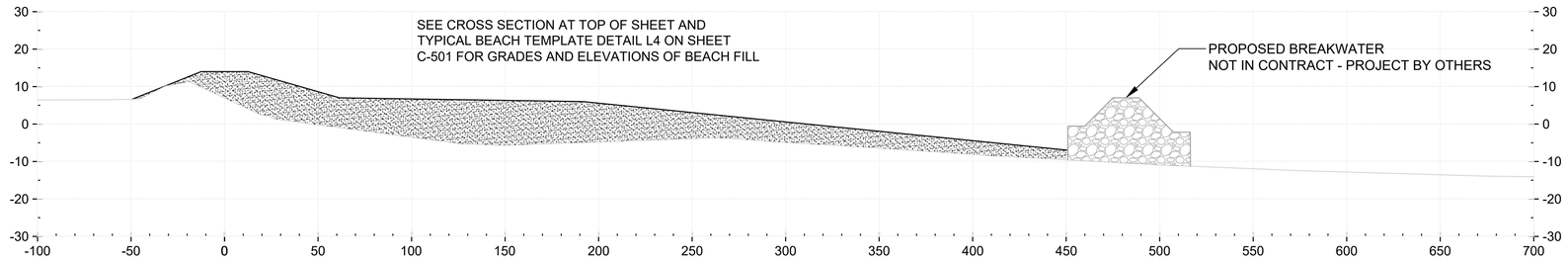
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SHEET ID
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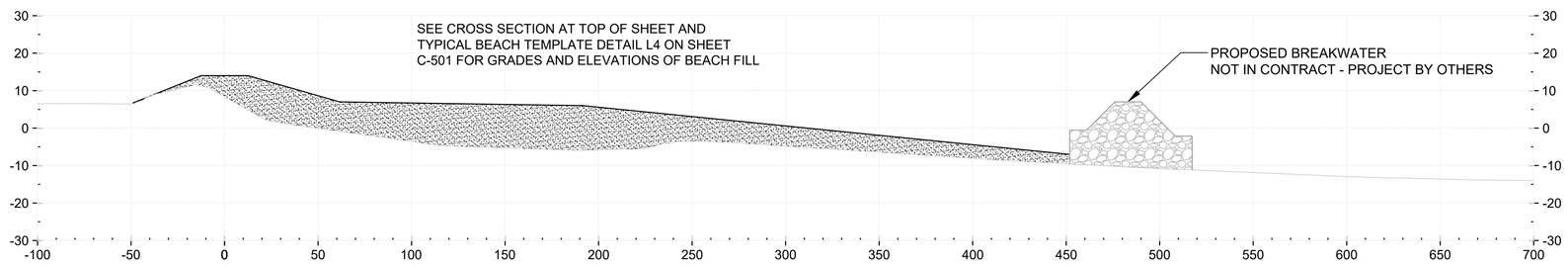
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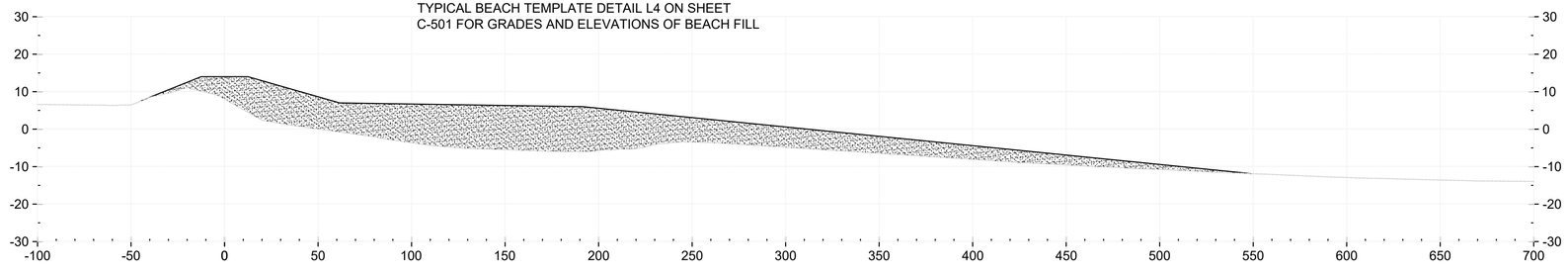
STA. 72+00



STA. 73+00



STA. 74+00



STA. 75+00

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

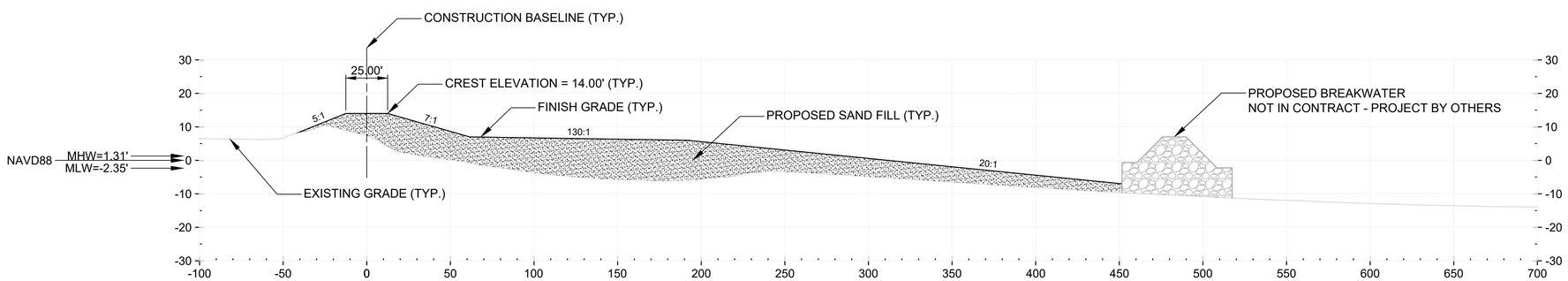
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

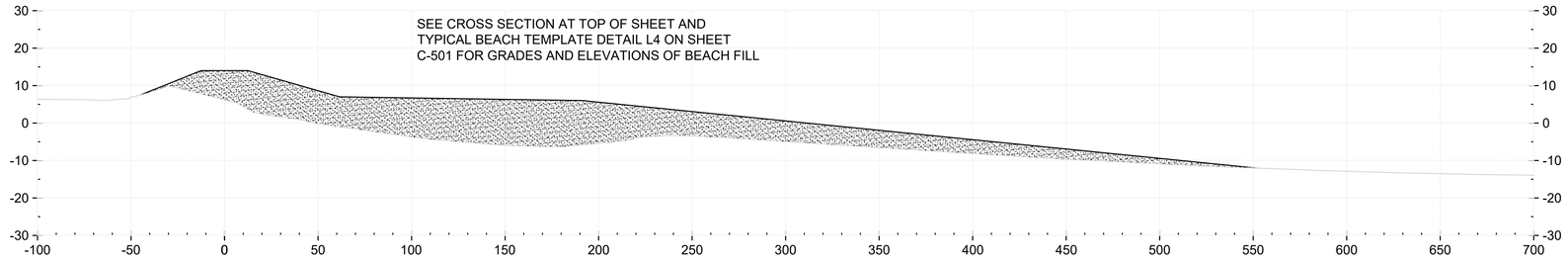
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STA 72+00 TO STA 75+00

SHEET ID
C-309

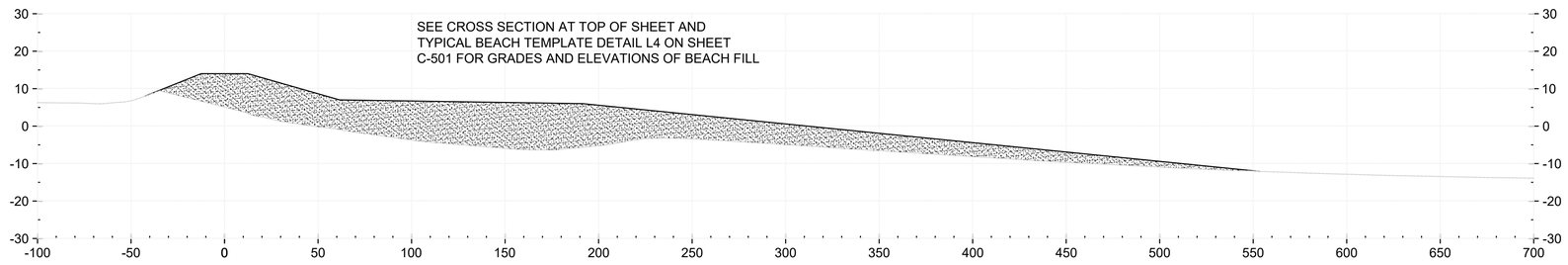
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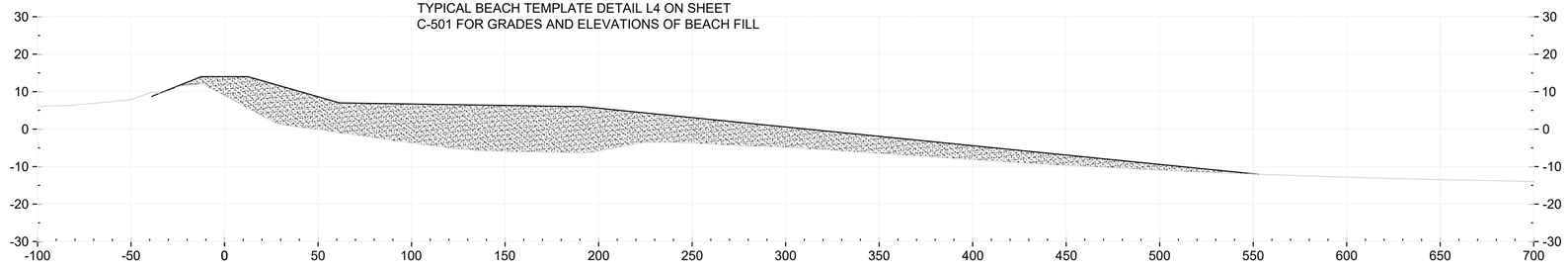
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STA. 77+00



STA. 78+00



STA. 79+00

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

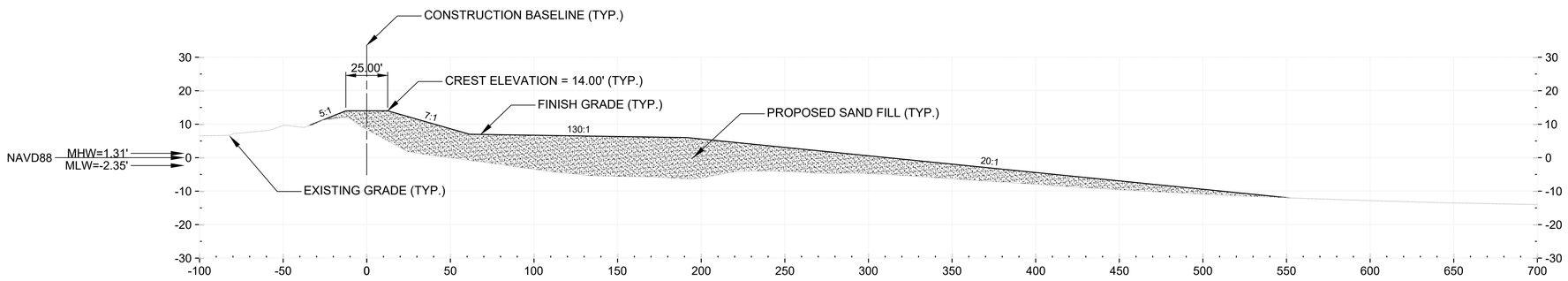
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

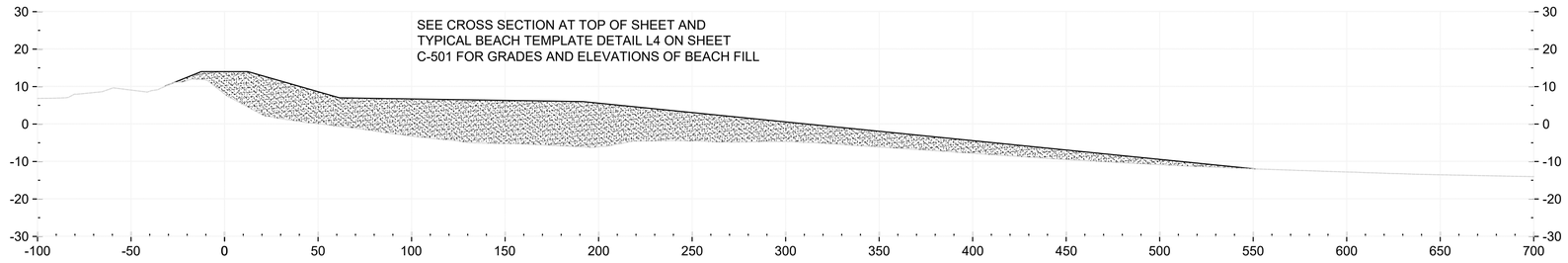
CROSS SECTIONS
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SHEET ID
C-310

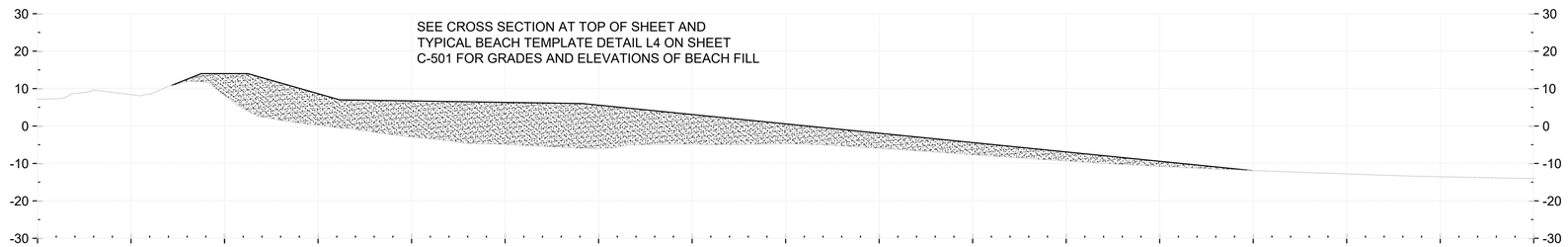
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AEC_B&W.STB
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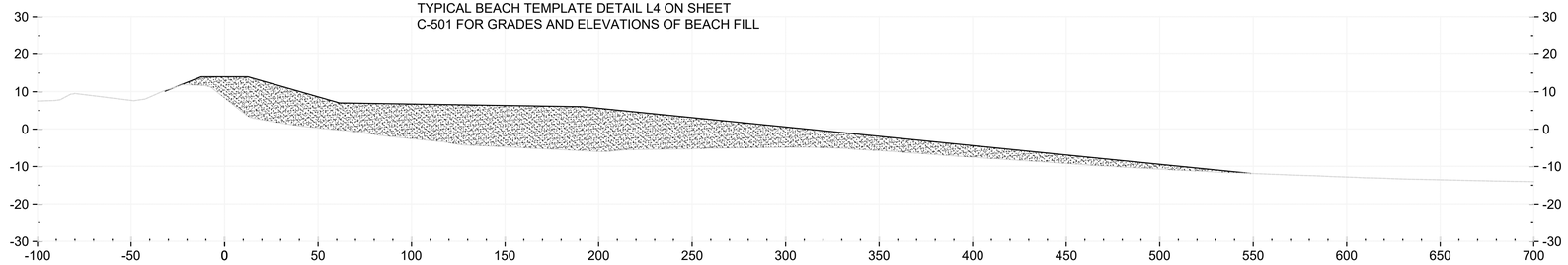
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STA. 81+00



STA. 82+00



STA. 83+00

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE:	ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

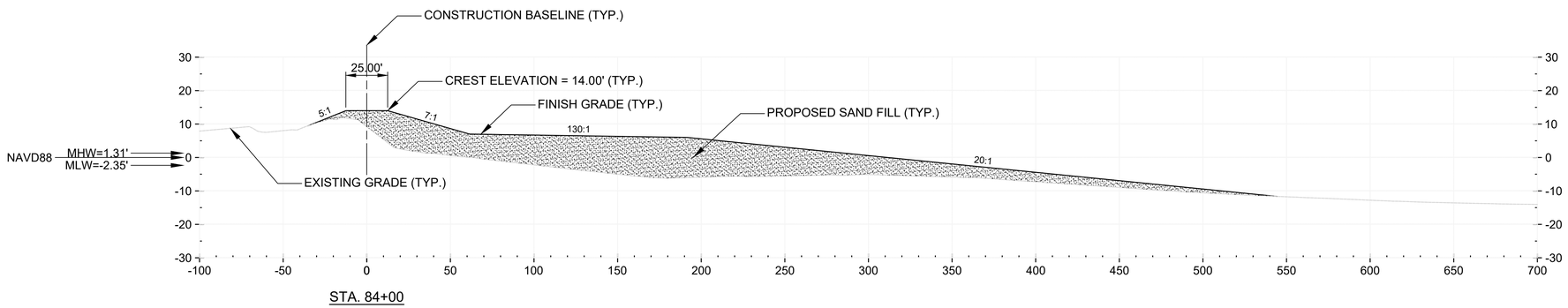
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

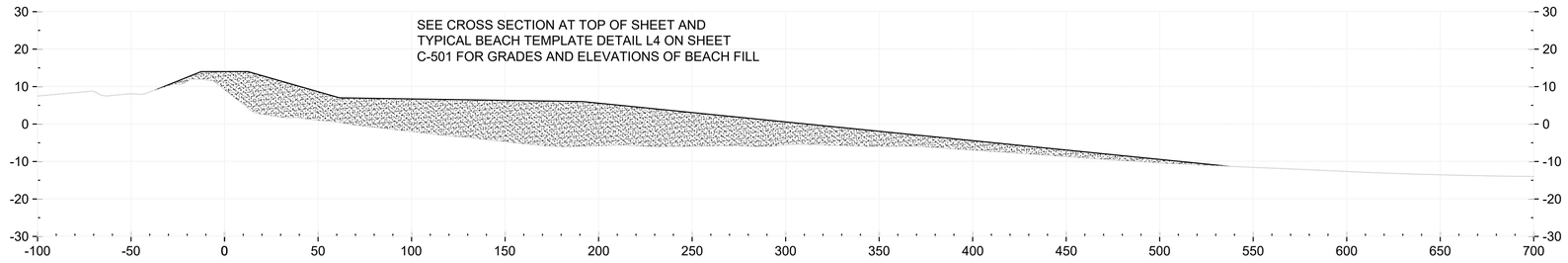
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SHEET ID
C-311

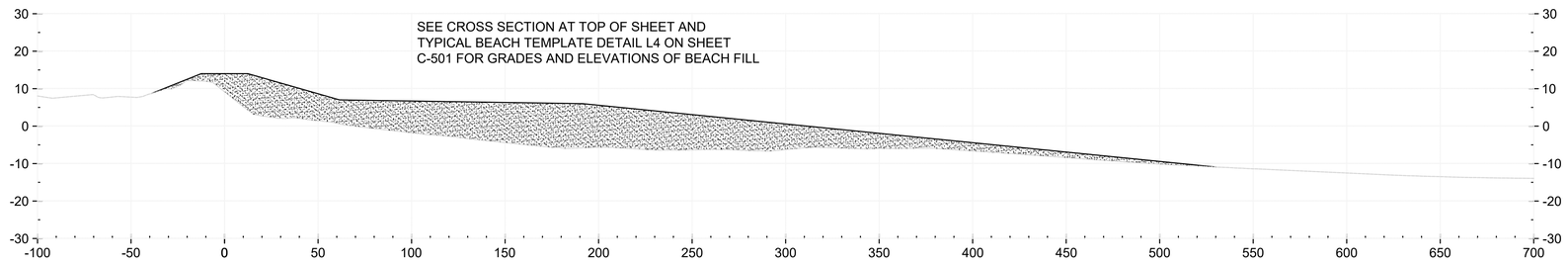
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E4ECENWI
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AEC_B&W.STB



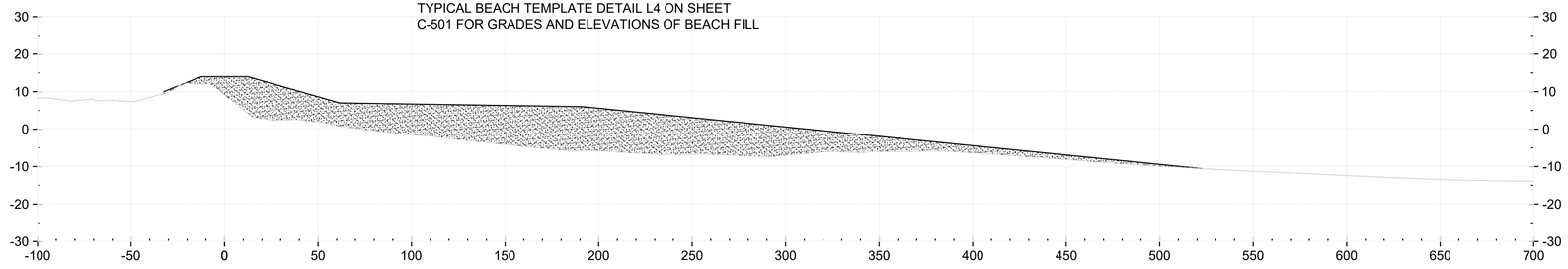
STA. 84+00



STA. 85+00



STA. 86+00



STA. 87+00

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
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CHECKED BY: R. WILLIAMS	CONTRACT NO.: +AEC_MAN_CONTRNUM
SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

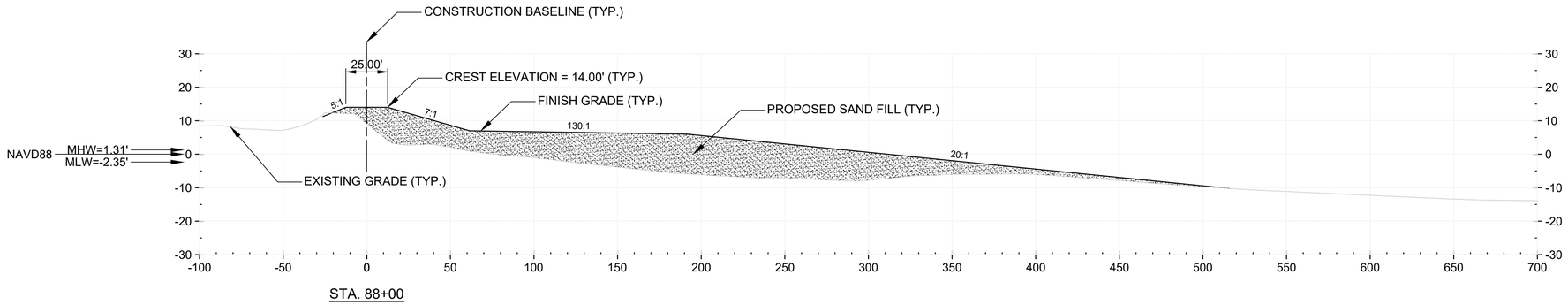
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

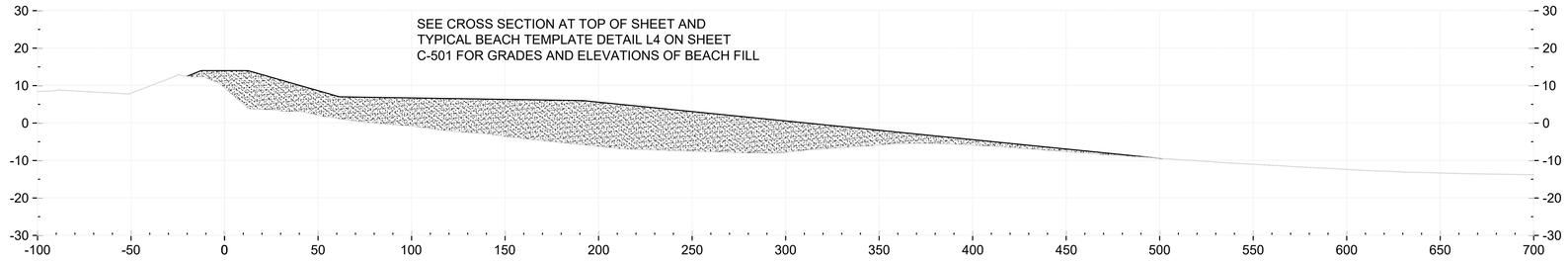
CROSS SECTIONS
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SHEET ID
C-312

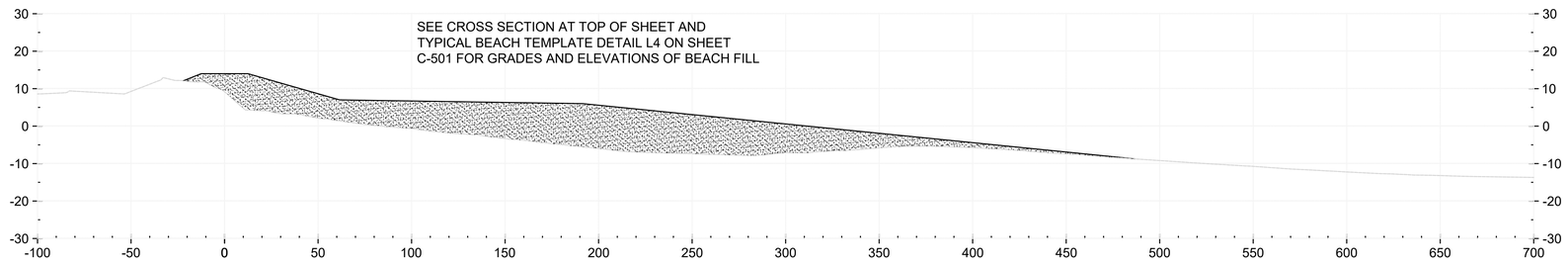
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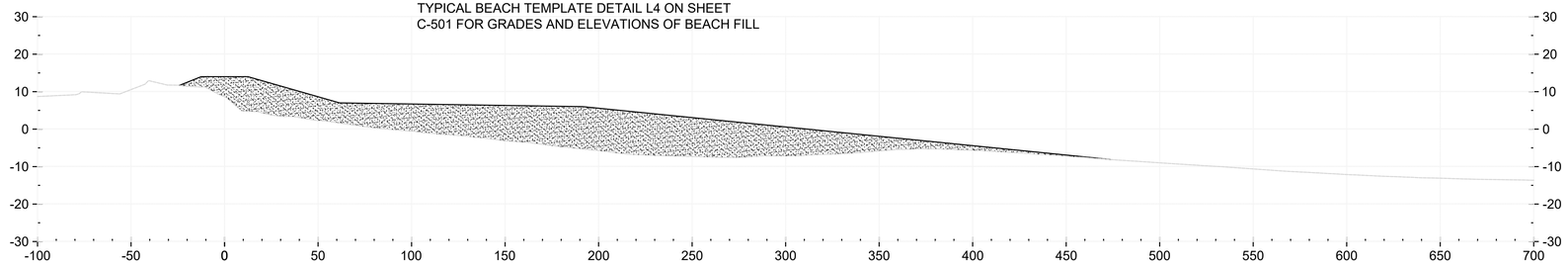
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STA. 89+00



STA. 90+00



STA. 91+00

US Army Corps of Engineers®

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DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

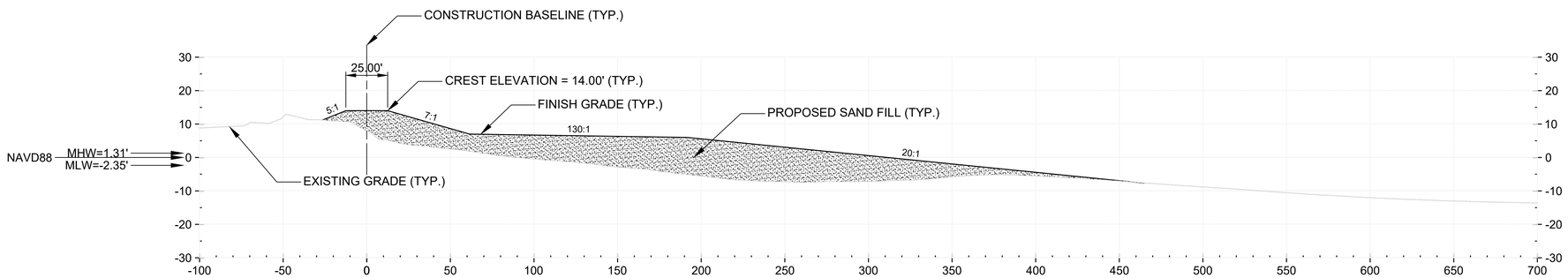
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

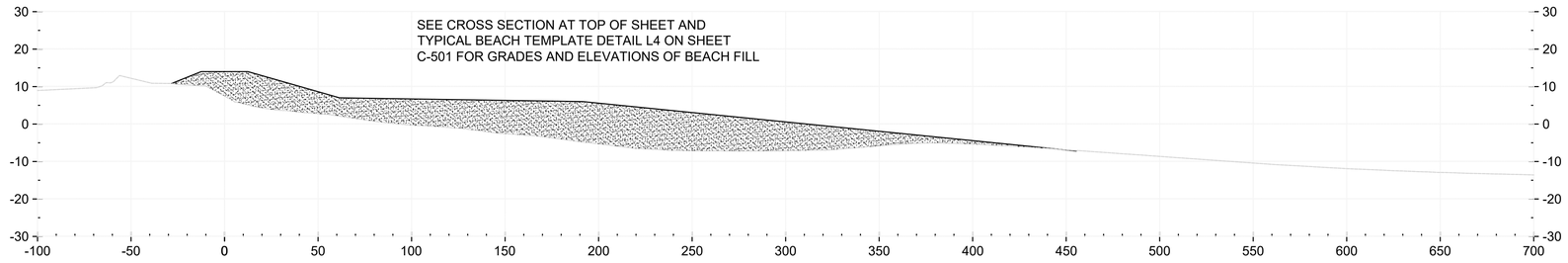
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SHEET ID
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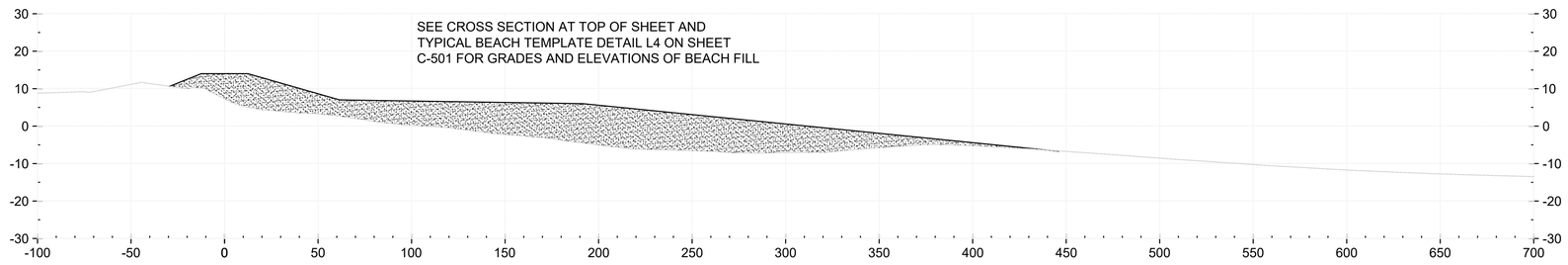
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AEC_B&W.STB
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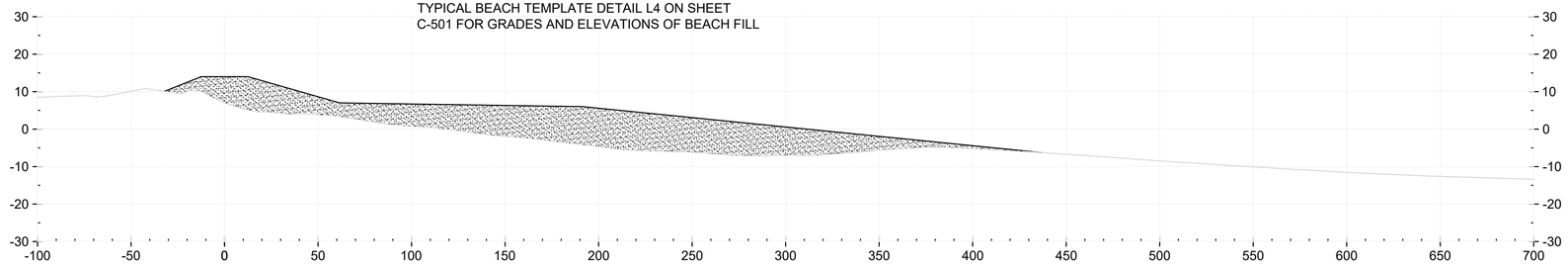
STA. 92+00



STA. 93+00



STA. 94+00



STA. 95+00

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
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SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

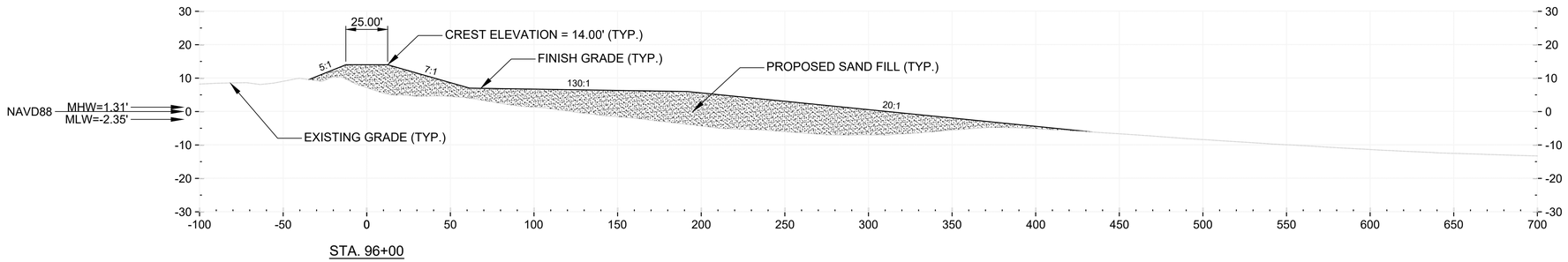
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

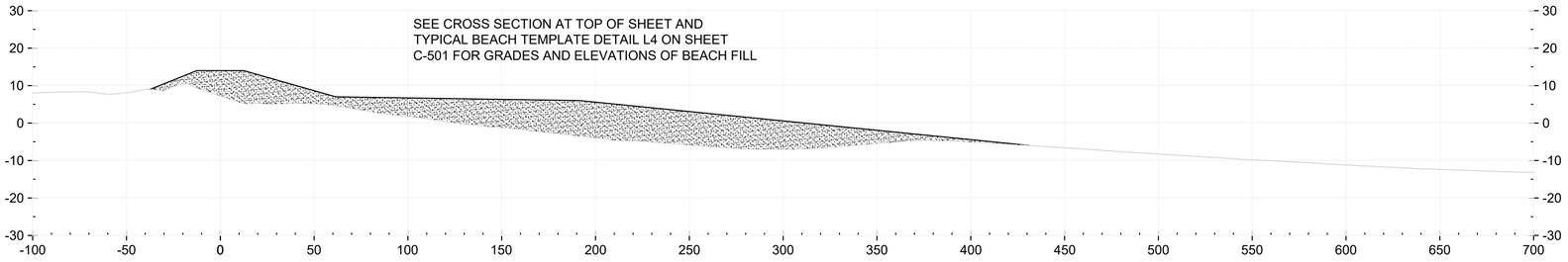
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SHEET ID
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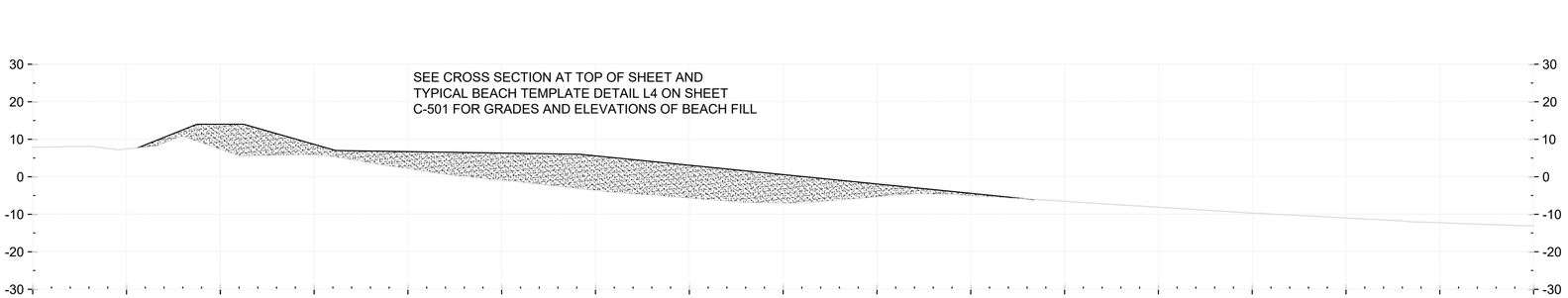
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4:20:53 PM 3/23/2026



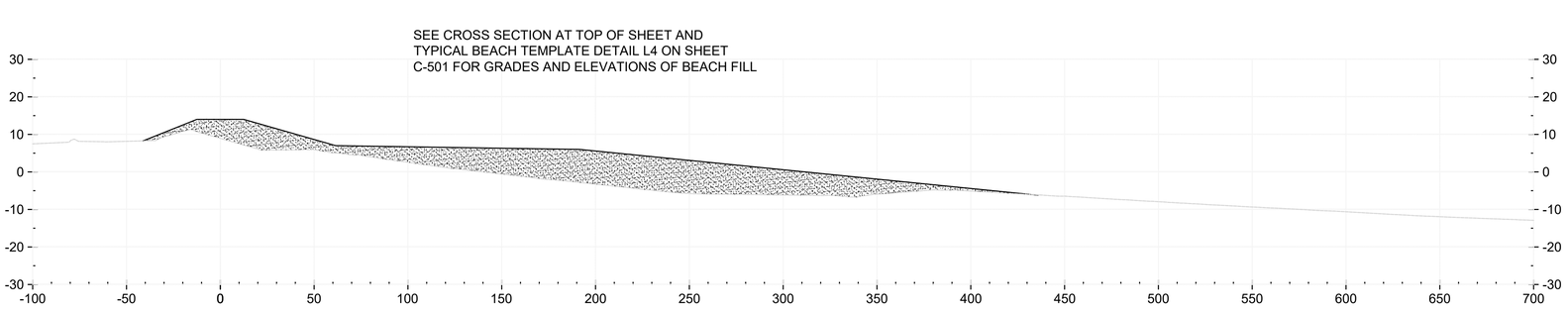
STA. 96+00



STA. 97+00



STA. 98+00



STA. 99+00

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
DRAWN BY: N. INGOLD	SOLICITATION NO.: +AEC_MAN_SOLICNUM
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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
SIZE: ANSI D	

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

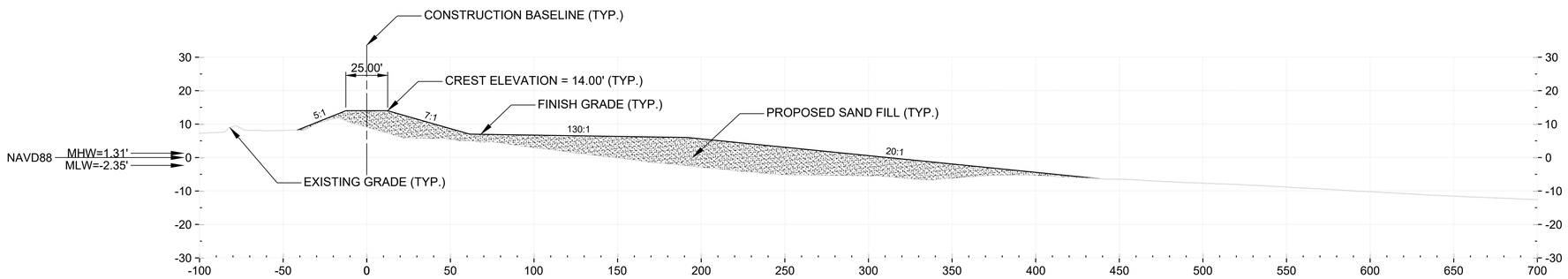
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

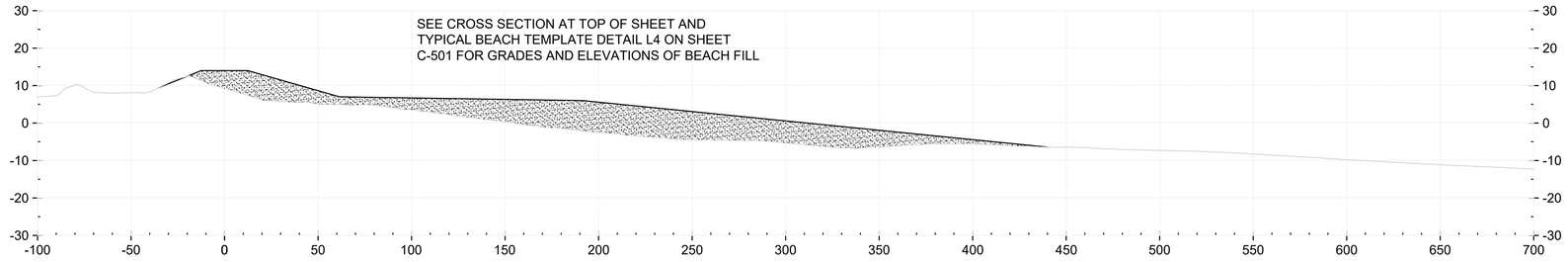
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SHEET ID
C-315

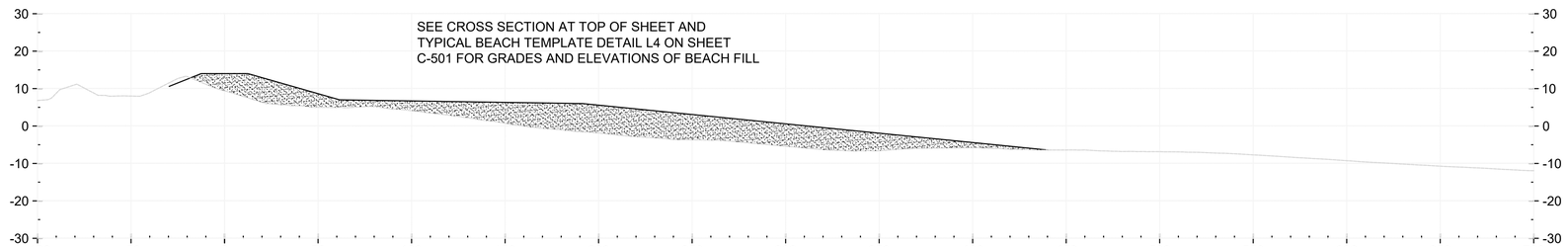
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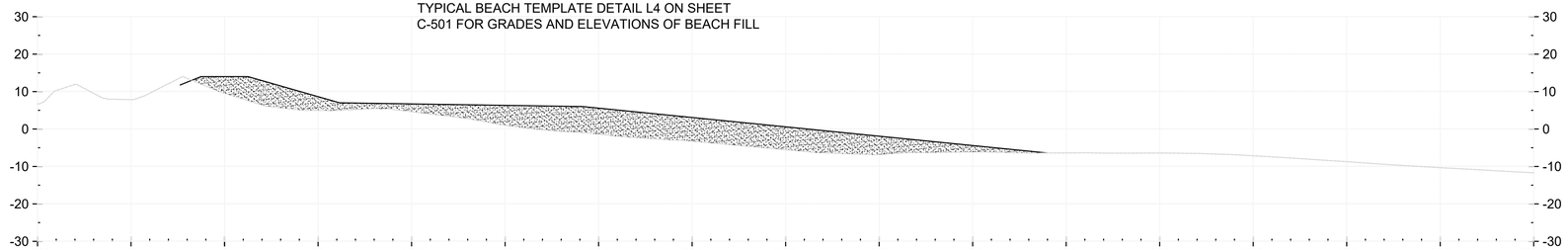
STA. 100+00



STA. 101+00



STA. 102+00



STA. 103+00

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SIZE: ANSI D	

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NORFOLK, VA 23510

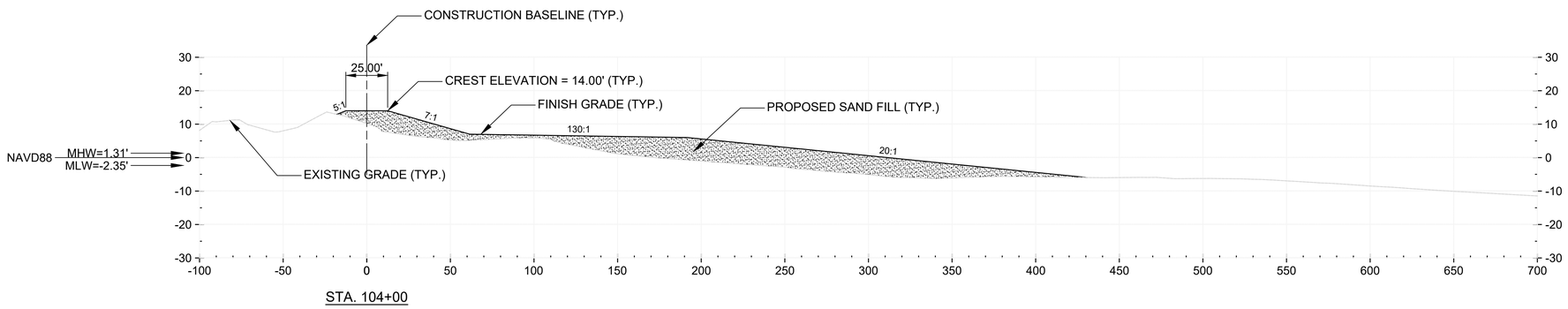
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

CROSS SECTIONS
STA 100+00 TO STA 103+00

SHEET ID
C-316

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STA. 104+00

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NORFOLK, VA 23510

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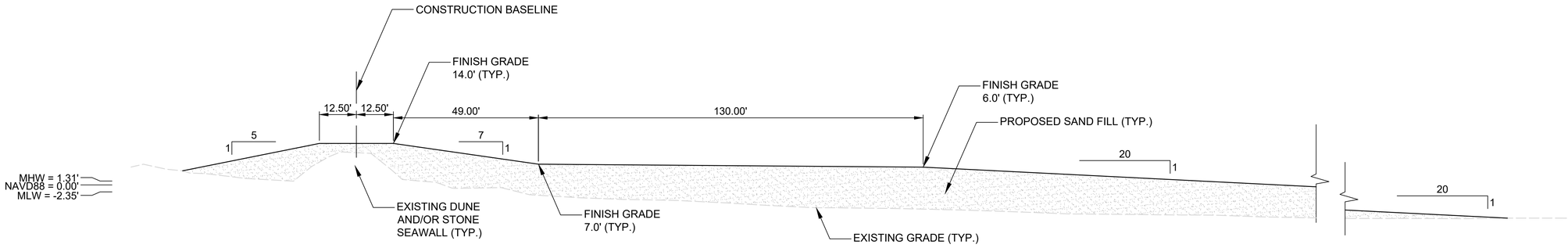
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

CROSS SECTIONS
STA 104+00

SHEET ID

C-317

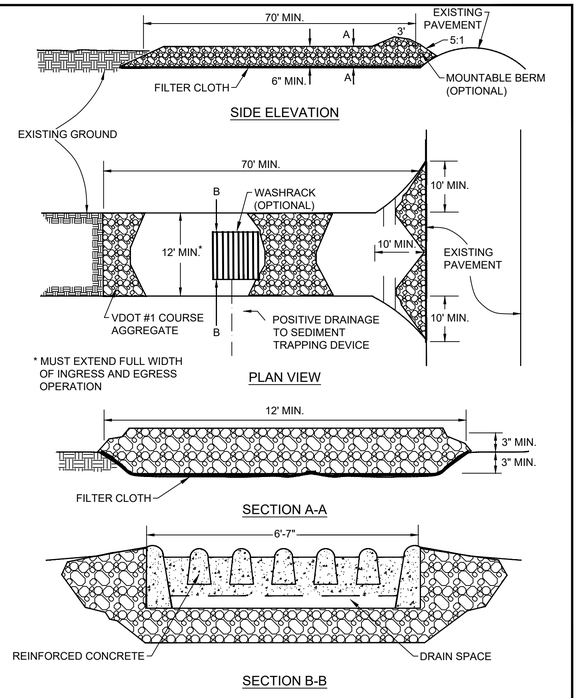
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L4 TYPICAL BEACH TEMPLATE PROFILE

1" = 20'-0"

0 20' 40'

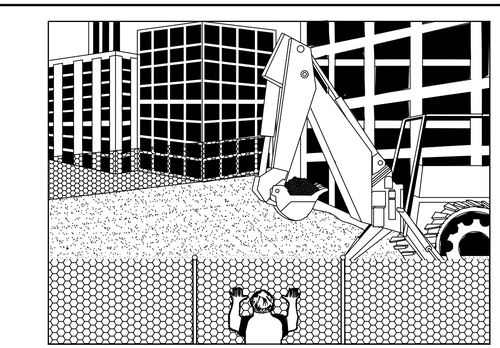


DEQ VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

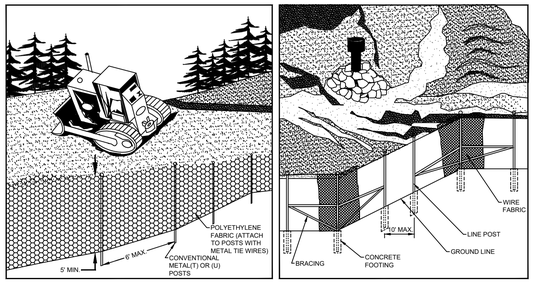
STONE CONSTRUCTION ENTRANCE

v1.1 SOURCE: VA. DSWC, MD ESC STDS C-SCM-03-1

A2 CONSTRUCTION ENTRANCE



PERSPECTIVE VIEW



PERSPECTIVE VIEW
PLASTIC FENCE

PERSPECTIVE VIEW
METAL FENCE

DEQ VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

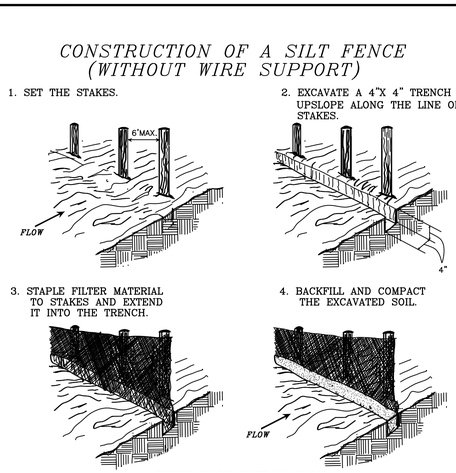
SAFETY FENCE

v1.1 SOURCE: VDOT STDS., VA DSWC, CONWED PLASTICS C-PCM-01-1

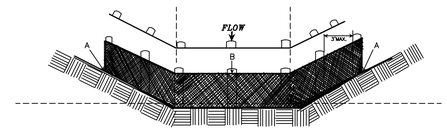
A9 SAFETY FENCE

CONSTRUCTION OF A SILT FENCE (WITHOUT WIRE SUPPORT)

1. SET THE STAKES.
2. EXCAVATE A 4"X 4" TRENCH UPSLOPE ALONG THE LINE OF STAKES.
3. STAPLE FILTER MATERIAL TO STAKES AND EXTEND IT INTO THE TRENCH.
4. BACKFILL AND COMPACT THE EXCAVATED SOIL.



SHEET FLOW INSTALLATION
(PERSPECTIVE VIEW)



POINTS A SHOULD BE HIGHER THAN POINT B.

DRAINAGEWAY INSTALLATION
(FRONT ELEVATION)

DEQ VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

SILT FENCE

v1.1 SOURCE: VA. DSWC, MD ESC STDS C-PCM-04

A17 SILT FENCE

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CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

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(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

DETAILS
BEACH TEMPLATE
EROSION AND SEDIMENT CONTROL

SHEET ID
C-501

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MATERIAL FILL VOLUME - BEACH TEMPLATE

STATION	AREA (SQFT)	VOLUME (CUYD)	CUMULATIVE VOLUME (CUYD)
40+00.00	1,038.75	1,924	1,924
41+00.00	1,432.61	4,577	6,500
42+00.00	1,701.95	5,805	12,305
43+00.00	2,620.63	8,005	20,310
44+00.00	3,516.94	11,366	31,676
45+00.00	4,204.58	14,299	45,975
46+00.00	4,650.25	16,398	62,373
47+00.00	4,730.47	17,372	79,744
48+00.00	4,823.23	17,692	97,436
49+00.00	4,691.14	17,619	115,055
50+00.00	4,679.10	17,352	132,408
51+00.00	4,672.39	17,318	149,725
52+00.00	4,671.30	17,303	167,028
53+00.00	4,675.81	17,309	184,338
54+00.00	4,683.51	17,332	201,670
55+00.00	4,692.49	17,363	219,033
56+00.00	4,700.10	17,394	236,427
57+00.00	4,706.29	17,419	253,846
58+00.00	4,711.08	17,440	271,285
59+00.00	4,621.40	17,282	288,568
60+00.00	4,551.17	16,986	305,554
61+00.00	4,475.75	16,717	322,271
62+00.00	4,163.67	15,999	338,270
63+00.00	4,085.62	15,276	353,546
64+00.00	4,323.93	15,573	369,119
65+00.00	4,097.57	15,595	384,715
66+00.00	4,251.88	15,462	400,177
67+00.00	4,184.32	15,623	415,799
68+00.00	4,097.78	15,337	431,136
69+00.00	3,984.52	14,967	446,104
70+00.00	3,888.44	14,580	460,683
71+00.00	3,797.92	14,234	474,917
72+00.00	3,712.96	13,909	488,826
73+00.00	3,503.18	13,363	502,189
74+00.00	3,488.95	12,948	515,138
75+00.00	3,643.72	13,209	528,346
76+00.00	3,548.39	13,319	541,665
77+00.00	3,729.45	13,477	555,143
78+00.00	3,785.84	13,917	569,060
79+00.00	3,621.36	13,717	582,777

MATERIAL FILL VOLUME - BEACH TEMPLATE

STATION	AREA (SQFT)	VOLUME (CUYD)	CUMULATIVE VOLUME (CUYD)
80+00.00	3,602.79	13,378	596,155
81+00.00	3,577.95	13,298	609,453
82+00.00	3,548.36	13,197	622,650
83+00.00	3,513.04	13,077	635,726
84+00.00	3,483.08	12,956	648,682
85+00.00	3,441.60	12,823	661,505
86+00.00	3,407.25	12,683	674,189
87+00.00	3,378.31	12,566	686,754
88+00.00	3,361.40	12,481	699,235
89+00.00	3,297.16	12,331	711,566
90+00.00	3,228.98	12,085	723,651
91+00.00	3,167.08	11,845	735,496
92+00.00	3,112.05	11,628	747,124
93+00.00	3,063.46	11,436	758,560
94+00.00	2,969.28	11,172	769,732
95+00.00	2,857.45	10,790	780,522
96+00.00	2,745.73	10,376	790,898
97+00.00	2,634.11	9,963	800,861
98+00.00	2,524.74	9,553	810,415
99+00.00	2,420.82	9,158	819,573
100+00.00	2,295.72	8,734	828,307
101+00.00	2,187.57	8,302	836,610
102+00.00	2,106.69	7,952	844,562
103+00.00	2,040.21	7,679	852,242
104+00.00	1,838.25	7,182	859,424
105+00.00	0.00	3,404	862,828
106+00.00	0.00	0	862,828
107+00.00	0.00	0	862,828
108+00.00	0.00	0	862,828
109+00.00	0.00	0	862,828
110+00.00	0.00	0	862,828
111+00.00	0.00	0	862,828
112+00.00	0.00	0	862,828
113+00.00	0.00	0	862,828
114+00.00	0.00	0	862,828
115+00.00	0.00	0	862,828
116+00.00	0.00	0	862,828
117+00.00	0.00	0	862,828
118+00.00	0.00	0	862,828
119+00.00	0.00	0	862,828

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U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

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(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BEACH RENOURISHMENT

MATERIAL SCHEDULE

SHEET ID

C-601

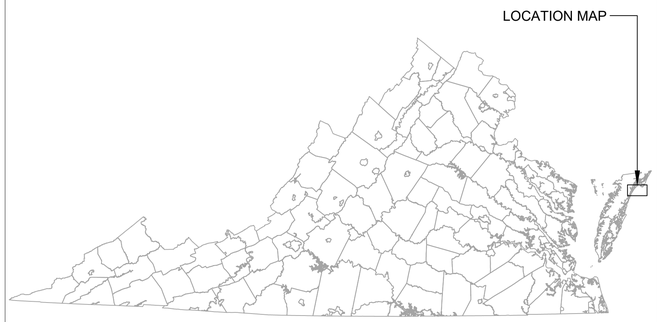
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NORFOLK DISTRICT

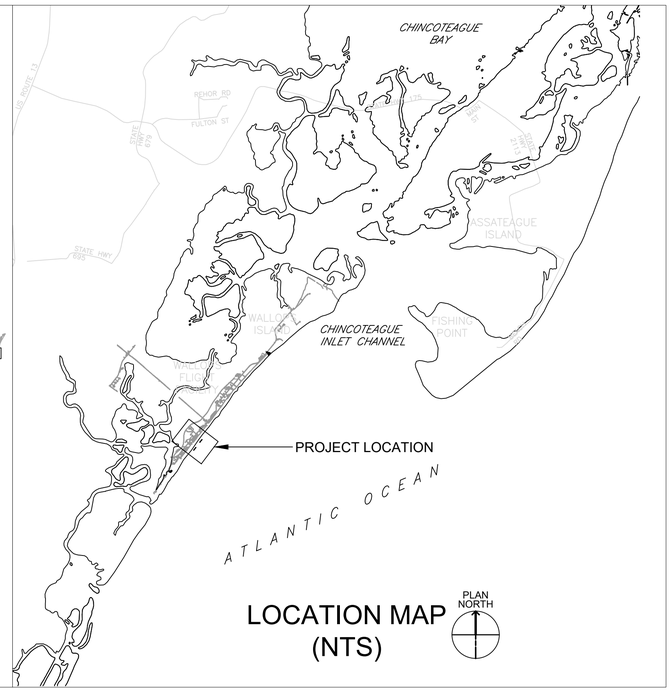
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

LOCATION MAP



VICINITY MAP
(NTS)

PLAN NORTH



LOCATION MAP
(NTS)

PLAN NORTH

SOLICITATION NO.:

CONTRACT NO.:

ISSUE DATE: MAR 2026

INDEX OF DRAWINGS	
Sheet Number	Sheet Title
G-001	COVER SHEET
G-002	ABBREVIATIONS
G-003	GENERAL OVERVIEW
G-004	LAYDOWN AND STAGING AREAS
V-101	EXISTING CONDITIONS
V-102	EXISTING CONDITIONS
B-101	GEOTECHNICAL EXPLORATIONS
B-102	GEOTECHNICAL EXPLORATIONS
CH101	SHORE PROTECTION
CH102	SHORE PROTECTION
C-301	CROSS SECTIONS
C-302	CROSS SECTIONS
C-501	DETAILS
C-502	DETAILS
C-601	MATERIAL SCHEDULE

SIGNATURES AFFIXED BELOW INDICATE OFFICIAL RECOMMENDATION AND APPROVAL OF ALL DRAWINGS IN THIS SET AS INDICATED ON INDEX OF DRAWINGS.
RECOMMENDED DESIGN BRANCH LEAD
APPROVED CHIEF, DESIGN BRANCH
APPROVED CHIEF, ENGINEERING DIVISION

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U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

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(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

COVER SHEET

SHEET ID
G-001

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ABBREVIATIONS

L	ANGLE
A/C	AIR CONDITIONING
A/C UNIT	AIR CONDITIONING UNIT
AB	ANCHOR BOLT
ABV	ABOVE
AC	ALTERNATING CURRENT
ACC	ACCESSIBLE
ACI	AMERICAN CONCRETE INSTITUTE
ACR	ACRYLIC PLASTIC
ACS DR	ACCESS DOOR
ACS PNL	ACCESS PANEL
ACSR	ALUMINUM CABLE STEEL REINFORCED
ACST	ACOUSTIC
ACT	ACOUSTICAL CEILING TILE
ADDM	ADDENDUM
ADH	ADHESIVE
ADJ	ADJACENT, ADJOINING, ADJUSTABLE
ADO	AUTOMATIC DOOR OPERATOR
AFF	ABOVE FINISHED FLOOR
AGGR	AGGREGATE
AHR	ANCHOR
AHU	AIR HANDLING UNIT
AI	AREA INLET
AIC	AMPERE INTERRUPTING CAPACITY
AISC	AMERICAN INSTITUTE OF STEEL CONSTRUCTION
A.L.	ACTIVE LEAF
ALT	ALTERNATE
ALUM	ALUMINUM
AMB	AMBIENT
AMP	AMPERE
ANOD	ANODIZE
ANSI	AMERICAN NATIONAL STANDARDS INSTITUTE
APPD	APPROVED
APPROX	APPROXIMATE
ARCH	ARCHITECT
ARI	AMERICAN REFRIGERATION INSTITUTE
ASB	ASBESTOS
ASC	ABOVE SUSPENDED CEILING
ASPH	ASPHALT
ATC	ACOUSTICAL TILE CEILING
AUTO	AUTOMATIC
AVG	AVERAGE
AWG	AMERICAN WIRE GAUGE
AWT	ACOUSTICAL WALL TREATMENT
BB	BULLETIN BOARD
BC	BOOKCASE
BD	BOARD
BDRY	BOUNDARY
BEJ	BRICK EXPANSION JOINT
BEV	BEVEL
BITUMINOUS	BITUMINOUS
BJT	BED JOINT
BL	BUILDING LINE
BLDG	BUILDING
BLW	BELOW
BM	BENCHMARK
BO	BOTTOM OF
BOT	BOTTOM
BP	BACK PLASTER(ED)
BRCG	BRACING
BRDG	BRIDGING
BRG	BEARING
BRG PL	BEARING PLATE
BRK	BRICK
BRKT	BRACKET
BRZ	BRONZE
BS	BOTH SIDES
BSMT	BASEMENT
Btu	BRITISH THERMAL UNIT
BtuH	BTU PER HOUR
BTWN	BETWEEN
BUR	BUILT-UP ROOFING
BW	BOTH WAYS
CAB	CABINET
CAP	CAPACITY
CB	CATCH BASIN
CCT	CUBICLE CURTAIN TRACK
CCTV	CLOSED CIRCUIT TELEVISION
CE	COVER ELEVATION
CEM	CEMENT
CEM PLAS	CEMENT PLASTER
CER	CERAMIC
CFI	CONDUCTIVE FLOORING
CFLG	COUNTERFLASHING
CFM	CUBIC FEET PER MINUTE
CG	CORNER GUARD
CH BD	CHALKBOARD
CHFR	CHAMFER
CHIM	CHIMNEY
CHK	CHECK
CHR PL	CHROME PLATED
CI	CAST IRON
CI	CURB INLET
CIP	CAST-IN-PLACE
CIRC	CIRCULAR
CJ	CONTROL JOINT
CJ	CONSTRUCTION JOINT
CKT	CIRCUIT
CKT BRKR	CIRCUIT BREAKER
CL	CENTER LINE
CLG	CEILING
CLG HT	CEILING HEIGHT
CLGL	CLEAR GLASS
CLL	CONTRACT LIMIT LINE
CLO	CLOSET
CLOS	CLOSURE
CLR	CLEAR(ANCE)
CLWG	CLEAR WIRED GLASS
cm	CENTIMETER(S)
CMP	CORRUGATED METAL PIPE
CMPST	COMPOSITE
CMU	CONCRETE MASONRY UNIT
CND	CONDUIT
CNL	CONDUCTIVE NEOPRENE LATEX
CNR	CORNER
CNTR	COUNTER
CO	CLEANOUT
CO2	CARBON DIOXIDE
COL	COLUMN
COM	COMMON
COMB	COMBUSTION
COMPT	COMPARTMENT
CONC	CONCRETE
CONN	CONNECT
CONSTR	CONSTRUCTION
CONT	CONTINUE
CONTR	CONTRACTOR
CORR	CORRIDOR
COV	COVER
CPRS	COMPRESSIBLE
CPT	CARPET
CRCMF	CIRCUMFERENCE
CRES	CORROSIVE RESISTANT STEEL
CRG	CROSS GRAIN
CRS	COURSE(S)
CS	CAST STONE
CSK	COUNTERSUNK
CSMT	CASEMENT
CT	CERAMIC TILE
CT	CURRENT TRANSFORMER
C TO C	CENTER TO CENTER
CTR	CENTER
CU	CONDENSING UNIT
Cu	COPPER
CU FT	CUBIC FEET
CUH	CABINET UNIT HEATER
CU YD	CUBIC YARDS
CV	CEILING VENT
CVH	CONDUCTIVE VINYL HOMOGENEOUS (SHEET TYPE)
CW	COLD WATER
CYL	CYLINDER
d	PENNY (AS IN NAIL - 10D)
DAT	DATUM
DB	DRY BULB
DBL	DOUBLE
DBL ACT DR	DOUBLE ACTING DOOR
DCJ	DOWELED CONTROL JOINT
DCJT	DUMMY CONTROL JOINT
DEG	DEGREE
DEMO	DEMOLITION
DEPR	DEPRESSION
DEPT	DEPARTMENT
DET	DETAIL
DF	DRINKING FOUNTAIN
DH	DOUBLE HUNG
DH	DUCT HEATER
DIA	DIAMETER
DIAG	DIAGONAL
DIM	DIMENSION
DISC	DISCONNECT
DISP	DISPENSER
DISTR PNL	DISTRIBUTION PANEL
DIV	DIVISION
DL	DEAD LOAD
DMPF	DAMPPROOFING
DMPR	DAMPER
DMT	DEMOUNTABLE
DN	DOWN
DR	DOOR
DR	DRAIN
DRB	DRAINBOARD
DR CL	DOOR CLOSER
DS	DOUBLE STRENGTH (GLASS)
DS	DOWNSPOUT
DT	DRAIN TILE
DVTL	DOVETAIL
DWG	DRAWING
DWLS	DOWELS
DWR	DRAWER
DWTR	DUMBWAITER
DX	DIRECT EXPANSION
E	EAST
EA	EACH
EAT	ENTERING AIR TEMPERATURE
EF	EACH FACE
EJ	EXPANSION JOINT
EL	ELEVATION - GRADE OR BUILDING
ELEC	ELECTRIC
EM	EXPANDED METAL
EMD	ESTIMATED MAXIMUM DEMAND
EMER	EMERGENCY
ENCL	ENCLOSE(URE)
ENTR	ENTRANCE, ENTERING
EP	ELECTRICAL PANELBOARD
EPRF	EXPLOSION PROOF
EPY	EPOXY COATING
EQ	EQUAL
EQUIP	EQUIPMENT
ESCAL	ESCALATOR
EST	ESTIMATE(D)
EWC	ELECTRIC WATER COOLER
EWT	ENTERING WATER TEMPERATURE
EXC	EXCAVATE
EXH	EXHAUST
EXH A	EXHAUST AIR
EXST	EXISTING
EXP	EXPANSION
EXP	EXPOSED
EXP BT	EXPANSION BOLT
EXT	EXTERIOR
F	FAHRENHEIT
FA	FIRE ALARM
FA	FRESH AIR
FAC	FIRE APPARATUS CLOSET
FAI	FRESH AIR INTAKE
F BRK	FIRE BRICK
FC	FOOT CANDLE
FC BRK	FACE BRICK
FCG	FACING
FCJ	FLOOR CONSTRUCTION JOINT
FCO	FLOOR CLEANOUT
FCU	FAN COIL UNIT
FD	FLOOR DRAIN
FDMPR	FIRE DAMPER
FDTN	FOUNDATION
FE	FIRE EXTINGUISHER
FEB	FIRE EXTINGUISHER BRACKET
FEC	FIRE EXTINGUISHER CABINET
FF	FACTORY FINISH
FGL	FIBERGLASS
FH	FIRE HYDRANT
FH	FLAT HEAD
FHC	FIRE HOSE CABINET
FHMS	FLAT HEAD MACHINE SCREW
FHR	FIRE HOSE RACK
FHS	FIRE HOSE STATION
FHWS	FLAT HEAD WOOD SCREW
FIG	FIGURE
FIN	FINISH
FIN FLR	FINISH FLOOR
FIXT	FIXTURE
FJT	FLUSH JOINT
FLASH	FLASHING
FLR	FLOOR
FLEX	FLEXIBLE
FLG	FLOORING
FLR PL	FLOOR PLATE
FLUOR	FLUORESCENT
FN	FENCE
FOC	FACE OF CONCRETE
FOF	FACE OF FINISH
FOM	FACE OF MASONRY
FOS	FACE OF STUD
FP	FIRE PARTITION
FP	FIREPROOF
FPM	FEET PER MINUTE
FR	FIRE RESISTANT
FR	FRAME
FRG	FORGED
FRMG	FRAMING
FRT	FIRE-RETARDANT
FS	FULL SIZE
FSTNR	FASTEN(ER)
FT	FEET
FTG	FOOTING
FURG	FURRING
FUT	FUTURE
FW	FIRE WATER
FWC	FABRIC WALL COVERING
G	NATURAL GAS
GA	GAGE
GAL	GALLON(S)
GALV	GALVANIZED
GALV STL	GALVANIZED STEEL
GB	GRAB BAR
GC	GENERAL CONTRACTOR
GEN	GENERAL
GF	GROUND FACE
GFCI	GROUND FAULT CIRCUIT INTERRUPTER
GFE	GOVERNMENT-FURNISHED EQUIPMENT
GFE/CI	GOVERNMENT-FURNISHED EQUIPMENT CONTRACTOR INSTALLED
GI	GALVANIZED IRON
GIP	GALVANIZED IRON PIPE
GKT	GASKET(ED)
GL	GLASS
GL BLK	GLASS BLOCK
GLF	GLASS FIBER
GLZ	GLAZING
GLZ CMU	GLAZED CONCRETE MASONRY UNITS
G	GROUND
GOVT	GOVERNMENT
GPM	GALLONS PER MINUTE
GPT	GYPSUM TILE
GRAN	GRANITE
GR LN	GRADE LINE
GRTG	GRATING
GST	GLAZED STRUCTURAL TILE
GSU	GLAZED STRUCTURAL UNITS
GT	GROUT
GWT	GLAZED WALL TILE
GYP	GYPSUM
GYP BD	GYPSUM BOARD
GYP PLAS	GYPSUM PLASTER
HB	HOSE BIBB
HC	HOLLOW CORE
HCD	HALON CONTAINMENT DAMPER
HCP	HANDICAPPED
HD	HEAD
HD	HEAVY DUTY
HDBD	HARDBOARD
HD JT	HEAD JOINT
HDR	HEADER
HDW	HARDWARE
HDWD	HARDWOOD
HES	HIGH EARLY-STRENGTH CEMENT
HEX	HEXAGON
HH	HANDHOLE
HK	HOOK(S)
HM	HOLLOW METAL
HNDRL	HANDRAIL
HORIZ	HORIZONTAL
HP	HIGH PRESSURE
HP	HORSEPOWER
HPT	HIGH POINT
HR	HOUR
HS	HIGH STRENGTH
HSGYP	HIGH-STRENGTH GYPSUM PLASTER
HSKPG	HOUSEKEEPING
HT	HEIGHT
HTG	HEATING
HTR	HEATER
HVAC	HEATING, VENTILATING AND AIR CONDITIONING
HYDR	HYDRAULIC
Hz	HERTZ
IC	INTERCOM
ID	INSIDE DIAMETER
IESNA	ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA
ILK	INTERLOCK
IN	INCH
INCIN	INCINERATOR
INCL	INCLUDED
INSF	INSULATING FILL
INSUL	INSULATION
INT	INTERIOR
INTM	INTERMEDIATE
INV	INVERT
IP	IRON PIPE
IPS	IRON PIPE SIZE
I.P.S.	INSIDE PIPE SIZE
JAN CLO	JANITOR'S CLOSET
J-BOX	JUNCTION BOX
JCT	JUNCTION
JST	JOIST
JT	JOINT
KIP	KILOPOUND (1000 POUNDS)
KIT	KITCHEN
KOP	KNOCKOUT PANEL
KPL	KICKPLATE
kV	KILOVOLTS
kVA	KILOVOLT AMPERES
kVAR	KILOVOLT AMPERES REACTIVE
kW	KILOWATT
KWY	KEYWAY
LAB	LABORATORY
LAD	LADDER
LAM	LAMINATE
LAT	LEAVING AIR TEMPERATURE
LAU	LAUNDRY
LAV	LAVATORY
LB	LAG BOLT
LB	POUND
LBL	LABEL
LBR	LUMBER
LC	LIGHT CONTROL
LD	LOAD
LDG	LOADING
LG	LENGTH
LH	LEFT HAND(ED)
LIN	LINEAR
LKR	LOCKER
LL	LIVE LOAD
LLD	LEAD-LINED DOOR
LM	LUMEN
LMST	LIMESTONE
LNTL	LINTEL
LONG	LONGITUDINAL
LP	LIGHTPROOF
LPD	LIGHTPROOF DOOR
LPL	LIGHTPROOF LOUVER
LPT	LOW POINT
LR	LIVING ROOM
LS	LAWN SPRINKLER
LT	LIGHT
LT WT	LIGHTWEIGHT
LTG	LIGHTING
LTNG	LIGHTNING
LVR	LOUVER
LWC	LIGHTWEIGHT CONCRETE
LWT	LEAVING WATER TEMPERATURE
m	METER(S)
M&B	MATCHED AND BEADED
MACH	MACHINE
MAS	MASONRY
MATL	MATERIAL(S)
MAX	MAXIMUM
MB	MACHINE BOLTS
MBR	MEMBER
MC	MEDICINE CABINET
MCJ	MASONRY CONTROL JOINT
MCO	METAL-CASED OPENING
MDS	METAL DIVIDER STRIP
MECH	MECHANICAL
MECH RM	MECHANICAL ROOM
MED	MEDIUM
MEMB	MEMBRANE
MES	METAL EDGE STRIP
MFD	METAL FLOOR DECKING
MFG	MANUFACTURING
MFR	MANUFACTURER
MG	MOTOR GENERATOR
MGT	MATTE-GLAZED TILE
MH	MANHOLE
MI	MALLEABLE IRON
MIN	MINIMUM
MIRR	MIRROR
MISC	MISCELLANEOUS
ML	METAL LATH
ML	MONOLITHIC
MLDG	MOULDING
MLWK	MILLWORK
mm	MILLIMETER(S)
MNIC	MATERIAL NOT IN CONTRACT (INSTALLATION BY CONTRACTOR)
MO	MASONRY OPENING
MOD	MODULAR
MOD.	MODIFIED
MOT	MOTOR
MP	MOVABLE PARTITION
MR	MOP RECEIVOR
MRB	MARBLE BASE
MRD	METAL ROOF DECKING
MS	MACHINE SCREWS
MT	METAL THRESHOLD
MT	MOUNT
MTD	MOUNTED
MTFR	METAL FURRING
MTL	METAL
MVBL	MOVABLE
MULL	MULLION
N	NORTH
NAT	NATURAL
NC	NORMALLY CLOSED
NEC	NATIONAL ELECTRICAL CODE
NEMA	NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
NFPA	NATIONAL FIRE PROTECTION ASSOCIATION
Ni	NICKEL
NIC	NOT IN CONTRACT
NL	NAILABLE
N.L.	NEOPRENE LATEX
NM	NONMETALLIC
NO	NORMALLY OPEN
NO	NUMBER
NOM	NOMINAL
NR	NOISE REDUCTION
NRC	NOISE REDUCTION COEFFICIENT
N"REQD	NOT REQUIRED
NTS	NOT TO SCALE
OA	OUTSIDE AIR
OBSC	OBSCURE
OBW	OBSERVATION WINDOW
OC	ON CENTER
OCEW	ON CENTER EACH WAY
OD	OUTSIDE DIAMETER
OFC	OFFICE
OGL	OBSCURE GLASS
OH	OVERHEAD
OHMS	OVALHEAD MACHINE SCREW
OHWS	OVALHEAD WOOD SCREW
OPH	OPPOSITE HAND
OPNG	OPENING
OPP	OPPOSITE
OPQ	OPAQUE
OPS	OPERATIONS
OS & Y	OUTSIDE SCREW AND YOKE
OWGL	OBSCURE WIRED GLASS
P	POLE
PA	PUBLIC ADDRESS
PAR	PARALLEL
PB	PANIC BAR
PBD	PARTICLE BOARD
PBS	PUSH BUTTON STATION
PC	PIECE
PCC	PRECAST CONCRETE
PCF	POUNDS PER CUBIC FOOT
PCP	CEMENT PLASTER (PORTLAND)
PD	PAVEMENT DRAIN
PED	PEDESTAL
PERF	PERFORATE(D)
PERIM	PERIMETER
PH	PHASE
PHAR	PHARMACY
PI	POINT OF INTERSECTION
PIPU	PREFAB ISOLATION POWER UNIT
PIV	POST INDICATING VALVE
PL	PLATE
PL	PROPERTY LINE
PLAM	PLASTIC LAMINATE
PLAS	PLASTER
PLAT	PLATFORM
PLBG	PLUMBING
PLF	POUNDS PER LINEAR FOOT
PLG	PILING
PL GL	PLATE GLASS
PLYWD	PLYWOOD
PNL	PANEL
PT	PAINT(ED)
POL	POLISHED
PORC	PORCELAIN
PORT	PORTABLE
PPGL	POLISHED PLATE GLASS
PPM	PARTS PER MILLION
PR	PAIR
PREFAB	PREFABRICATE(D)
PREFIN	PREFINISHED
PREFMD	PREFORMED
PRKG	PARKING
PROJ	PROJECT
PRV	PRESSURE-REGULATING VALVE
PS	PIPE SPACE
P.S.	PRESSED STEEL
PS CONC	PRESTRESSED CONCRETE
PSF	POUNDS PER SQUARE FOOT
PSI	POUNDS PER SQUARE INCH
PT	PNEUMATIC TUBE
PT.	POINT
PT CONC	POST-TENSIONED CONCRETE
PTD	PAPER TOWEL DISPENSER
PTN	PARTITION
PTR	PAPER TOWEL RECEPTACLE
PV	PAVED
PVC	POLYVINYL CHLORIDE
PVG	PAVING
PW	PASS WINDOW
QT	QUARRY TILE
QT.	QUART
QTR	QUARTER
1/4 RND	QUARTER ROUND
QTY	QUANTITY
R	RADIUS
R	RANGE
R	RISER
RA	RETURN AIR
RAB	RABBETED
RA GR	RETURN AIR GRILLE
RAR	RETURN AIR REGISTER
RB	RUBBER BASE, RESILIENT BASE
RBL	RUBBLE STONE
RBR	RUBBER
RC	REMOTE CONTROL
RCP	REINFORCED CONCRETE PIPE
RCVR	RECEIVER
RD	ROOF DRAIN
RDG INS	RIGID INSULATION
RECPT	RECEPTACLE
REC ROOM	RECREATION ROOM
RECT	RECTIFIER
REF	REFERENCE
REFL	REFLECT
REFR	REFRIGERATION
REG	REGISTER
REG	REGLET
REINF	REINFORCE
REM	REMOVE(ABLE)
REQD	REQUIRED
RESIL	RESILIENT
RET	RETURN
REV	REVISION
RFG	ROOFING
RH	RELATIVE HUMIDITY
RH	RIGHT HAND
RH	ROOF HATCH
RK	RACK
RLG	RAILING
RM	ROOM
RND	ROUND
RO	ROUGH OPENING
ROW	RIGHT OF WAY
RP	RETRACTABLE PARTITION
RPM	REVOLUTIONS PER MINUTE
RPRT	RAISED PATTERN RUBBER TILE
RTF	RUBBER TILE FLOOR
RVS	REVERSE
RVT	RIVET
RWC	RAINWATER CONDUCTOR
S	SOUTH
SA	SUPPLY AIR
SB	SPLASH BLOCK
S.B.	SECURITY BARS
SC	SOLID CORE
SCHED	SCHEDULE
SCRN	SCREEN
SCT	STRUCTURAL CLAY TILE
SD	STORM DRAIN
SDI	STEEL DOOR INSTITUTE
SECT	SECTION
SEQ	SEQUENCE
SFGL	SAFETY GLASS
SFTU	STRUCTURAL FACING TILE UNIT
SFU	STRUCTURAL FACING UNIT
SG	SHEET GLASS
SHLDR	SHOULDER
SHT	SHEET
SHTHG	SHEATHING
SHV	SHELVING
SIM	SIMILAR
SJI	STEEL JOIST INSTITUTE
SKLT	SKYLIGHT
SLNT	SEALANT
SLV	SLEEVE
SM	SHEET METAL
SMS	SHEET METAL SCREWS
SOV	SHUT OFF VALVE
SPC	SPACER
SPCL	SPECIAL
SPD	SOUNDPROOF DOOR
SPEC	SPECIFICATION
SPF	SOUNDPROOF
SP FIN	SPECIAL FINISH
SPH	SPACE HEATER
SPKR	SPEAKER
SQ	SQUARE
SQHD	SQUARE HEAD
S&R	SHELF AND ROD
SS	SERVICE SINK
SS	STANDING SEAM (ROOF)
SST	STAINLESS STEEL
STA	STATION
STD	STANDARD
STG	SEATING
STL	STEEL
STOR	STORAGE
ST PR	STATIC PRESSURE
STR	STRINGER
STRUCT	STRUCTURAL
STWY	STAIRWAY
SUB FL	SUBFLOOR
SUSP	SUSPENDED
SV	SHEET VINYL
SW	SWITCH
SWBD	SWITCHBOARD
SYMM	SYMMETRICAL
SYNTH	SYNTHETIC
SYS	SYSTEM
T	TREAD
TAN	TANGENT
TB	TOWEL BAR
TC	TERRA COTTA
TEL	TELEPHONE
TEMP	TEMPERATURE
TEMP	TEMPORARY
TER	TERRAZZO
TERM	TERMINAL
T&G	TONGUE AND GROOVE
TGL	TOGGLE
TH	TRUSS HEAD
THK	THICK(NESS)
THRES	THRESHOLD
TK BD	TACKBOARD
TKS	TACK STRIP
TO	TOP OF
TOL	TOLERANCE
TOPO	TOPOGRAPHY
TOS	TOP OF SLAB
TOS	TOP OF STEEL
TOW	TOP OF WALL
TPD	TOILET PAPER DISPENSER
TPTN	TOILET PARTITION
TRANS	TRANSOM
TRANS	TRANSVERSE
TSTAT	THERMOSTAT
TV	TELEVISION
TYP	TYPICAL
UC	UNIT COOLER
UGND	UNDERGROUND
UH	UNIT HEATER
UL	UNDERWRITERS LABORATORIES
UNEX	UNEXCAVATED
UNFIN	UNFINISHED
UPS	UNINTERRUPTABLE POWER SUPPLY
URINAL	URINAL
UTIL	UTILITY
UV	UNIT VENTILATOR
V	VOLT
VAR	VARNISH
VB	VINYL BASE
VCT	VINYL COMPOSITION TILE
VCT	VITRIFIED CLAY TILE
VD	VAULT DOOR
VENT	VENTILATOR(TION)
VERT	VERTICAL
VEST	VESTIBULE
VF	VINYL FABRIC
VG	VERTICAL GRAIN
VH	VINYL HOMOGENEOUS
VJ	V-JOINT(ED)
VNR	VENEER
VOL	VOLUME
VR	VAPOR RETARDER
VRM	VERMICULITE
VS	VENT STACK
V.T.	VOLTAGE TRANSFORMER
VTR	VENT THRU ROOF
VWC	VINYL WALL COVERING
W	WEST
W/	WITH
WB	WET BULB
WBL	WOOD BLOCKING
WC	WATER CLOSET
WC	WHEELCHAIR
WCO	WOOD-CASED OPENING
WD	WOOD
WD	WOOD DOOR
WDSP	WASTE DISPOSER
WDW	WINDOW
WF	WIDE FLANGE
WGL	WIRED GLASS
WH	WALL HUNG
WH	WATER HEATER
WHB	WHEEL BUMPER
WHM	WATT-HOUR METER
WI	WROUGHT IRON
WKSH	WORK SHOP
WM	WIRE MESH
W/O	WITHOUT
WP	WATERPROOF(ING)
WP	WEATHERPROOF
WP	WORKING POINT
WR	WASTE RECEPTACLE
WRB	WARDROBE
WS	WATERSTOP
W.S.	WASTE STACK
WSCT	WAINSCOT
WT	WEIGHT
WTH	WIDTH
WW	WALL TO WALL
WWF	WELDED WIRE FABRIC
WWM	WELDED WIRE MESH
WWR	WELDED WIRE REINFORCEMENT
XFMR	TRANSFORMER
YD	YARD
YD	YARD DRAIN

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD
DRAWN BY: N. INGOLD
CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN SOLICNUM
CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

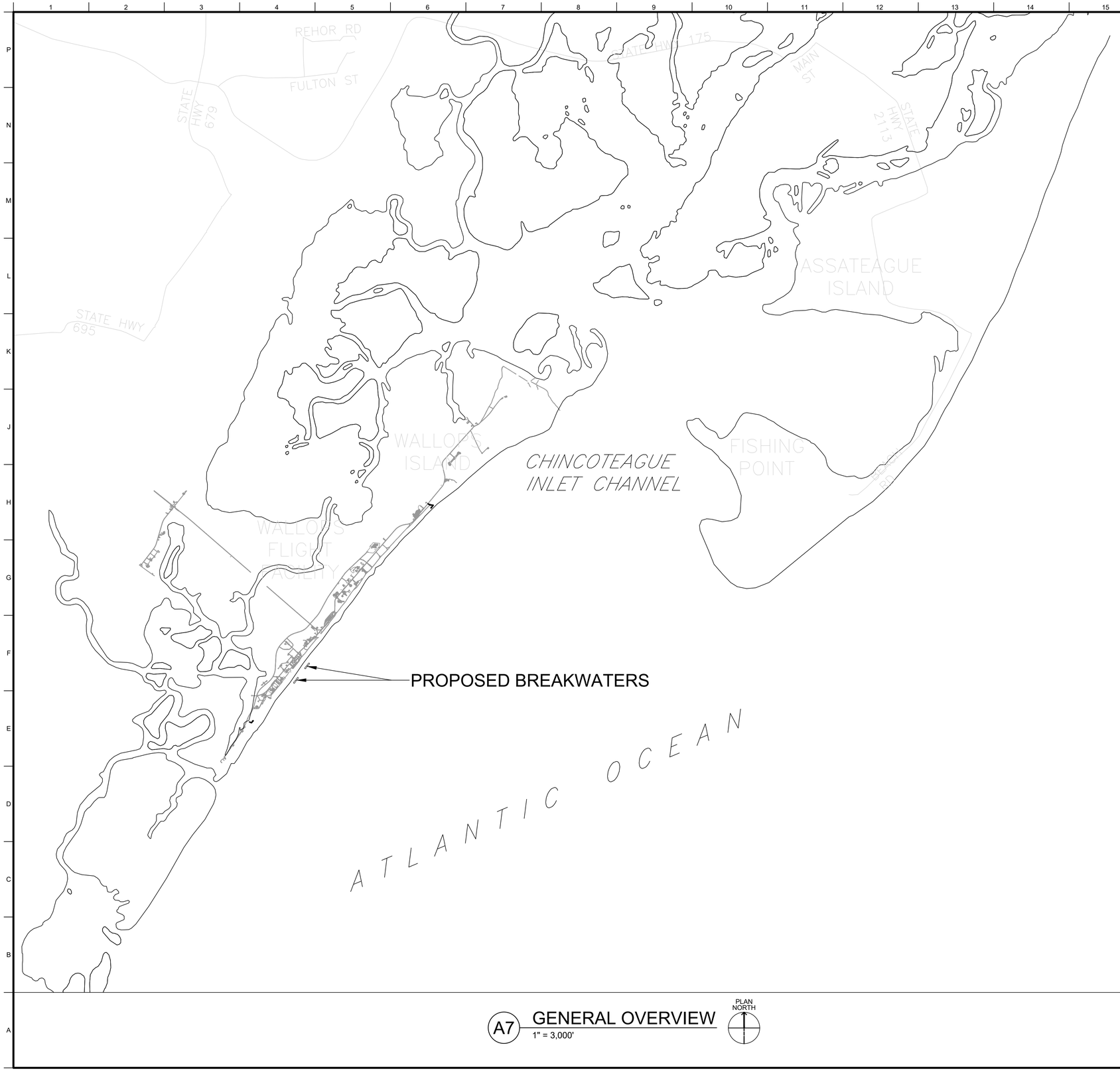
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

ABBREVIATIONS

SHEET ID
G-002

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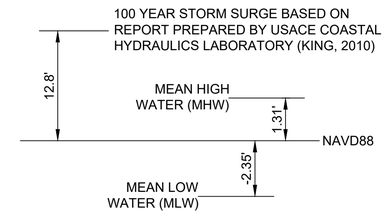


A7 GENERAL OVERVIEW
1" = 3,000'

PLAN NORTH

GENERAL NOTES:

1. THE EXISTING UTILITIES AND OBSTRUCTIONS SHOWN ARE FROM THE BEST AVAILABLE RECORDS AND SHALL BE VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION.
2. NECESSARY PRECAUTIONS SHALL BE TAKEN BY THE CONTRACTOR TO PROTECT EXISTING SERVICES AND STRUCTURES. ANY DAMAGE TO THEM SHALL BE REPAIRED IMMEDIATELY AT THE CONTRACTOR'S EXPENSE.
3. TIDAL DATUM BASED ON USACE PROJECT *NASA-WALLOPS ISLAND BREAKWATER AND BEACHFILL PROJECT, 2018*
4. PUBLISHED MEAN TIDAL RANGE IS 3.66 FEET.
5. HORIZONTAL CONTROL: NORTH ATLANTIC DATUM OF 1983 (NAD83), VIRGINIA STATE PLANE, SOUTH
6. VERTICAL CONTROL: NORTH ATLANTIC VERTICAL DATUM OF 1988 (NAVD88)
7. PROPERTY LINES SHOWN ARE APPROXIMATE ONLY. THIS PLAN IS NOT INTENDED TO BE A PROPERTY LINE SURVEY.
8. DISTURBED AREAS WILL BE RESTORED TO A CONDITION EQUAL TO OR BETTER THAN FOUND. THIS INCLUDES THE TEMPORARY STAGING AREAS.
9. A LOW PROBABILITY EXISTS THAT MUNITIONS AND EXPLOSIVES OF CONCERN (MEC) COULD BE ENCOUNTERED AND AWARENESS TRAINING (PERFORMED BY NASA) IS REQUIRED PRIOR TO GRADING ACTIVITIES. IF ANY MEC IS ENCOUNTERED, STOP WORK, CLEAR THE AREA, AND CONTACT WALLOPS FLIGHT FACILITY PROTECTION SERVICES DIVISION AT 757-824-1333. SEE SPECIFICATIONS FOR DETAILS.
10. PROJECT AND BEACH AREA IS DYNAMIC IN NATURE DUE TO EROSIVE FORCES AND MAY NOT REPRESENT CURRENT CONDITIONS AT THE TIME OF CONSTRUCTION. SEE SPECIFICATIONS FOR PRE- AND POST-SURVEY REQUIREMENTS.



1983-2001 NTDE

TIDAL DATUM DIAGRAM

DATE: 06/12/2024
SCALE: NTS

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

ISSUE DATE:	MAR 2026
SOLICITATION NO.:	+AEC_MAN_SOLICNUM
CONTRACT NO.:	+AEC_MAN_CONTRNUM
NAO FILE NO.:	1196

DESIGNED BY:	N. INGOLD
DRAWN BY:	N. INGOLD
CHECKED BY:	K. THEVERAPPERUMA
SUBMITTED BY:	N. INGOLD
SIZE:	ANSI D

U.S. ARMY CORPS OF ENGINEERS
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BCOES SUBMITTAL
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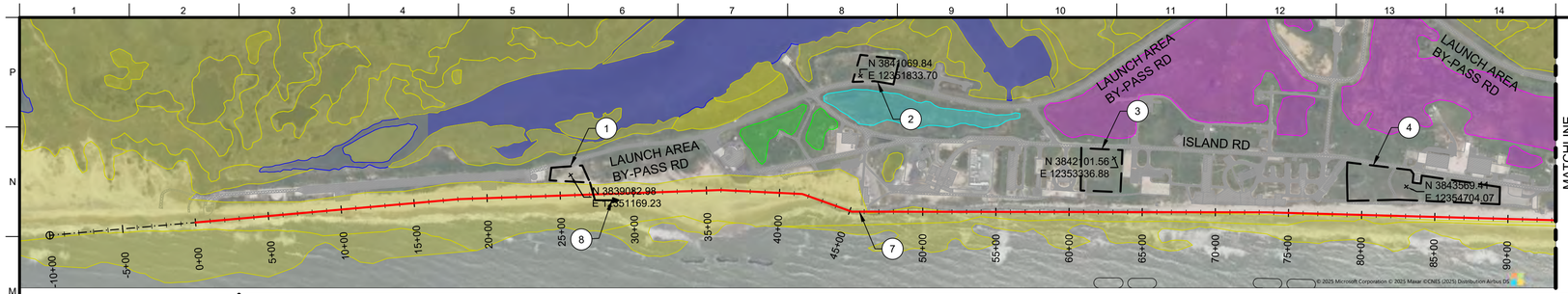
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

GENERAL OVERVIEW

SHEET ID

G-003

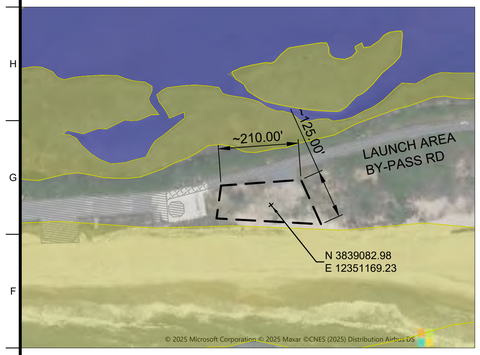
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L6 LAYDOWN AND STAGING AREA OVERVIEW
1" = 800'

PLAN NORTH



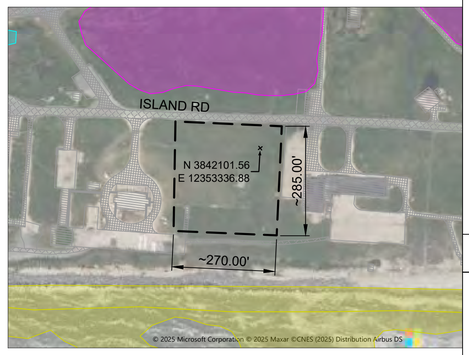
E1 LAYDOWN AREA 1
1" = 200'-0"

PLAN NORTH



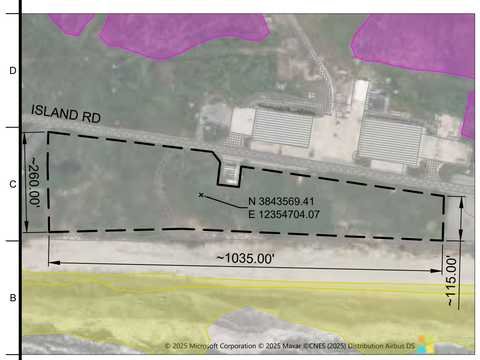
E7 LAYDOWN AREA 2
1" = 200'-0"

PLAN NORTH



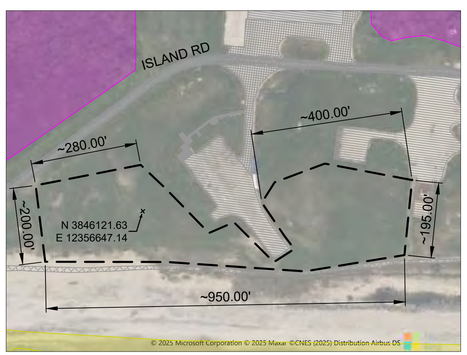
E13 LAYDOWN AREA 3
1" = 200'-0"

PLAN NORTH



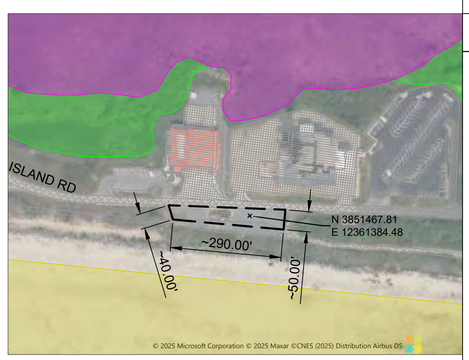
A1 LAYDOWN AREA 4
1" = 200'-0"

PLAN NORTH



A7 LAYDOWN AREA 5
1" = 200'-0"

PLAN NORTH



A13 LAYDOWN AREA 6
1" = 200'-0"

PLAN NORTH

GENERAL NOTES:

1. AREAS SHOWN ARE POTENTIAL LAYDOWN AND STAGING AREAS FOR THE CONTRACTOR TO USE. AREAS WILL BE DETERMINED AFTER CONTRACT AWARD AND APPROVED BY THE COR.
2. ALL AREA BOUNDARIES ARE APPROXIMATE.
3. LAYDOWN AND STAGING AREAS SHALL NOT IMPACT ANY WETLANDS.
4. OTHER NON-OCCUPIED UPLAND AREAS NOT IDENTIFIED ON THE PLANS MAY BE REQUESTED FOR LAYDOWN OR STAGING BY THE CONTRACTOR AND MUST BE APPROVED BY THE COR.
5. NO ADDITIONAL CLEARING OR EARTHWORK IS PERMITTED IN LAYDOWN OR STAGING AREAS.
6. LAYDOWN AND STAGING AREAS ARE TO HAVE THE APPROPRIATE EROSION AND SEDIMENT CONTROL MEASURES, PER THE LATEST EDITION OF THE VIRGINIA STORMWATER MANAGEMENT HANDBOOK.
7. INSTALL SAFETY FENCE (A2/C-501) AROUND THE PERIMETER OF ALL DESIGNATED LAYDOWN AND STAGING AREAS. INSTALL SILT FENCE (A17/C-501) AND STABILIZED CONSTRUCTION ENTRANCE (A9/C-501) AS A PRECAUTIONARY MEASURE.
8. LAYDOWN AND STAGING AREAS MUST BE RESTORED TO ORIGINAL CONDITION PRIOR TO COMPLETION OF CONSTRUCTION.
9. CONTRACTOR IS RESPONSIBLE FOR THE SAFETY AND SECURITY OF THEIR EQUIPMENT AND MATERIALS.
10. ALL EQUIPMENT AND MATERIALS MAY BE LEFT IN LAYDOWN AND STAGING AREAS DURING PRE-LAUNCH AND LAUNCH ACTIVITIES.
11. NASA HAZARDOUS OPERATIONS (HAZ OPS) MAY IMPACT ACCESS TO ALL LAYDOWN AREAS. DURING HAZ OPS, PORTIONS OF OR ENTIRE LAYDOWN AREAS MAY BE IMPACTED. DURING HAZ OPS, ALL MATERIALS AND EQUIPMENT MAY REMAIN IN AN AREA, HOWEVER PERSONNEL WILL BE REQUIRED TO LEAVE. LAYDOWN AREAS 1, 3, AND 4 WILL BE IMPACTED AT A HIGHER RATE THAN OTHER LAYDOWN AREAS.
12. SITE ACCESS TO THE PROJECT SITE IS SHOWN. OTHER ACCESS POINTS MAY OCCUR BETWEEN STA 0+00 AND STA 150+00 WITH APPROVAL FROM THE COR AND OWNER.
13. WETLAND AREAS SHOWN WERE OBTAINED FROM THE NATIONAL WETLAND INVENTORY ON NOVEMBER 2025.
14. SEE V-SHEETS FOR DETAILS OF EXISTING CONDITIONS AND SITE FEATURES.

KEYNOTES:

1. LAYDOWN AREA 1
2. LAYDOWN AREA 2
3. LAYDOWN AREA 3
4. LAYDOWN AREA 4
5. LAYDOWN AREA 5
6. LAYDOWN AREA 6
7. POTENTIAL SITE ACCESS BETWEEN STA 0+00 TO STA 150+00
8. SITE ACCESS POINTS

LEGEND

- ESTUARINE AND MARINE DEEPWATER
- ESTUARINE AND MARINE WETLAND
- FRESHWATER AND EMERGENT WETLAND
- FRESHWATER FORESTED AND SHRUB WETLAND
- FRESHWATER POND
- OTHER
- PROJECT ALIGNMENT BETWEEN STA 0+00 TO STA 150+00

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN_SOLICNUM
CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196

DESIGNED BY: N. INGOLD
DRAWN BY: N. INGOLD
CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

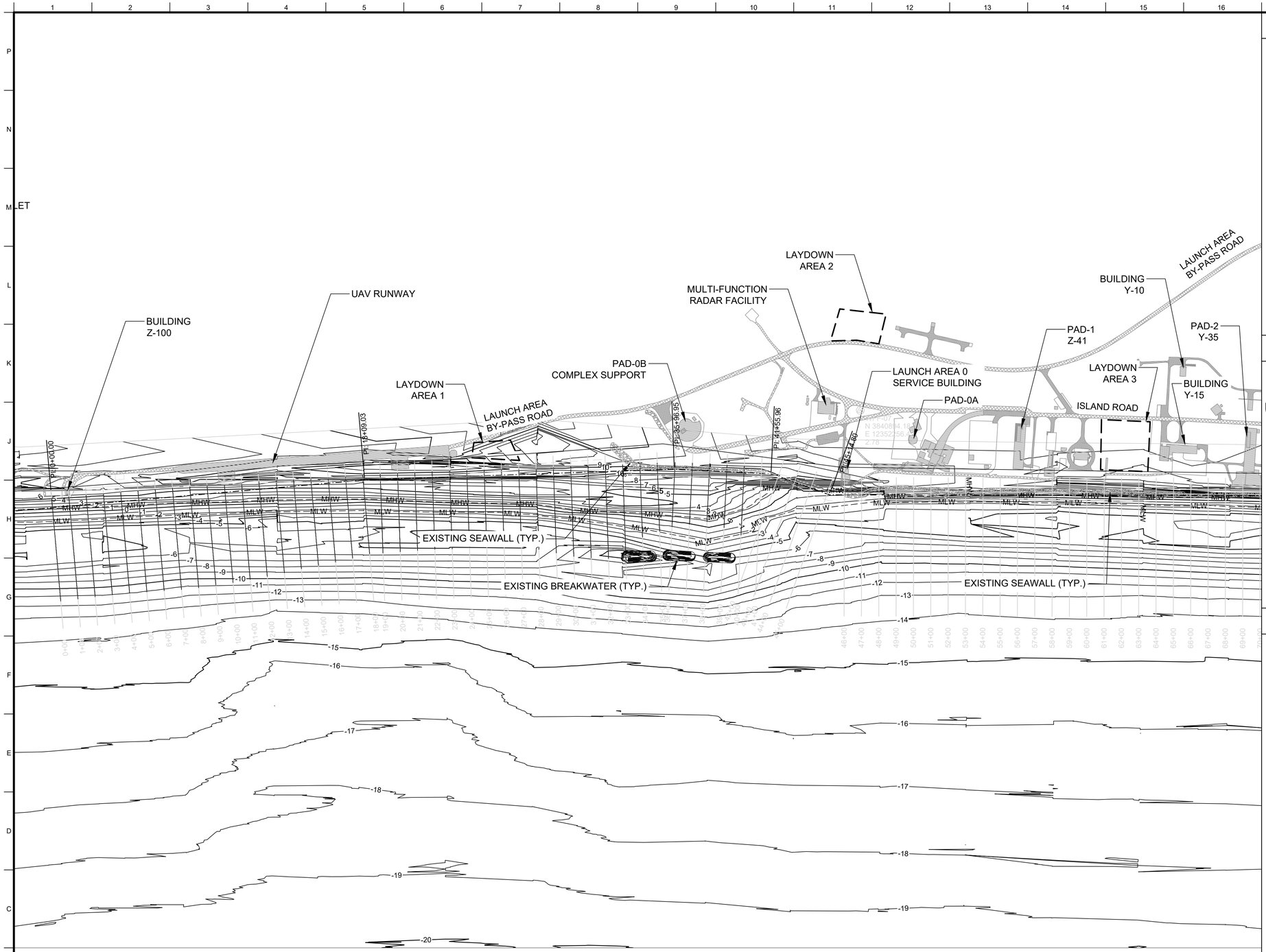
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

LAYDOWN AND STAGING AREAS

SHEET ID
G-004

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B7 EXISTING CONDITIONS
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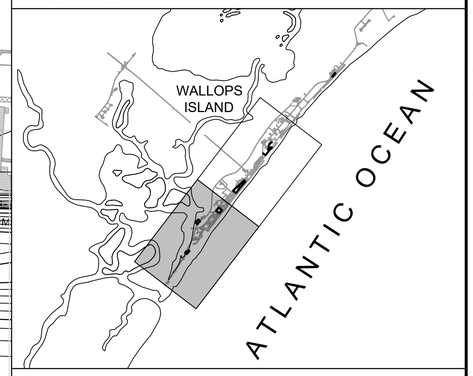
PLAN NORTH

300 0 300 600
SCALE IN FEET

GENERAL NOTES:

1. SURVEY NOTES:
   1.1. SURVEY PERFORMED BY GEODYNAMICS ON SEPTEMBER 9 TO 12, 2024 VIA SINGLEBEAM BATHYMETRIC AND TOPOGRAPHIC.
   1.2. HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
   1.3. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88), US FEET
   1.4. ADDITIONAL SURVEY WAS CONDUCTED BY NORFOLK DISTRICT IDENTIFY EXISTING SITE FEATURES AND EXISTING BREAKWATER ELEVATIONS. RTK TS SURVEY PERFORMED JUNE 2 TO 10, 2025 AND PROCESSED ON JUNE 26, 2025. CONTROL MONUMENT: WFF-09.
2. SITE ACCESS TO THE PROJECT SITE MAY OCCUR BETWEEN STA 0+00 AND STA 150+00 WITH APPROVAL FROM COR AND OWNER. SEE SHEET G-004 FOR ADDITIONAL DETAILS REGARDING PROJECT SITE ACCESS AND LAYDOWN AND STAGING AREAS.

KEY PLAN



LEGEND:

- 5 — EXISTING CONTOUR (MAJOR)
- 1 — EXISTING CONTOUR (MINOR)
- MHW — MEAN HIGH WATER (MHW) ELEVATION
- MLW — MEAN LOW WATER (MLW) ELEVATION

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD	ISSUE DATE: MAR 2026
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CHECKED BY: K. THEVERAPPERUMA	CONTRACT NO.: +AEC_MAN_CONTRNUM
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SIZE:	ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

EXISTING CONDITIONS

SHEET ID
V-101

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B7 EXISTING CONDITIONS
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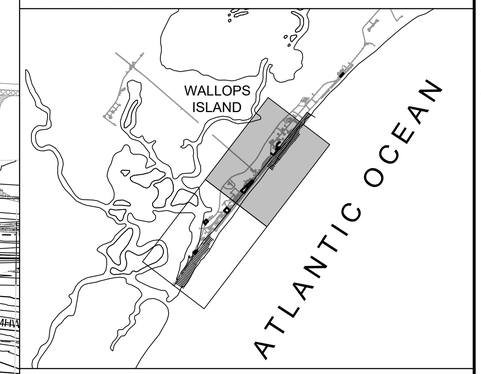
PLAN NORTH

300 0 300 600
SCALE IN FEET

GENERAL NOTES:

1. SURVEY NOTES:
   - 1.1. SURVEY PERFORMED BY GEODYNAMICS ON SEPTEMBER 9 TO 12, 2024 VIA SINGLEBEAM BATHYMETRIC AND TOPOGRAPHIC.
   - 1.2. HORIZONTAL DATUM: VIRGINIA STATE PLANE (SOUTH ZONE), NORTH AMERICAN DATUM OF 1983 (NAD 83), US FEET
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2. SITE ACCESS TO THE PROJECT SITE MAY OCCUR BETWEEN STA 0+00 AND STA 150+00 WITH APPROVAL FROM COR AND OWNER. SEE SHEET G-004 FOR ADDITIONAL DETAILS REGARDING PROJECT SITE ACCESS AND LAYDOWN AND STAGING AREAS.
3. LAYDOWN AREA 6 NOT SHOWN. SEE G-004 FOR MORE INFORMATION.

KEY PLAN



LEGEND:

- EXISTING CONTOUR (MAJOR)
- EXISTING CONTOUR (MINOR)
- MHW — MEAN HIGH WATER (MHW) ELEVATION
- MLW — MEAN LOW WATER (MLW) ELEVATION

US Army Corps of Engineers®

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U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

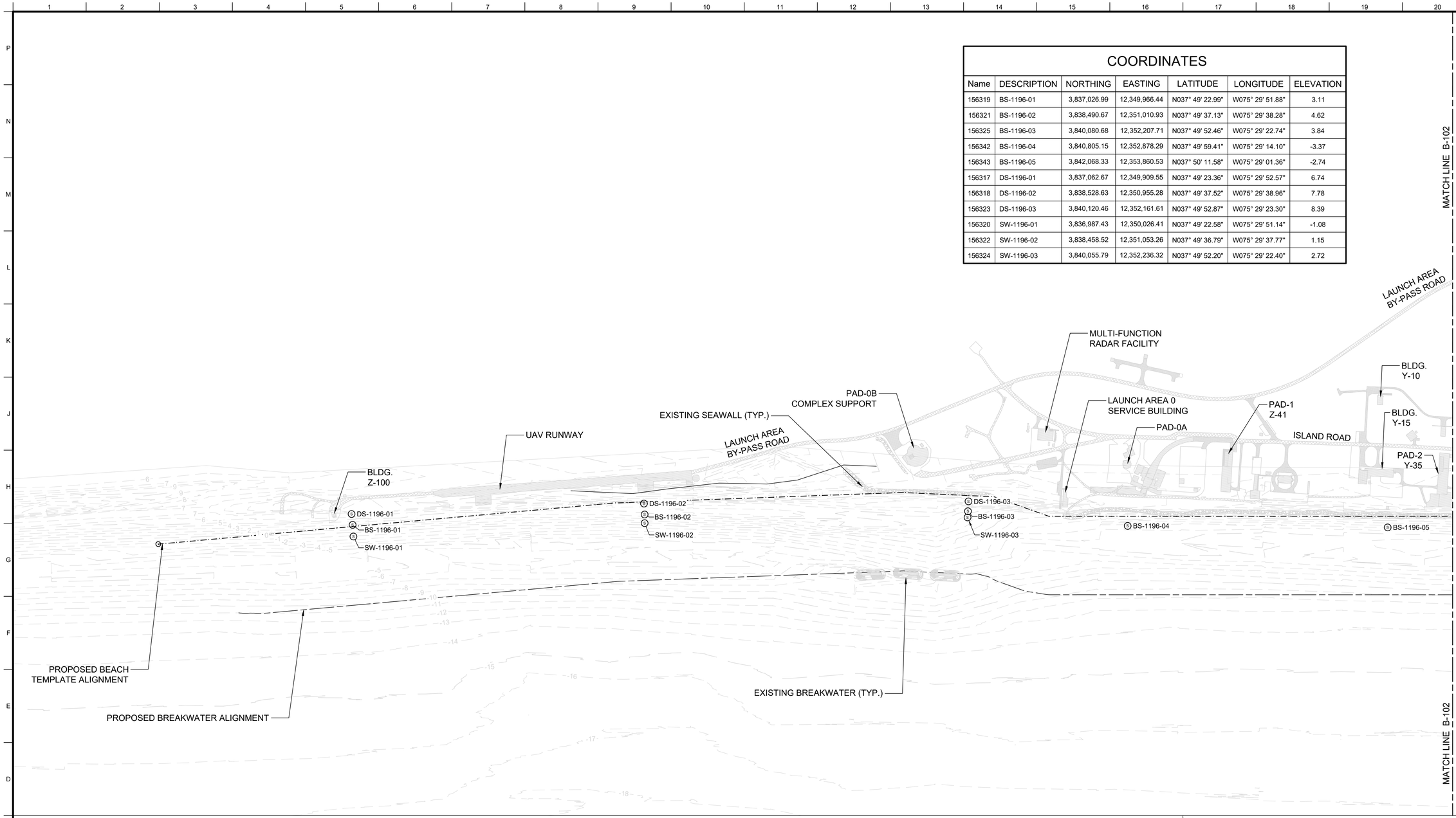
EXISTING CONDITIONS

SHEET ID
V-102

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COORDINATES

Name	DESCRIPTION	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEVATION
156319	BS-1196-01	3,837,026.99	12,349,966.44	N037° 49' 22.99"	W075° 29' 51.88"	3.11
156321	BS-1196-02	3,838,490.67	12,351,010.93	N037° 49' 37.13"	W075° 29' 38.28"	4.62
156325	BS-1196-03	3,840,080.68	12,352,207.71	N037° 49' 52.46"	W075° 29' 22.74"	3.84
156342	BS-1196-04	3,840,805.15	12,352,878.29	N037° 49' 59.41"	W075° 29' 14.10"	-3.37
156343	BS-1196-05	3,842,068.33	12,353,860.53	N037° 50' 11.58"	W075° 29' 01.36"	-2.74
156317	DS-1196-01	3,837,062.67	12,349,909.55	N037° 49' 23.36"	W075° 29' 52.57"	6.74
156318	DS-1196-02	3,838,528.63	12,350,955.28	N037° 49' 37.52"	W075° 29' 38.96"	7.78
156323	DS-1196-03	3,840,120.46	12,352,161.61	N037° 49' 52.87"	W075° 29' 23.30"	8.39
156320	SW-1196-01	3,836,987.43	12,350,026.41	N037° 49' 22.58"	W075° 29' 51.14"	-1.08
156322	SW-1196-02	3,838,458.52	12,351,053.26	N037° 49' 36.79"	W075° 29' 37.77"	1.15
156324	SW-1196-03	3,840,055.79	12,352,236.32	N037° 49' 52.20"	W075° 29' 22.40"	2.72



C9 GEOTECHNICAL EXPLORATIONS

1" = 300'

0 300' 600'

PLAN NORTH

LEGEND:

⊙ GRAB SAMPLE

US Army Corps of Engineers®

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SUBMITTED BY: N. INGOLD	NAO FILE NO.: 1196
	SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

GEOTECHNICAL EXPLORATIONS

SHEET ID
B-101

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COORDINATES

Name	DESCRIPTION	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEVATION
156328	BS-1196-06	3,843,174.42	12,354,723.68	N037° 50' 22.24"	W075° 28' 50.16"	-0.95
156330	BS-1196-07	3,844,731.80	12,355,975.19	N037° 50' 37.23"	W075° 28' 33.95"	5.03
156333	BS-1196-08	3,846,299.41	12,357,220.66	N037° 50' 52.32"	W075° 28' 17.80"	3.32
156336	BS-1196-09	3,847,412.68	12,358,225.24	N037° 51' 03.00"	W075° 28' 04.84"	5.08
156339	BS-1196-10	3,848,579.48	12,359,173.16	N037° 51' 14.23"	W075° 27' 52.56"	6.11
156332	DS-1196-08	3,846,321.24	12,357,190.02	N037° 50' 52.55"	W075° 28' 18.18"	5.86
156335	DS-1196-09	3,847,480.63	12,358,142.29	N037° 51' 03.70"	W075° 28' 05.85"	13.43
156338	DS-1196-10	3,848,658.01	12,359,071.45	N037° 51' 15.04"	W075° 27' 53.80"	10.67
156331	SW-1196-07	3,844,684.44	12,356,037.03	N037° 50' 36.74"	W075° 28' 33.20"	0.78
156334	SW-1196-08	3,846,273.38	12,357,254.35	N037° 50' 52.06"	W075° 28' 17.39"	0.76
156337	SW-1196-09	3,847,374.06	12,358,272.41	N037° 51' 02.61"	W075° 28' 04.27"	2.65
156340	SW-1196-10	3,848,469.39	12,359,313.60	N037° 51' 13.10"	W075° 27' 50.85"	3.68

MATCHLINE B-101

LAUNCH AREA BY-PASS ROAD

CAUSEWAY RD

LAUNCH AREA BY-PASS ROAD

LAUNCH AREA BY-PASS ROAD

AEGIS ENGINEERING AND TRAINING COMPLEX

BLDG. Y-50

BLDG. Y-30

PAD-2 Y-39

BLDG. X-15

BLDG. X-35

BLDG. X-85

HORIZONTAL INTEGRATION FACILITY (HIF)

BLDG. W-65

BLDG. W-20

DDX, DDG, WIETCI

ISLAND ROAD

ISLAND ROAD

BS-1196-06

BS-1196-07

SW-1196-07

DS-1196-08

BS-1196-08

SW-1196-08

DS-1196-09

BS-1196-09

SW-1196-09

DS-1196-10

BS-1196-10

SW-1196-10

PROPOSED BEACH TEMPLATE ALIGNMENT

EXISTING BREAKWATER (TYP.)

PROPOSED BREAKWATER ALIGNMENT

MATCHLINE B-101

C9 GEOTECHNICAL EXPLORATIONS

1" = 300'

0 300' 600'

PLAN NORTH

LEGEND:

⊙ GRAB SAMPLE

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD
DRAWN BY: N. INGOLD
CHECKED BY: R. WILLIAMS
SUBMITTED BY: N. INGOLD
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NAO FILE NO.: 1196

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

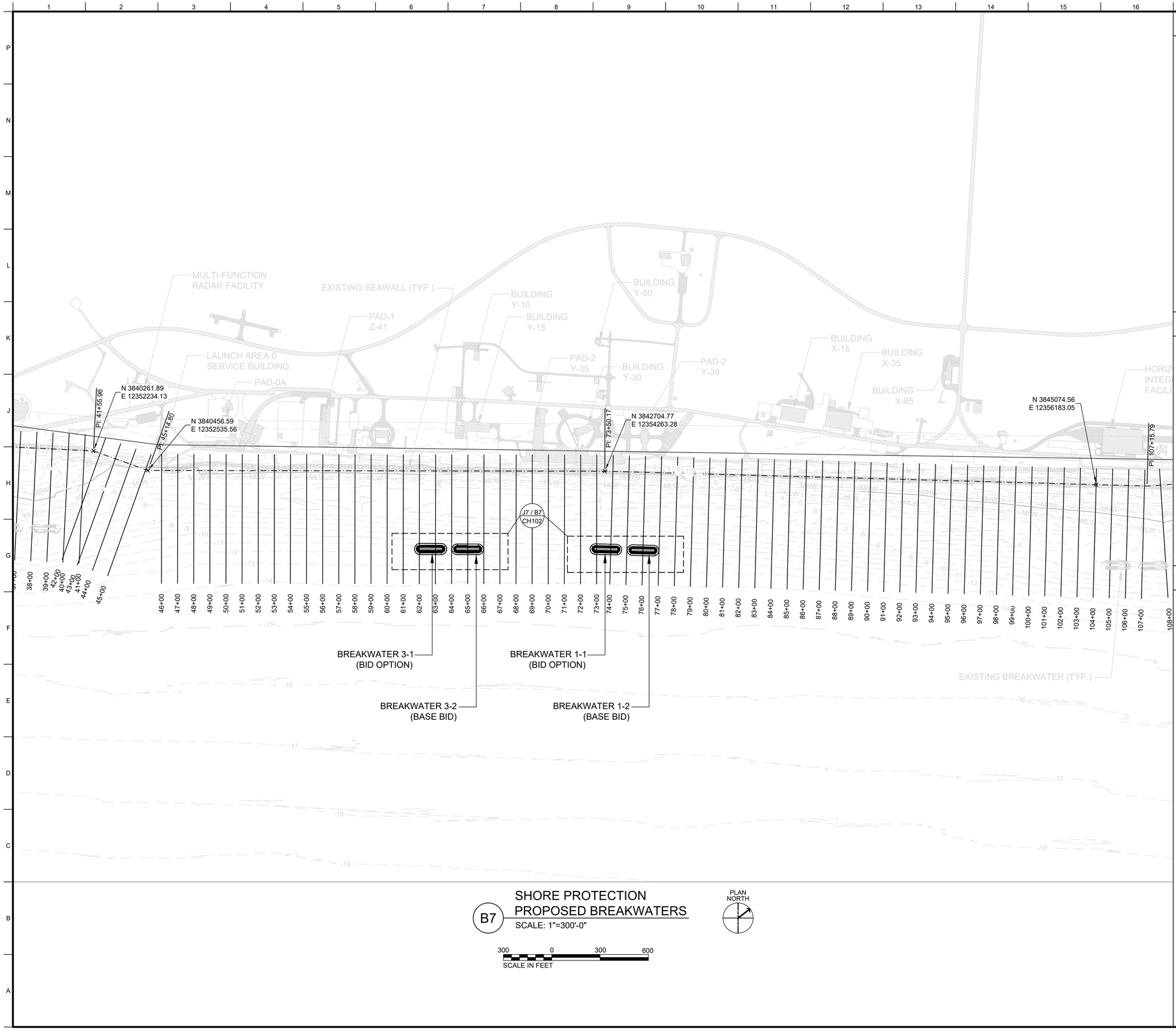
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

GEOTECHNICAL EXPLORATIONS

SHEET ID

B-102

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B7 SHORE PROTECTION PROPOSED BREAKWATERS

SCALE: 1"=300'-0"

PLAN NORTH

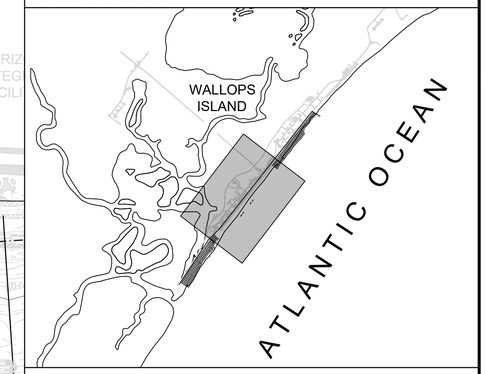
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SCALE IN FEET

GENERAL NOTES:

1. BREAKWATERS TO BE CONSTRUCTED APPROXIMATELY 200 FEET FROM FINAL MHW.
2. BEACH FILL PROJECT NOT IN CONTRACT.
3. BREAKWATERS TO BE CONSTRUCTED ON MARINE MATTRESS. SEE SHEET C-502 FOR MARINE MATTRESS DETAILS.
4. CORE STONE SHALL CONSIST OF VDOT CLASS III STONE.
5. ARMOR STONE SHALL CONSIST OF VDOT TYPE III RIPRAP.
6. BREAKWATER SPACING REFERENCED FROM CENTERLINE OF CREST.
7. BREAKWATERS TO BE CONSTRUCTED FROM EXISTING GRADE TO CREST ELEVATION 7' NAVD88. OVERALL BREAKWATER HEIGHT VARIES.
8. BREAKWATER TOE SHALL BE CONSTRUCTED AROUND ENTIRE STRUCTURE.
9. ACCESS TO CONSTRUCT BREAKWATERS ARE THE RESPONSIBILITY OF THE CONTRACTOR. SEE SPECIFICATION 35 31 19.40 FOR DETAILS AND SHEET G-004 FOR LAYDOWN AND BEACH ACCESS DETAILS.
10. SEE SHEET C-501 FOR BREAKWATER DETAILS.
11. SEE SHEET C-601 FOR BREAKWATER QUANTITIES.

KEY PLAN



LEGEND:

- EXISTING CONTOUR (MAJOR)
- EXISTING CONTOUR (MINOR)
- PROPOSED CONTOUR (MAJOR)
- PROPOSED CONTOUR (MINOR)

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:	ISSUE DATE:
N. INGOLD	MAR 2026
DRAWN BY:	SOLICITATION NO.:
N. INGOLD	+AEC_MAN_SOLICNUM
CHECKED BY:	CONTRACT NO.:
R. WILLIAMS	+AEC_MAN_CONTRNUM
SUBMITTED BY:	NAO FILE NO.:
N. INGOLD	1196
SIZE:	ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

BCOES SUBMITTAL
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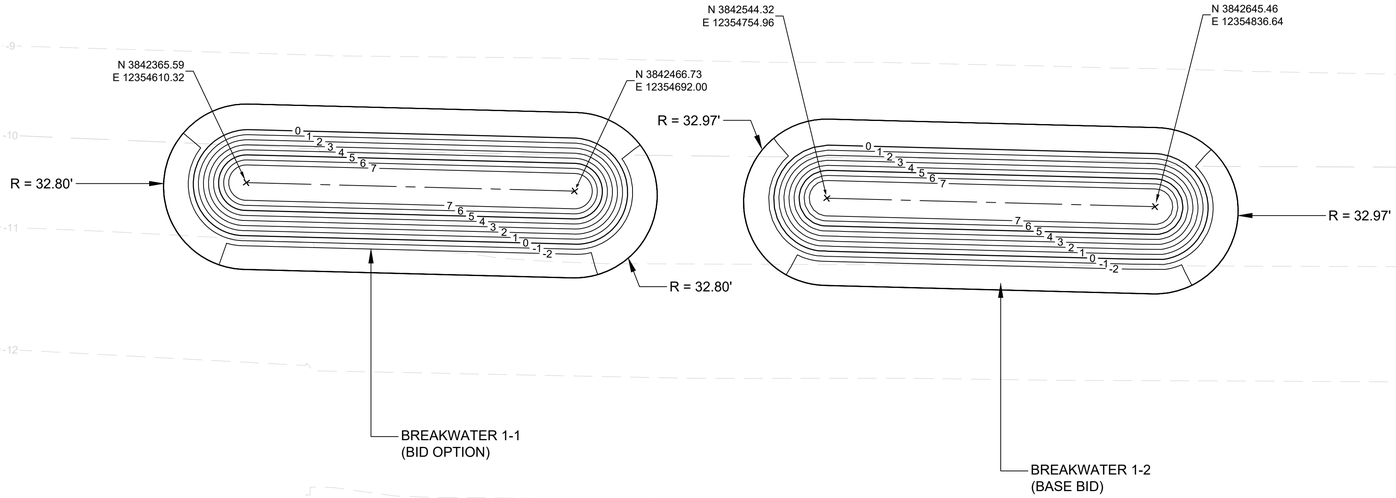
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

SHORE PROTECTION
BREAKWATERS

SHEET ID

CH101

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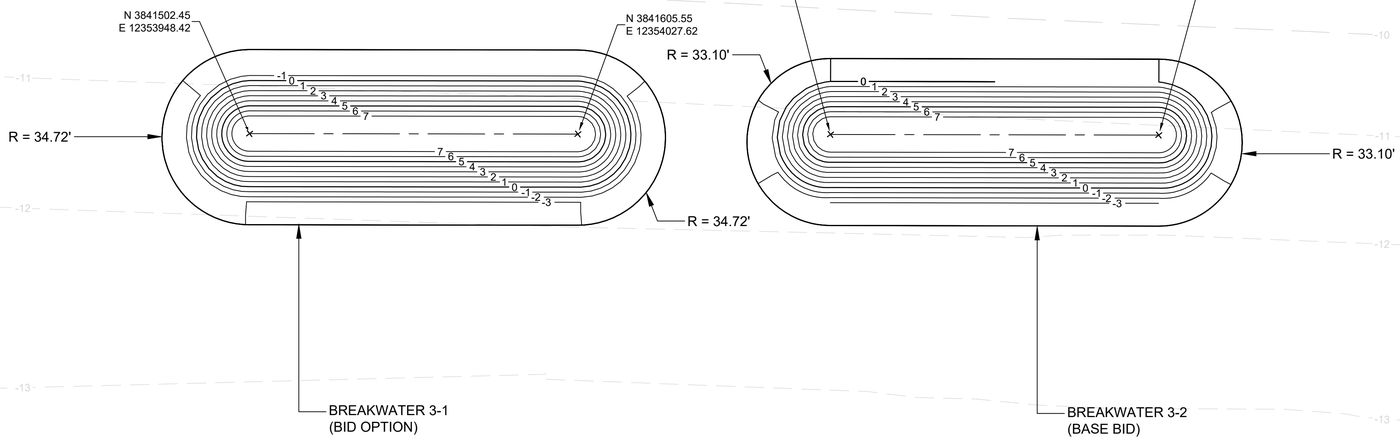
J7 SHORE PROTECTION PRIORITY AREA 1

SCALE: 1"=30'-0"

PLAN NORTH

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SCALE IN FEET



B7 SHORE PROTECTION PRIORITY AREA 3

SCALE: 1"=30'-0"

PLAN NORTH

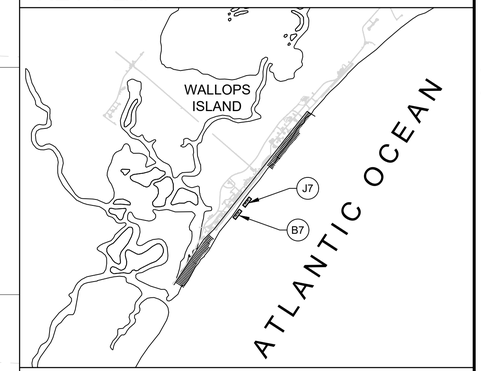
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SCALE IN FEET

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KEY PLAN



LEGEND:

- 5 — EXISTING CONTOUR (MAJOR)
- 1 — EXISTING CONTOUR (MINOR)
- 5 — PROPOSED CONTOUR (MAJOR)
- 1 — PROPOSED CONTOUR (MINOR)

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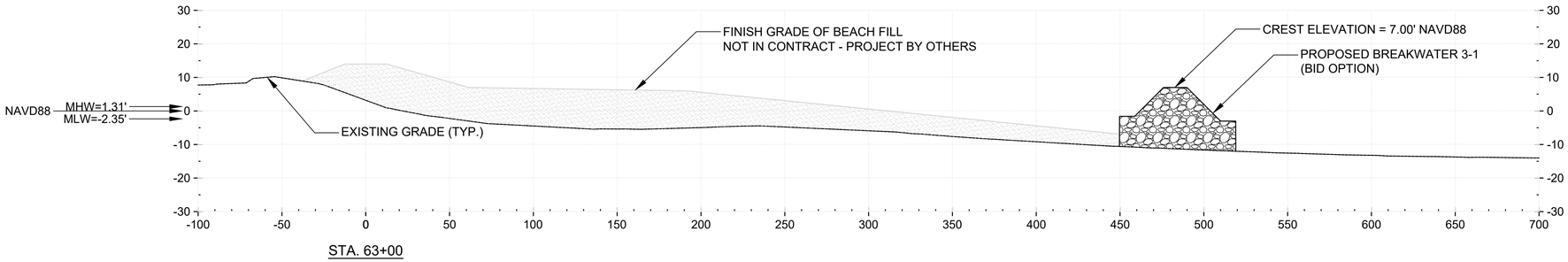
ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

SHORE PROTECTION
BREAKWATERS

SHEET ID

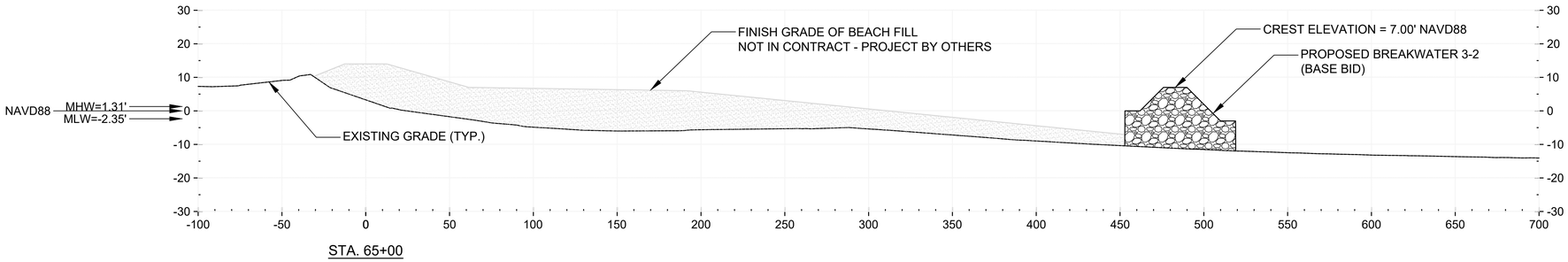
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BREAKWATER 3-1
STA 63+00

L3



BREAKWATER 3-2
STA 65+00

E3

US Army Corps of Engineers®

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N. INGOLD	MAR 2026
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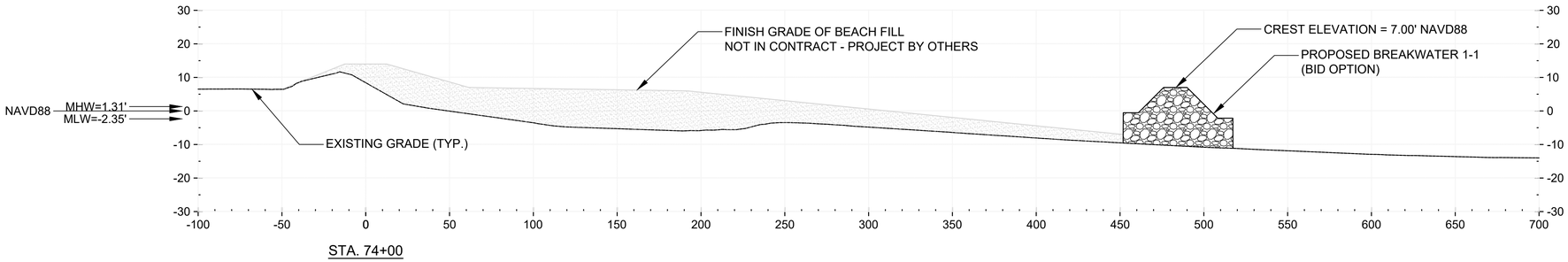
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(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

CROSS SECTIONS
BREAKWATER 3-1 (STA 63+00)
BREAKWATER 3-2 (STA 65+00)

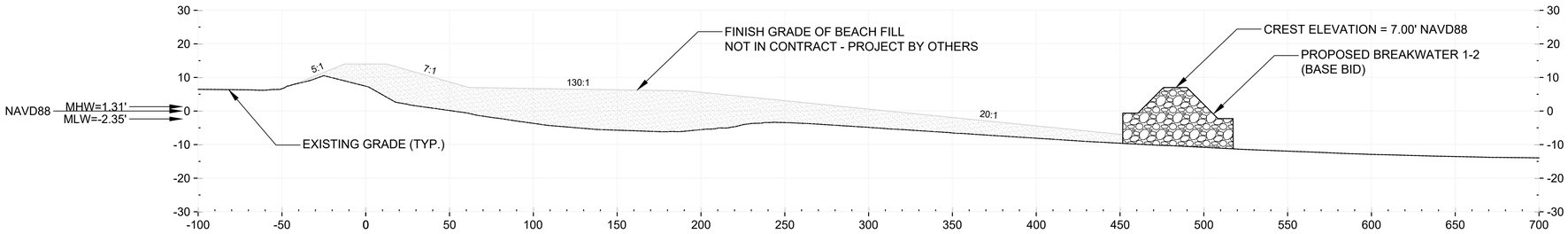
SHEET ID
C-301

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AEC_B&W.STB



STA. 74+00

BREAKWATER 1-1
L3 STA 74+00



STA. 76+00

BREAKWATER 1-2
E3 STA 76+00

US Army Corps of Engineers®

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N. INGOLD	1196
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NORFOLK, VA 23510

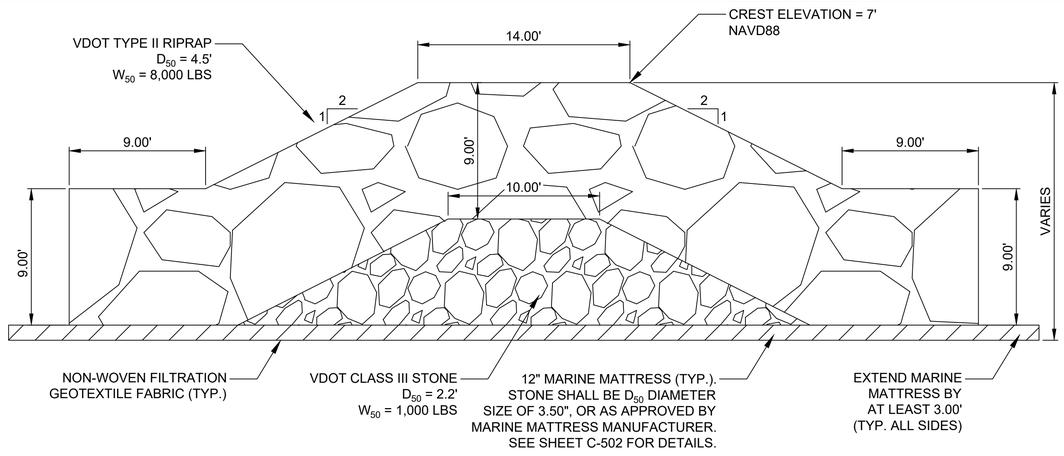
BCOES SUBMITTAL
(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

CROSS SECTIONS
BREAKWATER 1-1 (STA 74+00)
BREAKWATER 1-2 (STA 76+00)

SHEET ID
C-302

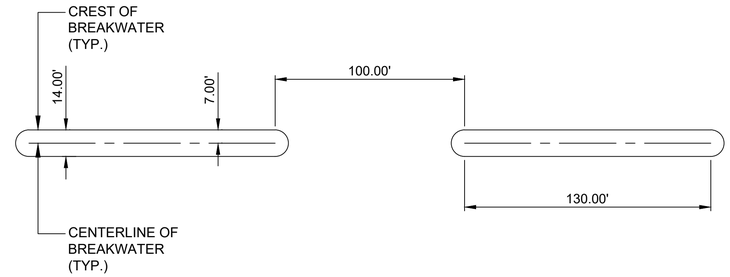
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K3 TYPICAL BREAKWATER SECTION

1" = 5'-0"

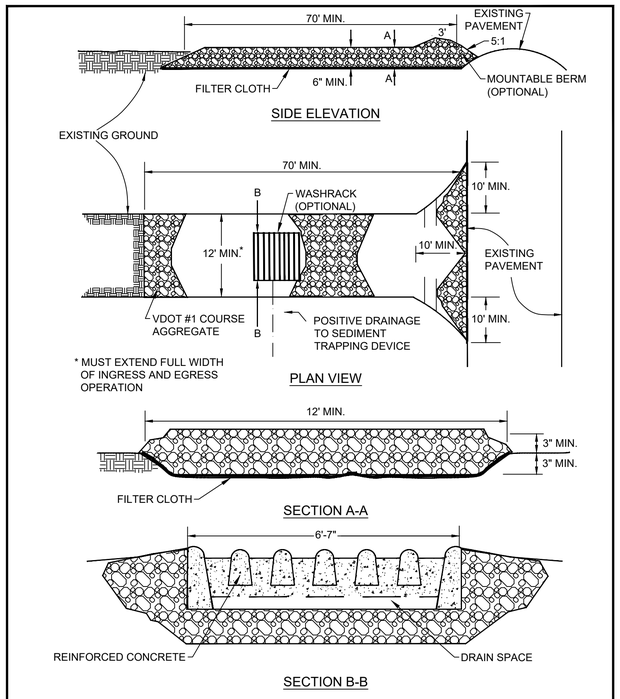
0 5' 10'



K14 TYPICAL BREAKWATER LAYOUT

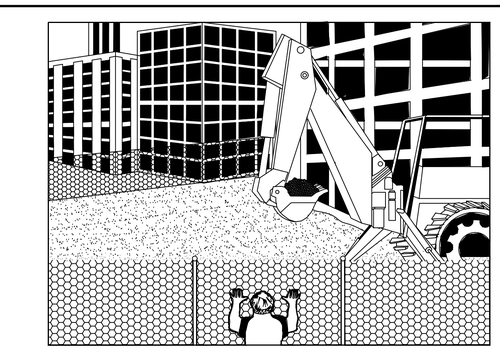
1" = 40'-0"

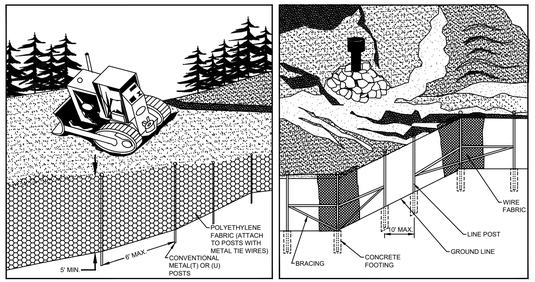
0 40' 80'



VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY — v1.1 — SOURCE: VA. DSWC, MD ESC STDS — C-SCM-03-1

A2 CONSTRUCTION ENTRANCE

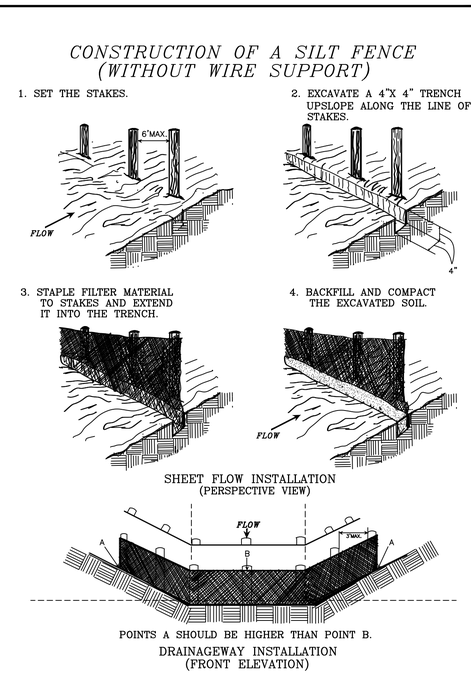




VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY — v1.1 — SOURCE: VDOT STDS., VA DSWC, CONWED PLASTICS — C-PCM-01-1

A9 SAFETY FENCE

CONSTRUCTION OF A SILT FENCE (WITHOUT WIRE SUPPORT)



VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY — v1.1 — SOURCE: VA. DSWC, MD ESC STDS — C-PCM-04

A17 SILT FENCE

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CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
ISSUE DATE: MAR 2026
SOLICITATION NO.: +AEC_MAN_SOLICNUM
CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196
SIZE: ANSI D

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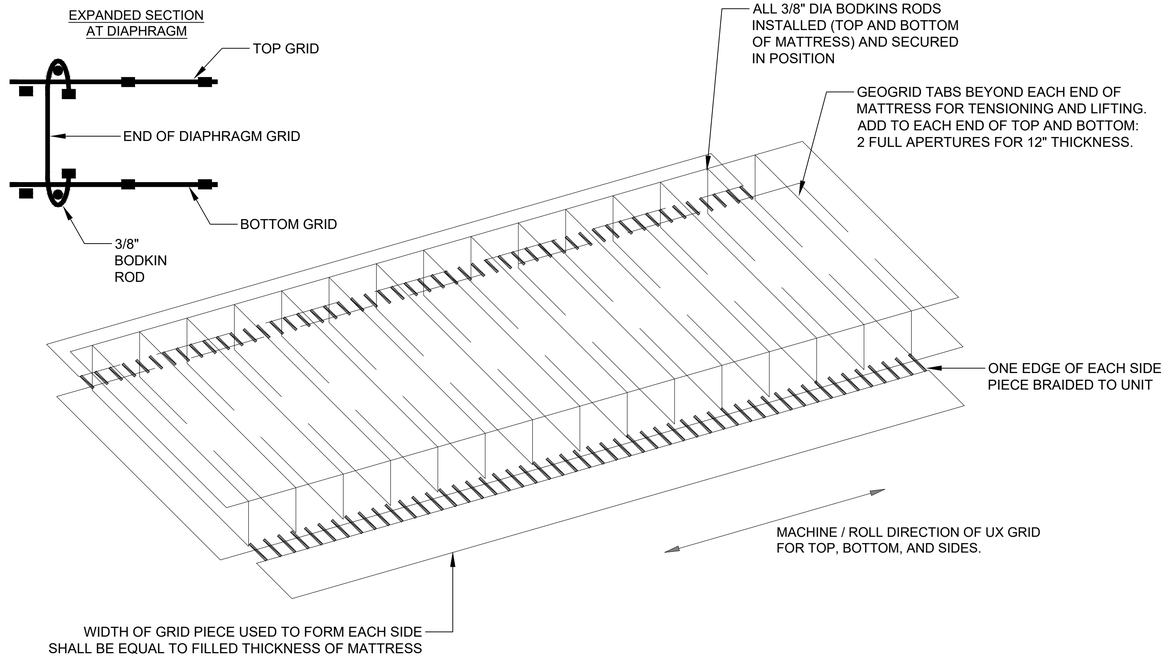
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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

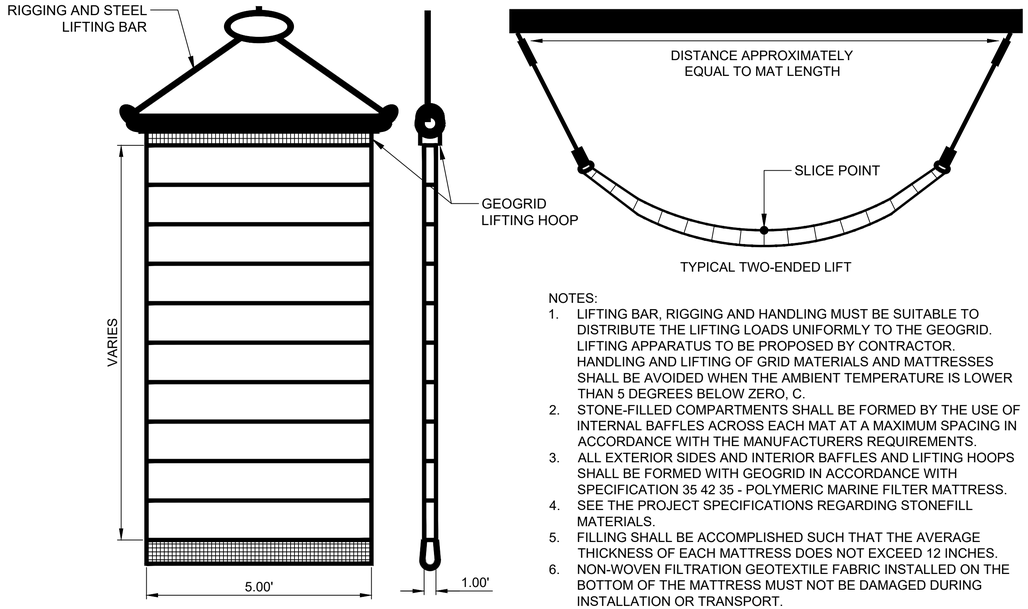
DETAILS
BREAKWATER CROSS SECTION & LAYOUT
EROSION AND SEDIMENT CONTROL

SHEET ID
C-501

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J3 TYPICAL CONFIGURATION OF MARINE MATTRESS
NTS

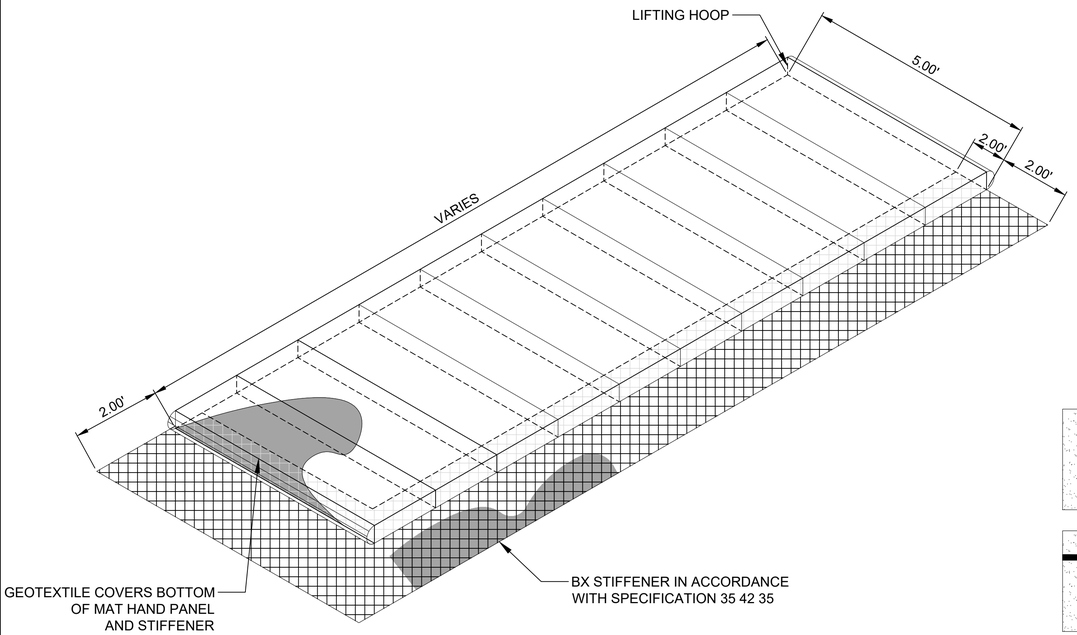


TYPICAL ONE-ENDED LIFT

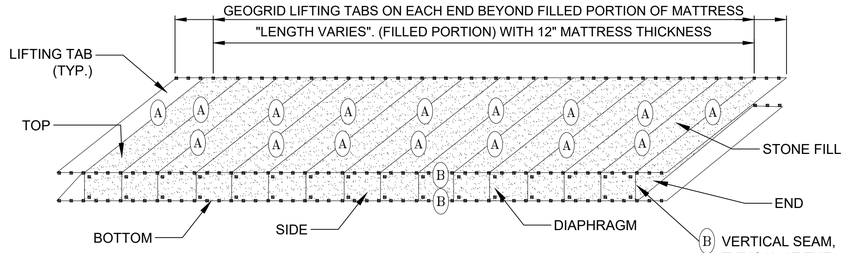
TYPICAL TWO-ENDED LIFT

NOTES:
1. LIFTING BAR, RIGGING AND HANDLING MUST BE SUITABLE TO DISTRIBUTE THE LIFTING LOADS UNIFORMLY TO THE GEOGRID. LIFTING APPARATUS TO BE PROPOSED BY CONTRACTOR. HANDLING AND LIFTING OF GRID MATERIALS AND MATTRESSES SHALL BE AVOIDED WHEN THE AMBIENT TEMPERATURE IS LOWER THAN 5 DEGREES BELOW ZERO, C.
2. STONE-FILLED COMPARTMENTS SHALL BE FORMED BY THE USE OF INTERNAL BAFFLES ACROSS EACH MAT AT A MAXIMUM SPACING IN ACCORDANCE WITH THE MANUFACTURERS REQUIREMENTS.
3. ALL EXTERIOR SIDES AND INTERIOR BAFFLES AND LIFTING HOOPS SHALL BE FORMED WITH GEOGRID IN ACCORDANCE WITH SPECIFICATION 35 42 35 - POLYMERIC MARINE FILTER MATTRESS.
4. SEE THE PROJECT SPECIFICATIONS REGARDING STONEFILL MATERIALS.
5. FILLING SHALL BE ACCOMPLISHED SUCH THAT THE AVERAGE THICKNESS OF EACH MATTRESS DOES NOT EXCEED 12 INCHES.
6. NON-WOVEN FILTRATION GEOTEXTILE FABRIC INSTALLED ON THE BOTTOM OF THE MATTRESS MUST NOT BE DAMAGED DURING INSTALLATION OR TRANSPORT.

H14 MARINE MATTRESS LIFTING
NTS

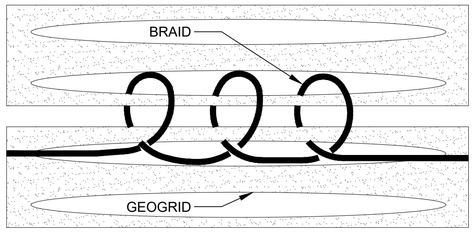


A3 MARINE MATTRESS DETAIL
NTS



NOTES:
1. ENDS, TOPS, BOTTOMS, SIDES, AND ANY EXTRA LENGTHS USED FOR LIFTING OR ANCHORING PURPOSES SHALL BE COMPOSED OF GEOGRID IN ACCORDANCE WITH SPECIFICATION 35 42 35 - POLYMERIC MARINE FILTER MATTRESS.
2. INTERNAL DIAPHRAGMS SHALL BE COMPOSED OF GEOGRID IN ACCORDANCE WITH SPECIFICATION 35 42 35 - POLYMERIC MARINE FILTER MATTRESS.
3. NOMINAL WIDTH OF UNITS: 5 FT (FILLED), 4.3 FT (UNFILLED)
4. TYPICAL THICKNESS (FILLED): 12 INCHES

D14 TYPICAL CONFIGURATION OF FILLED MARINE MATTRESS
NTS



NOTES:
1. ALL CUT ENDS OF BRAID MATERIAL SHALL BE KNOTTED WITHIN 1/2" TO 2" OF THE END TO PREVENT RAVELING OF BRAID.
2. AT ALL ENDS ENDS OF ALL BRAIDED SEAMS THE BRAID SHALL BE SECURELY KNOTTED TO THE GEOGRID.
3. AT ALL ENDS OF ALL PIECES OF BRAID MATERIAL USED, THE BRAID SHALL BE KNOTTED TO SPLICE IT TO THE NEXT PIECE OF BRAID, OR TO SECURE IT TO THE GEOGRID. EACH BRAID SEAM SHALL BE CONTINUOUS, WITH SECURELY KNOTTED SPLICES ALLOWED. THE BRAID SHALL BE SECURELY KNOTTED TO THE GEOGRID AT A SPACING NOT EXCEEDING 6 FT ALONG ANY SEAM.
4. THE BRAID SHALL BE STITCHED THROUGH EACH PAIR OF APERTURES ALONG THE SEAM AT LEAST ONCE, AND THE MINIMUM NUMBER OF STITCHES PER FOOT ALONG THE SEAM SHALL BE SIX (6). THE SPACING OF STITCHES ALONG EACH SEAM SHALL BE REASONABLY UNIFORM.
5. ALL KNOTS SHALL BE TIED IN A MANNER TO PREVENT SLIPPING AND CINCHING.
6. THE WRAPS ALONG THE SEAM SHALL BE SUFFICIENTLY TIGHT TO CLOSE THE GAP BETWEEN THE ADJACENT PIECES OF GEOGRID, BUT SHALL NOT BE OVER-TIGHTENED SUCH THAT THE GEOGRID BINDS ALONG THE SEAM.

A12 TYPICAL STITCHED SEAM DETAIL
NTS

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ISSUE DATE: MAR 2026
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CONTRACT NO.: +AEC_MAN_CONTRNUM
NAO FILE NO.: 1196
DESIGNED BY: N. INGOLD
DRAWN BY: N. INGOLD
CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

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ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

DETAILS
MARINE MATTRESS

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STRUCTURE NAME	CORE STONE VDOT CLASS III (TON)	ARMOR STONE VDOT TYPE II (TON)	MARINE MATTRESS (SQYD)	GEOTEXTILE FABRIC (SQYD)	MARINE MATTRESS STONE (TON)
BREAKWATER 1-1	3,300	6,500	1,870	1,870	1,120
BREAKWATER 1-2	3,300	6,600	1,880	1,880	1,130
BREAKWATER 3-1	3,600	7,200	1,990	1,990	1,200
BREAKWATER 3-2	3,500	7,000	1,920	1,920	1,150

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY: N. INGOLD
DRAWN BY: N. INGOLD
CHECKED BY: K. THEVERAPPERUMA
SUBMITTED BY: N. INGOLD
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SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
803 FRONT STREET
NORFOLK, VA 23510

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(NOT FOR CONSTRUCTION)

ACCOMACK COUNTY, VA
WALLOPS ISLAND
SHORELINE PROTECTION PROJECT
BREAKWATER CONSTRUCTION

MATERIAL SCHEDULE

SHEET ID
C-601

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U.S. ARMY CORPS
OF ENGINEERS®
NORFOLK DISTRICT

Wallops Island Shoreline Protection Project
Wallops Island Flight Facility

Design Analysis

BCOES Submittal

March 2026

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Appendix **87**

Appendix A: Geotechnical Figures and Maps
Appendix B: Geotechnical Calculations
Appendix C: Schnabel Engineering Report, Wallops Island Breakwaters, July 18, 2018
Appendix D: 2026 Unnamed Shoal A Borrow Area Geotechnical Report
Appendix E: 2026 Terracon Beach Grab Sample Report

1 GENERAL DESCRIPTION

1.1 PURPOSE

The purpose of the NASA's Shoreline Protection Program (SPP) is to reduce the potential for damage to, or loss of, NASA, U.S. Navy, and Virginia Spaceport Authority's Mid-Atlantic Regional Spaceport (MARS) assets on Wallops Island from impacts associated with storm events and sea level rise. The current efforts and the associated SPP Environmental Assessment (EA) is the third construction effort involving USACE Norfolk District, with each environmental assessment document being tiered off of the initial February 2010 Shoreline Restoration and Infrastructure Protection Program Programmatic Environmental Impact Statement (SRIPP PEIS), available at: https://www.nasa.gov/goddard/memd/nepa/shoreline/

In the SRIPP PEIS, NASA evaluated potential environmental effects from a 50-year design life program with an initial construction phase followed by subsequent renourishment cycles that would be determined through monitoring and adaptive management. Various alternatives were considered, including: extending the existing seawall; recurring nourishment of the beach on Wallops Island (every 3-7 years); and constructing a parallel nearshore breakwater. The preferred action at that time consisted of extending the seawall approximately 4,600 feet and nourishing the beach with approximately 3.2 million cubic yards of sand dredged from Unnamed Shoal A.

Following the first round of beach nourishment in 2012, Superstorm Sandy struck the U.S. East Coast. While the newly expanded Wallops Island beach successfully protected NASA, Navy, and MARS assets, it suffered significant damage. In June 2013, NASA released the Wallops Island Post-Hurricane Sandy Shoreline Repair Final Environmental Assessment (Shoreline Repair EA). The Shoreline Repair EA built upon (or tiered from) the SRIPP PEIS and evaluated potential environmental impacts associated with a shortened renourishment cycle and repair of the Wallops Island seawall. Repairs to the seawall and second beach renourishment of 650,000 cubic yards of sand were completed in September 2014. Subsequent storms in 2015 (Hurricane Joaquin), in 2016 (Winter Storm Jonas), and in 2018 (Winter Storm Riley) resulted in a reduction of over a million cubic yards of sand in the southern portion of the island.

In 2018, NASA requested that the U.S. Army Corps of Engineers, Norfolk District Hydraulics and Hydrology Section evaluate the effectiveness of constructing a breakwater or series of breakwaters along the Wallops Island shoreline to reduce the rate of sediment transport since previous renourishments provided only temporary protection. In June 2019, NASA released the Wallops Flight Facility Shoreline Enhancement and Restoration Project Final Environmental Assessment (SERP EA). The project placed approximately 1.1 million cubic yards of sand

sourced from the north Wallops Island beach and constructed a total of five breakwaters placed approximately 200 feet offshore and parallel to the shoreline.

USACE District Jacksonville (SAJ) provided Coastal Engineering support to review the 2019 USACE design effort. Two Coastal Engineers at the U.S. Army Engineer Research and Development Center (ERDC) were identified to support the current project. Kick off occurred on 5 December 2023. Schedule at kick-off estimated project award in May 2025 and construction NTP June 2025. The ERDC Coastal Engineers and PM attended a two-day site visit at WFF 25 and 26 March 2024. A requirement for updated topographic and bathymetric survey of current conditions was scoped in Dec 23/Jan 24 and awarded as a NAO TO to GeoDynamics on 27 June 2024.

NASA's objective is to use USACE's expertise to design and construct a hybrid beach renourishment (via dredge) and breakwater solution to best utilize the IA amount of $40M. Construction procurement, oversight/management, and inspection services will be through the USACE Norfolk District. The goal of the project is shoreline protection of Wallops Island Assets, focusing on vulnerable areas of the shoreline subject to higher erosion. For a 5-year return period, provide a beach renourishment with a target fill and sacrificial fill volume which is based on current shoreline conditions. Focus is the Pad 2 to HIF corridor for breakwater locations. Provide an option for seawall repairs on the contract.

NASA and Norfolk District met at the Waterfield Building, Norfolk, on 24 May 2023, to discuss the project. Team members were introduced, agency intentions stated and lessons learned from past projects were discussed. CENAO expressed interest in taking on the project. An interagency agreement was completed and funding ("o" year supplemental funding) transferred via MIPR in the amount of $40M to the Corps with a funding acceptance document 448-2 from the Corps received on 9/28/23.

The approach focuses on determining a "target" fill volume, which is a level of fill that will remain after 5 years, as well as a sacrificial fill volume, a level of fill in addition to the target fill, that is expected to erode by the 5-year mark. Target and sacrificial fill volumes will be updated to current shoreline conditions, given the recent 2020 addition of breakwaters and incorporating any changes to sediment transport trends. The approach will also take into consideration an observed trend south of the southern set of breakwaters, where it indicates a lack of sediment transport just south of the breakwaters is occurring. Upon completion of topo/bathy survey, volume deficit will be determined which will effect the number of breakwaters that can be accommodated in the budget after renourishment needs are addressed.

NASA's intent is for USACE team to decide most effective locations for one to two sets of breakwaters, considering effect on the entire shoreline. Approach to prioritizing breakwater locations

was model heavy and could result in delays in design. Limitations for breakwater locations include some owner-related complexities. Breakwater installation in Pad 0A area may encounter massive delays and project constraints due to hazard areas surrounding the Pad in pre-launch and launch scenarios. Both agencies agreed that placement of breakwaters south of the southern Pad 0B existing breakwater set presents an unacceptable risk, as the effects south of those sets is not fully understood. The best solution is to focus breakwater placement in corridor, south edge of Pad 2 to HIF. Provide locations for 2 sets. Base bid, option breakout to be determined after renourishment needs are determined through the upcoming survey.

Modeling approach includes three scenarios. No project – effect on shoreline with no intervention. Beach renourishment only – effect on shoreline with renourishment only. Final approach is Hybrid – renourishment and breakwaters.

1.2 AUTHORIZATION AND DIRECTIVES

Because of damaging coastal storm activities, NASA received supplement/emergency funding in the amount of $40M to address the facility's eroding shoreline and to better protect the near-by launch sites and supporting infrastructure.

1.3 SCOPE OF WORK

The U.S. Army Corps of Engineers USACE Norfolk District is tasked to provide Ready to Advertise (RTA) plans and specifications, full construction procurement services, and construction oversight and administration for a Wallops Island Shoreline Protection Project at Wallops Flight Facility, VA. The project will provide a combination of breakwaters and beach fill that will protect the mid to southern reaches of Wallops Beach and provide for protection of mission critical infrastructure at Wallops Flight Facility. Although the two sets of breakwaters installed at Wallops Island in 2020 have successfully demonstrated the ability to protect portions of the island, the USACE shall provide an optimal layout for additional breakwaters on the island in combination with beach nourishment, weighing both the minimization of erosion on the island and protection of critical infrastructure to determine the placement of those breakwaters. The final number of breakwaters, sizing of the breakwaters, and location of the breakwaters will be determined following the results of shoreline modeling. Additionally, the beach nourishment parameters, primarily berm width, station limits, and transitions, will be designed with the aid of coastal process modeling, incorporating the impacts of the offshore breakwaters. The number of breakwaters and volume of nourishment will account for available funding provided via Hurricane Ian supplemental funds.

Tasks associated with this project include:

- Design and construct a hybrid beach renourishment (via dredge) and breakwater solution to best utilize $40M. For a 5-year periodic nourishment cycle, provide a beach renourishment with a target fill and sacrificial fill volume which is based on current shoreline conditions. Focus is the Pad 2 to HIF corridor for breakwater locations. Provide an option for seawall repairs on the contract. Target and sacrificial fill volumes will be updated to current shoreline conditions, given the recent 2020 addition of breakwaters and incorporating any changes to sediment transport trends.
- Project site is bounded between Station 0+00 and Station 150+00. Use modeling to determine the effect of breakwater placement and adjustment based on results.

NASA is the lead agency to produce the EA and for submission of permit applications. USACE Norfolk District will be a cooperating agency and will provide input and reviews during that process. For NEPA purposes, the 35% design submission will provide maximum footprint of the project area of disturbance. Max footprint will include area of shoreline renourishment, breakwaters, laydown areas, max footprint of temporary disturbances including areas effected by breakwater construction.

1.4 CRITERIA

The following lists are references and/or design criteria for the project:

- NASA/USACE Memorandum of Agreement (MOA) 2022, signed 17 Feb 2022
- 7600A, referencing NASA/USACE MOA Date 02/17/2022
- 7600B, Order Number 80GSFC23TA047, GT&C NNH230B133, 09 Aug 2023
- NASA/USACE Enterprise Program Management Plan (EPgMP), DRAFT January 2024
- Unified Facilities Criteria (UFC)
- Unified Facilities Guide Specifications (UFGS)
- *Beach Erosion Mitigation and Sediment Management Alternatives at Wallops Island, VA.* ERDC/CHL TR-06-21, September 2006
- *Storm Damage Reduction Project Design for Wallops Island, Virginia (Version 1.01).* ERDC/CHL TR-11-9, October 2011
- *Breakwater(s) Analysis, Design, & Modeling Report.* NAO, 2018
- *Wallops Island, VA Spring 2019 Monitoring Report (Final Report).* 2019
- *NASA-WALLOPS ISLAND BREAKWATERS AND BEACH FILL PROJECT.* USACE NAO, 2019

1.5 PROJECT DESCRIPTION

1.5.1 Functional Objective

- Protect critical infrastructure from storm damage, inundation, wave attack and erosion.
- Minimize seawall damage and beach erosion.
- Optimize a combination of renourishment and breakwaters for shoreline protection. Improvements may be made to the existing breakwater design.

1.5.2 Performance Requirements

NASA identified the need to prioritize protection of NASA-owned assets. Based on this input, three locations were identified as Priority Areas 1, 2, and 3, which are located at the following stations:

- Priority Area 1: Station 76+00
- Priority Area 2: Station 22+00
- Priority Area 3: Station 65+00

Designs progressed to show three breakwaters at each priority area. Based on modeling results and available funding, this was reduced to one breakwater at Priority Area 1 and one breakwater at Priority Area 3. There will be bid options for one additional breakwater at each Priority Area.

Initial designs were for beach renourishment to be conducted from Station 0+00 to Station 150+00. Because of available funding, the extent of beach renourishment was reduced to the critical area where fill is needed between Station 40+00 to Station 104+00.

1.5.3 Personnel and Equipment

The project take place at the NASA's Wallops Flight Facility (WFF). The facility is responsible for providing agile, low-cost flight and launch range services to meet government and commercial sector needs for accessing flight regimes worldwide form the Earth's surface to the moon and beyond. The flight assets range from research aircraft, unmanned aerial systems, and high-altitude ballons to suborbital and orbital rockets. Other partners part of the facility's mission include: U.S. Navy, National Oceanic and Atmospheric Administration (NOAA), the Federal Aviation Administration (FAA), Virginia Space, and the Mid-Atlantic Regional Spaceport.

1.5.4 Facility Operational Requirements

WFF is a federal installation that operates a various hours depending on mission requirements. There are approximately 1,100 employee who work and support WFF. Visitors and contractors to WFF are to abide by the strict security requirements set forth by the facility.

1.5.5 Constructability

Industry input and the availability of limited dredging companies indicated that two separate contracts are preferred for the beach renourishment and construction of the breakwaters. Because of this, each will be contracted separately. Two separate plan sets and two separate specification documents are created for each effort.

Beach renourishment will be conducted by dredging sand material offsite from the unnamed "Shoal A" borrow area and transporting to the shoreline where heavy equipment/material handing equipment will grade and finish to the desired beach template. Breakwaters are to be constructed from the shore and approximately 200 feet from MHW. The means and methods for constructing the breakwaters are being left unspecified and will be the responsibility of the contractor. Typical means and methods are expected to include:

- Access and constructed by land
    - By using dredged or hauled-in sand material confined by sheetpiles or geotubes or
    - Fabricated system, such as a bridge or trussell
- Access and constructed by water
    - By using floating or jack-up barge

1.5.6 Accessibility

Since this project does not pertain to a particular federal building or facility, the standards of the Architectural Barriers Act (ABA) of 1968 are not applicable.

2 DESIGN REQUIREMENTS AND PROVISIONS

2.1 CIVIL

2.1.1 General Parameters

- Site plan (grading plan for beach nourishment), erosion and sediment control measures (construction entrances, silt fencing, seeding/sprigging)
- Drafting support (AutoCAD Civil 3D) for plan set development and generating material quantities (beach fill and breakwater stones)

2.1.2 Design Objectives and Provisions

- Obtain topographic and bathymetric survey
- Perform grading design to determine material quantities
- Ensure proper erosion and sediment control requirements

2.1.3 Survey

- A topographic and bathymetric survey was contracted and performed by Geodynamics. The beach and nearshore was surveyed between September 8 to 12, 2024. The offshore borrow area was surveyed between October 15 and 23, 2024. The horizontal datum is based on North Atlantic Datum of 1983 (NAD83), Virginia State Plan – South, US Feet. The vertical datum is based on North American Vertical Datum of 1988 (NAVD88), US Feet.

- The survey data of the beach and nearshore was used to create an 'existing surface' in AutoCAD Civil 3D. This 3-dimensional surface is compared to the proposed site features (beach fill and breakwaters) to determine material quantities.

- Additional topographic survey was conducted by Norfolk District's Survey Section to identity existing site features along the beach and topographic elevation of the existing breakwaters. This data was obtained June 2025 and is incorporated into the existing conditions plan sheets.

2.1.4 Calculations

- Using the beach template from Station 40+00 to Station 104+00, site grading was performed using AutoCAD Civil 3D to determine the material quantity for the beach fill. Comparing this to the existing grade, the fill volume is estimated to be 870,000 cubic yards. It was determined that an overfill ratio of 10% would be used for this project. Using this overfill ratio, the total quantity estimated for beach fill is 957,000 cubic yards.
- Site grading was performed using AutoCAD Civil 3D to determine the material quantity for the proposed breakwaters. The overall height of the breakwaters vary. The depth breakwaters will be constructed to is between -9.6 feet to -12.0 feet NAVD88. An average cross section was used to determine material tonnage for the core stones (33%) and armor stones (66%). An assumed 1.8 tons/cubic yards was used a the bulk unit weight for stone. Table 2.1 shows the material quantities for the proposed breakwaters and Table 2.2 shows the material quantities for the marine mattresses.

Table 2.1 – Material Quantities for the Proposed Breakwaters

STRUCTURE NAME	COMPARISON SURFACE	TOTAL VOLUME (CU.YD.)	CORE STONE – CLASS III (TON)	ARMOR STONE – VDOT Type II (TON)
BREAKWATER 1-1	Existing Grade	5,465	3,246	6,492
BREAKWATER 1-2	Existing Grade	5,490	3,261	6,522
BREAKWATER 3-1	Existing Grade	6,055	3,597	7,193
BREAKWATER 3-2	Existing Grade	5,825	3,460	6,920

Table 2.2 – Material Quantities for the Marine Mattresses

STRUCTURE NAME	BREAKWATER AREA (SQ.FT.)	GEOTEXTILE FABRIC (SQ.FT)	FILL STONE – VDOT #2 (TON)
BREAKWATER 1-1	16,767	16,767	1,118
BREAKWATER 1-2	16,855	16,855	1,124
BREAKWATER 3-1	17,870	17,870	1,191
BREAKWATER 3-2	17,245	17,245	1,150

2.1.5 Coordination with Installation, Centers of Expertise, or Outside Agencies

- Coastal modeling efforts are being conducted by the Engineering Research and Development Center (ERDC) to determine shoreline response to proposed breakwater locations. Additional details of this effort are provided in Section 2.4.
- Coordinate/assistance with EA and permitting (JPA).

2.2 GEOTECHNICAL

2.2.1 Beach Renourishment

2.2.1.1 Native Beach Sampling and Borrow Area Exploration

The Norfolk District, US Army Corps of Engineers (NAO) awarded a geotechnical exploration contract to Burns & McDonnell in April 2025 to conduct vibracore sampling within Unnamed Shoal A borrow area and beach sampling at the NASA Wallops Flight Facility. Schnabel Engineering was subcontracted by Burns & McDonnell to execute the borrow area exploration, soil laboratory testing of the vibracore samples, and provide a Geotechnical Data Report (GDR). Terracon was subcontracted by Burns & McDonnell to collect composite beach samples, conduct laboratory testing of the beach samples, conduct a geotechnical exploration in-situ testing within the proposed breakwater alignment Priority Area 2, and provide a GDR. After the contract was awarded, ERDC modeling results were received and it was determined that breakwater structures would not be placed within the shoreline of Priority Area 2. This work was later descoped and was not executed by Terracon.

Terracon collected ten (10) beach composite samples for the purpose of determining the material properties of the native beach material on 9 July 2025. The samples were collected by utilizing a hand auger to a maximum depth of 1-foot below the ground surface at specified locations by the NAO Geotechnical Engineer along the beach. Up to three samples were collected at each location, one in the dune, one in the mid-berm, and one in the swash zone of the beach. All three of these samples were placed in a clean 5-gallon bucket and mixed to create a composite sample. Locations BS-1196-04 through BS-1196-07 were located near the seawall where the beach area was limited. Dune and swash samples were not collected in these areas, only berm samples. Laboratory testing to identify the sand properties of the composite samples were conducted in accordance with NAO specified ASTM standards. In accordance with ASTM D1140, the Terracon soil testing laboratory was directed by the NAO Geotechnical Engineer to wash samples over the No. 230 sieve. For each tested sample the Terracon soil testing laboratory also identified the color of the sand for three conditions: wet, dry before wash, and dry after wash.

Munsell colors were provided for each of these conditions. Due to the amount of fines passing the No. 230 sieve being less than 5 %, hydrometer testing and Atterberg limits testing were not performed. Refer to the geotechnical data report (memorandum) attached as an appendix to the specifications for the complete Terracon report.

Schnabel Engineering collected a total of 18 vibracore samples for 12 locations provided by the NAO Geotechnical Engineer within Unnamed Shoal A borrow area. Additional samples were collected at some locations due to low recovery. Total penetration depth provided in the scope of work was 20-feet. The exploration was conducted by subcontractor Ocean Surveys, Inc. (OSI) between August 16 and 27, 2025. During the exploration Hurricane Erin was forecasted to come close to the borrow site. Due to this circumstance, the exploration team demobilized from the borrow site and mobilized back to the site within a week when tidal and weather conditions were safe to operate. The vibracore equipment and personnel used an Aries Ram XV Class 175-foot Liftboat to travel to the site and to use as a work platform to collect the vibracores. The vibracore equipment consisted of a 32-foot-long polyethylene lined hollow steel sampling barrel advanced from a NAVCO vibracore unit. The lift boat mounted 100-ton hydraulic crane that was used to hoist the vibracore from the deck to the seafloor. The samples were processed, photographed, visually classified in accordance with ASTM D2487, and soil laboratory tested by Schnabel Engineering's soil testing laboratory. The NAO Geotechnical Engineer selected the soil samples for testing after receipt of the draft vibracore logs. Laboratory testing was conducted in accordance with NAO specified ASTM standards. In accordance with ASTM D1140, the Schnabel Engineering soil testing laboratory was directed by the NAO Geotechnical Engineer to wash samples over the No. 230 sieve. For each tested sediment sample Schnabel Engineering's soil testing laboratory also identified the color of the material for three conditions: wet, dry before wash, and dry after wash. Munsell colors were provided for each of these conditions. Due to the percentage of fines passing the No. 230 sieve being less than 5 %, hydrometer testing and Atterberg limits testing were not performed. Refer to the geotechnical data report (memorandum) attached as an appendix to the specifications for the complete Schnabel Engineer report.

Note that when the soil laboratories performed ASTM D1140 they were directed by the NAO Geotechnical Engineer to wash samples over the No. 230. Per information received from the Baltimore District (NAB) soils testing laboratory technician and the Wilmington District (SAW) Professional Geologist, for beach renourishment projects the sediment samples are typically washed over the No. 230 sieve. Note that EM 1110-2-1100 (Part III) Table III-1-2 on page III-1-8 provides two different classification systems the Unified Soil Classification System (USCS) and the Modified Wentworth Classification System. The Modified Wentworth Classification System is typically used in geologic work while the USCS is typically used by engineering groups. Based on previous project experience, it was advised by the SAW Professional Geologist that dredging companies rely on the USCS for data presentation in the Geotechnical Data Report (GDR). Because fine grained soils are defined by the No. 230 sieve under the Wentworth Classification vs.

the No. 200 sieve for the USCS, the purpose for washing the samples over the No. 230 sieve is to further refine the classification boundary between sand and fine-grained soil (silt and clay). This grain size data washed over the No. 230 sieve is also generally used for environmental purposes.

2.2.1.2 Suitable Borrow Material/Beach Fill Defined

A successful beach renourishment project requires finding a source of sand that is similar in character to the native beach. Three scenarios, described by Dean (1974; 1991; 2002) are possible:

- Borrow area sediment is finer than the native beach-resulting in excessive sand migration offshore and flattening of the beach profile.
- Borrow area sediment is coarser than the native beach-resulting in higher "stand-up" of fill material and a steeper beach profile through the surf zone.
- Borrow area sediment matches the native beach-the placed fill material will follow existing surface contours, mimicking the existing profile.

As described in the Native Beach Sand and Borrow Area Exploration section, the vibracore samples were visually classified in accordance with ASTM D2487 and particle size analysis was conducted on representative soil stratum selected from each vibracore. For USACE CSRM projects, suitable beach fill material consists of sand with less than 10% fines. A portion of material considered to be "suitable" for beach-fill may consist of Poorly Graded Sand (SP), Poorly Graded Sand with Silt (SP-SM), Silty Sand (SM), Poorly Graded Sand with Clay (SP-SC), and Clayey Sand (SC) per the USCS, if the portion of material meets the following criteria*:

- Less than 10 percent, by weight, material passes No. 200 sieve over weighted average.
- Less than 10 percent, by weight, material retained on the No. 4 sieve over weighted average.
- Material retained on the No. 4 sieve, minus shell content, does not exceed 5% over weighted average.
- Contains no construction debris, toxic material, or other foreign matter.
- Contains no cemented sands or rock fragments.

* This criterion is based upon plans and specifications for the Myrtle Beach CSRM project.

Unsuitable materials for beach renourishment may typically consist of SM, SP-SC, or SC not meeting the criteria listed above, as well as, Gravels (GP, GM or GC), Low Plasticity Silt (ML), High Plasticity Silt (MH), Low Plasticity Clay (CL), and High Plasticity Clay (CH) per the USCS.

2.2.1.3 Sand Compatibility Analysis

The purpose of a sand compatibility analysis is to evaluate whether sand from Unnamed Shoal A borrow area matches the physical and chemical characteristics of the native beach sand to ensure successful beach renourishment. Laboratory tests were conducted for selected representative sediment samples collected within Unnamed Shoal A borrow area and the native beach. The results of these tests provided:

1. Grain size distribution curves that were generated by the soil laboratories for the purpose of determining if the Unnamed Shoal A borrow area sand is similar in size and sorting to the native beach sand, which is essential for stability; and
2. Mineralogy and Color of the sand to determine the differences in color, mineral type (mainly quartz), and shell content.

A template of a granularmetric report was provided to Terracon and Schnabel Engineering to complete for each soil sample. The template was taken from the previous Vibracore Sampling Wallops Island Sand Search report dated 20 January 2008. Terracon and Schnabel Engineering's soils laboratories populated the spreadsheet with the requested φ5, φ16, φ25, φ50, φ75, φ84, and φ95 values. Utilizing these phi values, the Mean φ, Mean (mm), Median Diameter grain size (D50), Sorting (i.e. Standard Deviation), Skewness, and Kurtosis were all calculated utilizing the following equations from EM 1110-2-1100 (Part III) dated 30 April 2002:

Mean = $$M_{\varphi} = \frac{(\varphi_{16} + \varphi_{50} + \varphi_{84})}{3}$$ Equation (III-1-2)

Sorting (i.e. Standard Deviation) = $$\sigma_{\varphi} = \frac{(\varphi_{84} - \varphi_{16})}{4} + \frac{(\varphi_{95} - \varphi_{5})}{6}$$ Equation (III-1-3), following Folk (1974)

Skewness = $$\alpha_{\varphi} = \frac{\varphi_{16} + \varphi_{84} - 2(\varphi_{50})}{2(\varphi_{84} - \varphi_{16})} + \frac{\varphi_{5} + \varphi_{95} - 2(\varphi_{50})}{2(\varphi_{95} - \varphi_{5})}$$ Equation (III-1-4)

Kurtosis = $$\beta_{\varphi} = \frac{\varphi_{95} - \varphi_{5}}{2.44\ (\varphi_{75} - \varphi_{25})}$$ Equation (III-1-5)

The grain size diameters phi (φ) and millimeters (mm) can be interchangeably converted by the following equations:

$$\varphi = -\log_2 D$$, where D = mm, Equation (III-1-1a)

$$D = 2^{-\varphi}$$, where D = mm, Equation (III-1-1b)

Although the NAO Geotechnical Engineer requested that Terracon and Schnabel Engineering calculate the skewness and kurtosis with the grain size data, it was unknown at the time if the information would be needed for the compatibility analysis. The information is available with the project data sheets but was not evaluated during the analysis.

2.2.1.3.1 Weighted Composite Grain Size Distribution-Methodology

The NAO Geotechnical Engineer developed weighted composite grain size distribution for usable sand strata within each vibracore from the laboratory test grain size data. The purpose of this is to ensure material grain sizes encountered within the upper 10-feet of the vibracore sample are representative of the material to be dredged from specified depths within the borrow area. Laboratory data provided grain size statistical measurements of mean, median, and standard deviation (Std Dev), together with selected grain size data for %passing No. 4, % passing No. 10, and % passing No. 200. This data was weighed based on the respective fraction occurring within each core length and then summed based on total core length to proposed maximum dredge depth of 10 feet. Equations are as follows:

1. Representative Sample Thickness = Bottom Depth of Sample – Top Depth of Sample

2. Calculated Percent Thickness (% Thickness) =
   Representative Sample Thickness ÷ Bottom Depth that will be dredged

3. Weighted Precent of Sample ((% passing No. 4, % passing No. 10, % passing No. 200, Mean, Median, or Std Dev) =
   (% passing No. 4, % passing No. 10, % passing No. 200, Mean, Median, or Std Dev) x Calculated % Thickness (length of the core represented by the sample)

4. Composite Percent ((% passing No. 4, % passing No. 10, % passing No. 200, Mean, Median, or Std Dev) = Σ (Sample Weighted Percentages of similar material over the length of the core to dredge depth 10 feet)

Note that the methodology for the equations above vary depending on the stratigraphic conditions observed within the vibracore samples. The vibracore samples obtained from the Unnamed Shoal A borrow area show a consistent Poorly Graded SAND (SP) throughout the entire core. Note that the soil samples that were not tested by the Schnabel Engineering soils laboratory were visually classified in the field as Silty SAND (SM).

2.2.1.3.2 Determination of Native Beach Sand Grain Size

Using Terracon's grain size data the mean, median, and standard deviation phi and millimeter (mm) sizes were averaged for all 10-grab samples. The equation is as follows:

1. Native Beach Grain Size (mean, median, or standard deviation) = Σ(each grab sample mean, median, or standard deviation value) ÷ 10 (total number of samples)

The native beach sand grain sizes were calculated below in Table 2.2.1.2.2-1.

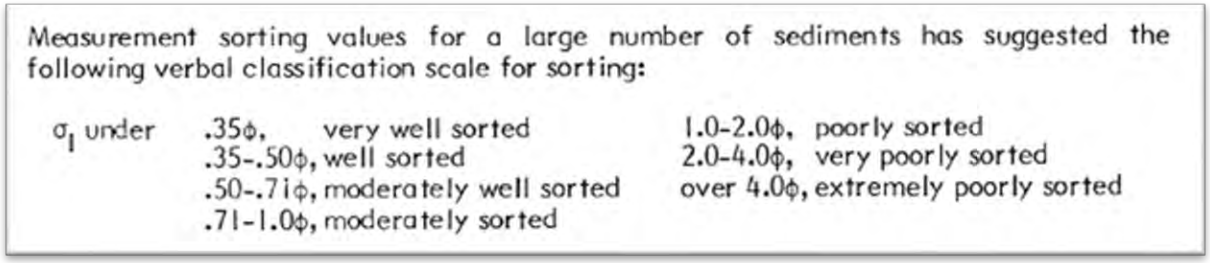
Table 2.2.1.3.2-1 – NASA Wallops Flight Facility Native Beach Sand Properties

Mean (Phi)	Median (Phi)	Std. Dev. (Phi)	Mean (mm)	Median (mm)	Std. Dev. (mm)
2.04	2.11	0.68	0.25	0.23	0.63
Coarse Sand (% Passing #4)		Medium Sand (% Passing #10)		Fines (% Passing #200)	Shell % Visible
99.68		99.07		0.93	0

The laboratory test results for the native beach shows that the USCS classification for the material is Poorly Graded SAND (SP). The native beach mean grain size is 0.25 mm and median grain size is 0.25 mm. When correlating sieve sizes to mm in EM 1110-2-1100 (Part III) 31 July 2003 Table III-1-2, in accordance with the USCS soil classification, the material falls between the No. 50 > Material (Sand) > No. 100 sieves, which indicates Fine Sand. The low standard deviation size (0.63 mm) indicates a tight grouping of grain sizes around the mean and median. This indicates wind winnowed dune sands or mature dunes, which is a geologic process of

selective erosion where wind removes finer, lighter sand particles (such as silt and fine sand) from the dunes, leaving behind heaver particles like coarse sand, granules, and pebbles.

According to Folk (1974), sorting (standard deviation) phi values are defined in Figure 2.2.1.2.3-1:


Measurement sorting values for a large number of sediments has suggested the following verbal classification scale for sorting:

σ_I under
.35ϕ, very well sorted
.35-.50ϕ, well sorted
.50-.71ϕ, moderately well sorted
.71-1.0ϕ, moderately sorted
1.0-2.0ϕ, poorly sorted
2.0-4.0ϕ, very poorly sorted
over 4.0ϕ, extremely poorly sorted

Figure 2.2.1.3.2-1. Folk (1974) sorting values.

Table 2.2.1.2.3-4 provides the sorting description based on the native beach calculated standard deviation value.

Table 2.2.1.3.2-2 – Native Beach Sorting Value

Std. Dev (Phi)	Folk (1974) Phi Range	Description
0.68	0.50-0.71ϕ	Moderately Well Sorted

2.2.1.3.3 Determination of Unnamed Shoal A Sub-Areas Grain Size

Using Schnabel Engineering's grain size data the mean, median, and standard deviation phi and mm sizes were averaged for all vibracore locations within each sub-area. The vibracores located within each sub-area area are as follows:

1. Sub-Area A-1: VC-1196-01, VC-1196-06, VC-1196-07, VC-1196-08, VC-1196-09, VC-1196-11A, and VC-1196-12

2. Sub-Area A-2: VC-1196-02C, VC-1196-03, VC-1196-04, VC-1196-06, VC-1196-07, VC-1196-08, and VC-1196-09

3. Sub-Area A-3: VC-1196-05 and VC-1196-10

For all vibracore locations listed for each sub-area above, the composite weighted percent values for each corresponding vibracore location were averaged producing a representative mean, median, and standard deviation size. The average composite percent results for mean, median, and standard deviation (Std. Dev.) are provided in Tables 2.2.1.2.3-1 through 2.2.1.2.3-3. The laboratory test results for all material sampled within the Unnamed Shoal A borrow Sub-Areas yields a USCS classification as Poorly Graded SAND (SP).

Table 2.2.1.3.3-1 – Unnamed Shoal A, Sub-Area A-1

Mean (Phi)	Median (Phi)	Std. Dev. (Phi)	Mean (mm)	Median (mm)	Std. Dev. (mm)
1.49	1.58	0.63	0.37	0.35	0.63
Coarse Sand (% Passing #4)		Medium Sand (% Passing #10)		Fines (% Passing #200)	Shell % Visible
98.7		96.29		0.50	0

For Sub-Area A-1 the mean grain size is 0.37 mm and median grain size is 0.35 mm. When correlating sieve sizes to mm in EM 1110-2-1100 (Part III) 31 July 2003 Table III-1-2, in accordance with the USCS soil classification, the material falls between the No. 40 > Material (Sand) > No. 50 sieves, which indicates Fine Sand. The low standard deviation size (0.63 mm) indicates a tight grouping of grain sizes around the mean and median. When performing a grain size comparison of the native beach sand to the Sub-Area A-1, the sand that is deposited within Sub-Area A-1 is slightly coarser with a stronger degree of sorting, meaning grain size particles are highly uniform in size (low variance) with few to no particles that are significantly larger or smaller than the average.

Table 2.2.1.3.3-2 – Unnamed Shoal A, Sub-Area A-2

Mean (Phi)	Median (Phi)	Std. Dev. (Phi)	Mean (mm)	Median (mm)	Std. Dev. (mm)
1.57	1.57	0.80	0.38	0.35	0.59
Coarse Sand (% Passing #4)		Medium Sand (% Passing #10)		Fines (% Passing #200)	Shell % Visible
98.3		95.7		0.57	0

For Sub-Area A-2 the mean grain size is 0.38 mm and median grain size is 0.35 mm. In accordance with the USCS soil classification, the material falls between the No. 40 > Sand > No. 50 sieves, which again indicates Fine Sand. The low standard deviation size (0.59 mm) also indicates a tight grouping of grain sizes around the mean and median. Similar to the results for Sub-Area A-1, the sand that is deposited in Sub-Area A-2 is also slightly coarser than the native beach sand with a stronger degree of grain size sorting.

Table 2.2.1.3.3-3 – Unnamed Shoal A, Sub-Area A-3

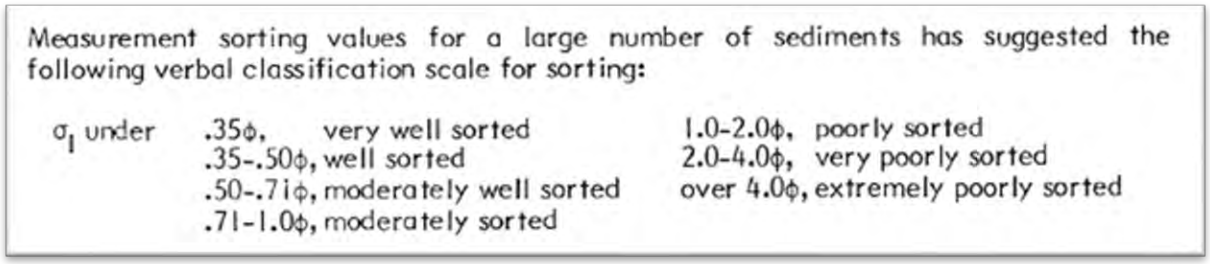
Mean (Phi)	Median (Phi)	Std. Dev. (Phi)	Mean (mm)	Median (mm)	Std. Dev. (mm)
1.99	2.01	0.46	0.25	0.25	0.73
Coarse Sand (% Passing #4)		Medium Sand (% Passing #10)		Fines (% Passing #200)	Shell % Visible
99.9		99.6		0.81	0

For Sub-Area A-3 the U.S. Standard Sieve size for the mean grain size is 0.25 mm and median grain size is 0.25 mm. When correlating sieve sizes to mm in accordance with the USCS soil classification, the material falls between No. 50 > Material (Sand) > No. 100 sieves, which also classifies as Fine Sand. The standard deviation size (0.73 mm) also indicates a tight grouping of grain sizes around the mean and median. Of the three sub-areas located within Unnamed Shoal A borrow area, Sub-Area A-3 contains the closest match in grain size to the native beach.

Note that the soil testing laboratory did identify shell fragments and hash within the vibracore samples. If shell fragments were encountered, this information is provided in the vibracore logs. The visual descriptions for the percentages of shell fragments or hash observed in the samples was identified in the vibracore logs by the Geologist in accordance with ASTM D2488.

One vibracore location VC-1196-11A within Unnamed Shoal A Sub-Area A-1 was observed to have approximately 5.38% gravel retained on the No. 4 sieve for depth interval 0 to 2-feet. Sample interval 2 to 4-feet was not tested, but a composite analysis with general assumptions was performed up to depth of 6-feet. The results of the general composite analysis showed that the percentage of gravel over a depth interval up to 6-feet is less than 5%. A composite analysis was also performed for the 5.87% observed for VC-1196-02C Sub-Area A-2, sample depth 0 to 2 feet. The percentage of gravel up to 6 feet was also determined to be less than 5%.

According to Folk (1974), sorting (standard deviation) phi values are defined in Figure 2.2.1.2.3-1:


Measurement sorting values for a large number of sediments has suggested the following verbal classification scale for sorting:

σ_I under
.35ϕ, very well sorted
.35-.50ϕ, well sorted
.50-.71ϕ, moderately well sorted
.71-1.0ϕ, moderately sorted
1.0-2.0ϕ, poorly sorted
2.0-4.0ϕ, very poorly sorted
over 4.0ϕ, extremely poorly sorted

Figure 2.2.1.3.3-1. Folk (1974) Sorting Values.

According to Figure 2.2.1.2.3-1 above, the following descriptions can be made in Table 2.2.1.2.3-4 regarding the sorting (Std. Dev.) for the Unnamed Shoal A Sub-Areas:

Table 2.2.1.3.3-4 - Unnamed Shoal A Sub-Area Sorting Values

Sub-Area	Std Dev. (Phi)	Folk (1974) Phi Range	Description
A-1	0.63	0.50-0.71ϕ	Moderately Well Sorted
A-2	0.80	0.71-1.0ϕ	Moderately Sorted
A-3	0.46	0.35-0.50ϕ	Well Sorted

As previously stated an exploration scope requirement for Terracon and Schnabel Engineering's soils testing laboratories was to document the color of each tested sediment sample for the following three conditions: wet, dry before wash, and dry after wash. Munsell color chromas were provided by the laboratories for each of these conditions. A comparison of the native beach material and all Unnamed Shoal A borrow sub-area material was performed for the dry after wash condition. This condition is considered to be more realistic to the color of the material on the beach after the borrow area material is placed and has time to dry. Refer to Table 2.2.1.2-5. Color descriptions are provided by the NAO Geotechnical Engineer referencing the Munsell Soil Color Book 2009 Year Revised edition/2024 Production.

Table 2.2.1.3.3-5 – Unnamed Shoal A, Sub-Area A-3

Location	Munsell Color Chroma Range	Color Description
Native Beach	10YR 7/2	Light Gray

Sub-Area A-1	2.5Y 7/1; 2.5Y 7/2; 2.5Y 6/2; 2.5Y 8/1; and 5Y 7/2	Light Gray, Light Brownish Gray, and White
Sub-Area A-2	2.5Y 7/1; 2.5Y 7/2; 2.5Y 7/3; 2.5Y 8/1; 5Y 7/1; and 5Y 7/2	Light Gray, Pale Brown, and White
Sub-Area A-3	2.5Y 7/1 and 2.5Y 7/2	Light Gray

2.2.1.3.4 Sand Compatibility Analysis Results: Native Beach and Unnamed Shoal A Borrow Area

An overall summary of the laboratory test results and compatibility analysis results are provided in Table 2.2.1.3.4-1 below.

Table 2.2.1.3.4-1 – Summary Compatibility Analysis Results

Location	USCS	% Fines Passing No. 200 Sieve	Highest % Gravel Identified in Core Sample	Mean (Phi)	Median (Phi)	Sorting (Folk 1974)	Color	% **Shell**
Native Beach	SP	Approx. 1 %	0	2.04	2.11	Moder-ately Well Sorted	Light Gray	N.R.
Borrow Sub-Area A-1	SP	Approx. 1%	5.38% (1)	1.49	1.58	Moder-ately Well Sorted	Light Gray, Light Brown-ish Gray, and White	N.R.
Sub-Area A-2	SP	Approx. 1%	5.87% (2)	1.57	1.57	Moder-ately Sorted	Light Gray, Pale Brown, and White	N.R.

Borrow Sub-Area A-3	SP	Approx. 1%	Less than 1%	1.99	2.01	Well Sorted	Light Gray	N.R.

(1) 5.38% gravel retained on No. 4 sieve for vibracore VC-1196-11A, sample depth 0 to 2 feet.
(2) 5.87% gravel retained on No. 4 sieve for vibracore VC-1196-02C, sample depth 0 to 2 feet.

Suitable Borrow Material/Beach Fill Defined section in this report states that a successful beach renourishment project requires finding a source of sand that is similar in character to the native beach. Based on the results shown in Table 2.2.1.3.4-1, it appears that the borrow area sand within Unnamed Shoal A Sub-Areas A-1 and A-2 is slightly coarser than the native beach sand with a strong degree of sorting. When referencing EM 1110-2-1100 (Part III) 31 July 2003, page III-1-8 to compare the phi sizes of the native beach sand to the borrow area, all phi sizes for native beach and the borrow area correlate to the USCS classification for Fine Sand. When comparing the phi sizes to the Wentworth Classification, the borrow area contains Medium Sand while the native beach is on the boundary of a Medium and Fine Sand. Because the grain sizes for the borrow area sand within Sub-Areas A-1 and A-2 are slightly coarser, the following condition may exist as described by Dean (1974; 1991; 2002): Borrow area sediment is coarser than the native beach-resulting in higher "stand-up" or fill material and a steeper beach profile through the surf zone. Of the three sub-areas located within Unnamed Shoal A borrow area, Sub-Area A-3 contains the closest match in grain size to the native beach.

As also indicated in the Suitable Borrow Material/Beach Fill section, suitable beach fill material consists of sand less than 10% fines, may consist of Poorly Graded Sand (SP), material retained on the No. 4 sieve does not exceed 5% over weighted average, contains no foreign matter such as construction debris or toxic material, and does not contain cemented sands or rock fragments. As discussed in the previous section, vibracore location VC-1196-11A within Unnamed Shoal A Sub-Area A-1 was observed to have approximately 5.38% gravel retained on the No. 4 sieve for depth interval 0 to 2-feet. Sample 2 to 4-feet was not tested, but a general composite analysis up to depth of 6-feet was performed. The results of the composite analysis showed that the percentage of gravel over a depth interval of 6-feet is less than 5%; therefore, it is assumed that the gravel should mix with the dredged material. The NAO Geotechnical Engineer also requested for vibracore sample VC-1196-11A depth interval 2 to 4 feet be mailed to the District for visual observation. After conducting a visual observation of the sample, no gravel or larger shell fragments were observed in the sample. Schnabel Engineering had indicated during a telephone call that the percentages of gravel are most likely shell fragments that have been retained on the No. 4 sieve. It was determined that no dredge constraints would be included with the plan sheets for the area surrounding locations VC-1196-11A. A general composite analysis was also performed for location VC-1196-02C, and it was also determined that the percentage of gravel over the

interval depth of 6-feet is less than 5 %. For Unnamed Shoal A, all Sub-Areas meet the recommended requirements for suitable borrow material/beach fill.

The percentage of shell content for all beach and vibracore samples was not recorded (N.R.). According to Schnabel Engineering who performed the sediment laboratory testing for the vibracore samples, there was no available test standard that can be used to measure the percentage of shell. The NAO Geotechnical Engineer requested that Schnabel Engineering provide visual percentages of the shell fragments or hash in the samples in accordance with ASTM D2488, (2017) Standard Practice for Description and Identification of Soils (Visual-Manual Procedures) in the vibracore logs of the final report. In the vibracore logs provided with the GDR, Schnabel Engineering included the following percentage descriptions for the shell fragments:

- Trace-Particles are present but estimated to be less than 5%:
- Few-5 to 10%;
- Little-15 to 25%;
- Some-30 to 45%; and
- Mostly-50 to 100%.

Contractor requirements included with the dredging specification will be as follows:

- The material to be dredged and placed on the beach for replenishment shall be classified in accordance with ASTM D2478 as SP or SW containing not more than 10 percent fines passing a U.S. Standard Sieve No. 200, and not more than 5 percent gravel retained on the U.S. Standard Sieve No. 4. If significant shell has is encountered, the Contractor through the Contracting Officer is to locally mix the sand to even it out during placement. If the Contractor determines that the material placed on the beach does not meet this standard, they shall notify the Contracting Officer Representative immediately.

2.2.1.4 Overfill Ratios

2.2.1.4.1 General

Overfill ratios were calculated for each Sub-Area of Unnamed Shoal A borrow area. The overfill ratio is defined as the volume of borrow area required to produce a "stable" unit of suitable beach fill material that has the same grain size characteristics as the native beach (James, 1975). For example an overfill ratio of 1.2 indicates that 1.2 units of borrow material will behave similarly to 1 unit of native beach fill. The purpose of the overfill ratio is to account for the natural loss due to winnowing of the borrow sediment that is finer than the native beach sediment. The overfill ratio is computed by numerically comparing the grain size distribution characteristics of

the native beach sand with that of the borrow area, which includes a final adjustment for the percentage of the fines within the borrow area.

2.2.1.4.2 Overfill Ratio Methodology

Two methods were used to calculate overfill ratios for each Unnamed Shoal A borrow Sub-Area. This process was performed to evaluate the accuracy of each method and determine whether the methods yielded comparable results. The first method used was based on USACE's Technical Memorandum No. 60, Techniques for Evaluating Suitability of Borrow Material for Beach Nourishment (James, 1975). This document reviews various methods for determining overfill ratios, such as the Adjusted Fill Factor (AFF) method, which was used in this study. This graphical method was used to develop the overfill ratios for each Sub-Area. Because all material collected in the vibracores was determined to be similar and suitable beach fill, Sub-Area composite statistics such as mean grain size, standard deviation, and percent fines for each Sub-Area were determined. These calculations were then used to calculate the Sub-Area composite X values, Y values*,†, and silt correction factor. Once the X and Y values for each Sub-Area were calculated, the cumulative mean X and Y values were then plotted using the James (1975) AFF plot (Figure 90) to

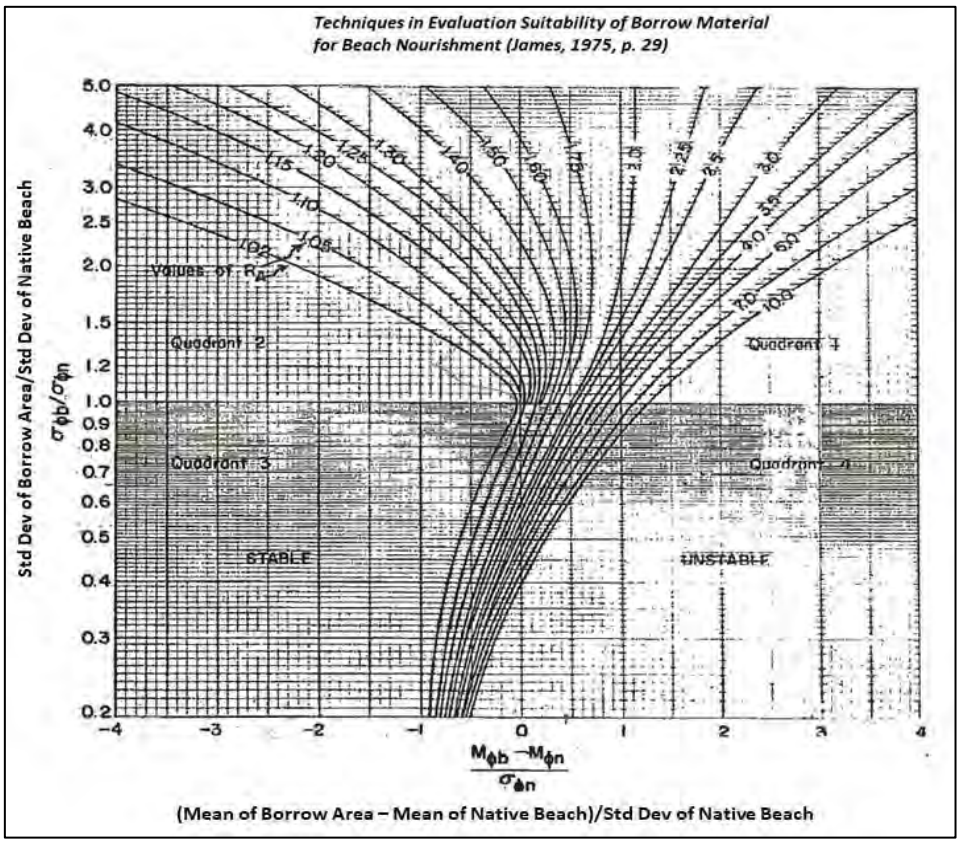


Figure 2.2.1.4.2-1. Adjusted Fill Factor Plot. After finding the cumulative mean X and Y values this graph was used to determine the "initial overfill ratio" (James, 1975).

* X = [MEAN (PHI) BORROW – MEAN (PHI) NATIVE / STD. DEV. NATIVE (PHI)]

† Y = STD. DEV. (PHI) BORROW / STD. DEV. (PHI) NATIVE

determine an "initial overfill ratio"*. Using Figure 2.2.1.4.2-1, the point on the graph where the X and Y values intersected was the "initial overfill ratio."

The second method for overfill ratio calculations involved the Coastal Engineering Design and Analysis System (CEDAS). The CEDAS method is a computerized program that uses the same variables as the graphical method. The CEDAS software method uses the cumulative borrow means of the mean grain size and standard deviation, native mean grain size and standard deviation, and calculated "in-situ" borrow area volume. Once this information is inputted into the computer software the "initial overfill ratio" is provided.

Once the "initial overfill ratio" values for both the graphical and CEDAS method were determined, one final adjustment was made, the "silt correction factor." This is defined mathematically by (1/(1-((composite % passing No. 200)/100))). Once the "silt correction factor" was determined, the value was multiplied by the "initial overfill ratio" to obtain a final overfill ratio value for each specific borrow sub-area.

2.2.1.4.3 Overfill Ratio Results

Refer to Appendix B for AFF and CEDAS analyses screenshot results. When conducting the AFF method in accordance with James, 1975, it was noticed that the plotted values for Unnamed Shoal A Sub-Areas A-1 and A-2 did not fall within the array of adjusted fill factors (R_A) on the graph. The reason for this is due to the fact that the sand within these Sub-Areas is coarser than the native beach sand. Because these plotted values did not plot with the array of adjusted fill factors values, the selected adjusted fill factor was the graphical line closest to the plotted points. For Sub-Areas A-1 and A-2, 1.02 was the closest R_A value. For Sub-Area A-3 which matches closest to the native beach sand, the plotted value falls within the array of R_A values which was interpolated to be approximately 1.5. After multiplying the silt correction factor value of 1.01 for both Sub-Areas A-1 and A-2, the overfill ratio was calculated to be 1.03. After multiplying the silt factor value of 1.01 for Sub-Area A-3, the overfill ratio was calculated to be 1.52. The results of the overfill ratios for the AFF and CEDAS methods including the silt factor correction for each Sub-Area are provided in Table 2.2.1.4.3-1.

* The "initial overfill ratio" does not consider the applied silt correction factor.

Table 2.2.1.4.3-1 – Summary Overfill Ratio Results

Unnamed Shoal A Sub-Area	Initial Volume (CY)	Graphic Overfill Ratio	CEDAS Overfill Ratio	Delta	Volume w/Overfill $Ratio_{CEDAS}$ (CY)
A-1	867,000	1.03	1.01	0.02	875,670
A-2	867,000	1.03	1.01	0.02	875,670
A-3	867,000	1.52	1.29	0.23	1,118,430

The NAO Civil Engineer provided the NAO Geotechnical Engineer with a total beach fill volume of 867,000 cubic yards. After further discussion with the NAO design team, it was determined that the overfill ratio for the beach renourishment project will be conservatively increased to a value of 1.1 to accommodate any losses that may occur during construction due to site conditions such as storm events or tidal washout. This yields an approximate volume for Sub-Areas A-1 and A-2 of 953,700 cubic yards, which is rounded up to 954,000 cubic yards for the project beach fill volume. It has been discussed with the NAO Cost Engineer and the NAO Dredging Expert in the Operations Section that other losses such as mechanical losses need to be considered with the estimate. These losses should be considered separate from the beach fill volume due to certain dredge plan inefficiencies. The NAO Dredging Expert in the Operations Section has included the estimates for the assumed losses separately from the overfill ratio volume.

It must be made aware to the NAO design team if during construction it is determined that beach fill material will be dredged from Sub-Area A-3, the overfill ratio for this area was calculated to have a higher CEDAS overfill ratio value of 1.29, which would increase the previously estimated beach fill volume as provided for Sub-Areas A-1 and A-2. It is unlikely that this would occur since the preference is for the Contractor to dredge within Sub-Areas A-1 and A-2 per direction from the NASA Wallops Flight Facility, but it is documented in this report for situational awareness during construction. If the Contractor were to dredge from Sub-Area A-3, the overfill ratio for this sub-area must be re-evaluated by the design team and a new estimated beach fill volume must be calculated.

2.2.1.5 Historical Project Information

Based on information provided by the NASA Wallops Flight Facility, there have been three (3) previous shoreline protection projects for the NASA Wallops Flight Facility shoreline. They are listed below as follows:

- 2012 Dredge Project: Contract Awarded to Great Lakes, 3.3 million cubic yards of beach fill

- 2014 Dredge Project: Contract Awarded to Weeks Marine, 650,000 cubic yards of beach fill
- 2020 Breakwater/Backpassing Project: Awarded to Continental Heavy Civil Corp (CHC), 1.1 million cubic yards of beach fill trucked from the northern end of the island (referred to as beach fill backpassing) and five (5) breakwater structures constructed

Geology Unnamed Shoal A

Final Programmatic Environmental Impact Statement, Wallops Island Flight Facility Shoreline Restoration and Infrastructure Protection Program, Volume I of II, dated October 2010, page 145, Section 3.1.4.4 Offshore Sand Shoals, provides historical geological information about Unnamed Shoal A. The coastal plain and continental shelf are closely related geologically. Both originate from the deposition and erosion of sediments on the eastern edge of North America caused by changes in sea level over geologic timescale. Swift and Field (1981) categorized Unnamed Shoal A with other explored shoals during this study (Blackfish Bank Shoal and Unnamed Shoal B) off Maryland into three groups based on their geomorphic characteristics: shoreface, nearshore, and offshore. Unnamed Shoal A is an offshore sand ridge that is located at the southern end of the Assateague ridge field. In general, the offshore shoal (Unnamed Shoal A) in the ridge field is oriented with the long or main axis in a southwest/northeast orientation directly into the predominant storm wave approach direction. The orientation suggests that the wave forces from nor'easters either directly or indirectly account for origin and maintenance of these features (Hayes and Nairn, 2004). The offshore shoal is asymmetrical with a seaward flank approximately three times as steep as the landward flanks. The coarsest sediment generally occurs on the shoreward flank of the shoal (Swift and Field, 1981; Hayes and Nairn, 2004). Based on numerous studies, Hayes and Narin (2004) concluded that once formed, most ridges in depths of less than 20 m (66 ft) are maintained and even enlarged by present-day hydrodynamics.

As also stated in the 2010 Environmental Impact Statement on page 83, Unnamed Shoal A under Section 2.4.3.3, the total predicted volume of Unnamed Shoal A is approximately 68 million cubic yards. This shoal covers an area of approximately 1,800 acres. The shoal is carried forward for detailed analysis because sediment analyses and a review of the bathymetric data conducted by USACE indicate that this borrow site would provide adequate volumes and appropriate size sediment for nourishment of the beach through the Shoreline Restoration and Infrastructure Protection Program's (SRIPP's) 50-year design life.

Historical Dredge Cycle 2012 and Grain Size Information

It must be made aware that the last dredge cycle from the Unnamed Shoal A sub-area A-1 occurred in 2012. Historical information form a ERDC report ERDC/CHL TR-11-9, Storm Damage Reduction Project Design for Wallops Island, Virginia, dated October 2011 states: "Norfolk District personnel collected grab samples from the subaerial and subaqueous portions of the active beach. The samples were analyzed, and the native beach composite mean diameter was determined to be between 0.20 and 0.21 mm. A D50 value of 0.20 mm was applied to characterize the native beach material in the modeling effort." The report also states under section 3.3.3 Vibracore Sediment Analysis, on page 27: "Table 3-2 shows that the average median grain diameter for Site A (Unnamed Shoal A), the preferred location, is about 0.32 mm." The report goes on to recommend, "Thus, the most likely median grain diameter for the sediment at Site A is the range of 0.32 mm to 0.34 mm. However, there are relatively few cores available to characterize the sediment in this two square mile area, and an overestimate of the true grainsize value would lead to an underestimate of the volume of initial fill material needed for the project. The consequences of this are discussed in Chapter 6. Therefore, to be conservative, a smaller median grain diameter, 0.29 mm was chosen for modeling purposes."

The Final Environmental Assessment (EA), Wallops Island Post-Hurricane Sandy Shoreline Repair dated June 2013 also provides some information on the beach fill material also provides some additional information regarding grain size and overfill ratio:

- Page 2-8, Section 2.3.3 Dredging and Sand Placement: "Because of overflow from the hopper dredge at the borrow area during dredging and losses during discharge and placement, a larger volume of material would need to be dredged to meet the targeted fill volume. Based on information from other shoreline restoration projects, sediment losses during dredging and placement operations may be up to 25 percent. Assuming a conservative 25 percent loss, the dredged volume for the proposed renourishment would be approximately 1,000,000 CY." (NOTE: The estimated beach renourishment volume was approximately 800,000 cubic yards before the overfill ratio (25% overfill assumption)).
- Page 3-6, third paragraph under Offshore section: "The limited sediment sampling effort conducted at the borrow area prior to the beach fill indicated that mean grain size was approximately 0.29 mm. However, as discussed above, additional sampling of the material indicates that it is generally coarser than originally expected."

Previous Beach Renourishment 2020-2021

The beach was recently renourished during the 2020-2021 shoreline protection project, but the beach fill material was trucked from the northern end of the island to the project area. Previous studies have suggested that this beach fill material had previously eroded from the NASA Wallops Flight Facility shoreline, migrated northward, and was later deposited on the northern end of the island. Native beach samples were not collected from the northern end of the island

during for this current project since the area is outside the construction limits. From the conversations with NASA Wallops Island Flight Facility personnel during discussion about constructability, that beach fill material can be trucked from the northern end of the island, but it must be within a period of approximately every 10-12 years.

2.2.1.6 Dredging Constraints

In August 2025 while the borrow area vibracore exploration was being performed the NAO Geotechnical Engineer was informed by the NASA Wallops Flight Facility Environmental Planning Group Lead that the dredging contractor would be limited to only one section of the Unnamed Shoal A borrow area, which is Sub-Area A-1. The vibracore exploration included sampling in all areas of the shoal. Although this new information had been presented, it was determined that the vibracore sampling would continue to be conducted in all sections of the borrow area. According to the Final Environmental Assessment (EA), Wallops Island Post-Hurricane Sandy Shoreline Repair dated June 2013 an agreement was made with the NOAA Fisheries' Habitat Conservation Division (HCD) that sub-area A-1 was the priority area that will be dredged. To meet the requirements that the NASA Wallops Flight Facility had agreed upon, NASA Wallops Flight Facility would:

- Target Shoal A sub-area A-1 (an accretional area) for beach fill material. Shoal A sub-area A-2 would only be used during off-nominal conditions (e.g. discovery of incompatible material, ordnance, archeological resource, etc.);
- Dredge over a large area and not create deep pits;
- Require that cut depth not be excessive at approximately 7-10 feet; and
- Require that dredging not occur over the entire length of the shoal.

When the question was asked by the NAO Geotechnical Engineer if areas that were dredged during the previous dredge cycle (which occurred around 2012) could be dredged for this current dredge cycle, for environmental considerations it was confirmed by the NAO Environmental Scientist by information found in the October 2010 Final Programmatic Environmental Impact Statement (EIS), Wallops Flight Facility Restoration and Infrastructure Protection Program, Volume I of II, page 216 Alternative One (Preferred Alternative): Full Beach Fill, Seawall Extension. The second paragraph states: "Dredging would be conducted in a manner to remove a uniform thickness of material from the chosen borrow area. Dredging could deepen parts of the shoal within the proposed borrow area by approximately 3-meters (10-feet) during each dredging event (dredging for initial fill and each renourishment cycles). Also, stated on page 273, Alternative One (Preferred Alternative): Full Beach Fill, Seawall Extension, Offshore Borrow Sites states: "To be conservative, it is assumed that the entire 210 ha (515 ac) sub-area A-1 on Shoal A would be dredged for the initial beach fill requirements at a dredging depth of approximately 2-3 meters (7-10 feet). The paragraph continues: "For renourishment cycles, either Shoal A or

Shoal B would be used. Under Alternative One, each renourishment cycle would require the dredging of approximately 770,000 m^3 (1,007,500 yd^3) of sand. Assuming a conservative uniform dredging depth of 2-meters (7-feet) approximately 39 ha (95 ac) or approximately 6 percent of the total area of Shoal A or 3 percent of the total area of Shoal B would be dredged under each renourishment cycle." Also page 335 second paragraph under Summary: "The USACE (2008) assumed that the maximum thickness of material that would be removed for future Ocean City beach fill requirements could be up to 3-meters (10-feet). It is assumed that the maximum thickness of material removed from offshore shoals for the Shoreline Restoration and Infrastructure Protection Program (SRIPP) would be approximately 3-meters (10-feet)." After this information was received from the NAO Environmental Scientist and further discussion with the NAO Design Section, Operations Branch, Water Resources Division, 7-feet maximum depth (to include over depth) was agreed upon.

The NAO Environmental Scientist conducted a further review of the suggested limited approximate volume of 1,007,500 yd^3 of sand that could be dredged out of the Shoal A borrow area as suggested by the 2010 EIS report above for each dredge cycle. According to the NAO Environmental Scientist, regarding the National Environmental Policy Act (NEPA) (EIS), the US Army Corps of Engineers does not reinitiate NEPA for minor discrepancies in volume. However, the Biological Opinion (ESA, Section 7) would be more of a hard line with volume changes due to the Incidental Take Statements. The BIOP states 1,007,500 yd^3 of material removed from the borrow area for each cycle with cycles occurring approximately every 5-years. If the beach fill overfill ratio for the project increases the volume of dredged material over the suggested 1,007,500 yd^3, NASA Wallops Island Flight Facility will need to provide a letter to National Marine Fisheries Service (NMFS) stating the change, tracking total project volume historically, and requesting concurrence that reinitiation is not needed unless the 50-year volume is met earlier. This would prevent a limitation of the 1,007,500 yd^3 volume. If the beach fill volume exceeds the 1,007,500 yd^3 amount, NASA Wallops would need to evaluate the need to seek concurrence from the NMFS. The design team concluded that the 1,007,500 yd^3 is a maximum approximate volume limit that would need to be included with the design specifications for the dredging contractor if a NMFS concurrence has not been received by NASA Wallops. For this current project, NASA Wallops is in the process of sending a request to NMFS to receive concurrence for up to 4,500,000 yd^3 of sand for this dredge cycle. Over the next 7 years, the beach along the Wallops Island shoreline infrastructure protection area would be renourished using up to 3 million cubic yards of sand sourced from Unnamed Shoal A. Because of overflow from the hopper dredge at the borrow site during dredging and losses during discharge and placement, a larger volume of material would need to be dredged to meet the targeted fill volume. Sediment losses during dredging and placement operations are assumed to be up to 50 percent, resulting in an estimated 4,500,000 yd^3 dredged in order to renourish the beach with 3 million cubic yards of sand. The dredging and beach fill portion of the project would take approximately 3 months.

The post dredging survey file, which was identified by the NAO Civil Engineer as the AD survey file dated August 17, 2012 was compared to the most recent borrow area survey conducted in October 2024 to determine an approximate quantity of material that had since accumulated within Sub-Area A-1. The rough results of the survey file comparisons suggest that approximately 690,000 cubic yards of material have accumulated, with some areas of the Sub-Area A-1 showing up to 5-feet of accumulation since the previous dredge event.

The NAO Geotechnical Engineer informed the design team that all material within Sub-Area A-1 is dredgeable. The only constraint within Sub-Area A-1 is the 7-foot limit for dredge depth. The NAO Design Section, Operations Branch, Water Resources Division will provide dredging constraints within the plan sheets for the Contractor.

2.2.2 **Breakwater Structure Design**

During the 65% design phase, NASA Wallops Flight Facility identified three (3) priority areas to the Norfolk District, US Army Corps of Engineers (NAO) design team where critical infrastructure required protection. A map showing the priority areas is provided in Appendix A Figure 2. ERDC conducted a modeling study for the shoreline, which focused on protecting these priority areas. ERDC modeled one to three breakwater structures during the study for each area. The results of the ERDC study showed that breakwater structures are expected to further protect Priority Areas 1 and 3. According to the NAO Hydraulics and Hydrology (H&H) Engineer, the study also showed for Priority Area 2 that installing breakwater structures would have a detrimental effect on the beach, causing further erosion and a lack of sediment in the area. It was determined by the design team that Priority Area 2 would not receive breakwater structures at this time, but survey monitoring of the area will continue after construction. Priority Areas 1 and 3 will each receive at least one (1) breakwater structure for the base bid contract and additional structures for each area will be contracted as bid options pending availability of project funds. Once it was determined that only Priority Areas 1 and 3 would receive breakwater structures, a modification to the geotechnical exploration contract was issued by NAO contracting, and an exploration was not performed near the Priority Area 2 shoreline.

The design of the breakwater structure was provided by the NAO H&H Engineer as determined by the results of the ERDC Modeling Study. The location of the proposed breakwater structures are within the same alignment of the existing breakwaters previously constructed in 2020 approximately 200 feet offshore. Sea bottom elevations range from approximately elevation -10 feet to -11 feet. Each breakwater structure will vary in height and width depending on the elevation of the sea bottom and will be constructed with 2 horizontal to 1 vertical (2H:1V) side slopes. The crest elevation for each structure must be +7-feet NAVD88. Specification 35 31 19.40 BREAKWATER STONE AND CONSTRUCTION allows for a construction tolerance of the armor stone to be up to 1-foot above neatline, and the core stone to be up to 0.5-foot above neatline.

Given these tolerances, the breakwater structure would not exceed a crest elevation of +8-feet NAVD88. The breakwater structures are rubble-mound structures with a 9-foot Type II Armor Stone layer and a center core of VDOT Class III stone, and will be placed over an underlying 12-inch marine filter mattresses filled with a median diameter stone size (D50) of 3.5-inches or as approved by the marine mattress manufacturer with a bottom layer of non-woven filtration geo-textile fabric. The updated breakwater structure is designed to include two toe berms, one on the seaside and one on the landside. The current design detail for the breakwater structure is provided on design plan sheet C-501.

2.2.3 Schnabel Engineering Geotechnical Engineering Report

The NAO Geo-Environmental Engineering Section determined during the 35% to 65% design phase that the geotechnical data provided in the Geotechnical Engineering Report, Wallops Island Breakwaters, Wallops Island, Virginia by Schnabel Engineering dated July 18, 2018, would be used for the current project breakwater design for Priority Areas 1 and 3. The 2018 Schnabel Engineering report includes site information such as site geology and generalized subsurface stratigraphy. The report provides a summary of the exploration methods used. Generally, the geotechnical exploration consisted of 5-standard penetration test (SPT) boring locations, 7-cone penetration tests (CPT), and 8-dilatometer tests (DMT). Soil laboratory testing consisted of gradation analysis, Atterberg Limits, and moisture content analyses on selected samples. Three one-dimensional consolidation tests on samples of fine-grained soil encountered during the exploration were also performed. The report also includes geotechnical recommendations for the breakwater bearing capacity and settlement based on the previous breakwater design which was constructed in 2020. A copy of the report without the previous project calculations is attached to the geotechnical data report (memorandum) as an appendix to the project specifications.

The report suggests the soils within the region are preconsolidated and exhibit high strength and low compressibility. Yorktown Formation soils are sensitive to disturbance and exhibit higher strengths than would be indicated by Standard Penetration Test data.

2.2.4 Calculations and Future Project Design Considerations

2.2.4.1 Bearing Capacity

The 2018 Schnabel Engineering report recommends a net allowable soil bearing pressure of 2,000 psf for the previous design of the breakwater structures. A review of the calculations performed by Schnabel Engineering (Appendix D of the report) shows that the calculated allowable bearing capacity was greater than the recommended 2,000 psf (when considering a factor of safety of 3). The bearing pressure was calculated in accordance with NAVFAC DM 7.2, page 131 for a strip foundation. Conservative assumptions were made with the calculation by assuming the top 4-feet sand had a friction angle of 25 degrees. This is due to the soft clays that were encountered underneath the 4-feet of sand.

The NAO Geotechnical Engineer calculated the allowable bearing capacity for the current project design and considered the same conservative assumptions and equation used by Schnabel Engineering. Boring location B-2 was used to define the stratigraphy within the current project area. From a depth range of 0 to 2.8-feet below the sea bottom, the material was encountered to be a fine to medium grained, poorly graded and silty SAND (SP-SM) with an average blow count N value of 8. From a depth range of 2.8-feet to 27-feet below the sea bottom the material was encountered to be a plastic clay (CH) with an average blow count N value of weight of hammer (WOH) throughout the entire layer except for at depth 13-feet which shows an average blow count N value of 2. The allowable bearing capacity for the current breakwater structure design was also calculated to be greater than 2,000 psf while considering a factor of safety of 3. Typically soils within the Tidewater region are generally known to have an allowable bearing capacity that can range from 2,000 psf to 2,500 psf. The assumed allowable bearing capacity for the current project was determined to be 2,000 psf.

Punching failure was also evaluated in accordance with EM 1110-1-1905 Engineering and Design Geotechnical Design of Shallow Foundations on Soils, 31 July 2025, equation 5-18 on page 102. An undrained shear strength value of 500 psf was assumed for the underlying CH layer. Further information for how the undrained shear value was determined is provided in section 2.2.7.2 Slope Stability. The results of the calculation show that punching failure is not a concern, where the bearing capacity of the underlying SP-SM layer will govern.

The largest breakwater structure proposed to be constructed, Breakwater 3-1 as labeled by the design team, is expected to have a total width from edge of toe on the seaside to edge of toe the landside of approximately 65-feet. Generally, the breakwater structure will have a varied height of approximately 18-feet to 19-feet (including construction tolerance) and a crest width of 14-feet. The crest must maintain an elevation of +7-feet NAVD88 (+8-feet NAVD88 including

construction tolerance). The surcharge load of the breakwater structure was calculated to be approximately 2,000 psf meeting the requirements for allowable bearing capacity.

When evaluating the breakwater structure for bearing capacity, it was also suggested to consider that the underlaying sea bottom material may be CH rather than SP-SM material. Boring logs for boring locations B-1 through B-5 were reviewed for sea bottom material. For each boring location, SP-SM material was encountered to a depth of approximately 0-feet to 12-feet below the sea bottom. The surface materials for the CPT and DMT tests were also evaluated, but readings generally did not begin until an approximate depth of 2-feet to 6-feet below the sea bottom. The CPT results also show that a casing was installed within the upper 0-feet to 6-feet below the sea bottom. Due to these circumstances with the CPT and DMT data, it was determined that the boring logs provide the most accurate interpretation of the material type for the sea bottom. The SP-SM material was identified as the sea bottom material for all for all geotechnical analyses.

2.2.4.2 Settlement

Table 2.2.4.2-1 shows Schnabel Engineering's expected maximum settlements for sections of their exploration area. The expected maximum settlements were calculated for the previous breakwater design and are based on a design life of 50 years. The structures were constructed in 2020.

Table 2.2.4.2-1. Table 5 from the 2018 Schnabel Engineering Geotechnical Report

Table 5: Summary of Expected Maximum Settlements

Breakwater Structure	Applicable Borings & Soundings	Elastic Settlement (in)	Primary Consolidation Settlement (in)	Secondary Consolidation Settlement (in)	Total Settlement (in)
1	C-1, B-1, D-1	1.1	7.0	2.7	10.8
2	C-2, D-2, C-3, B-2, D-3	0.6	9.1	6.6	16.3
3	C-4, B-3, D-4	1.1	6.8	2.4	10.3
4	C-5, D-5, B-4, D-6, C-6	0.8	1.5	2.5	4.8
5	D-7, C-7, B-5, D-8	1.2	1.2	3.4	5.8

The above table shows boring and sounding locations that were utilized for specific areas of the shoreline that were explored. For the purposes of this project, Breakwater Structure 2 boring and sounding data was utilized to estimate settlement. The NAO Geotechnical Engineer calculated the settlement for the breakwater structures utilizing Dilatometer (DMT) data from locations D-2 and D-3 by plugging the DMT data into spreadsheets that calculate settlement in

accordance with Schmertmann's Ordinary Method. The calculated settlement at both DMT locations utilizing this method yielded values of approximately 5.1-inches and 5.7-inches. Because the DMT readings did not start until 4-feet to 5-feet below the sea bottom, the first 4-feet to 5-feet was assumed to have the same reading as the first reading recorded at each location. The settlement calculations are provided in Appendix B Geotechnical Calculations of this document. These values were significantly lower than what Schnabel Engineering had previously calculated in 2018. The NAO Geotechnical Engineer was not sure if the spreadsheet method used to calculate the settlement included secondary settlement. Online sources suggested that DMT calculations only take into consideration immediate settlement and do not include consolidation settlement. Further advice was provided by a Geotechnical Engineer at the Baltimore District (NAB). The NAB Geotechnical Engineer stated that he was fully confident that the DMT can be used to predict both immediate and consolidation settlement. He also stated that he would have less confidence in the DMT data for highly over consolidated clay. NAB has conducted extensive research on DMT data and has predicted settlements for both sand and clay. The DMT data analysis provides/estimates a constrained modulus, which is comparable to the constrained modulus from consolidation tests with an oedometer.

Although the information provided by NAB was helpful, the NAO Geotechnical Engineer decided to use Schnabel Engineering's expected maximum settlement recommendation of 16.3-inches. One reason for this decision was due to visual observations made of the landside of the southernmost breakwater structure located near Launch Pad 0-B during a site visit in August 2024. Refer to Figures 2.2.4.2-4 through 2.2.4.2-7. Without physically measuring the armor stone, the breakwater structure visually appeared to be possibly "slumping." Smaller diameter stone was observed where larger armor stone should be placed. One suggestion the NAO H&H Engineer provided was that the smaller sized stone may be the smaller stone within the gradation range of the armor stone supplied by the previous Contractor.

The previous 2019 design called for VDOT Type I armor stone average weight 2,000 lbs and VDOT Class II core stone average weight 300 lbs, and a 6-inch marine mattress. Crest elevation was determined to be +6-feet NAVD88. Refer to Figure 2.2.4.2-1. It was discovered by the NAO H&H Engineer during the current project design phase that a decision was made during construction to change the size of the armor stone and increase the thickness of the marine mattresses. It is unknown why this decision was made. The existing breakwater design at the project site consists of an armor stone with an average weight of 5,300 lbs, core stone with an average weight of 300 lbs, and a 12-inch marine mattress with a filtration geotextile installed on the bottom of the mattresses. A review of the 2020 as-built survey profiles show the armor stone was placed entirely on the outside of the structure and the core stone should not be visible. It was noticed that some of the armor stone at the seaside and landside toes, in the 2020 as-built profiles, was not placed on the marine mattress but directly on the sea floor. The crest elevations in the as-built drawings show a general elevation for all profiles to be generally elevation

+6 to +7.5-feet. As-built profiles for existing breakwater structure (BK-1), which is the southernmost structure near Launch Pad 0-B where photographs were taken during the August 2024 site visit, is shown in Figures 2.2.4.2-2 and 2.2.4.2-3.

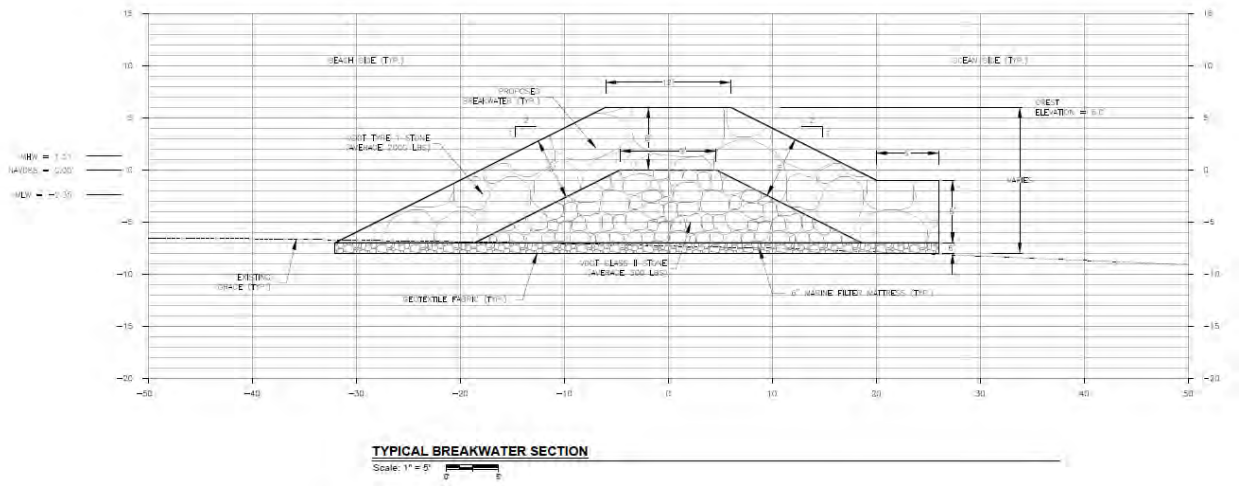


Figure 2.2.4.2-1. Breakwater detail from the 2019 awarded design plans.

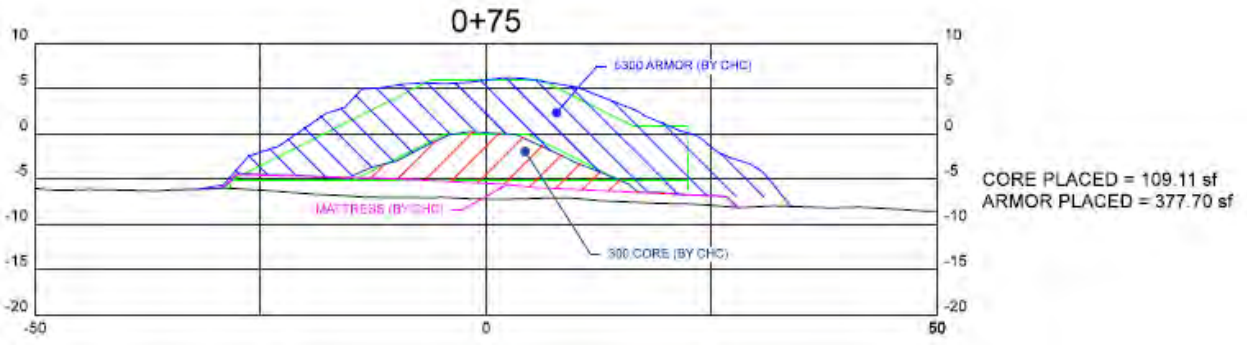


Figure 2.2.4.2-2. As-built profile taken at station 0+75 existing breakwater structure BK-1 at NASA Wallops Flight Facility. Armor stone not entirely on mattress on the seaside toe. Approximate crest elevation +6-feet at this station.

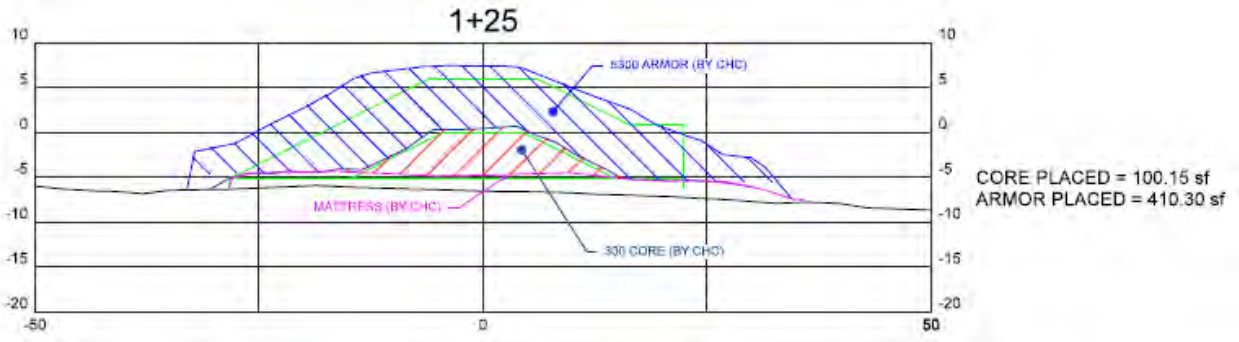


Figure 2.2.4.2-3. Profile taken at station 1+25 existing breakwater structure BK-1 at NASA Wallops Flight Facility. Armor stone not entirely on mattress on the landside. Approximate crest elevation +7-feet at this station.

A more recent survey of the existing breakwater structures was conducted in June 2025. Refer to Figures 2.2.4.2-8 and 2.2.4.2-9. Survey points taken on southernmost set of existing breakwaters near Launch Pad 0-B show crest point elevations appear to range for the southernmost structure +6.32 to +6.50-feet, middle structure +5.43 to +7.01-feet, and northernmost structure +4.36 to +6.95-feet. Survey points taken on northernmost set of existing breakwaters near the intersection of Causeway Road and N. Seawall Road (near the Horizontal Integration Facility as shown on Google Earth). Crest point elevations appear to range for the southernmost structure +7.07 to +7.22-feet and the northernmost structure +5.49 to +6.35-feet. When comparing the crest point elevations of the existing breakwater structures to the 2020 as-built breakwater profiles, it is possible there could be some stone slumping or differential settlement that may be occurring. But to better determine this, the above point elevations taken during the June 2025 survey would need to be further verified that they were taken on the actual crest of the breakwater structures. Some of the point elevations may have been taken on the side slopes. Survey profiles were also not generated with the June 2025 survey data, which would allow for better interpretation of the existing conditions when comparing conditions to the 2020 as-built breakwater profiles.

It is also suggested in the ERDC document ERDC/CHL CHETN-III-72 Uses of Marine Mattresses in Coastal Engineering, February 2006, section Underlayer of Rubble-Mound Structures: “Because of the geogrid smoothness and the uniformity of the mattress surface, the interface between the mattress and the overlying layer has less shear resistance than a comparable unconfined underlayer. Thus, there could be a greater risk of armor layer slumping on steep slopes with a marine mattress underlayer unless a reliable toe is placed.” The 2019 design only included a toe on the seaside of the breakwater structure. Possible “slumping” was observed on the landside of one of the existing breakwater structures (BK-1) in August 2024. During the design phase it was recommended by ERDC to include a second toe on the landside of the structure.

Due to the expected total settlement of 16.3-inches, the NAO H&H Engineer modified the current 100% working design from a crest elevation of +6-feet to +7-Feet NAVD88. The height of the core stone was increased by 1-foot to accommodate this design change.



Figure 2.2.4.2-4. Red circle shows location of southernmost breakwater structure near Launch Pad 0-B (Google Earth).



Figure 2.2.4.2-5. Right side of pictures shows the observed southernmost breakwater structure near Launch Pad 0-B.



Figure 2.2.4.2-6. Landside of southernmost breakwater structure near Launch Pad 0-B. Red arrows show general areas where smaller stone observed.



Figure 2.2.4.2-7. Close-up landside of southernmost breakwater structure near Launch Pad 0-B. Red arrows show general areas where smaller stone observed.



Figure 2.2.4.2-8. Survey points taken on southernmost set of existing breakwaters near Launch Pad 0-B. Crest point elevations appear to range for the southernmost structure +6.32 to +6.50-feet, middle structure +5.43 to +7.01-feet, and northern-most structure +4.36 to +6.95-feet.

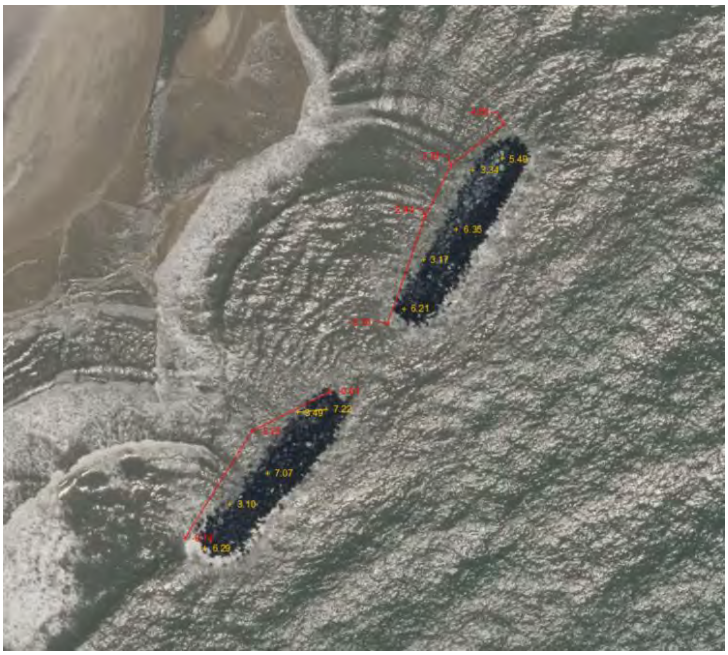


Figure 2.2.4.2-9. Survey points taken on northernmost set of existing breakwaters near the intersection of Causeway Road and N. Seawall Road (near the Horizontal

Integration Facility). Crest point elevations appear to range for the southernmost structure +7.07 to +7.22-feet and the northernmost structure +5.49 to +6.35-feet.

2.2.7.2 Slope Stability

The NAO H&H Engineering Section provided the Geo-Environmental Engineering (Geo) Section with the breakwater structure design shown on the plan sheet. GeoStudio software version 2024.2.1 was utilized to conduct the slope stability analyses for the breakwater structure.

The factor of safety requirements in Table 3-1 of Slope Stability EM 1110-2-1902 are used for the design of new embankment dams. Section 3-4 of the EM also provides criteria for structures indicated as "Other Slopes". The criteria provided in Table 3-1 of new embankment dams take into consideration greater uncertainties and consequences of failure. When taking into consideration the uncertainties and consequences of failure for the purposes of this project, these concerns are small. EM 1110-2-1902 states that when the uncertainty and consequences of failure are both small, it is acceptable to use smaller factors of safety, on the order of 1.3.

Two conditions were run in the GeoStudio software to verify the design slopes of the structure. The first condition evaluated if the design slope for the undrained soil conditions (end of construction) generally met the minimum factor of safety criteria of 1.3. The second condition evaluated the designed slope under drained consolidated soil conditions (long term) and evaluated if the slope generally met the minimum factor of safety criteria of 1.5. The soil layer parameters used for each condition is provided in Table 2.2.7.2-1. Breakwater stone parameters used for the breakwater structure for each condition are provided in Table 2.2.7.2-2. The property values for soil layer SP-SM were interpolated from boring location B-2. Moist unit weight values for each layer were interpolated from the DMT D-2 and D-3 data set. Refer to the Appendix B Moist Unit Weight vs. Depth scatter plot.

For the undrained condition, the undrained shear strength (Su) of the very soft, plastic clay (CH) layer was interpolated by correlating the CPT data with the DMT raw data. Two sets of data were graphed and interpolated: C-2 and D-2 (seperated by 500-feet horizontal distance), and C-3 and D-3 (seperated by 1,500-feet distance). Because C-3 and D-3 were a greater distance apart, boring location B-2 was used to verify any changes in stratigraphy between the test locations. For each data set the CPT Su data was correlated and compared with the DMT Su data, and site specific Nkt and Ndu cone factors were determined. Baltimore District, US Army Corps of Engineers provide the NAO Geotechnical Engineer with a Microsoft Excel spreadsheet which was used to calculate undrained shear strength values. The CPT and DMT undrained shear strength (Su) equations used in the spreadsheet are as follows:

1. CPT undrained shear strength: (Vesic, 1972, Battaglio et al, 1981; Randolph and Wroth, 1979: Massarch and Broms, 1981; Campanella et al, 1985)

   - Su = (u2-uo)/Ndu

Where:
Su = undrained shear strength (psf)
u2 = pore pressure behind cone tip (feet)
uo = hydrostatic water pressure (feet)
Ndu = cone factor used to estimate undrained shear strength based on the excess pore water pressure measured behind the cone

And

2. CPT undrained shear strength: (Lunne et al, 1985)

   - Su = (qt – σvo)/Nkt

Where:
Su = undrained shear strength (psf)
qt = corrected cone tip resistance (tsf)
σvo = in-situ total vertical stress (psf)
Nkt = cone factor applied to the net cone resistance (qn), (qn = qt- σvo) to estimate the undrained shear strength for cohesive soils

3. DMT undrained shear strength Marchetti et al. 2001:

   - $Su = 0.22*\sigma'vo*(0.5*K_D)^{1.25}$

Where:
Su = undrained shear strength (psf)
σ'vo = effective stress (tsf)
K_D = horizontal stress index

The graphed CPT and DMT Su data sets are provided in Appendix B of this document. According to FHWA-PA-87-023+84-24, Guidelines for Using the CPT, CPTU, and Marchetti DMT for Geotechnical Design, Volume II (of IV) – Using CPT and CPTU Data, March 1988, Nkt can vary in value between 4 and 30, depending on factors such as sensitivity, stress history, stiffness, fissuring (microfabric) and definition of Su. Values higher than 20 for very soft clays can be derived. Ndu can vary between 2 and 20 (on a global basis). This reference also suggests for soft

clays there is an advantage of increased accuracy in the measurement of change in pore water pressure. For soft clays, the cone resistance can be very small and typically the cone tip load cell may be required to record loads less than 1% of rated capacity with the with an associated inaccuracy of up to 50% of the measured values. However, in soft clays, the pore pressures generated can be very large and the pressure transducer may record pressures up to 80% of its rated capacity with an associated accuracy of better than 1% of the measured value. Therefore, estimates of Su in soft clays will inherently be more accurate using pore pressure data as opposed to the tip resistance.

Due to the thick and very soft CH layer encountered at the NASA Wallops Flight Facility project site, the Su values produced by the Ndu cone factor (which are dependent upon pore pressure) are considered to be more reliable when correlating the CPT Su values to the DMT Su values. The Su values produced by the Nkt cone factor were also correlated to the DMT Su values but are considered to be less reliable since the values are dependent upon tip resistance.

The following Nkt and Ndu cone factors were interpolated to best fit the DMT Su data trends for the NASA Wallops Flight Facility project site:

- Nkt = 12
- Ndu = 9

Unfortunately vane shear tests, unconsolidated undrained tests (UU), and consolidated undrained tests (CU), were not performed by Schnabel Engineering during the geotechnical exploration, which would have aided for a more accurate correlation of the CPT Su data.

As indicated in the previous Bearing Capacity Section, boring logs for boring locations B-1 through B-5 were reviewed for sea bottom material. For each boring location, SP-SM material was encountered to a depth of approximately 0-feet to 12-feet below the sea bottom. The surface materials for the CPT and DMT tests were also evaluated, but readings generally did not begin until an approximate depth of 2-feet to 6-feet below the sea bottom. The CPT results also show that a casing was installed within the upper 0-feet to 6-feet below the sea bottom. Due to these circumstances with the CPT and DMT data, it was determined that the boring logs provide the most accurate interpretation of the material type for the sea bottom. The SP-SM material was identified as the sea bottom material for all geotechnical analyses.

Two observations are made while evaluating the undrained shear strength plots. First, it is observed that undrained shear strength increases with depth. The interpolated undrained shear strength value for the top of the CH layer was approximately 260 psf. The maximum value for the bottom of the CH layer was interpolated to be 675 psf. Second, it is generally known that the top several feet of CPT and DMT data is usually not considered since the cone just penetrates the

surface and requires some depth to produce consistent, accurate readings. If the first several feet of the Su data are not considered, generally it is observed that the Su values appear to be greater than 500 psf and no greater than 700 psf. Due to this general observation, a Su value of 600 psf was also considered for the CH layer.

The unit weights of the armor and core stone were calculated as follows:

- Current design breakwater stone specification states maximum unit weight of 175 pcf
- Assumed 25% void space (porosity) conservative assumption for core and armor stone
    - Therefore: 175 pcf x 0.75 (note: 25% porosity) = 132 pcf (reference: unit weights for rock embankments generally range from 130 to 140 pcf)
- Internal friction angle for armor and core stone: 40-degrees (conservative), generally 40 to 45 degrees

To consider the effects of construction tolerance, all GeoStudio analyses were run with an armor stone thickness of 10-feet. As discussed earlier, design elevation is +7-feet NAVD88 (9-foot-thick armor stone layer). It was determined that even if the specification requires that the core stone have an above neatline tolerance of 0.5-foot and the armor stone have an above neatline tolerance of 1-foot, it can be assumed that the tolerance will not allow the contractor to construct the breakwater structures greater than elevation +8-feet NAVD88.

For the end of construction condition, undrained condition, a total of five analyses were run in GeoStudio. The first three were run utilizing the Mohr-Coulomb material method. First, the S=f(depth) option under material properties was selected for the CH layer to run a model which considered 300 psf for the top of the CH layer and 675 psf maximum value for the bottom of the CH layer. The material properties of all materials other than the CH layer, including the stone, were considered Mohr-Coulomb. The breakwater slip surface direction of movement was performed from left to right for this analysis. Second, a Mohr-Coulomb material method was run for the slope considering an undrained shear strength of 600 psf. The breakwater slip surface direction of movement was performed from left to right for this analysis. Third, a Mohr-Coulomb material method was run to verify the S=f(depth) option was stable if the breakwater slip surface direction of movement was performed in the opposing direction right to left as requested by the Wilmington District Quality Control (DQC) reviewer.

For end of construction, an additional fourth and fifth model were performed utilizing the surcharge method, which considers that the armor stone will act as a vertical surcharge load when placed overtop the core stone and mattresses. The surcharge method considers that the armor stone has no shear strength (effective cohesion) or effective friction angle and acts only as a vertical surcharge load. When the armor stone is placed during construction, the armor stone is considered to behave similar to a surcharge load due to its large, rounded size and how each

rock or boulder is placed one at a time by heavy equipment. If the rocks are not well interlocked, they can become loose. Unlike the Mohr-Coulomb method, the surcharge method assumes the armor stone is not a uniform mass layer of rock material with cohesive and friction angle properties. Both Mohr-Coulomb and surcharge methods were analyzed for the project because it was determined that neither method is an inaccurate assumption for the behavior of the armor stone although the surcharge method is the most conservative of the two models. The results for both methods were compared. Because approximately 20% of the breakwater structure is above the Mean High Water (MHW) elevation (+1.31 feet), three surcharge loads were drawn in the model so that the slope stability analyses would be representative of the site conditions. Including 1-foot construction tolerance, the armor stone extends to approximately 10-feet in height above the core stone and mattresses (9-feet + 1-foot tolerance = 10-feet). Refer to Appendix A. The surcharge loads were calculated as follows:

- Surcharge Areas 1 and 3
    - Unit weight armor stone = 132 pcf
    - Unit weight of salt water = 64 pcf
    - Buoyant unit weight = 132 pcf – 64 pcf = 68 pcf
- Surcharge Area 2: (132 pcf + 68 pcf)/2 = 100 pcf (average of area above and below water level)

These fourth and fifth surcharge models were run each considering the different CH property options as used for the Mohr-Coulomb models: 1) the S=f(depth) option under material properties was selected for the CH layer to run a model which considered 300 psf for the top of the CH layer and 675 psf maximum value for the bottom of the CH layer; and 2) considering an undrained shear strength of 600 psf. All five analyses were found to meet the minimum criteria factor of safety of 1.3. The factor of safety results for the undrained condition GeoStudio Analyses are provided in Table 2.2.7.2-3.

For the drained condition (long term), the Mohr-Coulomb material method was used when assuming material properties for the CH layer. Two models were run, one considering the armor stone has material properties utilizing the Mohr-Coulomb method, and a second model considering the armor stone behaves like a vertical surcharge load. The breakwater slip surface direction of movement was performed from left to right for both models. The Mohr-Coulomb method was found to meet the minimum criteria for factor of safety of 1.5, but the surcharge method was slightly below the 1.5 (1.438) requirement. Although the surcharge method is slightly below the 1.5 factor of safety requirement, it was determined not to be a concern. The factor of safety value is close to 1.5, the Mohr-Coulomb method passed with a factor of safety value greater than 1.5 (1.660), and the uncertainty and consequences of failure for the breakwater structures are both small. When uncertainty and consequences of failure for a structure are small, it is acceptable to use smaller factors of safety in accordance with EM 1110-2-1902. The

factor of safety results for the drained condition GeoStudio Analyses are provided in Table 2.2.7.2-3.

Table 2.2.7.2-1. Soil parameters used for GeoStudio analysis.

Soil Type (USCS)	Depth Below Sea Bottom (feet)	Elevation (feet)	Moist Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)	**Phi Angle (degrees)	Assumed Drain Shear Strength (psf)
				First Condition End of Construction	First Condition End of Construction	Drained Condition Long Term	Drained Condition Long Term
SP-SM	0 to 3	-11 to -14	106	30	0	30	0
CH	3 to 27	-14 to -38	104	0	(Range 300 to 675) and 600	25	0
SC	27 to 32	-38 to -43	112	34	0	34	0

**Phi Angle Degrees drained condition for CH layer, based on plasticity index value of 27 from laboratory test results at boring location B-2. Reference EM 1110-2-1913 Design and Construction of Levees, 31 March 1978, Figure 3-2 page 3-7. Mississippi River Soil Data.

Table 2.2.7.2-2. Breakwater stone parameters used in GeoStudio analysis.

Stone Type	Unit Weight (pcf)	Phi Angle (degrees)
VDOT Type II	132	40
VDOT Class III	132	40
12” Marine Mattress #2 Stone	125	34

The stability for each of these conditions was run for the seaward side of the breakwater structure from the left to right direction utilizing the Spencer Analysis. The elevation of the pore water pressure was assumed to be MHW elevation at +1.31-feet, which is assumed to be realistic to

site conditions. A summary of the GeoStudio slope stability analysis results are provided in Table 2.2.7.2-3. Refer to Appendix B for GeoStudio analysis results profiles.

Table 2.2.7.2-3. Summary GeoStudio analysis factor of safety results.

Condition	Stable Design Slope (Horizontal:Vertical)	Factor of Safety
Undrained, End of Construction, Mohr-Coulomb, Su 300 psf top and 675 psf bottom of layer (left to right) (Min. Requirement 1.3)	2H:1V	1.543
Undrained, End of Construction, Mohr-Coulomb, Su 300 psf top and 675 psf bottom of layer (right to left) (Min. Requirement 1.3)	2H:1V	1.636
Undrained, End of Construction, Mohr-Coulomb, Su 600 psf (left to right) (Min. Requirement 1.3)	2H:1V	1.740
Undrained, End of Construction, Surcharge, Su 300 psf and 675 psf bottom of layer (Min. Requirement 1.3)	2H:1V	1.822
Undrained, End of Construction, Surcharge, Su 600 psf (Min. Requirement 1.3)	2H:1V	1.822
Drained, Long Term, Mohr-Coulomb, (Min. Requirement 1.5)	2H:1V	1.660
Drained, Long Term, Surcharge, (Min. Requirement 1.5)	2H:1V	1.438

2.2.4.3 Seismic Evaluation

The American Society of Civil Engineers (ASCE) 7-16 Seismic Loads Chapter 4, Table 20.3-1 was used to determine the site classification for the project area. Table 20.3-1 is shown in Figure 2.2.4.3-1. Standard Penetration Test (SPT) location B-2 was evaluated to determine the seismic

site classification. The subsurface conditions were predominantly a very soft, plastic clay (CH) that extends from an approximate depth of 2.8 to 27 feet below the sea floor with some minor thicknesses of poorly graded sand and silty sand (SP-SM) and clayey sand (SC) material. Organic clay (OH) was encountered from approximately 34 feet to 42-feet below the seafloor surface. The plasticity Index (PI) value for the one sample that was collected and laboratory tested in this layer is 27 (greater than 20). Moisture content was 34.3% but due to its value being within close range of 40%, it should be assumed to be saturated and greater than 40% due to the submerged, offshore environment where the sample was collected. N values are predominantly weight of hammer (WOH) throughout the layer, and DMT data gathered at locations D-2 and D-3 show undrained shear strength values range from approximately 260 pounds per square foot (psf) to 675 psf. Therefore, the project site is Seismic Site Classification E. Site Classification F were also evaluated but did not meet the category requirements.

***Table G4-1.* Site Classification**

Site class	$\overline{v}_s$ *(ft/s)*	$\overline{N}$ *or* $\overline{N}_{ch}$ *(blows/ft)*	$\overline{s}_u$ *(lb/ft²)*
A. Hard rock	>5,000	NA	NA
B. Rock	2,500 to 5,000	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500	>50	>2,000
D. Stiff soil	600 to 1,200	15 to 50	1,000 to 2,000
E. Soft clay soil	<600	<15	<1,000
	Any profile with more than 10 ft of soil that has the following characteristics: • Plasticity index PI > 20, • Moisture content $w \geq 40\%$, and • Undrained shear strength $\overline{s}_u < 500$ lb/ft².		
F. Soils requiring site response analysis in accordance with Section 21.1.	See Section 20.3.1.		

Source: Table 20.3-1 of ASCE 7-16.

Figure 2.2.4.3-1. Table 20.3-1 of ASCE 7-16 Chapter 4 Seismic Site Classification

In accordance with the International Building Code (IBC) 2024, Table 1604.5-Risk Category of Buildings and Other Structures page 437, the breakwater structure represents a low hazard to human life in the event of failure. Therefore, the project site meets the requirements for Risk Category I. Refer to Appendix B for calculations.

Seismic site data was gathered from the ASCE Hazard tool website (https://ascehazardtool.org/), and the United States Geological Survey (USGS) Motions Website (https://seismicmaps.org/). The data from these websites are provided in Appendix B. According to the USGS Motions Website, the project area contains a peak ground acceleration (PGA) value of 0.038. In accordance with ER 1110-2-1806 Engineering and Design Earthquake Analysis, Evaluation, and Design for Civil Works Projects dated 29 June 2024, the seismic ground motion hazard region is classified as low since PGA is less than or equal to 0.1g. Because these structures have been identified in accordance with the IBC as a Risk Category I, which represents a low hazard to human life in the event of failure, the structure can be considered as Non-Critical. Direct loss of life is not expected, damages could be repaired pending available funds, property loss is minimal, and minimal adverse environmental impacts are expected.

ER 1110-2-1806 states that additional seismic criteria and guidelines can be found in structure-specific or feature-specific engineer regulations, engineer manuals (EM), building codes, and other applicable federal criteria and guidelines, as appropriate. EM 1110-2-1100 (Part VI) Change 3 (28 Sep 2011) Coastal Engineering Manual, number 8 on page VI-3-7 states: "The prospect of project damage by seismic activity should be evaluated for projects located in high seismic risk zones. Generally, seismic-related damage to rubble-mound structures does not result in catastrophic failure, and it is possible for earthquake-damaged rubble-mound structures to continue to fulfill their intended function."

2.2.5 Construction

During the 65% and 100% design phase constructability of the breakwater structures were further discussed. The previous breakwater structures installed in 2020 were constructed from land due to the shallow sea bottom conditions that prevented barges from accessing the area. The beach was also renourished. Sand that migrated to the northern end of the island was trucked from the northern end to renourish the project area. Access roads were constructed by the Contractor from the beach and extended approximately 200-feet offshore to the breakwater structures. It was discussed with the NAO H&H Engineering during the design phase that the existing breakwater structures were previously designed as salient structures. Current Google Earth images show that the structures have "connected" to the beach, acting more as tombolo structures. It is unknown why this is occurring, but one suggestion from the NAO H&H Engineer is that it may be due to the access roads that were constructed during the previous project. It was also determined by the design team, and after information received from dredging contractors during the December 2024 Industry Day, that issuing this project as two separate contracts (breakwater and beach renourishment) would further benefit the award of the project. NAO plans to issue this project as two separate contracts but the two Contractors must coordinate during construction. It is unsure which portion of the project will be reconstructed first, the beach renourishment or breakwaters. If the Contractor chooses to construct the breakwater structures from the beach, sand is a material that may be needed to build a temporary access road to the structures and it cannot be mined from the beach. It was suggested that material could be trucked from the northern end of the island, but after discussions with NASA Wallops Flight Facility personnel, excavating material on the northern end of the island is only permitted approximately every 10-12 years. Means and methods for construction will be determined by the Contractors.

As-built surveys of the existing 2020 breakwater structures show some profiles where the armor stone was not placed overtop the marine mattress at the seaside toe or the landside. Statements have been written in the specifications directing the Contractor to place the armor stone overtop the mattress and not the sea bottom.

Because the dredging and breakwater construction will be solicited to the contractor in two separate contracts, it is possible the breakwaters may not be concurrently constructed while the beach is being renourished. When the existing breakwater structures were constructed in 2020, it was determined by the contractor that the breakwaters could not be constructed from the water, they were constructed from land. Access roadways were constructed from the beach to the breakwater construction locations. Sea bottom elevation within the current breakwater alignment area for this current project ranges from elevations -9 to -12 feet NAVD88. It is possible that the contractor may choose to construct the breakwaters from land. The current proposed locations for the breakwaters lie directly eastward of the sea wall where there is no beach. Due

to these circumstances, the contractor may need offsite borrow material to construct breakwater access. After approval was received by the NASA Environmental Planning Group Lead, geotechnical requirements for offsite borrow material was included in the BREAKWATER STONE AND CONSTRUCTION specification for the contractor to use if needed. The borrow material supplied by the contractor will be required to match the existing beach sand. It was also requested if the contractor could mine beach sand at a site located on the NASA Wallops facility and the request was denied by NASA.

Construction tolerances for the breakwater structure were recommended by NAP based on previous project experience. For the core stone, it was recommended that the contractor be permitted to construct it up to +0.5-feet above the neatline and 0-feet below the neatline. For the armor stone, it was recommended that the contractor be permitted to construct it up to +1.0-feet above the neatline and 0-feet below the neatline. When taking into consideration total tolerances of the core and armor stone for the structure, it should only be up to +1.0-foot above the neatline, as this will be the maximum elevation the contractor will be permitted to construct. Design crest elevation of the breakwater structure is +7-feet but tolerances will allow for construction up to +8-feet.

2.2.6 Future Project Geotechnical Considerations

2.2.6.1 Priority Area 2 Shoreline Protection Structure Design

As previously stated the results of ERDC's modeling study showed if breakwater structures were to be installed for Priority Area 2, they would have a detrimental effect on the beach, causing further erosion and a lack of sediment in the area. It was determined by the NAO design team that Priority Area 2 would not receive breakwater structures. If in the future it is determined that breakwater structures or any shoreline protection structures are to be placed offshore of Priority Area 2, it is highly recommended that a geotechnical exploration be performed within this area. This area lies within the location of the historical Assawoman Inlet. It is highly possible that geologic conditions in this area may significantly vary from the previously explored areas in the 2018 geotechnical report. It was suggested by the NAO H&H Engineer that survey monitoring of the shoreline and beach conditions in this area will continue after construction of this current project. A figure showing the location of the historical Assawoman Inlet is provided in Figure 3 Appendix A.

2.2.6.2 Future Geotechnical Exploration Testing for Undrained Shear Strength Determination

If future additional geotechnical shoreline testing is required, to better correlate data for undrained shear strength determination include standard penetration tests (SPT) along with the in-situ cone penetration tests (CPT) and dilatometer (DMT) tests. With the SPT include

additional tests such as vane shear tests, unconsolidated undrained tests (UU), and consolidated undrained tests (CU). The stratigraphy of the project site generally consists of a thin poorly graded and silty SAND (SM-SP) layer ranging approximately 3-feet to 12-feet below the sea bottom surface. Beneath this layer is a very soft (generally weight of hammer), thick plastic CLAY (CH) layer encountered at a depth range of approximately 3-feet to 42-feet below the sea bottom surface. Because the only available in-situ data available were CPTs and DMTs, for this project the CPT Su data was correlated to best fit the DMT Su data, and site specific Nkt and Ndu cone factor values were determined. After consulting with the Baltimore District, US Army Corps of Engineers for guidance for correlating this data, it was discussed that one of their most recent project site explorations within the Chesapeake Bay area that the cones from the CPT tests experience temperature effects. This was discovered when comparing the results of the CPT testing from their 2020 and 2024 investigations. A different cone manufacturer was used during each exploration (Hogentogler 2020 and Vertek 2024). This phenomenon is best described by Lunne (1986). Laboratory testing was undertaken on Vertek cones following Lunne (1986) procedures. Differences in tip resistance were found to be up to approximately 1-3 tons per square foot (tsf). The 2020 investigation was performed during the summer in which negative shifts in temperature were observed, and the 2024 investigation was performed during the winter in which positive shifts in temperature were observed.

As described in their James and Barren Island geotechnical report, these thermal effects can be of great concern for soils that have the lowest tip resistances and the error introduced by thermal baseline shifts can be nearly as large as the measurement. It was mentioned by the NAB Geotechnical Engineer that the ASTM standards allow for a large margin of error in tip measurement, which for soft soils even small errors can increase or decrease the undrained shear strength readings. It was also suggested that for soft soils, CPT is not good due to these errors. Refer to the James Geotechnical Appendix to Design Documentation Report on file for additional information.

2.2.6.3 Future Survey Monitoring Breakwater Structures

It is recommended after construction of the current project to continue to survey monitor the conditions of the beach and all breakwater structures. As-build 2020 profiles of the existing breakwaters suggest there could be some collapse of the structures or differential settlement, but more survey data is needed to determine this. To have a better understanding for the conditions of the breakwater structures, survey profiles of all breakwater structures should be generated and compared to the as-built drawings and profiles. This should be done during the design phase for all shoreline protection projects at the NASA Wallops Island Flight Facility so that design modifications can be implemented if needed.

2.2.6.4 Beach Renourishment

Known environmental information for beach renourishment the NASA Wallops Flight Facility has been included under section Dredging Constraints. Information provided in this section was shared by the NASA Wallops Environmental Planning Group Lead, and further information and interpretation was provided by the NAO Environmental Scientist. There are environmental constraints within Unnamed Shoal A borrow area that will impact the dredging constraints and the planning process for future geotechnical explorations. Note that the preferred section to dredge within this area is sub-area A-1 and the maximum depth is 10-feet per dredging cycle (which includes a couple feet of over depth), given these environmental constraints. Sub-area A-2 is an alternate area for dredge material as defined with limitations in section 2.2.1.3 Dredging Constraints. NASA Wallops Flight Facility has documented these environmental constraints well within their 2010 Environmental Impact Statement (EIS) document and their 2013 Environmental Assessment (EA) document. Historical project dredging and beach renourishment information is provided in section Dredging Constraints as well.

The vibracore samples for the 2025 geotechnical borrow area exploration penetrated to a depth of approximately 20-feet below the sea floor. Although the dredge depth is limited to a maximum of 10-feet, sampling to 20-feet will give the Geologist or Geotechnical Engineer a general interpretation of the deeper materials that can be used for future dredging cycles. Note that the material identified in the vibracore logs in accordance with the USCS is predominantly SP. Deeper depth intervals that were not laboratory tested are visually classified in most vibracore logs as SP-SM. Additional testing of the deeper depth samples would be needed to determine this. Schnabel Engineering is planning to store the samples for up to 1-year, but Bureau of Ocean Energy Management (BOEM) has requested to take custody of the samples after design is complete. NAO plans to give custody of the samples to BOEM after the design is complete.

It is recommended that a site visit be performed for the area of the beach to be renourished prior to any future beach renourishment projects. Within the project area because this is a historical Naval Base, old foundations were observed sticking up out of the sand on the beach as well as wooden pilings. NASA Wallops Flight Facility also has several linear feet of geotubes between the dune and berm areas. Verify that the existing site conditions are accurately captured during the site survey.

For this project it was confirmed with NASA Wallops Flight Facility that beach fill placement may occur around and overtop the existing seawall between stations 40+00 and 104+00 along the beach renourishment alignment. A requirement in specification 35 20 24 BEACH FILL paragraph 3.2.2 Beach Fill Placement Area Control letter (g) was provided to the contractor for placing beach fill around the existing seawall. The Government is not responsible for any damage that may be caused to heavy equipment that will be used to place beach fill around and overtop the existing seawall. The contractor will be required to use proper means and methods for beach fill placement and must locate the seawall for the duration of construction. Generally, the existing seawall is riprap rock that was placed directly on top of the beach. It was also brought

to the NAO design team's attention by NASA Wallops that the existing seawall was covered during the previous beach renourishment project.

The template used for the beach design was derived from the ERDC/CHL Oct 2010 TR-11-9 report, "Storm Damage Reduction Project Design for Wallops Island, Virginia". The beach template was used in the 2013-2014 Sandy post nourishment and for the 2019 nourishment.

2.2.6.4.1 Future Laboratory Testing Plan

Terracon and Schnabel Engineering were directed by the NAO Geotechnical Engineer to include sieve sizes that are not typically used when conducting ASTM D6913 Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis. The previous 2007 and 2008 NASA Wallops borrow area reports included several sieve sizes from the Wentworth Classification that at the time during the exploration planning, it was uncertain if they were required. After completing the exploration and design for this project, it is recommended to include some of the gradation sizes from the Wentworth scale to better define boundaries between materials (i.e. for sand No. 4, No. 5, No. 10, No. 18, No. 35, No. 40, No. 60, No. 120, No. 200, and No. 230). Consider including gravel sieves as well in case gravel is encountered. For this project sieve sizes 1.25", 1", 5/8", ½", 5/16", and ¼" were used. Refer to EM 1110-2-1100 (Part III) 31 July 2003, Table III-1-2 Sediment Particle Sizes, page III-1-8 for the USCS and Wentworth classification scales. Including the granularmetric report as a requirement for the contractor to complete was helpful when utilizing the data for the compatibility analysis.

Note that the soil samples that were not tested by the Schnabel Engineering soils laboratory were visually classified in the field as Silty SAND (SM). For future projects additional testing is recommended to determine if the visual classification of the SM material is correct.

2.2.6.5 Stone Quantity Calculation Estimates

The NAO H&H Engineer calculated the quantities of armor stone and core stone for the project. Specification section 35 31 19.40 BREAKWATER STONE AND CONSTRUCTION, paragraph 1.4.1 Factors of Converting In-Place Volume to Weights requires that the designer provide parameters for how the estimated tonnage of stone was calculated so that the Contractor may use these parameters to re-calculate any additional quantities of stone. The column headings from the specification template were revised to the following titles: Specific Gravity (SSD) Range, Percent Voids, and Unit Weight Pounds Per Cubic Foot of Material. The FAR clause within this paragraph locks the contractor in their contract bid price so the price of the stone cannot be renegotiated if during construction additional stone may be needed to complete the project. If in the event during construction the estimated quantity of stone is overestimated by the designer of

record by more than 15% (15% variation in estimated quantity), after the contractor performs due diligence to verify the quantities used are correct, the clause allows the contractor to re-negotiate the price since a larger quantity of stone was guaranteed to the quarry to be supplied and is now less than what is needed for the project.

After discussions with the NAO H&H Engineer designer of record, the unit weight of the stone used to calculate the volumes of stone is 165 pcf and the void percent was assumed to be 20%. The specific gravity range was included to be 2.60 to 2.80 (as required in the specification). The NAO H&H Engineer has stated that the void percentage of 20% is based on previous project experience. The NAO Geotechnical Engineer found the preconstruction submittal for the stone from the 2020 project. The unit weight of the stone used by the contractor from the previous project was 175 pcf but the NAO H&H Engineer pointed out it was supplied from a quarry in Maryland. The current design specification references Virginia Department of Transportation (VDOT) materials.

During ITR the Philadelphia District, US Army Corps of Engineers (NAP) geotechnical reviewer provided a different, typical method used by NAP for calculating the volumes of the stone materials when discussing Specification section 35 31 19.40 BREAKWATER STONE AND CONSTRUCTION, paragraph 1.4.1 Factors of Converting In-Place Volume to Weights. The table within this paragraph includes column titles for specific gravity (SSD), percent voids, and Pounds per Cubic Foot of Material Including Compensation of Voids (For Excess Quantity Calculations). Based on Table VI-5-51 Layer of Coefficient and Porosity for Various Armor Units, provided in the Coastal Engineering Manual 1110-2-1100 (Part VI) 28 September 2011 (provided in Appendix B under Slope Stability), the porosity of Quarrystone can range from 27 to 40 -degrees (depending on the texture and shape of quarrystone assumed). For most publications, generally the void percentage ranges from 30% to 40%. Based on NAP's project experience, the NAP geotechnical reviewer suggested for the armor and core stone to assume 35% voids, and for the mattress stone assume 30% (more tightly packed in mattress, less void space). This percentage is typically included with the unit weight of the stone. For armor and core stone 175 pcf was assumed (maximum unit weight requirement in the breakwater stone specification), including the void percentage with the unit weight calculates to be approximately 175 pcf x 0.65 (35% less) = 114 pcf. For the mattress stone, 175 pcf x 0.70 (30% less) = 123 pcf.

2.2.7 Coordination with Installation, Centers of Expertise, or Outside Agencies

2.2.7.1 MEC Assessment: While developing a scope of work for the geotechnical exploration AE contract, it was discovered that a Munitions and Explosives of Concern (MEC) probability assessment needed to be completed and signed by the District Commander prior to the AE performing the geotechnical exploration. The Norfolk District Geotechnical Engineer contacted the Baltimore District Ordnance and Explosive Safety Specialist. Baltimore District has worked with the Norfolk District to develop and provide a MEC probability assessment. The assessment report states that all three (3) project areas of the Wallops Island Flight Facility which are the beach, breakwater shoreline, and Unnamed Shoal A borrow area are considered to be "Low Probability" for encountering MEC. It is recommended that Baltimore District be on-call for MEC support when the AE performs the exploration, and that all contractors who will be performing the work for the exploration review the 3R's of Explosive Safety (Recognize, Retreat, Report) awareness online training. The report also provides recommendations for dredging and beach renourishment activities. Contractor requirements for MEC will be included in the design specifications for the project.

2.3 ENVIRONMENTAL

2.3.1 General Parameters

- NASA is the lead agency for the production of the Environmental Assessment (EA) and for submission of permit applications.
- USACE NAO is a cooperating agency in that process and would provide input and reviews during that process.

2.3.2 Functional and Technical Requirements

- Project orientation relative to environmentally sensitive areas on or adjacent to the site.
- Sound and vibration control.

2.3.3 Design Objectives and Provisions

- Functional relationship of the project to the environment.

2.3.4 Calculations

- Include the full environmental data report as an Appendix to the BOD.

2.3.5 Coordination with Installation, Centers of Expertise, or Outside Agencies

- Validation (check) of the approved siting relative to the designated areas of the installation for preservation and pollution protection requirements.
- Federal, state, territorial, and local governmental approvals as required for wetlands and other environmental protection laws.

2.4 HYDRAULIC AND HYDROLOGY (COASTAL)

2.4.1 General Parameters

Reference the previous 2018 design report, "Breakwater(s) Design & Analysis Report Version 2" that is the basis for design for the breakwaters. That methodology was used to design the breakwater.

Updates since the 2019 breakwater design include larger stone, higher crest elevation, and an added rear toe for stability.

Reference the Draft ERDC report, ERDC/TR/SR/CHL-21-?? Mon 2025 "Beach Erosion Mitigation and Breakwater Design at Wallops Island, Virginia", that explains the latest modeling performed to support updated the design parameters (hazard curves, wave heights, wave periods, and shoreline response).

2.4.2 Functional and Technical Requirements

The Coastal Engineering Manual (CEM) Engineer Manual EM 1110-2-1100 Part VI, Chapter 3 for Rubble-Mound Structure Loading and Response was referenced for the design of the breakwaters.

The 2019 breakwater design methodology was used for this design as well. That report should be referenced, Breakwater(s) Design & Analysis Report_Version 3. The Hudson equation was not used for the stone sizing of the breakwaters.

Revised frequency water levels and wave heights were calculated by ERDC. A storm suite was reduced, and C-Storm software was used to apply those storms therefore generating refined wave height statistics and frequency stillwater elevations.

The tables below are the statistics for the Priority areas for the Breakwater locations –

76+00 priority 1	AEF (1/year)	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002
	ARI (year)	2	5	10	20	50	100	200	500
	Max SWL (m) 50% CL	2.66	3.54	3.83	3.98	4.12	4.17	4.26	4.27
	Max SWL (m) 16% CL	2.36	3.22	3.52	3.66	3.81	3.86	3.94	3.95
	Max SWL (m) 84% CL	2.97	3.85	4.15	4.29	4.44	4.49	4.58	4.59
	Hm0 (m) 50% CL	2.40	2.92	3.10	3.21	3.31	3.36	3.44	3.45
	Hm0 (m) 16% CL	2.14	2.66	2.83	2.94	3.04	3.09	3.17	3.18
	Hm0 (m) 84% CL	2.66	3.19	3.36	3.48	3.58	3.63	3.71	3.72
	Tm (s) 50% CL	6.52	7.87	8.30	8.64	8.93	9.21	9.38	9.58
	Tm (s) 16% CL	5.88	7.10	7.49	7.80	8.06	8.31	8.46	8.64
	Tm (s) 84% CL	7.16	8.63	9.11	9.49	9.81	10.11	10.30	10.51

Priority Area 1 (units are in meters) – for the location of a breakwater

69+00 priority 3	AEF (1/year)	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002
	ARI (year)	2	5	10	20	50	100	200	500
	Max SWL (m) 50% CL	2.85	3.36	3.49	3.58	3.71	3.72	3.81	3.81
	Max SWL (m) 16% CL	2.54	3.04	3.17	3.27	3.40	3.41	3.49	3.49
	Max SWL (m) 84% CL	3.16	3.67	3.80	3.90	4.02	4.03	4.12	4.12
	Hm0 (m) 50% CL	2.32	2.87	3.05	3.17	3.28	3.33	3.40	3.41
	Hm0 (m) 16% CL	2.06	2.60	2.79	2.90	3.01	3.06	3.13	3.14
	Hm0 (m) 84% CL	2.57	3.13	3.32	3.44	3.55	3.60	3.67	3.68
	Tm (s) 50% CL	6.52	7.87	8.28	8.62	8.89	9.18	9.34	9.54
	Tm (s) 16% CL	5.89	7.10	7.47	7.78	8.03	8.28	8.43	8.61
	Tm (s) 84% CL	7.16	8.64	9.09	9.46	9.76	10.07	10.25	10.48

Priority Area 3 (units are in meters) – for the location of a breakwater

2.4.3 Design Objectives and Provisions

Design objective is stabilizing the shoreline for the Priority areas identified through the use of Breakwaters.

Several scenarios were modeled in GenCade by the ERDC team. The scenarios had combinations of either 1, 2, or 3 breakwaters at each Priority area. The ERDC report for their analysis will be provided as an attachment to this design analysis.

2.4.4 Calculations

From the ERDC/CHL Oct 2010 TR-11-9 report, "Storm Damage Reduction Project Design for Wallops Island, Virginia", the beach design supports a wave height 7 feet. Using the latest Coastal Calculator supplied by ERDC, the breakwaters were designed to permit waves less than or equal to at least 7 feet in height. That parameter is

Wave Transmission past revetment / seawall
Wave height behind breakwater at desired CL, *Hm0*

on the calculator sheet.

Several frequencies (5,10,20, and 100) were analyzed, but the 10-year calculations are listed below.

Screenshots of the calculations performed at station 69 + 00 are below for the 10- year hazard:

User Input: green cells are for user inputs, orange cells are secondary calculations, yellow cells are design outputs. Design parameters are inputted on rows 4-7. The only design criteria used in the calculations are the confidence level and the stone stability number - the rest are for reference. Starting at line 9, columns B-D are for offshore breakwater responses. The offshore breakwater is parameterized in rows 9-29. Wave transmission past the breakwater is computed on lines 31-51, and the waves and water leves for the desired return interval are inputted in cells D32-D34 **at the 50% confidence level**. Waves and water level hazards are found on the HazardCurve sheet for each transect modeled in Couwave. Wave transmission, runup, and overtopping are computed, and wave transmission is used as input for the seawall analysis. Breakwater stone sizing is computed in rows 54-89, and waves and water levels at the desired return interval are inputted in cells D55-D57 **at the 50% confidence level**. Seaward and leeward nominal 50% diameter stone sizes are computed, as well as median stone weight, armor thickness, and underlayer metrics. Starting at line 9, columns F-H are for the seawall responses. Seawall parameters are in lines 9-29. Wave transmission, runup, and overtopping for the seawall are on lines 31-48. Uncertainties are applied to the waves, water levels, and emperical equation coefficents using the z-score from a normal distribution, and the uncertanities are in M28-M44 with corresponding references. The validity range for each equation is below the uncertainty section.

Design criteria	
Confidence Level (%)	0.5
Goal *Ht*	0.35
Stone stability, S	4

Design Criteria
100- and 200- year ARI
wave transmission coeff = 0.1

			EN units
Structure Parameters - Offshore Breakwater			
Offshore bathymetry slope (cotα)	[]	0.01	
Seaside toe elevation of offshore breakwaters	m NAVD	-1.8	-6.00
Structure Seaside Slope of offshore breakwater (cotα)	[]	2.0	
Crest elevation of offshore breakwater	m NAVD	2.1	6.99
Crest Width of offshore breakwater, B	m	4.3	14.11
Structure Leeside slope of offshore breakwater (cotα)	[]	2.0	
Leeside toe elevation of offshore breakwater	m NAVD	-1.8	-6.00
Berm influence factor, γ_b	[]	1.0	
Wave obliquity influence factor, γ_β	[]	1.0	
Friction influence factor, γ_f	[]	0.55	
Specific Weight of Water, γw	kg/m^3	1043	1025.00
Specific Weight of Stone, γr	kg/m^3	2647	2706.00
Structure permeability, P	[]	0.4	
Zero damage level (Melby and Hughes), S	[]	4	
Number of waves in a storm, Nz	[]	7000	5000.00
Armor stability coefficient, Kd	[]	10	10.00
Fraction of underlayer weight, Kw	[]	0.1	
Roughness influence coefficient on crest for leeside stabilit	[]	0.6	0.50
Seaside slope with uncertainty (cotα)	[]	2.0	
Leeside slope with uncertainty (cotα)	[]	2.0	

Structure Parameters- Revetment / Seawall		
Gap between offshore breakwater to seaside toe of revetment	m	130
Seaside toe elevation of revetment	m NAVD	-0.9
Structure Seaside Slope of revetment (cotα)	[]	2.0
Crest elevation of revetment	m NAVD	3.9
Crest Width of rev	m	4.1
Structure Leeside slope of revetment (cotα)	[]	1.5
Leeside toe elevation of revetment	m NAVD	-0.9
Berm influence factor, γ_b	[]	1.0
Wave obliquity influence factor, γ_β	[]	1.0
Friction influence factor, γ_f	[]	0.55
Specific Weight of Water, γw	kg/m^3	1043
Specific Weight of Stone, γr	kg/m^3	2647
Structure permeability, P	[]	0.4
Zero damage level (Melby and Hughes), S	[]	4
Number of waves in a storm, Nz	[]	5000
Armor stability coefficient, Kd	[]	10
Fraction of underlayer weight, Kw	[]	0.1
Roughness influence coefficient on crest for leeside stability, $\gamma_{f,C}$	[]	0.5
Seaside slope with uncertainty (cotα)	[]	2.0
Leeside slope with uncertainty (cotα)	[]	1.5

Wave Transmission past offshore breakwater			
Wave height from HazardCurves sheet **at 50% CL**, *Hm* 0	m	3.05	4.17
Mean wave period from HazardCurves sheet **at 50% CL**, *Tm*	s	8.28	9.24
Storm Water Level from HazardCurves sheet **at 50% CL**, SWL	m, NAVD	3.49	4.06
Breaker ratio for breaker height, H_B/h_B	[]	0.6	
Hm 0 with uncertainty at prescribed CL	m	3.1	10.01
Spectral wave period *Tm-1,0* with uncertainty at prescribed	s	9.0	
SWL with uncertainty at prescribed CL	m, NAVD	3.5	11.45
Water depth, *h*	m	5.3	17.45
Spectral deepwater wavelength, L_0	m	127.4	417.94
Spectral wavelength at breakwater toe, *L*	m	114.5	375.74
Depth limited wave height at breakwater toe, *Hm* 0	m	3.1	10.01
Irribaran / Surf similarity parameter, ξ_{0}	[]	3.2	
Freeboard of breakwater	m	-1.4	-4.46
Ratio between freeboard and *Hm* 0	[]	-0.4	
Wave transmission coefficient, *Kt*	[]	0.64	
Transmitted wave height, *Ht*	m	1.95	6.40
Transmitted wave period, *Tt*	s	5.38	
Friction influence factor for surging wave, γfsurging	[]	0.62	
Runup elevation exceeded by 2% of waves plus SWL, *R* 2% +	m, NAVD	9.46	31.05
Total overflow and overtopping rate, *q*	m^3/s/m	4.18	

Wave Transmission past revetment / seawall			
Wave height behind breakwater at desired **CL**, *Hm* 0	m	2.0	**
Spectral wave period behind breakwater *Tm-1,0* with uncertainty at p	s	4.9	
Storm Water Level behind breakwater at desired **CL**, SWL	m, NAVD	3.5	
Breaker ratio for breaker height, H_B/h_B	[]	0.6	
Water depth, *h*	m	4.4	
Spectral deepwater wavelength, L_0	m	37.9	
Spectral wavelength at revetment toe, *L*	m	55.4	
Depth limited wave height at reetment toe, *Hm* 0	m	2.0	
Irribaran / Surf similarity parameter, ξ_{0}	[]	2.2	
Freeboard of revetment	m	0.4	
Ratio between freeboard and *Hm* 0	[]	0.2	
Wave transmission coefficient, *Kt*	[]	0.23	
Transmitted wave height, *Ht*	m	0.45	
Transmitted wave period, *Tt*	s	2.59	
Friction influence factor for surging wave, γfsurging	[]	0.6	
Runup height exceeded by 2% of waves plus SWL, *R* 2% + SWL	m, NAVD	6.74	
Total overflow and overtopping rate, *q*	m^3/s/m	#NUM!	

	kg/m^3 SI units	lb/cf English
Specific Wt of sea water is 65 pcf	1041.203	65
Specific Wt of stone is 165 pcf	2643.053	165
Specific gravity of stone is 2.64		
1 kg/m^3 is 0.062428 lbs per CF		
1 pcf is 16.0185 kg/m^3		
Line 21 has 2.64 x Specific Wt of sea water	2748.775	
Wave height used in 2019 design was 6 feet to 7 feet from the TR11	m	feet
**	2.0	6.3978141
	kg	lbs
weight	1247	2749.9031
	125	274.99031
	8398	18514.131
beach template is design to break a 7 foot wave per TR-11 report		
The beach is designed to break a 7 foot wave per TR-11 report.		

Stone Stability			
Wave height from HazardCurves sheet **at 50% CL**, *Hm* 0	m	3.05	10.01
Mean wave period from HazardCurves sheet **at 50% CL**, *Tm*	s	8.28	
Storm Water Level from HazardCurves sheet **at 50% CL**, SWL	m, NAVD	3.49	11.45
Breaker ratio for breaker height, H_B/h_B	[]	0.6	
Hm 0 with uncertainty at prescribed CL	m	3.1	10.01
Mean wave period *Tm* with uncertainty at prescribed CL	s	8.3	
Spectral wave period *Tm-1,0* with uncertainty at prescribed	s	8.9	
SWL with uncertainty at prescribed CL	m, NAVD	3.5	11.45
Water depth, *h*	m	5.3	17.45
Depth limited wave height at structure toe, *Hm* 0	m	3.1	10.01
Spectral deepwater wavelength, L_0	m	124.7	408.96
Wavelength at structure toe based on mean period, L_m	m	57.1	187.47
Irribaran / Surf similarity parameter, ξ_{s0}		3.2	10.49
Freeboard	m	-1.360	-4.46
Wave steepness at structure toe, s_m	[]	0.05	
Critical wave steepness at structure toe, s_{mc}	[]	0.03	
Spectral deepwater wave steepness, s_o		0.0	
Seaside slope *(tan α)*	[]	0.5	
Momentum flux parameter $M_F/\rho g h^2$ =	[]	0.61	
Stone specific gravity, $S_r = \rho_r/\rho_w = \gamma_r/\gamma_w$	[]	2.54	
Stone density coefficient with uncertainty $\Delta = S_r - 1$	[]	1.54	
Median nominal stone size - emergent (Melby and Hughes	m	1.03	3.37
Median nominal stone size - initial LCBW (Melby), D_{n50} = (	m	0.78	2.55
Median nominal stone size - constrained stability LCBW (M	m	1.32	4.34
Median nominal stone size - LCBW (Melby), $D_{n50} = (V_{50})^{1/}$	m	0.78	2.55
Final median nominal stone size, $D_{n50} = (V_{50})^{1/4}$	m	0.78	2.55
Median stone weight, W_{50}	kg	1247	
Armor layer thickness, t_a	m	1.56	5.11
Underlayer median stone size, $D_{u,n50}$	m	0.36	1.19
Underlayer median weight, $W_{u,50}$	kg	125	
Underlayer thickness, t_u	m	0.72	2.37
Runup height exceeded by 1% of waves, $z_{1\%}$	m	6.20	20.35
Maximum velocity exceeded by 1% of waves, $u_{1\%}$	m/s	12.83	
Median leeside nominal stone diameter, D_{n50}	m	1.47	4.82
Median leeside stone weight, W_{50}	kg	8398	

VDOT Type II D50=4.5 feet and W50 is 8000 lbs

4.820849813 ft

added a toe on leeward sie - different from the 2019 breakwater design

used the same stone size on the leeward side and the seaward side.

The 2019 Stone used was 5400 lbs = W50

The "OK" range for relative runup (R/H_s, or wave runup height divided by incident significant wave height) generally falls between **1.0 and 3.0**, heavily dependent on slope structure, surface roughness, and breaking conditions. Smooth, steep slopes (non-breaking) show higher relative runup ($R/H_s > 2.0$), while rough, porous armor units significantly reduce it, often keeping values below 1.0–1.5. apps.dtic.mil +1

For low-crested breakwaters (LCB), the stability parameter $H_{m0}/\Delta D_{n50}$ (often denoted as N_s or N_{s*}) varies depending on the freeboard, damage level, and whether the structure is submerged.

- **Typical Stability Range ($N_s = H_{m0}/\Delta D_{n50}$):** Generally ranges between **1.5 and 5.0** for typical design conditions.
- **Submerged Stability ($h_c/h > 0$):** Submerged breakwaters often show higher stability compared to conventional breakwaters. Stability numbers in tests often range from **1.5 to 3.0**, with damage levels (S) varying between 2 and 8.
- **Low-Crested (near sea level) Stability:** When the crest is at or near the still water level (SWL), stability is often described by a modified parameter (N_{s*}), with $H_{m0}/\Delta D_{n50}$ frequently falling in the range of **2.0 to 3.0** for lower damage.
- **Damage Progression:** Submerged structures can withstand higher waves, with $H_{m0}/\Delta D_{n50}$ values sometimes exceeding 3.5 to 5, depending on the severity of allowable damage. Texas Digital Library +4

Uncertainties and equation coefficients				
	Parameter	Coefficients	Standard Deviation	Reference
Structure	Slope	User input	0.1	CEM
	Delta	User input	0.06	CEM
Forcing Conditions	SWL	From HazardCurve	0.13	NACCS
	Hm 0	From HazardCurve	0.13	NACCS
	Tp	From HazardCurve	0.06	NACCS
Runup	Equation coeff	1.65	0.1	EurOtop
	Equation coeff	1	0.07	EurOtop
Overtopping	Equation coeff	0.09	0.0135	EurOtop
	Equation coeff	1.5	0.15	EurOtop
Seaside stability	Equation coeff, Km	5	0.3	Melby and Hughes
	Equation coeff, Km	5	0.4	Melby and Hughes
Seaside stability (low crested)	Equation coeff, a	0.6		Melby (personal comm)
	Equation coeff, b	1.5		Melby (personal comm)
Leeside Stability	c_0 =	1.45		
	c_1 =	5.1		
	$c_2 = 0.25\, c_1^2/c_{0-}$	4.48		
	$p = 0.5\, c_1/c_{0-}$	1.76		

Validity Check	Equation	Calculated value	OK range
Kt	Wave transmissio	0.6	0.075 to 0.8
Rc/Hm0	Leeside	0.0	0.3 to 6
Normalized crest width	Leeside	1.4	1.3 to 1.6
Stability number	Leeside	4.0	0.5 to 4.5
Relative runup	Leeside	1.3	1 to 3
Hm0/Dn50	LCBW	3.9	1 to 6*
Normalized crest width	LCBW	5.5	3.0 to 7.6
Normalized freeboard	LCBW	-1.7	-3.0 to 2.4
Normalized freeboard	Melby	-1.3	>1

*CEM low crested submerged page VI-5-53

The wave transmission coefficient (K_t), defined as the ratio of transmitted wave height (H_t) to incident wave height (H_i), typically indicates effective wave attenuation when $K_t < 1$. For low-crested and submerged breakwaters, which are commonly designed to allow some transmission, the acceptable "OK" range for efficient coastal protection generally falls within: ResearchGate +3

- **Optimal Performance Range: 0.3 to 0.7**.
- **Design Range: 0.1 to 0.8** (often used for rubble-mound breakwaters). ResearchGate +1

Key Considerations for K_t Ranges:

- **Low Submergence:** If the structure is nearly at the surface (R_c/d is low), K_t is typically between **0.4 and 0.7**.
- **High Submergence:** If the breakwater is deeply submerged, K_t will be closer to **0.7–0.8**, indicating lower performance.
- **3D Effects:** In some cases, such as 3D physical models or specific gap configurations, K_t values can exceed 1.0 (indicating wave height increase behind the structure) due to diffraction around the ends of the structure, even if 2D calculations show lower values.
- **Efficiency:** A lower K_t is generally preferred, but a K_t near 0.5 is often deemed an effective balance between protection and cost for submerged structures. SciSpace +2

The range $0.075 \leq K_t \leq 0.8$ is often used for validating empirical formulas for wave transmission over breakwaters. Ancient Coastal Settlements, Ports and H...

The normalized freeboard (R_c/H_i or $R_c/H_{s,i}$), defined as the ratio of the crest freeboard (R_c) to the incident wave height (H_i), typically ranges between **-1.0 and 1.0** for low-crested breakwaters (LCBs), with submerged scenarios extending to roughly **-2.0**. Coastal Wiki +2

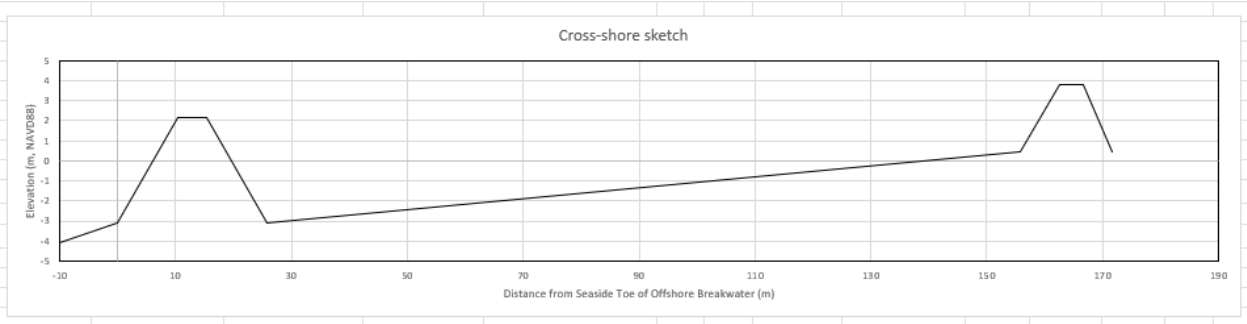
A common range in hydraulic studies and design scenarios is:

- **Submerged (Negative Freeboard):** $R_c/H_{s,i}$ often ranges from **-1.5 to 0**.
- **Emerged (Low-Crested):** $R_c/H_{s,i}$ often ranges from **0 to 1.0**.
- **Overall LCBs:** Research indicates a broad testing range of **$-1.5 < R_c/H_i < 1.0$** to analyze both wave transmission and stability. ScienceDirect.com +3

Key Aspects of Normalized Freeboard:

- **R_c (Freeboard):** The vertical distance between the still water level (SWL) and the crest of the structure. It is negative if the structure is submerged.
- **Wave Transmission (K_t):** As the normalized freeboard ($R_c/H_{s,i}$) increases, the wave transmission coefficient (K_t) decreases.
- **Design Utility:** The relative crest height (R_c/H_i) is critical for evaluating wave overtopping and energy dissipation. Coastal Wiki +4

Screenshots of the calculations performed at station 76 + 00 are below for the 10- year hazard:



Structure Parameters - Offshore Breakwater		
Offshore bathymetry slope (cotα)	[]	0.01
Seaside toe elevation of offshore breakwaters	m NAVD	-3.1
Structure Seaside Slope of offshore breakwater (cotα)	[]	2.0
Crest elevation of offshore breakwater	m NAVD	2.1
Crest Width of offshore breakwater, B	m	4.3
Structure Leeside slope of offshore breakwater (cotα)	[]	2.0
Leeside toe elevation of offshore breakwater	m NAVD	-3.1
Berm influence factor, γ_b	[]	1.0
Wave obliquity influence factor, γ_β	[]	1.0
Friction influence factor, γ_f	[]	0.55
Specific Weight of Water, γw	kg/m^3	1043
Specific Weight of Stone, γr	kg/m^3	2647
Structure permeability, P	[]	0.4
Zero damage level (Melby and Hughes), S	[]	4
Number of waves in a storm, Nz	[]	7000
Armor stability coefficient, Kd	[]	10
Fraction of underlayer weight, Kw	[]	0.1
Roughness influence coefficient on crest for leeside stability, $\gamma_{f\text{-}C}$	[]	0.6
Seaside slope with uncertainty (cotα)	[]	2.0
Leeside slope with uncertainty (cotα)	[]	2.0

Structure Parameters- Revetment / Seawall		
Gap between offshore breakwater to seaside toe of revetment	m	130
Seaside toe elevation of revetment	m NAVD	-0.9
Structure Seaside Slope of revetment (cotα)	[]	2.0
Crest elevation of revetment	m NAVD	3.9
Crest Width of revetment, B	m	4.1
Structure Leeside slope of revetment (cotα)	[]	1.5
Leeside toe elevation of revetment	m NAVD	-0.9
Berm influence factor, γ_b	[]	1.0
Wave obliquity influence factor, γ_β	[]	1.0
Friction influence factor, γ_f	[]	0.55
Specific Weight of Water, γw	kg/m^3	1041
Specific Weight of Stone, γr	kg/m^3	2748
Structure permeability, P	[]	0.4
Zero damage level (Melby and Hughes), S	[]	4
Number of waves in a storm, Nz	[]	5000
Armor stability coefficient, Kd	[]	10
Fraction of underlayer weight, Kw	[]	0.1
Roughness influence coefficient on crest for leeside stability, $\gamma_{f\text{-}C}$	[]	0.5
Seaside slope with uncertainty (cotα)	[]	2.0
Leeside slope with uncertainty (cotα)	[]	1.5

Wave Transmission past offshore breakwater		
Wave height from HazardCurves sheet **at 50% CL**, *Hm0*	m	3.10
Mean wave period from HazardCurves sheet **at 50% CL**, *Tm*	s	8.30
Storm Water Level from HazardCurves sheet **at 50% CL**, SWL	m, NAVD	3.83
Breaker ratio for breaker height, H_B/h_B	[]	0.6
Hm0 with uncertainty at prescribed CL	m	3.1
Spectral wave period *Tm-1,0* with uncertainty at prescribed CL	s	9.1
SWL with uncertainty at prescribed CL	m, NAVD	3.8
Water depth, *h*	m	6.9
Spectral deepwater wavelength, L_0	m	128.0
Spectral wavelength at breakwater toe, *L*	m	114.5
Depth limited wave height at breakwater toe, *Hm0*	m	3.1
Irribaran / Surf similarity parameter, ξ_0	[]	3.2
Freeboard of breakwater	m	-1.7
Ratio between freeboard and *Hm0*	[]	-0.6
Wave transmission coefficient, *Kt*	[]	0.69
Transmitted wave height, *Ht*	m	2.13
Transmitted wave period, *Tt*	s	5.61
Friction influence factor for surging wave, γfsurging	[]	0.62
Runup elevation exceeded by 2% of waves plus SWL, *R2%+SWL*	m, NAVD	9.92
Total overflow and overtopping rate, *q*	m^3/s/m	5.39

Wave Transmission past revetment / seawall		
Wave height behind breakwater at desired **CL**, *Hm0*	m	2.1
Spectral wave period behind breakwater *Tm-1,0* with uncertainty at	s	5.1
Storm Water Level behind breakwater at desired **CL**, SWL	m, NAVD	3.8
Breaker ratio for breaker height, H_B/h_B	[]	0.6
Water depth, *h*	m	4.7
Spectral deepwater wavelength, L_0	m	41.3
Spectral wavelength at revetment toe, *L*	m	55.4
Depth limited wave height at reetment toe, *Hm0*	m	2.1
Irribaran / Surf similarity parameter, ξ_0	[]	2.2
Freeboard of revetment	m	0.1
Ratio between freeboard and *Hm0*	[]	0.0
Wave transmission coefficient, *Kt*	[]	0.33
Transmitted wave height, *Ht*	m	0.70
Transmitted wave period, *Tt*	s	3.22
Friction influence factor for surging wave, γfsurging	[]	0.6
Runup height exceeded by 2% of waves plus SWL, *R2%+SWL*	m, NAVD	7.44
Total overflow and overtopping rate, *q*	m^3/s/m	#NUM!

Stone Stability		
Wave height from HazardCurves sheet **at 50% CL**, *Hm* 0	m	3.10
Mean wave period from HazardCurves sheet **at 50% CL**, *Tm*	s	8.30
Storm Water Level from HazardCurves sheet **at 50% CL**, SWL	m, NAVD	3.83
Breaker ratio for breaker height, H_B/h_B	[]	0.6
Hm 0 with uncertainty at prescribed CL	m	3.1
Mean wave period *Tm* with uncertainty at prescribed CL	s	8.3
Spectral wave period *Tm-1,0* with uncertainty at prescribed CL	s	9.0
SWL with uncertainty at prescribed CL	m, NAVD	3.8
Water depth, *h*	m	6.9
Depth limited wave height at structure toe, *Hm* 0	m	3.1
Spectral deepwater wavelength, L_0	m	125.3
Wavelength at structure toe based on mean period, L_m	m	64.3
Irribaran / Surf similarity parameter, ξ_{0}		3.2
Freeboard	m	-1.730
Wave steepness at structure toe, s_m	[]	0.05
Critical wave steepness at structure toe, s_{mc}	[]	0.03
Spectral deepwater wave steepness, s_o		0.0
Seaside slope *(tan α)*	[]	0.5
Momentum flux parameter $M_F/\rho g h^2$ =	[]	0.39
Stone specific gravity, $S_r = \rho_r/\rho_w = \gamma_r/\gamma_w$	[]	2.54
Stone density coefficient with uncertainty $\Delta = S_r - 1$	[]	1.54
Median nominal stone size - emergent (Melby and Hughes), $D_{n50} = (V_{50})^{1/3}$	m	1.07
Median nominal stone size - initial LCBW (Melby), $D_{n50} = (V_{50})^{1/3}$	m	0.65
Median nominal stone size - constrained stability LCBW (Melby), $D_{n50} = (V_{50})^{1/3}$	m	1.34
Median nominal stone size - LCBW (Melby), $D_{n50} = (V_{50})^{1/3}$	m	0.65
Final median nominal stone size, $D_{n50} = (V_{50})^{1/4}$	m	0.65
Median stone weight, W_{50}	kg	733
Armor layer thickness, t_a	m	1.30
Underlayer median stone size, $D_{u,n50}$	m	0.30
Underlayer median weight, $W_{u,50}$	kg	73
Underlayer thickness, t_u	m	0.61
Runup height exceeded by 1% of waves, $z_{1\%}$	m	6.29
Maximum velocity exceeded by 1% of waves, $u_{1\%}$	m/s	13.24
Median leeside nominal stone diameter, D_{n50}	m	1.55
Median leeside stone weight, W_{50}	kg	9800

	kg/m^3 SI units	lb/cf English
Specific Wt of sea water is 65 pcf	1041.203	65
Specific Wt of stone is 165 pcf	2643.053	165
Specific gravity of stone is 2.64		
1 kg/m^3 is 0.062428 lbs per CF		
1 pcf is 16.0185 kg/m^3		
Line 21 has 2.64 x Specific Wt of sea water	2748.775	
Wave height used in 2019 design was 6 feet to 7 feet from the TR11	m	feet
p 73		
**	2.1	6.971878442
	kg	lbs
weight	733	1616.322872
	73	161.6322872
	9800	21604.98311
beach template is design to break a 7 foot wave per TR-11 report		

Uncertainties and equation coefficients				
	Parameter	Coefficients	Standard Deviation	Reference
Structure	Slope	User input	0.1	CEM
	Delta	User input	0.06	CEM
Forcing Conditions	SWL	From HazardCurves	0.13	NACCS
	Hm 0	From HazardCurves	0.13	NACCS
	Tp	From HazardCurves	0.06	NACCS
Runup	Equation coeff	1.65	0.1	EurOtop
	Equation coeff	1	0.07	EurOtop
Overtopping	Equation coeff	0.09	0.0135	EurOtop
	Equation coeff	1.5	0.15	EurOtop
Seaside stability	Equation coeff, Km1	5	0.3	Melby and Hughes
	Equation coeff, Km2	5	0.4	Melby and Hughes
Seaside stability (low crested)	Equation coeff, a	0.6		Melby (personal comm)
	Equation coeff, b	1.5		Melby (personal comm)
Leeside Stability	c_0 =	1.45		
	c_1 =	5.1		
	$c_2 = 0.25\, c_1^2/c_0$ =	4.48		
	$p = 0.5\, c_1/c_0$ =	1.76		

Validity Check	Equation	Calculated value	OK range
Kt	Wave transmission	0.7	0.075 to 0.8
Rc/Hm0	Leeside	0.0	0.3 to 6
Normalized crest width	Leeside	1.4	1.3 to 1.6
Stability number	Leeside	4.2	0.5 to 4.5
Relative runup	Leeside	1.3	1 to 3
Hm0/Dn50	LCBW	4.8	1 to 6*
Normalized crest width	LCBW	6.6	3.0 to 7.6
Normalized freeboard	LCBW	-2.7	-3.0 to 2.4
Normalized freeboard	Melby	-1.6	>1

*CEM low crested submerged page VI-5-53 also, see below image

The "OK" range for relative runup (R/H_s, or wave runup height divided by incident significant wave height) generally falls between **1.0 and 3.0**, heavily dependent on slope structure, surface roughness, and breaking conditions. Smooth, steep slopes (non-breaking) show higher relative runup ($R/H_s > 2.0$), while rough, porous armor units significantly reduce it, often keeping values below 1.0–1.5. apps.dtic.mil +1

For low-crested breakwaters (LCB), the stability parameter $H_{m0}/\Delta D_{n50}$ (often denoted as N_s or N_{s*}) varies depending on the freeboard, damage level, and whether the structure is submerged.

- **Typical Stability Range ($N_s = H_{m0}/\Delta D_{n50}$):** Generally ranges between **1.5 and 5.0** for typical design conditions.
- **Submerged Stability ($h_c/h > 0$):** Submerged breakwaters often show higher stability compared to conventional breakwaters. Stability numbers in tests often range from **1.5 to 3.0**, with damage levels (S) varying between 2 and 8.
- **Low-Crested (near sea level) Stability:** When the crest is at or near the still water level (SWL), stability is often described by a modified parameter (N_{s*}), with $H_{m0}/\Delta D_{n50}$ frequently falling in the range of **2.0 to 3.0** for lower damage.
- **Damage Progression:** Submerged structures can withstand higher waves, with $H_{m0}/\Delta D_{n50}$ values sometimes exceeding 3.5 to 5, depending on the severity of allowable damage. Texas Digital Library +4

The wave transmission coefficient (K_t), defined as the ratio of transmitted wave height (H_t) to incident wave height (H_i), typically indicates effective wave attenuation when $K_t < 1$. For low-crested and submerged breakwaters, which are commonly designed to allow some transmission, the acceptable "OK" range for efficient coastal protection generally falls within: ResearchGate +3

- **Optimal Performance Range: 0.3 to 0.7**.
- **Design Range: 0.1 to 0.8** (often used for rubble-mound breakwaters). ResearchGate +1

Key Considerations for K_t Ranges:

- **Low Submergence:** If the structure is nearly at the surface (R_c/d is low), K_t is typically between **0.4 and 0.7**.
- **High Submergence:** If the breakwater is deeply submerged, K_t will be closer to **0.7–0.8**, indicating lower performance.
- **3D Effects:** In some cases, such as 3D physical models or specific gap configurations, K_t values can exceed 1.0 (indicating wave height increase behind the structure) due to diffraction around the ends of the structure, even if 2D calculations show lower values.
- **Efficiency:** A lower K_t is generally preferred, but a K_t near 0.5 is often deemed an effective balance between protection and cost for submerged structures. SciSpace +2

The range $0.075 \leq K_t \leq 0.8$ is often used for validating empirical formulas for wave transmission over breakwaters. Ancient Coastal Settlements, Ports and H...

The normalized freeboard (R_c/H_i or $R_c/H_{s,i}$), defined as the ratio of the crest freeboard (R_c) to the incident wave height (H_i), typically ranges between **-1.0 and 1.0** for low-crested breakwaters (LCBs), with submerged scenarios extending to roughly **-2.0**. Coastal Wiki +2

A common range in hydraulic studies and design scenarios is:

- **Submerged (Negative Freeboard):** $R_c/H_{s,i}$ often ranges from **-1.5 to 0**.
- **Emerged (Low-Crested):** $R_c/H_{s,i}$ often ranges from **0 to 1.0**.
- **Overall LCBs:** Research indicates a broad testing range of **$-1.5 < R_c/H_i < 1.0$** to analyze both wave transmission and stability. ScienceDirect.com +3

Key Aspects of Normalized Freeboard:

- **R_c (Freeboard):** The vertical distance between the still water level (SWL) and the crest of the structure. It is negative if the structure is submerged.
- **Wave Transmission (K_t):** As the normalized freeboard ($R_c/H_{s,i}$) increases, the wave transmission coefficient (K_t) decreases.
- **Design Utility:** The relative crest height (R_c/H_i) is critical for evaluating wave overtopping and energy dissipation. Coastal Wiki +4

Trunk section stability.

K_D-values by *Shore Protection Manual*, H = $H_{1/10}$, 0% to 5% damage

Placement	Layers	Breaking waves[1]	Nonbreaking waves[2]	Slope angle cot α
Random	2	9.0	10.0	1.5 - 3.0
Pattern-placed	1	12.0	15.0	(not given)

[1] Depth-limited breaking with waves breaking in front of and on the armor slope.
[2] No depth-limited breaking occurs in front of the armor slope.

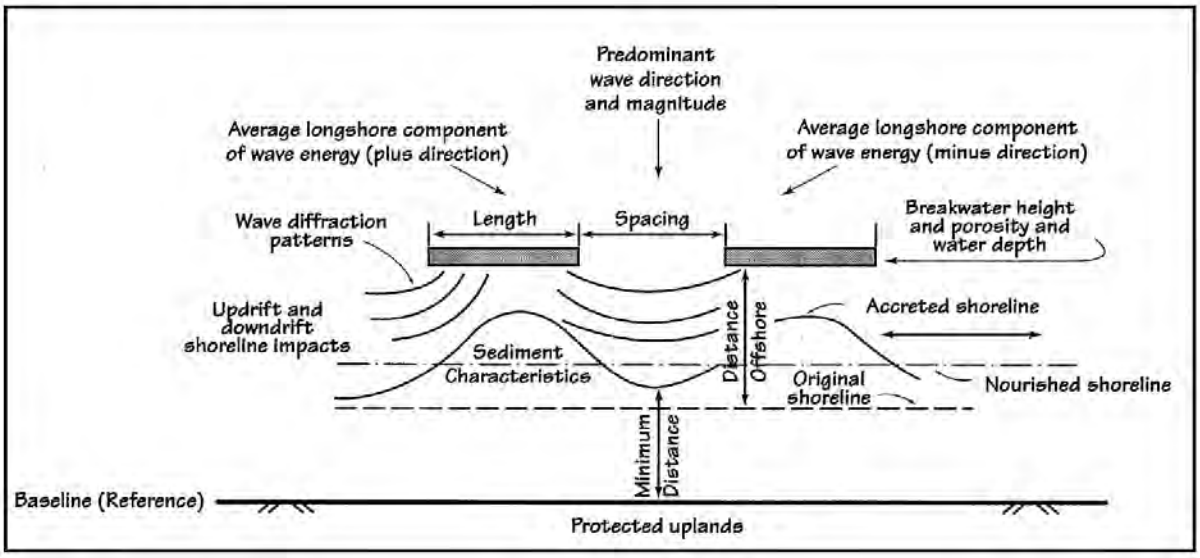
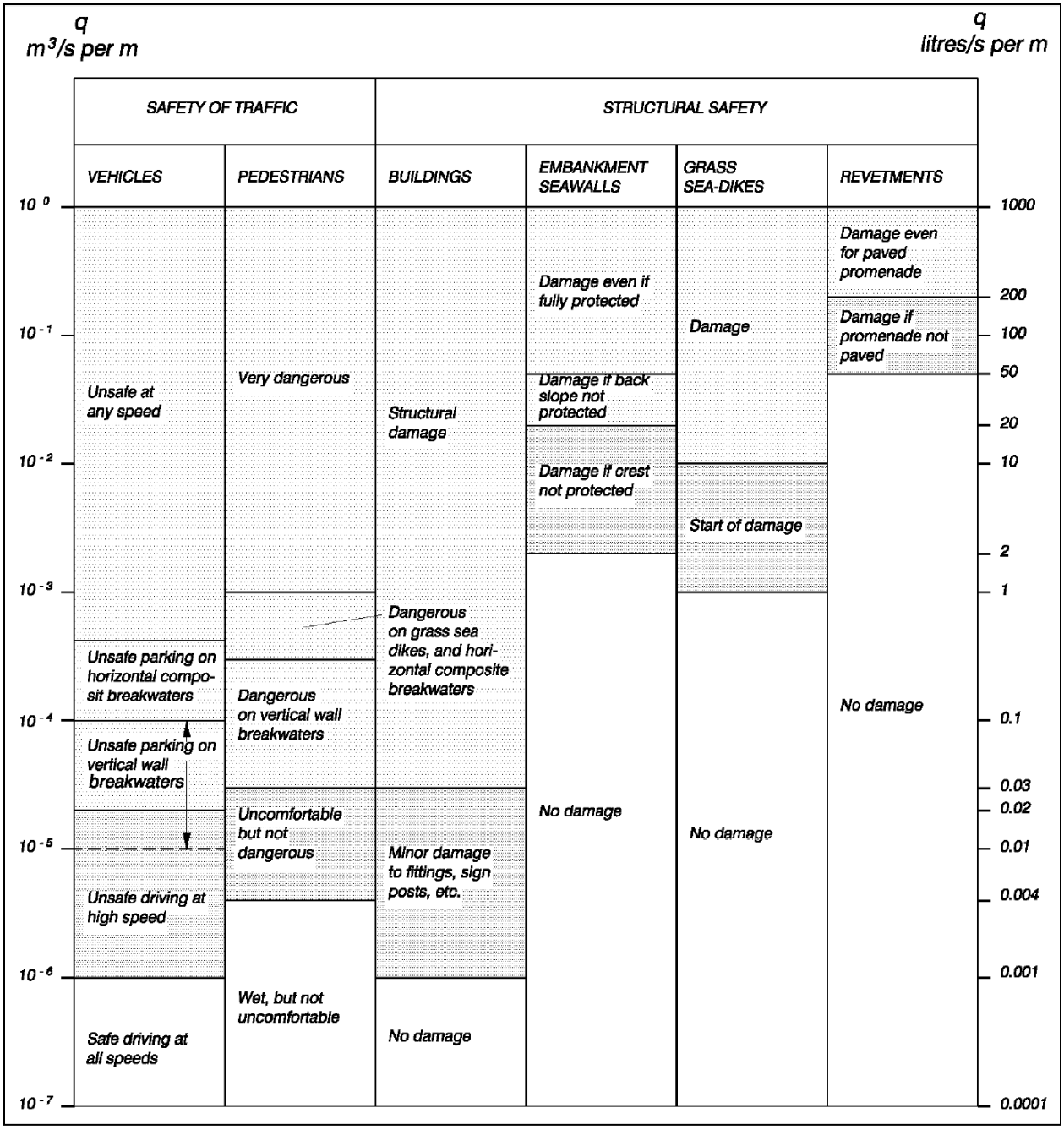


Figure V-3-20. Definition schematic for nearshore breakwaters

(9) Underlayers.

(a) The first underlayer directly beneath the primary armor units (see Figures VI-5-54 and VI-5-55) should have a minimum thickness of two quarrystones ($n = 2$). The first underlayer stones should weigh about one-tenth of the weight of the overlying armor units ($W/10$) if the cover layer and first underlayer are both quarrystone, or the first underlayer is quarrystone and the cover layer is concrete armor units with a stability coefficient of K_D □ 12 (see Tables VI-5-29, VI-5-33, VI-5-34, VI-5-36). When the cover layer armor unit $K_D > 12$ (dolosse, Core-Loc, and uniformly-placed tribars) the first underlayer quarrystone weight should be about one-fifth the weight of the overlying unit ($W/5$). The larger size promotes increased interlocking between the first underlayer and the concrete armor units of the primary cover layer. Hydraulic model tests (Carver and Davidson 1977; Carver 1980) indicate for quarrystone armor units and dolosse on a breakwater trunk exposed to nonbreaking waves that the underlayer stone size could range from $W/5$ to $W/20$ with little effect on armor stability, wave runup or rundown. If the underlayer stone proposed for a given structure is available with a gradation in the range of $W/5$ to $W/20$, the structure should be model tested with that underlayer gradation to determine if this economical material will support a stable primary cover layer of planned armor units when exposed to the site design conditions.

(b) The second underlayer beneath the primary cover layer and upper secondary cover layer (above -2.0 H) should have a minimum equivalent thickness of two quarrystones and a weight about 1/20 the weight of the stones in the first underlayer. In terms of primary armor unit



Scour calculations below follow the CEM, EQN VI-5-264:

breakwater head and trunk. Fredsøe and Sumer presented the following empirical equation for maximum scour depth (S_m) due to plunging breaking waves

$$\frac{S_m}{H_s} = 0.01\, C_u \left(\frac{T_p \sqrt{g\, H_s}}{h} \right)^{3/2} \qquad \text{(VI-5-264)}$$

where C_u is an uncertainty factor with a mean value of unity and a standard deviation of σ_u = 0.34, h is water depth, and the other parameters are as defined previously.

- As noted by Fredsøe and Sumer, these equations were developed for impermeable, smooth breakwater heads. The permeability and roughness of rubble-mound breakwaters will effectively decrease both scour mechanisms, thus scour estimates may be somewhat conservative. The previous empirical expressions for predicting maximum scour depths are based on a limited number of data points derived primarily from laboratory experiments, and the equations should be considered tentative until additional studies are conducted. Also, scour is caused by waves only; superimposed currents are expected to increase appreciably maximum scour depth. Design of scour protection for sloping-front breakwater heads is discussed in Part VI-5-6*c*, "Design of scour protection."

(3) Scour at piles. The majority of methods for estimating scour at vertical piles were developed for piles with circular cross section, which are widely used in coastal and offshore engineering applications. However, there are estimation techniques for piles with noncircular cross sections and for specialized structures such as noncircular bridge piers and large bottom-resting structures. Scour at small vertical piles (pile diameter, D, is less than one-tenth of the incident wavelength) is caused by three simultaneously acting mechanisms: formation of a horseshoe-shaped vortex wrapped around the front of the pile; vortex shedding in the lee of the pile; and local flow accelerations due to streamline convergence around the pile. The pile does not significantly affect the incident wave. Large diameter piles, in which the diameter is greater than one-tenth of the incident wavelength, do have an impact on the incident waves which are reflected by the pile and diffracted around the pile. The key parameters governing scour formation appear to be current magnitude, orbital wave velocity, and pile diameter. Less important parameters are sediment size and pile shape (if the pile has noncircular cross section). For detailed descriptions of the physical mechanisms responsible for scour at vertical piles see Niedoroda and Dalton (1986) or some of the following references. A general, and somewhat conservative, rule-of-thumb is: Maximum depth of scour at a vertical pile is equal to twice the pile diameter. This rule-of-thumb appears to be valid for most cases of combined waves and currents. Smaller maximum scour depths are predicted by the equations in the following sections. Estimation formulas for maximum scour depth have been proposed for the cases of currents only, waves only, and combined waves and currents. The flow problem and associated sediment transport are beyond a complete theoretical formulation, and even numerical modeling attempts have not been able to describe fully the scour process at vertical piles (see Sumer and Fredsøe 1998a for a summary of numerical modeling approaches).

Station 76+00 EQN VI-5-264

from the calc sheet row 39

Scenario	g [m/s]	H_s [m]	T_p [s]	Y_i [m]	Cu [-]	Sm [m]	Sm [ft]
5yr	9.81	2.92	7.87	6.6	1	0.47	1.54
10 yr	9.81	3.1	8.3	6.9	1	0.53	1.74
20 yr	9.81	3.21	8.64	7.1	1	0.57	1.88
100 yr	9.81	3.36	9.21	7.3	1	0.66	2.15

Station 69+00 EQN VI-5-264

from the calc sheet row 39

Scenario	g [m/s]	H_s [m]	T_p [s]	Y_i [m]	Cu [-]	Sm [m]	Sm [ft]
5yr	9.81	2.87	7.87	4.5	1	0.81	2.66
10 yr	9.81	3.05	8.28	4.6	1	0.94	3.09
20 yr	9.81	3.17	8.62	4.7	1	1.04	3.40
100 yr	9.81	3.3	9.18	4.8	1	1.18	3.89

The specifications have included that the one foot thick marine mattress be extended at a minimum of 3 feet beyond the armor stone.

Recommendations –

1. Highly recommend a monitoring program be implemented for this project and that will monitor the shoreline response and sediment losses, which would determine the erosion rates of the project.
2. Highly recommend a regular beach nourishment interval be implemented for this project.

Lessons learned from the 2019 breakwater construction –

1. The breakwaters were intended to be constructed from the water. A submittal in 2019 revised that approach to have the contractor install sheetpile and then backfill with sand and possibly a gravel path for the crane to place stone from the landward side. Detail plans for this submittal have not been located.

2. Could the construction of the breakwaters have affected the non-tombolo condition?
3. Feedback from Industry Day for this project has indicated to the design team cost engineer to estimate an approach to build the breakwaters from the landward side. The feedback indicates that rough seas and shallow water may present challenges in constructing the breakwaters.
4. In 2019 the beach was nourished via truck loads from moving sand on the landward side in the north and to build the breakwaters first and then place the sand to the template. This was accomplished by one contractor.
5. It is planned to present two contracts for this 2026 design. One contractor will build the breakwaters, and one contractor will dredge sand to the beach. The proposed method to build the breakwaters will be a submittal for the design team to review. A challenge with this approach is the timing of the construction of the features and the coordination between the two contracts.

2.4.5 Coordination with Installation, Centers of Expertise, or Outside Agencies

2.5 COST AND ECONOMIC ANALYSIS

2.5.1 General Parameters

2.5.2 Functional and Technical Requirements

2.5.3 Design Objectives and Provisions

2.5.4 Calculations

2.5.5 Coordination with Installation, Centers of Expertise, or Outside Agencies

3 OPERATIONS AND MAINTENANCE PROVISIONS

Operation and Maintenance (O&M) is based on U.S. Army Corps of Engineers (USACE) regulations and best practices, particularly EM 1110-2-1100 (Coastal Engineering Manual), ER 1110-2-1150 (Engineering and Design for Coastal Projects), and other relevant USACE guidance.

3.1 PURPOSE

This Operation and Maintenance (O&M) Plan provides guidance for the post-construction care, inspection, and upkeep of the beach fill and breakwater system constructed under U.S. Army Corps of Engineers (USACE) standards. The objective is to ensure project integrity, functionality, and environmental compliance over its design life.

3.2 PROJECT COMPONENTS

3.2.1 Beach Fill

- Engineered beach with nourished sand profile
- Dune systems (natural or constructed)
- Vegetative stabilization measures (e.g., dune grasses)
- Shoreline structures (e.g., sand fencing, walkovers)

3.2.2 Breakwater Structures

- Rubble-mound offshore or nearshore breakwaters
- Toe protection and armor layers (primary and secondary armor stone)
- Crest and filter layers

3.3 OPERATION RESPONSIBILITIES

3.3.1 Project Owner/Operator

Typically, the local sponsor or non-federal partner is responsible for daily operations and non-structural maintenance.

3.3.2 USACE Role

Oversight, periodic inspections (especially for federally cost-shared projects), and support during major rehabilitation and renourishment cycles.

3.4 INSPECTION AND MONITORING

3.4.1 Inspection Frequency

- Monthly (visual inspections by site staff)
- Quarterly (formal documented inspection)
- Annually (joint USACE/local sponsor inspection)
- Post-Storm Events (Category 1+ hurricanes or extreme nor'easters)

3.4.2 Monitoring Activities

- Beach profile surveys (per EM 1110-2-1100 guidance)
- Aerial or drone surveys
- Sediment sampling and volumetric analysis
- Visual and sonar inspections of breakwaters

3.5 MAINTENANCE ACTIVITIES

3.5.1 Beach Fill

- Renourishment: Scheduled every 5–7 years or as needed based on sediment loss analysis
- Vegetation Maintenance: Reseeding and replanting dune vegetation annually or after storm damage
- Fencing/Access: Repair or replace sand fencing, boardwalks, and signage as needed
- Erosion Repair: Address scarping, blowouts, and other minor erosion promptly

3.5.2 Breakwaters

- Stone Replacement: Reposition or replace armor stones displaced by storm events

- Toe Reinforcement: Maintain toe scour protection using additional filter stone or bedding material
- Debris Removal: Eliminate driftwood, marine debris, or sediment build-up
- Structural Stability: Monitor for crest settlement, displacement, and filter layer exposure

3.6 ENVIRONMENTAL COMPLIANCE

- Maintain consistency with NEPA, ESA, and CWA permits
- Monitor and protect adjacent wetlands, nesting areas, and marine habitats
- Implement Best Management Practices (BMPs) during any repair or renourishment work
- Ensure sediment sources meet USACE compatibility requirements for grain size, color, and composition (see EM 1110-2-1100)

3.7 DOCUMENTATION AND REPORTING

- Inspection Reports: Maintain records of all inspections and corrective actions
- Maintenance Logs: Document all repair activities, sediment volumes, and costs
- Monitoring Reports: Submit regular beach profile and breakwater condition reports to the District USACE office
- Emergency Action Plans: Keep updated contact lists and response protocols for rapid post-storm assessment

3.8 HEALTH AND SAFETY

All O&M activities shall comply with USACE EM 385-1-1 (Safety and Health Requirements Manual), including fall protection for breakwater inspections and traffic/pedestrian control during beach work.

3.9 FUNDING AND COST SHARE

- Identify funding sources for routine maintenance and emergency repairs
- Ensure compliance with cost-sharing provisions outlined in the Project Partnership Agreement (PPA)
- Maintain a reserve budget for post-disaster recovery efforts

3.10 ADAPTIVE MANAGEMENT

This O&M Plan should be reviewed and updated every 5 years or after major storm events. Incorporate lessons learned and advances in monitoring technology to ensure resilience and cost-effectiveness.

APPENDIX

APPENDIX A

FIGURES AND MAPS

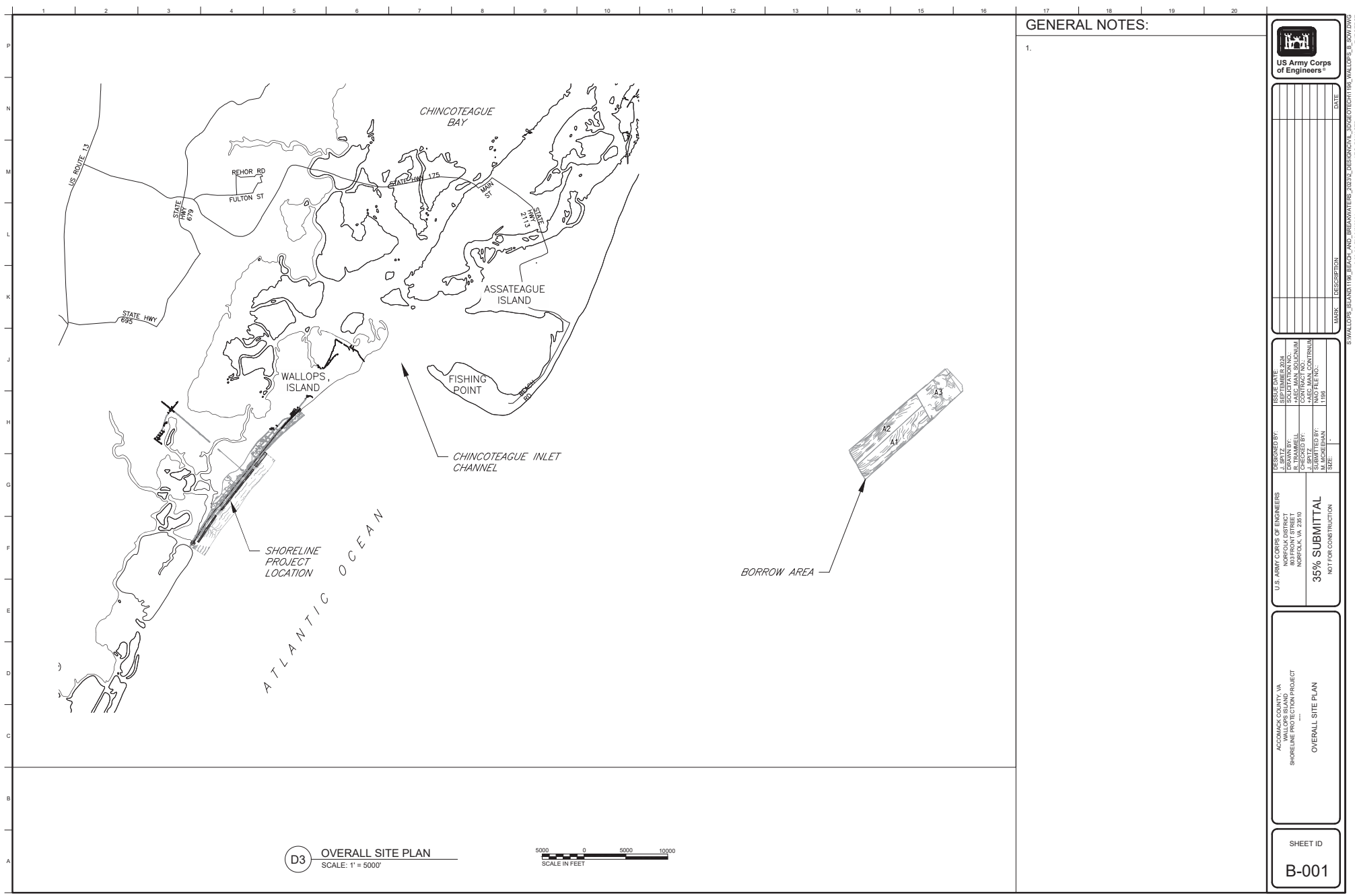


Figure 1. Overall Site Plan for NASA Wallops Flight Facility and Unnamed Shoal A Borrow Area



Figure 2. NASA Wallops Island Flight Facility three (3) Priority Areas with proposed breakwater locations.



Figure 4. Shoreline changes at Wallops Island from 1857 to mid-1980s. Shoreline data from NOAA and state of Virginia. NASA's facilities are located on narrow sand strip. Aerial photograph: 1994 Digital Ortho Quarter Quadrangle downloaded from Virginia Economic Development Partnership.

Figure 3. Excerpt from ERDC/CHL TR-06-21 showing the location of the Assawoman Inlet previously located near Priority Area 2.

APPENDIX B

GEOTECHNICAL CALCULATIONS

BEACH RENOURISHMENT

COMPATIBILITY ANALYSIS AND OVERFILL RATIO RESULTS

NASA Wallops Flight Facility Borrow Area Overfill Ratio Calculations and Compatibility Results Summary

Total cubic yards of proposed beach fill:	867,000 cubic yards

NASA Wallops Island Flight Facility Native Beach Grain Size					
Mean (Phi)	Median (Phi)	Std. Dev (Phi)	Mean (mm)	Median (mm)	Std Dev. (mm)
2.04	2.11	0.68	0.25	0.23	0.63

Crs Sand	Med Sand	Fines	Shell
% Pass #4	% Pass #10	% Pass #200	% Vis Shell
99.68	99.07	0.93	0

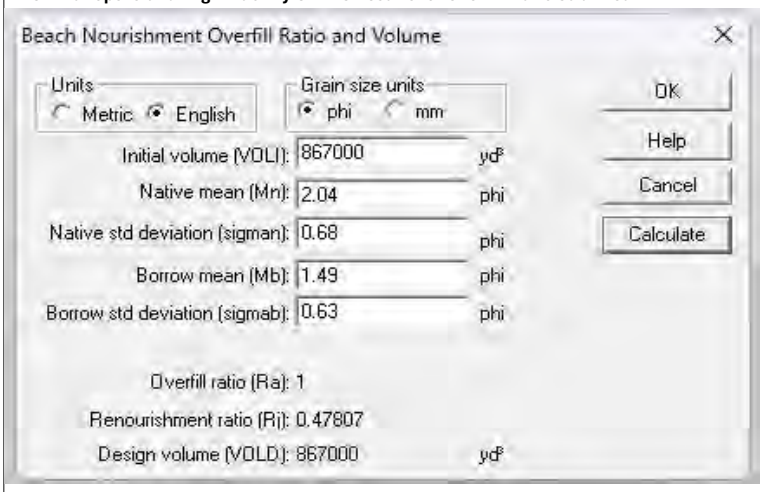
SUB-AREA A-1

Unnamed Shoal A, Sub-Area A-1 (CEDAS Input)					
Mean (Phi)	Median (Phi)	Std. Dev (Phi)	Mean (mm)	Median (mm)	Std Dev. (mm)
1.49	1.58	0.63	0.37	0.35	0.63

Crs Sand	Med Sand	Fines	Shell
% Pass #4	% Pass #10	% Pass #200	% Vis Shell
98.7	96.29	0.50	0

Vibracores: VC-1196-01, VC-1196-06, VC-1196-07, VC-1196-08, VC-1196-09, VC-1196-11A, VC-1196-12

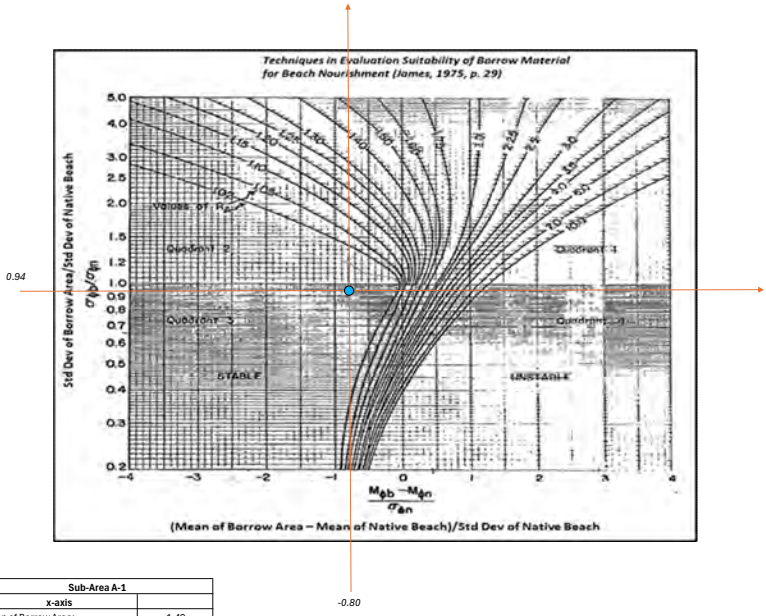
NASA Wallops Island Flight Facility CEDAS Results for Overfill Ratio Sub-Area A-1:



Initial Overfill Ratio (Ra):	1.0
Silt Correction Factor:	1.01
Overfill Ratio:	1.01

NASA Wallops Island Flight Facility Evaluation of Overfil Ratio Sub-Area A-1: Graphical Method

Reference: TM-60 December 1975, Techniques in Evaluating Borrow Material for Beach Nourishment



Sub-Area A-1	
x-axis	
Mean of Borrow Area:	1.49
Mean of Native Beach:	2.04
Std Dev of Native Beach:	0.68
Calculation:	-0.80
y-axis	
Std Dev of Borrow Area	0.63
Std Dev of Native Beach:	0.68
Calculation:	0.94

Initial Overfill Ratio (RA) Graph result:	1.02
Silt Correction Factor	1.01
Overfill Ratio	1.03

867,000 cubic yards x 1.03 = 893010 cubic yards

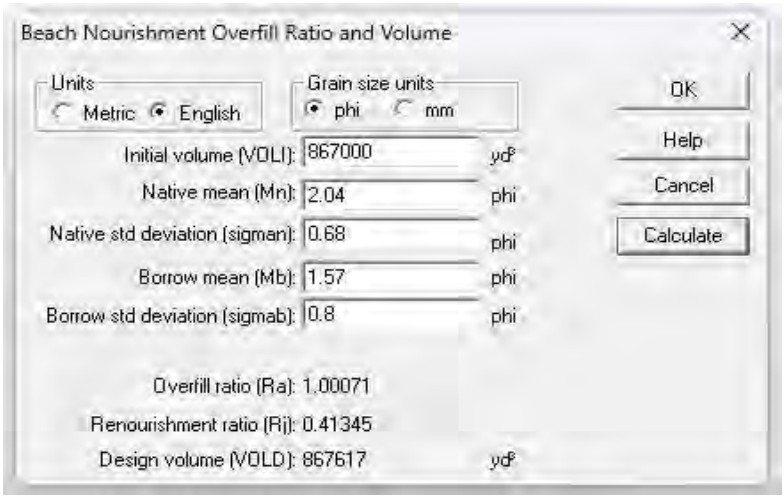
SUB-AREA A-2

Unnamed Shoal A, Sub-Area A-2 (CEDAS Input)					
Mean (Phi)	Median (Phi)	Std. Dev (Phi)	Mean (mm)	Median (mm)	Std Dev. (mm)
1.57	1.57	0.80	0.38	0.35	0.59

Crs Sand	Med Sand	Fines	Shell
% Pass #4	% Pass #10	% Pass #200	% Vis Shell
98.3	95.7	0.57	0

Vibracores: VC-1196-02C, VC-1196-03, VC-1196-04, VC-1196-06, VC-1196-07, VC-1196-08, VC-1196-09

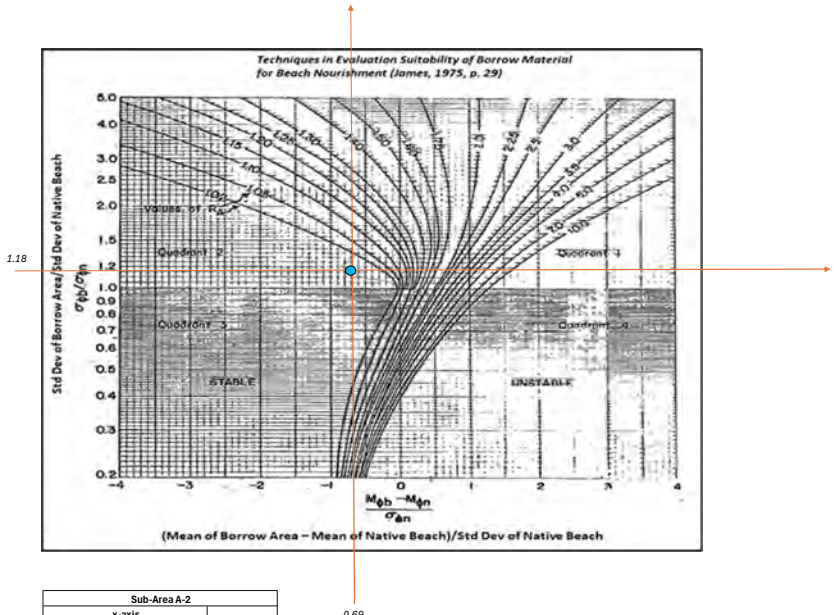
NASA Wallops Island Flight Facility CEDAS Results for Overfill Ratio Sub-Area A-2:



Initifal Overfill Ratio (Ra):	1.0
Silt Correction Factor:	1.01
Overfill Ratio:	1.01

NASA Wallops Island Flight Facility Evaluation of Overfil Ratio Sub-Area A-2: Graphical Method

Reference: TM-60 December 1975, Techniques in Evaluating Borrow Material for Beach Nourishment



Sub-Area A-2	
x-axis	
Mean of Borrow Area:	1.57
Mean of Native Beach:	2.04
Std Dev of Native Beach:	0.68
Calculation:	-0.69
y-axis	
Std Dev of Borrow Area	0.80
Std Dev of Native Beach:	0.68
Calculation:	1.18

Initial Overfill Ratio (RA) Graph result:	1.02
Silt Correction Factor	1.01
Overfill Ratio	1.03

867,000 cubic yards x 1.03 = 893010 cubic yards

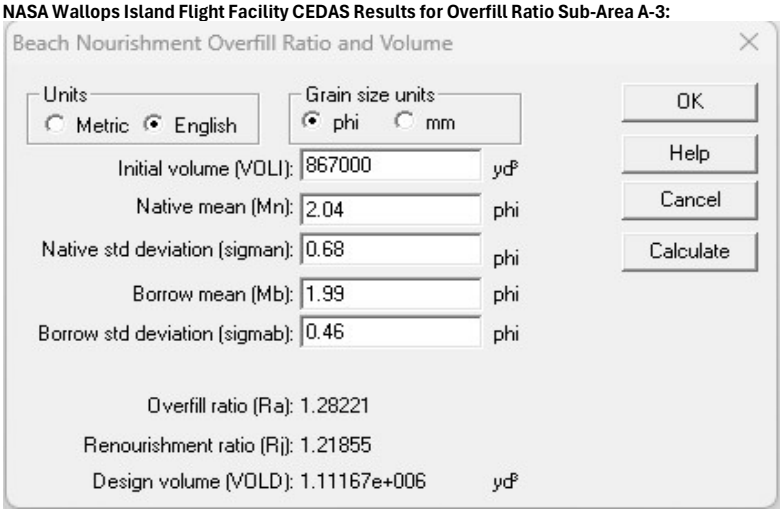
SUB-AREA A-3

Unnamed Shoal A, Sub-Area A-3 (CEDAS Input)					
Mean (Phi)	Median (Phi)	Std. Dev (Phi)	Mean (mm)	Median (mm)	Std Dev. (mm)
1.99	2.01	0.46	0.25	0.25	0.73

Crs Sand	Med Sand	Fines	Shell
% Pass #4	% Pass #10	% Pass #200	% Vis Shell
99.9	99.6	0.81	0

Vibracores: VC-1196-05, VC-1196-10

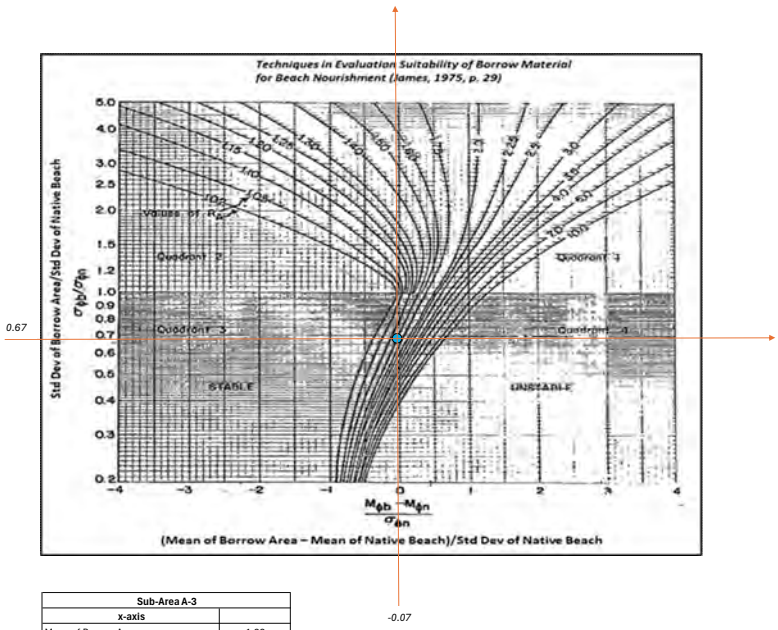
NASA Wallops Island Flight Facility CEDAS Results for Overfill Ratio Sub-Area A-3:



Initifal Overfill Ratio (Ra):	1.28
Silt Correction Factor:	1.01
Overfill Ratio:	1.29

NASA Wallops Island Flight Facility Evaluation of Overfil Ratio Sub-Area A-3: Graphical Method

Reference: TM-60 December 1975, Techniques in Evaluating Borrow Material for Beach Nourishment



Sub-Area A-3	
x-axis	
Mean of Borrow Area:	1.99
Mean of Native Beach:	2.04
Std Dev of Native Beach:	0.68
Calculation:	-0.07
y-axis	
Std Dev of Borrow Area	0.46
Std Dev of Native Beach:	0.68
Calculation:	0.67

Initial Overfill Ratio (RA) Graph result:	1.5
Silt Correction Factor	1.01
Overfill Ratio	1.52

867,000 cubic yards x 1.5 = 1317840 cubic yards

SILT CORRECTION FACTOR CALCULATIONS

Vibracore ID	Composite % Fines	Silt Correction Factor
VC-1196-01	0.61	1.01
VC-1196-02C	0.98	1.01
VC-1196-03	0.63	1.01
VC-1196-04	0.76	1.01
VC-1196-05	0.85	1.01
VC-1196-06	0.19	1.00
VC-1196-07	0.49	1.00
VC-1196-08	0.50	1.01
VC-1196-09	0.44	1.00
VC-1196-10	0.78	1.01
VC-1196-11A	0.66	1.01
VC-1196-12	0.64	1.01

Sub-Area	Silt Correction Factor
A-1	**1.01**
A-2	**1.01**
A-3	**1.01**

BREAKWATER STRUCTURE

BEARING CAPACITY AND SURCHARGE CALCULATIONS

Bearing Capacity

NAVFAC 7.2-131

- Cohesionless Foundation Continuous Footing

$$q_{ult} = \gamma D N_q + \frac{\gamma B}{2} N_\gamma$$

- Where: D (depth of footing) = 0, breakwater placed on mudline

  B = width of footing, widest structure proposed is = 65 ft

- Boring B-2, approximately 3 feet of SP-SM over CH
- Undrained shear strength of CH layer ranges top ≈ 260 psf to bottom ≈ 675 max
- Schrabel 2018 report assumes 25° = ϕ for sand layer due to soft clays, keep this assumption based on DMT data for D-2 & D-3

$$\gamma_{SP-SM} = 106\ pcf = 106\ pcf - 62.4\ pcf = 43.6\ pcf \approx 44\ pcf$$

$$q_{ult} = \gamma D N_q^{\nearrow 0} + \frac{\gamma B}{2} N_\gamma, \quad N_\gamma = 7$$

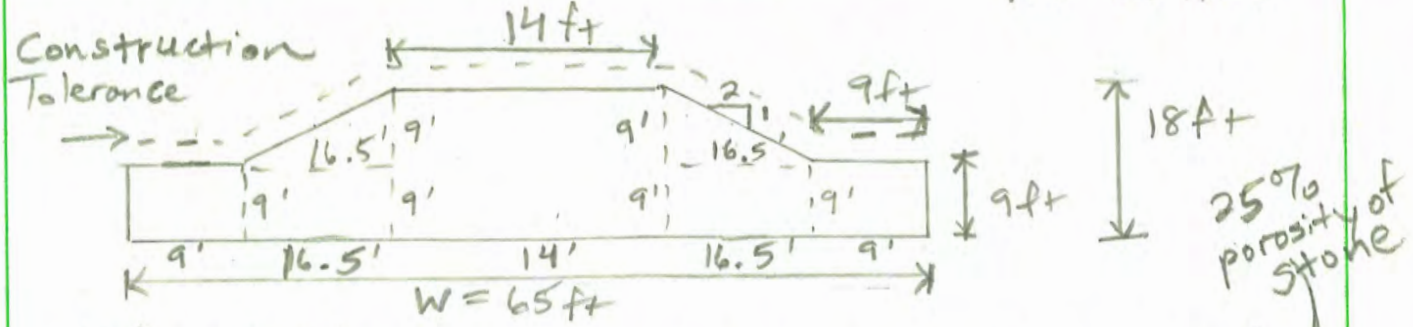
$$q_{ult} = \frac{(44\ pcf)(65\ ft)}{2}(7)$$

$$q_{ult} = 10{,}010\ psf, \text{ assume } FS = 3$$

$$q_{all} = \frac{10{,}010\ psf}{3} = 3{,}336.7\ psf$$

Assume 2,000 – 2,500 psf
Typical for Area

NASA WALLOPS | Breakwater Surcharge | 12/4/25
rev 3/9/26



* Diagram Not to scale

Length of Breakwater 3-1: 195 ft

Stone unit weight: 175 pcf × 0.75 = 132 pcf

Volume

Toes: $[(9')(10')(195')] \times 2 = 35,100\ ft^3$ (9' + 1' tolerance)

Center: $(14')(19')(195') = 51,870\ ft^3$ (18' + 1' tolerance; 9' + 1')

Δ's: $\frac{1}{2} b \times h \times L = \frac{1}{2}(16.5')(10')(195') = 16,087.5$ (1 ft tolerance)

$= 32,175\ ft^3$

Inner □'s: $2[(16.5')(9')(195')] = 57,915\ ft^3$ (no tolerance)

Total: 177,060 ft³ (Stone)

Weight: $(132\ pcf)(177,060\ ft^3) = 23,371,920\ lb$

Area: $(W\ 65\ ft) \times (L\ 195\ ft) = 12,675\ ft^2$

* construction tolerance assumption 1 foot for stone.

Marine Mattress

Unit Weight: 125 pcf
Thickness: 1 ft

$(125\ pcf)(1\ ft)(195\ ft)(65\ ft) = 1,584,375\ lb$

Total Breakwater weight: 23,371,920 lb + 1,584,375 lb
$= 24,956,295\ lb$

Surcharge: $\frac{24,956,295\ lb}{12,675\ ft^2} = 1,969\ psf$

Approx = 2,000 psf

* Does not consider Void space for stone

- Total weight of armor + core stone = 23,371,920 lb
- Volume of Core Stone =
- Volume of Trapezoid : $\frac{1}{2}(b_1 + b_2) \times h \times L$

From Geostudio drawing :

$b_1 = 111.36 - 101.36 = 10$ ft

$b_2 = 128.68 - 85.36 = 43.32$ ft

$h = -2 - (-10.2) = 8.2$ ft

$L = 195$ ft

$V_{core} = \frac{1}{2}(10 + 43.32)(8.2)(195)$

$V_{core} = 42,629.34 \text{ ft}^3$

$W_{core} = (42,629.34 \text{ ft}^3)(132 \text{ pcf}) = 5,627,072.88$ lb

Weight armor stone : $23,371,920$ lb $- 5,627,072.88$ lb
$= 17,744,847.12$ lb

Vol Armor Stone above water : (Geostudio)

$b_1 = 125 - 87 = 38$ ft

$b_2 = 111 - 101 = 10$ ft

$h = 8 - 1 = 7$ ft

$L = 195$ ft

$Vol = \frac{1}{2}(38 + 10)(7)(195) = 32,760 \text{ ft}^3 \times 0.75$ (Voids)
$= 24,570 \text{ ft}^3$

Weight $= (132 \text{ pcf})(24,570 \text{ ft}^3) = 3,243,240$ lb

$\frac{3,243,240 \text{ lb}}{17,744,847.12 \text{ lb}} = 0.18 \simeq 20\%$ of Stone above water

Bearing Capacity Verify Punching Failure

EM 1110-1-1905, 31 July 2025, Equation 5-18 Continuous Footing Pg 117

$$q_{ult} = \min\left(q_{ult,1}, \frac{B' + H_s}{B'} q_{ult,2}\right)$$

$q_{ult,1} = 10{,}010$ psf (from previous calculation)

breakwater on mudline ∴ D = 0

$$q_{ult,2} = c N_c + \gamma' D N_q + \frac{\gamma' B}{2} N_\gamma$$

q_0; $N_q^0 = 1$; $N_\gamma^0 = 0$

$\phi = 0$ ∴ $q_{ult,2} = cN_c$

assume $c =$ psf

NAVFAC 7.2-131, $N_c = 5.53$

$q_{ult,2} = (600\text{psf})(5.53) = 3{,}318$ psf

$B' = 65$ ft = effective base width of footing

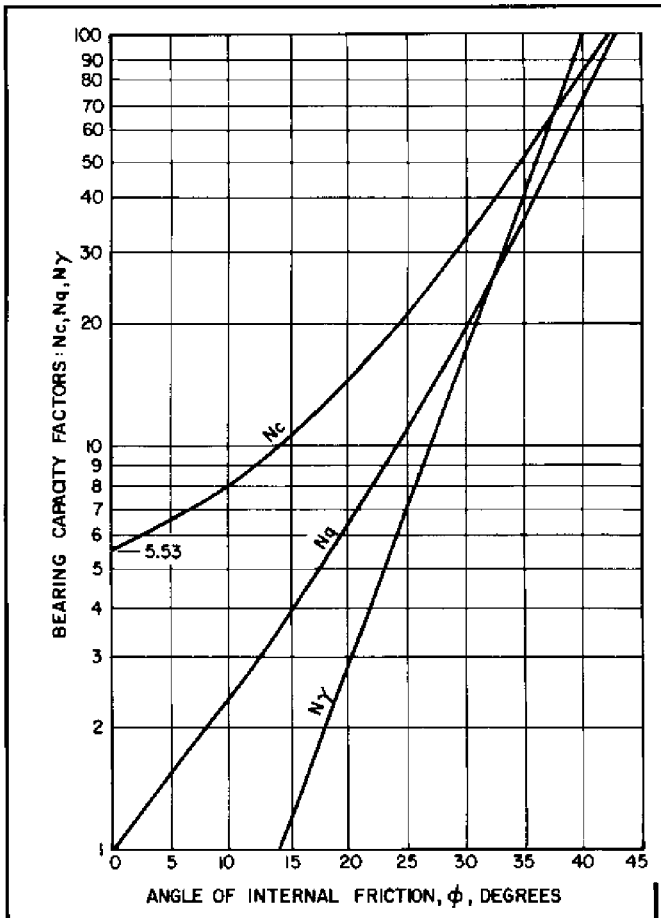
$H_s =$ ~~height~~ of strong surface layer (Layer 1) (ft)
$= 4$ ft

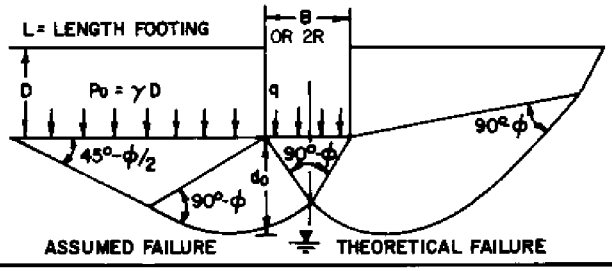
$$q_{ult} = \min\left(10{,}010\text{psf}, \frac{[65\text{ft} + 3\text{ft}]}{3\text{ft}}(3{,}318\text{psf})\right)$$

$$\min(10{,}010\text{psf}, 75{,}208\text{psf}) \div 3$$

$$q_{all} = \min\left(\underbrace{3{,}336.7\text{psf}}_{\text{Sand layer}}, 25{,}069.3\text{psf}\right)$$

assuming FS = 3





ASSUMED CONDITIONS:

1. $D \leq B$
2. SOIL IS UNIFORM TO DEPTH $d_o > B$.
3. WATER LEVEL LOWER THAN d_o BELOW BASE OF FOOTING.
4. VERTICAL LOAD CONCENTRIC.
5. FRACTION AND ADHESION ON VERTICAL SIDES OF FOOTING ARE NEGLECTED.
6. FOUNDATION SOIL WITH PROPERTIES c, ϕ, γ

ULTIMATE BEARING CAPACITY = q_{ult}

CONTINUOUS FOOTING; GENERAL CASE

$q_{ult} = q' + q''$

q' = PORTION OF BEARING CAPACITY ASSUMING WEIGHTLESS FOUNDATION SOIL

q'' = PORTION OF BEARING CAPACITY FROM WEIGHT OF FOUNDATION SOILS

$q' = cN_c + \gamma DN_q$

$q'' = \gamma \frac{B}{2} N_\gamma$

$q_{ult} = cN_c + \gamma DN_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING

$q_{ult} = cN_c \left(1 + .3 \frac{B}{L}\right) + \gamma DN_q + 0.4 \gamma BN_\gamma$

CIRCULAR FOOTING: R = B/2

$q_{ult} = 1.3 cN_c + \gamma DN_q + 0.6 \gamma RN_\gamma$

FOR COHESIONLESS FOUNDATION SOILS ($c = 0$)

CONTINUOUS FOOTING:

$q_{ult} = \gamma DN_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = \gamma DN_q + 0.4 \gamma BN_\gamma$

CIRCULAR FOOTING:

$q_{ult} = \gamma DN_q + 0.6 \gamma RN_\gamma$

FOR COHESIVE FOUNDATION SOILS ($\phi = 0$)

CONTINUOUS FOOTING:

$q_{ult} = cN_c + \gamma D$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = cN_c \left(1 + .3 \frac{B}{L}\right) + \gamma D$

CIRCULAR FOOTING:

$q_{ult} = 1.3 cN_c + \gamma D$

FIGURE 1
Ultimate Bearing Capacity of Shallow Footings With Concentric Loads

BREAKWATER STRUCTURE

SETTLEMENT CALCULATIONS

Project: NASA Wallops Island Shoreline Protection DMT Location D-2

SETTLEMENT ESTIMATE BASED ON DILATOMETER DATA BENEATH A TRAPEZOIDAL EMBANKMENT LOADING USING BOUSSINESQ SOLUTION FOR STRESS INCREASE

Calculated By: Jennifer Spitz Date: 3/16/2026 Checked By: Date:

Embankment Description:
Height: 18.0 feet 5.49 meters
Triangular Width, a: 25.5 feet 7.77 meters
Rectangular Width, B: 14.0 feet 4.27 meters
Bottom of Breakwater Elevation: -11.0 feet
Additional Surcharge Load: 0.0 ksf 0.00 bars
Offset Distance from Centerline, x: 0.0 feet = 0.00 meters
Change of Vertical Stress from time of DMT to initial conditions: 0.00 ksf bars

Dilatometer Sounding:
Unit Weight of Breakwater Stone: 165 pcf
Half Rectangular Width, b: 7.0 feet 2.13 meters
Dilatometer Ground Elev: -11.0 feet -3.35 meters
Total Breakwater Surcharge, q: 2000.00 psf (hand calculated)
FHWA Correction Factor: 1.00

DILATOMETER SOUNDING DATA

Depth Z (Feet)	Material Index Id	Effective Stress SV (psf)	Preconsolidation Pressure Pc (psf)	OCR	Constrained Deformation Modulus M (psf)	Soil Type
0						
0.00	0.53	160.06	1342556.43	4.92	70322.05	LEAN CLAY HEAVY SILT
1.00	0.53	160.06	1342556.43	4.92	70322.05	LEAN CLAY HEAVY SILT
2.00	0.53	160.06	1342556.43	4.92	70322.05	LEAN CLAY HEAVY SILT
3.00	0.53	160.06	1342556.43	4.92	70322.05	LEAN CLAY HEAVY SILT
4.00	0.53	160.06	1342556.43	4.92	70322.05	LEAN CLAY HEAVY SILT
5.00	0.53	160.06	1342556.43	4.92	70322.05	LEAN CLAY HEAVY SILT
6.00	0.38	201.05	3083187.04	11.31	192026.72	FAT CLAY SANDY
7.00	0.40	241.85	3203209.19	9.05	179565.13	FAT CLAY SANDY
8.00	0.35	282.59	3578622.33	8.20	162849.87	FAT CLAY SILTY
9.00	0.39	324.17	3896448.45	7.36	178880.64	FAT CLAY SANDY
10.00	0.34	365.70	4309512.95	6.88	164259.35	FAT CLAY SILTY
11.00	0.36	407.71	4660901.71	6.35	170048.44	FAT CLAY SILTY
12.00	0.35	449.86	5029497.78	5.91	165869.36	FAT CLAY SILTY
13.00	0.34	489.99	4606200.44	4.51	122064.35	FAT CLAY SILTY
14.00	0.41	530.62	4704415.25	3.99	132789.65	FAT CLAY SANDY
15.00	0.36	568.79	4378743.48	3.13	87541.86	FAT CLAY SILTY
16.50	6.20	644.28	3905145.16		952129.06	MEDIUM SAND
17.50	5.53	692.06	3736388.31		631035.47	MEDIUM SAND
18.00	4.32	713.76	3332562.48		307665.87	MEDIUM SAND
19.00	4.92	762.00	4249927.57		620530.76	MEDIUM SAND
20.00	9.31	807.48	3398661.87		425911.85	MEDIUM SAND
21.00	8.31	858.71	4669547.23		977586.26	MEDIUM SAND
22.00	4.53	909.51	5675673.71		784768.76	MEDIUM SAND
23.00	4.18	962.11	6681799.18		949226.85	MEDIUM SAND
24.00	0.22	1005.43	11004713.93	3.74	120533.08	FAT CLAY SILTY
25.00	0.26	1049.78	11423395.67	3.60	142752.46	FAT CLAY SILTY
26.00	0.31	1095.89	12465635.95	3.69	185893.64	FAT CLAY SILTY
27.00	0.30	1142.09	13061503.19	3.61	183852.65	FAT CLAY SILTY
28.00	0.32	1189.42	14315513.60	3.74	212020.16	FAT CLAY SILTY
29.00	3.05	1248.32	13278714.92		1665821.62	MEDIUM SAND
30.00	3.32	1304.15	11096002.55		1158795.90	MEDIUM SAND
31.00	2.87	1364.15	15423844.00		1786647.44	MEDIUM SAND
32.00	6.97	1415.34	7564037.35		662594.05	MEDIUM SAND
33.00	2.02	1473.59	16765502.59		1260002.24	FINE SAND SILTY
34.00	1.21	1523.90	12845523.27		382547.93	LEAN CLAY LIGHT SITLY
35.00	0.43	1580.39	29267458.55	5.33	633925.24	FAT CLAY SANDY
36.00	0.34	1635.29	29863661.49	5.12	481545.00	FAT CLAY SILTY
37.00	0.36	1690.84	30948827.85	5.02	525014.63	FAT CLAY SILTY
38.00	0.32	1746.65	33947765.52	5.27	515668.26	FAT CLAY SILTY
39.00	0.35	1802.23	33098715.39	4.82	507020.61	FAT CLAY SILTY
40.00	0.32	1856.15	31232214.10	4.25	400799.85	FAT CLAY SILTY
41.00	0.30	1907.69	28035121.68	3.52	286584.94	FAT CLAY SILTY
42.00	0.34	1960.98	30479502.94	3.69	367600.36	FAT CLAY SILTY
43.00	0.32	2014.33	31983780.20	3.71	360222.03	FAT CLAY SILTY
44.00	0.34	2068.49	34037841.78	3.80	397659.85	FAT CLAY SILTY
45.00	0.31	2122.36	35257770.28	3.77	371033.81	FAT CLAY SILTY
46.00	0.34	2176.23	34702611.88	3.51	374883.59	FAT CLAY SILTY
47.00	0.35	2230.63	36269924.93	3.52	399911.91	FAT CLAY SILTY
48.00	0.33	2285.09	37910496.76	3.54	392859.47	FAT CLAY SILTY
49.00	0.27	2337.68	36825488.02	3.26	291460.72	FAT CLAY SILTY
50.00	0.33	2390.31	34903451.95	2.90	303786.04	FAT CLAY SILTY
51.00	0.26	2440.93	34535531.88	2.73	216063.90	FAT CLAY SILTY
52.00	0.34	2494.81	39214140.99	3.07	350509.17	FAT CLAY SILTY
53.00	0.34	2546.79	35333362.90	2.56	269956.10	FAT CLAY SILTY
54.00	0.36	2598.65	34766962.54	2.39	266145.05	FAT CLAY SILTY
55.00	0.39	2652.01	38146669.89	2.59	326507.49	FAT CLAY SANDY
56.00	0.46	2707.01	40414031.55	2.67	416117.25	LEAN CLAY HEAVY SILT
57.00	0.73	2765.33	42650726.16	2.74	700373.27	LEAN CLAY HEAVY SILT
58.00	2.68	2826.55	31980884.62		1418361.67	MEDIUM SAND
59.00	0.63	2883.60	43141890.51	2.54	561757.35	LEAN CLAY HEAVY SILT
60.00	1.64	2945.43	40927674.11		1290215.58	SILTY CLAY
61.00	1.67	3004.72	35800135.76		925765.02	SILTY CLAY
62.00	0.76	3059.75	37603239.28	1.85	428347.70	LEAN CLAY HEAVY SAND
63.00	1.12	3115.10	34096600.25	1.53	475973.79	LEAN CLAY LIGHT SILTY
64.00	1.35	3175.45	43207881.80		975130.87	LEAN CLAY LIGHT SILTY
65.00	0.61	3231.80	46399496.96	2.18	474742.10	LEAN CLAY HEAVY SILTY
66.00	1.22	3289.53	39860449.17		654154.06	LEAN CLAY LIGHT SILTY
67.00	1.33	3344.10	33255299.53		411643.79	LEAN CLAY LIGHT SILTY
68.00	2.01	3410.47	56669958.12		2173567.52	FINE SAND SILTY

SETTLEMENT COMPUTATIONS (Schmertmann's Ordinary Method)

DMT Test Depth Below Embankment (Feet)	Layer Midpoint Depth (Feet)	Layer Thickness (Feet)	Stress Factor	Delta Stress (psf)	σ_i' (psf)	σ_i'/p_c Ratio	SETTLEMENT (Feet)	SETTLEMENT (Inches)
0.00	0.00	1.00	0.000	0.00	160.06	0.00	0.00000	0.000
1.00	1.50	1.50	0.999	1998.94	2158.99	0.00	0.04264	0.512
2.00	2.50	1.00	0.998	1995.31	2155.37	0.00	0.02837	0.340
3.00	3.50	1.00	0.994	1987.97	2148.02	0.00	0.02827	0.339
4.00	4.50	1.00	0.988	1976.42	2136.48	0.00	0.02811	0.337
5.00	5.50	1.00	0.980	1960.72	2120.78	0.00	0.02788	0.335
6.00	6.50	1.00	0.971	1941.25	2142.30	0.00	0.01011	0.121
7.00	7.50	1.00	0.959	1918.52	2160.37	0.00	0.01068	0.128
8.00	8.50	1.00	0.947	1893.11	2175.71	0.00	0.01162	0.139
9.00	9.50	1.00	0.933	1865.58	2189.75	0.00	0.01043	0.125
10.00	10.50	1.00	0.918	1836.41	2202.11	0.00	0.01118	0.134
11.00	11.50	1.00	0.903	1806.01	2213.72	0.00	0.01062	0.127
12.00	12.50	1.00	0.887	1774.76	2224.63	0.00	0.01070	0.128
13.00	13.50	1.00	0.871	1742.95	2232.94	0.00	0.01428	0.171
14.00	14.50	1.00	0.855	1710.83	2241.45	0.00	0.01288	0.155
15.00	15.75	1.25	0.835	1670.55	2239.34	0.00	0.02385	0.286
16.50	17.00	1.25	0.815	1630.43	2274.70	0.00	0.00214	0.026
17.50	17.75	0.75	0.803	1606.53	2298.59	0.00	0.00191	0.023
18.00	18.50	0.75	0.791	1582.83	2296.59	0.00	0.00386	0.046
19.00	19.50	1.00	0.776	1551.59	2313.59	0.00	0.00250	0.030
20.00	20.50	1.00	0.760	1520.83	2328.31	0.00	0.00357	0.043
21.00	21.50	1.00	0.745	1490.60	2349.31	0.00	0.00152	0.018
22.00	22.50	1.00	0.730	1460.95	2370.46	0.00	0.00186	0.022
23.00	23.50	1.00	0.716	1431.91	2394.03	0.00	0.00151	0.018
24.00	24.50	1.00	0.702	1403.52	2408.95	0.00	0.01164	0.140
25.00	25.50	1.00	0.688	1375.78	2425.56	0.00	0.00964	0.116
26.00	26.50	1.00	0.674	1348.71	2444.59	0.00	0.00726	0.087
27.00	27.50	1.00	0.661	1322.31	2464.40	0.00	0.00719	0.086
28.00	28.50	1.00	0.648	1296.59	2486.01	0.00	0.00612	0.073
29.00	29.50	1.00	0.636	1271.54	2519.86	0.00	0.00076	0.009
30.00	30.50	1.00	0.624	1247.16	2551.31	0.00	0.00108	0.013
31.00	31.50	1.00	0.612	1223.43	2587.58	0.00	0.00068	0.008
32.00	32.50	1.00	0.600	1200.36	2615.70	0.00	0.00181	0.022
33.00	33.50	1.00	0.589	1177.93	2651.52	0.00	0.00093	0.011
34.00	34.50	1.00	0.578	1156.12	2680.01	0.00	0.00302	0.036
35.00	35.50	1.00	0.567	1134.92	2715.31	0.00	0.00179	0.021
36.00	36.50	1.00	0.557	1114.32	2749.61	0.00	0.00231	0.028
37.00	37.50	1.00	0.547	1094.29	2785.13	0.00	0.00208	0.025
38.00	38.50	1.00	0.537	1074.84	2821.49	0.00	0.00208	0.025
39.00	39.50	1.00	0.528	1055.93	2858.16	0.00	0.00208	0.025
40.00	40.50	1.00	0.519	1037.56	2893.71	0.00	0.00259	0.031
41.00	41.50	1.00	0.510	1019.71	2927.40	0.00	0.00356	0.043
42.00	42.50	1.00	0.501	1002.36	2963.34	0.00	0.00273	0.033
43.00	43.50	1.00	0.493	985.49	2999.82	0.00	0.00274	0.033
44.00	44.50	1.00	0.485	969.10	3037.58	0.00	0.00244	0.029
45.00	45.50	1.00	0.477	953.16	3075.52	0.00	0.00257	0.031
46.00	46.50	1.00	0.469	937.66	3113.89	0.00	0.00250	0.030
47.00	47.50	1.00	0.461	922.60	3153.23	0.00	0.00231	0.028
48.00	48.50	1.00	0.454	907.94	3193.03	0.00	0.00231	0.028
49.00	49.50	1.00	0.447	893.68	3231.36	0.00	0.00307	0.037
50.00	50.50	1.00	0.440	879.81	3270.12	0.00	0.00290	0.035
51.00	51.50	1.00	0.433	866.31	3307.24	0.00	0.00401	0.048
52.00	52.50	1.00	0.427	853.18	3347.98	0.00	0.00243	0.029
53.00	53.50	1.00	0.420	840.39	3387.18	0.00	0.00311	0.037
54.00	54.50	1.00	0.414	827.94	3426.59	0.00	0.00311	0.037
55.00	55.50	1.00	0.408	815.81	3467.82	0.00	0.00250	0.030
56.00	56.50	1.00	0.402	804.00	3511.00	0.00	0.00193	0.023
57.00	57.50	1.00	0.396	792.49	3557.81	0.00	0.00113	0.014
58.00	58.50	1.00	0.391	781.27	3607.83	0.00	0.00055	0.007
59.00	59.50	1.00	0.385	770.34	3653.94	0.00	0.00137	0.016
60.00	60.50	1.00	0.380	759.69	3705.11	0.00	0.00059	0.007
61.00	61.50	1.00	0.375	749.29	3754.02	0.00	0.00081	0.010
62.00	62.50	1.00	0.370	739.16	3798.91	0.00	0.00173	0.021
63.00	63.50	1.00	0.365	729.27	3844.37	0.00	0.00153	0.018
64.00	64.50	1.00	0.360	719.63	3895.08	0.00	0.00074	0.009
65.00	65.50	1.00	0.355	710.21	3942.02	0.00	0.00150	0.018
66.00	66.50	1.00	0.351	701.02	3990.55	0.00	0.00107	0.013
67.00	67.50	1.00	0.346	692.05	4036.15	0.00	0.00168	0.020
68.00	34.00	1.00	0.583	1166.94	4577.42	0.00	0.00054	0.006
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000
0.00	0.00	1.00	0.000	0.00	0.00	0.00	0.00000	0.000

							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	93.08	0.00	0.259	518.89	518.89	0.00	0.00000	0.000
											TOTAL SETTLEMENT			0.42103 ft	5.052 in

NASA Wallops Island Shoreline Protection

DMT location D-2 Conversions

1bar = 2,088.54 psf

M	M
(ksf)	(psf)
70.32	70322.05
192.03	192026.7
179.57	179565.1
162.85	162849.9
178.88	178880.6
164.26	164259.3
170.05	170048.4
165.87	165869.4
122.06	122064.4
132.79	132789.7
87.54	87541.86
952.13	952129.1
631.04	631035.5
307.67	307665.9
620.53	620530.8
425.91	425911.9
977.59	977586.3
784.77	784768.8
949.23	949226.8
120.53	120533.1
142.75	142752.5
185.89	185893.6
183.85	183852.7
212.02	212020.2
1665.82	1665822
1158.80	1158796
1786.65	1786647
662.59	662594.1
1260.00	1260002
382.55	382547.9
633.93	633925.2
481.54	481545
525.01	525014.6
515.67	515668.3
507.02	507020.6
400.80	400799.9
286.58	286584.9
367.60	367600.4
360.22	360222
397.66	397659.8

p_0	Po
(bar)	(psf)
1.23	2571.515
2.66	5558.127
2.61	5453.7
2.76	5772.202
2.86	5970.614
3.01	6289.116
3.11	6492.749
3.21	6701.603
2.82	5881.851
2.76	5766.981
2.47	5161.304
2.08	4351.995
1.92	4017.829
1.69	3521.801
2.08	4341.553
1.61	3359.939
2.14	4472.086
2.52	5270.953
2.88	6022.827
4.61	9636.001
4.66	9724.764
4.94	10325.22
5.04	10534.07
5.39	11249.4
4.87	10173.8
3.97	8294.114
5.39	11254.62
2.58	5391.044
5.59	11677.55
4.19	8748.372
9.34	19499.13
9.32	19473.02
9.46	19760.2
10.17	21232.62
9.71	20287.56
8.99	18768.14
7.91	16522.96
8.44	17624.67
8.69	18152.02
9.08	18966.55

Po	u0
(psf)	(psf)
2571.515	1025.713
5558.127	1089.817
5453.7	1153.922
5772.202	1218.026
5970.614	1282.13
6289.116	1346.235
6492.749	1410.339
6701.603	1474.444
5881.851	1538.548
5766.981	1602.652
5161.304	1666.757
4351.995	1762.913
4017.829	1827.018
3521.801	1859.07
4341.553	1923.174
3359.939	1987.279
4472.086	2051.383
5270.953	2115.488
6022.827	2179.592
9636.001	2243.697
9724.764	2307.801
10325.22	2371.905
10534.07	2436.01
11249.4	2500.114
10173.8	2564.219
8294.114	2628.323
11254.62	2692.427
5391.044	2756.532
11677.55	2820.636
8748.372	2884.741
19499.13	2948.845
19473.02	3012.95
19760.2	3077.054
21232.62	3141.158
20287.56	3205.263
18768.14	3269.367
16522.96	3333.472
17624.67	3397.576
18152.02	3461.68
18966.55	3525.785

371.03	371033.8
374.88	374883.6
399.91	399911.9
392.86	392859.5
291.46	291460.7
303.79	303786
216.06	216063.9
350.51	350509.2
269.96	269956.1
266.15	266145.1
326.51	326507.5
416.12	416117.3
700.37	700373.3
1418.36	1418362
561.76	561757.3
1290.22	1290216
925.77	925765
428.35	428347.7
475.97	475973.8
975.13	975130.9
474.74	474742.1
654.15	654154.1
411.64	411643.8
2173.57	2173568

9.24	19295.5
8.93	18658.49
9.18	19164.97
9.43	19692.32
9.01	18809.91
8.40	17535.9
8.17	17071.2
9.13	19076.2
8.10	16919.78
7.85	16392.43
8.48	17713.43
8.85	18486.19
9.20	19222.4
6.80	14204.68
9.04	18888.23
8.46	17666.44
7.30	15238.51
7.56	15786.75
6.76	14121.14
8.45	17656
8.96	18710.71
7.60	15865.07
6.26	13066.43
10.53	21984.49

19295.5	3589.889
18658.49	3653.994
19164.97	3718.098
19692.32	3782.202
18809.91	3846.307
17535.9	3910.411
17071.2	3974.516
19076.2	4038.62
16919.78	4102.725
16392.43	4166.829
17713.43	4230.933
18486.19	4295.038
19222.4	4359.142
14204.68	4423.247
18888.23	4487.351
17666.44	4551.455
15238.51	4615.56
15786.75	4679.664
14121.14	4743.769
17656	4807.873
18710.71	4871.978
15865.07	4936.082
13066.43	5000.186
21984.49	5064.291

Project: NASA Wallops Island Shoreline Protection DMT Location D-3

SETTLEMENT ESTIMATE BASED ON DILATOMETER DATA BENEATH A TRAPEZOIDAL EMBANKMENT LOADING USING BOUSSINESQ SOLUTION FOR STRESS INCREASE

Calculated By Jennifer Spitz Date: 3/16/2026 Checked By: Date:

Breakwater Description:
Height: 18.0 feet 5.49 meters
Triangular Width, a: 25.5 feet 7.77 meters
Rectangular Width, B: 14.0 feet 4.27 meters
Bottom of Breakwater Elevation: -11.0 feet
Additional Surcharge Load: 0.0 ksf 0.00 bars
Offset Distance from Centerline, x: 0.0 feet = 0.00 meters
Change of Vertical Stress from time of DMT to initial conditions: 0.00 ksf bars

Dilatometer Sounding:
Unit Weight of Breakwater Stone: 165 pcf
Half Rectangular Width, b: 7.0 feet 2.13 meters
Dilatometer Ground Elev: -11.0 feet -3.35 meters
Total Breakwater Surcharge, q: 2000.00 psf (hand calculated)
FHWA Correction Factor: 1.00

DILATOMETER SOUNDING DATA

Depth Z (Feet)	Material Index Id	Effective Stress SV (psf)	Preconsolidation Pressure Pc (psf)	OCR	Constrained Deformation Modulus M (psf)	Soil Type
0						
0.00	0.32	142.73	2205331.21	10.29	102414.92	FAT CLAY SILTY
1.00	0.32	142.73	2205331.21	10.29	102414.92	FAT CLAY SILTY
2.00	0.32	142.73	2205331.21	10.29	102414.92	FAT CLAY SILTY
3.00	0.32	142.73	2205331.21	10.29	102414.92	FAT CLAY SILTY
4.00	0.32	142.73	2205331.21	10.29	102414.92	FAT CLAY SILTY
5.00	0.38	180.65	2632507.77	9.38	134706.60	FAT CLAY SANDY
6.00	0.35	217.02	2591036.08	6.95	101005.70	FAT CLAY SILTY
7.00	0.30	253.08	2867108.57	6.26	87179.62	FAT CLAY SILTY
8.00	0.31	291.18	3504169.58	6.59	109628.66	FAT CLAY SILTY
9.00	0.22	327.50	3682288.86	5.78	74780.43	FAT CLAY SILTY
10.00	0.36	363.79	3293284.84	4.08	82147.33	FAT CLAY SILTY
11.00	0.29	399.94	3685884.70	4.03	73134.23	FAT CLAY SILTY
12.00	0.42	438.94	4158895.23	4.05	116433.74	FAT CLAY SANDY
13.00	0.34	478.32	4861211.06	4.32	110955.39	FAT CLAY SILTY
14.00	0.33	519.37	5774945.54	4.73	133757.05	FAT CLAY SILTY
15.00	0.34	558.72	5330570.96	3.68	103095.74	FAT CLAY SILTY
16.00	0.35	600.74	6588095.50	4.32	146458.24	FAT CLAY SILTY
17.00	0.29	640.93	6529075.44	3.77	104267.03	FAT CLAY SILTY
18.00	0.31	682.37	7264277.47	3.87	122501.95	FAT CLAY SILTY
19.00	0.42	724.68	7149719.17	3.37	146201.27	FAT CLAY SANDY
20.00	0.27	766.70	8520030.13	3.85	122121.02	FAT CLAY SILTY
21.00	0.34	810.23	9102591.66	3.79	154612.08	FAT CLAY SILTY
22.00	0.29	852.57	9149706.73	3.44	123822.80	FAT CLAY SILTY
23.00	0.28	894.41	9294609.13	3.19	111501.26	FAT CLAY SILTY
24.00	3.40	944.10	6854947.09		619577.81	MEDIUM SAND
25.00	2.94	994.72	7810600.87		659505.98	MEDIUM SAND
26.00	1.22	1037.72	7019529.70		163578.01	LEAN CLAY LIGHT SILTY
27.00	4.54	1086.92	6926943.53		563207.05	MEDIUM SAND
28.00	3.49	1136.88	7987201.59		582164.35	MEDIUM SAND
29.00	1.89	1182.36	7852876.56		244073.60	SILTY CLAY SANDY
30.00	0.98	1230.36	11299751.56	2.19	299534.45	LEAN CLAY LIGHT SILTY
31.00	0.84	1271.55	8444218.08	1.23	95041.15	LEAN CLAY LIGHT SILTY
32.00	0.44	1315.20	12024662.42	2.05	128386.24	LEAN CLAY HEAVY SILTY
33.25	1.47	1371.54	9498502.69		191129.38	LEAN CLAY LIGHT SANDY
34.00	2.18	1408.20	10517301.64		379358.62	FINE SAND SILTY
35.00	2.01	1463.67	15868341.27		896353.08	FINE SAND SILTY
36.00	2.18	1520.06	16733201.10		1011328.03	FINE SAND SILTY
37.00	2.47	1574.74	14953675.80		830527.70	FINE SAND SILTY
38.00	1.83	1628.23	15860955.97		635048.54	SILTY CLAY
39.00	2.93	1685.57	17252751.66		1188604.51	MEDIUM SAND
40.00	2.19	1741.60	18135330.45		900084.03	FINE SAND SILTY
41.00	2.22	1798.83	19802265.86		1036181.90	FINE SAND
42.00	2.52	1853.77	17161204.69		785261.12	MEDIUM SAND
43.00	2.62	1911.31	19982358.01		1098957.99	MEDIUM SAND
44.00	1.86	1969.21	23475770.81		1020455.40	SILTY CLAY
45.00	1.50	2026.16	24539790.61		838543.99	LEAN CLAY LIGHT SANDY
46.00	1.98	2084.85	25153878.52		1111144.96	SILTY CLAY SANDY
47.00	2.48	2142.81	22830542.41		1067462.63	FINE SAND
48.00	2.68	2200.89	22909684.92		1096817.30	MEDIUM SAND
49.00	2.06	2257.62	23707765.78		833286.18	FINE SAND SILTY
50.00	2.30	2315.09	24326282.60		936187.03	FINE SAND
51.00	1.47	2370.21	25323009.20		593556.74	LEAN CLAY LIGHT SANDY
52.00	2.05	2426.19	24290180.86		717256.06	FINE SAND SILTY
53.00	1.99	2486.09	31084251.62		1177315.59	SILTY CLAY SANDY
54.00	1.42	2548.26	41120539.79		1393334.09	LEAN CLAY LIGHT SILTY
55.00	2.48	2611.80	36764406.15		1908384.89	FINE SAND
57.00	5.45	2744.71	33826822.72		3224952.48	MEDIUM SAND

SETTLEMENT COMPUTATIONS (Schmertmann's Ordinary Method)

DMT Test Depth Below Embankment (Feet)	Layer Midpoint Depth (Feet)	Layer Thickness (Feet)	Stress Factor	Delta Stress (psf)	σ_i' (psf)	σ_i'/p_c Ratio	SETTLEMENT (Feet)	SETTLEMENT (Inches)
0.00	0.00	1.00	0.000	0.00	142.73	0.00	0.00000	0.000
1.00	1.50	1.50	0.999	1998.94	2141.67	0.00	0.02928	0.351
2.00	2.50	1.00	0.998	1995.31	2138.04	0.00	0.01948	0.234
3.00	3.50	1.00	0.994	1987.97	2130.69	0.00	0.01941	0.233
4.00	4.50	1.00	0.988	1976.42	2119.15	0.00	0.01930	0.232
5.00	5.50	1.00	0.980	1960.72	2141.38	0.00	0.01456	0.175
6.00	6.50	1.00	0.971	1941.25	2158.27	0.00	0.01922	0.231
7.00	7.50	1.00	0.959	1918.52	2171.60	0.00	0.02201	0.264
8.00	8.50	1.00	0.947	1893.11	2184.29	0.00	0.01727	0.207
9.00	9.50	1.00	0.933	1865.58	2193.08	0.00	0.02495	0.299
10.00	10.50	1.00	0.918	1836.41	2200.19	0.00	0.02236	0.268
11.00	11.50	1.00	0.903	1806.01	2205.95	0.00	0.02469	0.296
12.00	12.50	1.00	0.887	1774.76	2213.70	0.00	0.01524	0.183
13.00	13.50	1.00	0.871	1742.95	2221.27	0.00	0.01571	0.189
14.00	14.50	1.00	0.855	1710.83	2230.20	0.00	0.01279	0.153
15.00	15.50	1.00	0.839	1678.60	2237.32	0.00	0.01628	0.195
16.00	16.50	1.00	0.823	1646.44	2247.19	0.00	0.01124	0.135
17.00	17.50	1.00	0.807	1614.48	2255.41	0.00	0.01548	0.186
18.00	18.50	1.00	0.791	1582.83	2265.20	0.00	0.01292	0.155
19.00	19.50	1.00	0.776	1551.59	2276.27	0.00	0.01061	0.127
20.00	20.50	1.00	0.760	1520.83	2287.52	0.00	0.01245	0.149
21.00	21.50	1.00	0.745	1490.60	2300.82	0.00	0.00964	0.116
22.00	22.50	1.00	0.730	1460.95	2313.52	0.00	0.01180	0.142
23.00	23.50	1.00	0.716	1431.91	2326.33	0.00	0.01284	0.154
24.00	24.50	1.00	0.702	1403.52	2347.61	0.00	0.00227	0.027
25.00	25.50	1.00	0.688	1375.78	2370.50	0.00	0.00209	0.025
26.00	26.50	1.00	0.674	1348.71	2386.43	0.00	0.00825	0.099
27.00	27.50	1.00	0.661	1322.31	2409.23	0.00	0.00235	0.028
28.00	28.50	1.00	0.648	1296.59	2433.47	0.00	0.00223	0.027
29.00	29.50	1.00	0.636	1271.54	2453.90	0.00	0.00521	0.063
30.00	30.50	1.00	0.624	1247.16	2477.51	0.00	0.00416	0.050
31.00	31.50	1.00	0.612	1223.43	2494.99	0.00	0.01287	0.154
32.00	32.63	1.13	0.599	1197.52	2512.73	0.00	0.01049	0.126
33.25	33.63	1.00	0.588	1175.17	2546.71	0.00	0.00615	0.074
34.00	34.50	0.88	0.578	1156.12	2564.32	0.00	0.00267	0.032
35.00	35.50	1.00	0.567	1134.92	2598.58	0.00	0.00127	0.015
36.00	36.50	1.00	0.557	1114.32	2634.37	0.00	0.00110	0.013
37.00	37.50	1.00	0.547	1094.29	2669.04	0.00	0.00132	0.016
38.00	38.50	1.00	0.537	1074.84	2703.07	0.00	0.00169	0.020
39.00	39.50	1.00	0.528	1055.93	2741.50	0.00	0.00089	0.011
40.00	40.50	1.00	0.519	1037.56	2779.16	0.00	0.00115	0.014
41.00	41.50	1.00	0.510	1019.71	2818.54	0.00	0.00098	0.012
42.00	42.50	1.00	0.501	1002.36	2856.12	0.00	0.00128	0.015
43.00	43.50	1.00	0.493	985.49	2896.80	0.00	0.00090	0.011
44.00	44.50	1.00	0.485	969.10	2938.31	0.00	0.00095	0.011
45.00	45.50	1.00	0.477	953.16	2979.32	0.00	0.00114	0.014
46.00	46.50	1.00	0.469	937.66	3022.52	0.00	0.00084	0.010
47.00	47.50	1.00	0.461	922.60	3065.40	0.00	0.00086	0.010
48.00	48.50	1.00	0.454	907.94	3108.83	0.00	0.00083	0.010
49.00	49.50	1.00	0.447	893.68	3151.30	0.00	0.00107	0.013
50.00	50.50	1.00	0.440	879.81	3194.90	0.00	0.00094	0.011
51.00	51.50	1.00	0.433	866.31	3236.53	0.00	0.00146	0.018
52.00	52.50	1.00	0.427	853.18	3279.36	0.00	0.00119	0.014
53.00	53.50	1.00	0.420	840.39	3326.48	0.00	0.00071	0.009
54.00	54.50	1.00	0.414	827.94	3376.20	0.00	0.00059	0.007
55.00	56.00	1.50	0.405	809.86	3421.67	0.00	0.00064	0.008
57.00	28.50	2.00	0.648	1296.59	4041.29	0.00	0.00080	0.010
	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000

							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.00000	0.000
							0.00	93.08	0.00	0.259	518.89	518.89	0.00	0.00000	0.000
											TOTAL SETTLEMENT			0.47087	5.650
														ft	in

NASA Wallops Island Shoreline Protection

DMT location D-3 Conversions

1bar = 2,088.54 psf

M	M
(ksf)	(psf)
102.41	102414.9
134.71	134706.6
101.01	101005.7
87.18	87179.62
109.63	109628.7
74.78	74780.43
82.15	82147.33
73.13	73134.23
116.43	116433.7
110.96	110955.4
133.76	133757.1
103.10	103095.7
146.46	146458.2
104.27	104267
122.50	122502
146.20	146201.3
122.12	122121
154.61	154612.1
123.82	123822.8
111.50	111501.3
619.58	619577.8
659.51	659506
163.58	163578
563.21	563207.1
582.16	582164.4
244.07	244073.6
299.53	299534.4
95.04	95041.15
128.39	128386.2
191.13	191129.4
379.36	379358.6
896.35	896353.1
1011.33	1011328
830.53	830527.7
635.05	635048.5
1188.60	1188605
900.08	900084
1036.18	1036182
785.26	785261.1
1098.96	1098958

p_0	Po
(bar)	(psf)
1.90	3976.058
2.15	4482.529
2.00	4179.691
2.10	4393.766
2.45	5114.312
2.46	5129.976
2.10	4388.545
2.25	4707.047
2.44	5098.648
2.74	5730.432
3.14	6555.405
2.79	5834.859
3.33	6962.67
3.19	6670.275
3.44	7181.967
3.28	6847.801
3.79	7912.956
3.93	8205.352
3.84	8012.162
3.79	7912.956
2.72	5678.218
3.02	6299.559
2.64	5516.356
2.54	5307.502
2.86	5970.614
2.74	5730.432
3.86	8053.932
2.82	5881.851
3.92	8189.687
3.01	6294.337
3.28	6858.243
4.85	10132.03
5.01	10466.2
4.39	9166.08
4.56	9531.574
4.87	10168.58
5.02	10487.08
5.38	11238.96
4.58	9562.903
5.24	10936.12

Po	u0
(psf)	(psf)
3976.058	1089.691
4482.529	1153.795
4179.691	1217.9
4393.766	1282.004
5114.312	1346.109
5129.976	1410.213
4388.545	1474.317
4707.047	1538.422
5098.648	1602.526
5730.432	1666.631
6555.405	1730.735
5834.859	1794.839
6962.67	1858.944
6670.275	1923.048
7181.967	1987.153
6847.801	2051.257
7912.956	2115.362
8205.352	2179.466
8012.162	2243.57
7912.956	2307.675
5678.218	2371.779
6299.559	2435.884
5516.356	2499.988
5307.502	2564.092
5970.614	2628.197
5730.432	2692.301
8053.932	2756.406
5881.851	2820.51
8189.687	2884.614
6294.337	2964.745
6858.243	3012.823
10132.03	3076.928
10466.2	3141.032
9166.08	3205.137
9531.574	3269.241
10168.58	3333.345
10487.08	3397.45
11238.96	3461.554
9562.903	3525.659
10936.12	3589.763

1020.46	1020455
838.54	838544
1111.14	1111145
1067.46	1067463
1096.82	1096817
833.29	833286.2
936.19	936187
593.56	593556.7
717.26	717256.1
1177.32	1177316
1393.33	1393334
1908.38	1908385
3224.95	3224952

6.04	12622.61
6.21	12967.22
6.26	13066.43
5.58	11661.89
5.51	11510.47
5.61	11719.32
5.67	11834.19
5.81	12126.59
5.48	11453.03
6.91	14434.42
9.01	18809.91
7.93	16569.95
7.09	14810.36

12622.61	3653.867
12967.22	3717.972
13066.43	3782.076
11661.89	3846.181
11510.47	3910.285
11719.32	3974.39
11834.19	4038.494
12126.59	4102.598
11453.03	4166.703
14434.42	4230.807
18809.91	4294.912
16569.95	4359.016
14810.36	4487.225

12/2/25

DMT Estimates For Spreadsheet

- Approx max width of breakwater is: 65 ft
- Top width = 14 ft

$$\frac{65\,ft - 14\,ft}{2} = 25.5\,ft$$ triangular width

(rough assumption given toe on each side)

- Rectangular width = 14 ft
- Height = 18 ft (-11 elev to +7 elevation)
- Assumed Bottom of Embankment Elevation and Dilatometa ground elevation same (-10 ft)

- P_c (psf) $\approx 0.509 (p_o - u_o)$ [Mayne + Bachus 1989]

preconsolidation pressure

- 1 bar = 2,088.54 psf conversion

Mayne, Paul W. and Schnieder, James A. Small and large strain soil properties from seismic flat dilatometer tests. Pre-failure Deformation Characteristics of Geomaterials, Jamiolkowski, Lancellotta & Lo Presti (eds). 1999.

For undrained loading of clays, the value of τ_{max} is defined by the undrained shear strength (s_u) and best obtained from the stress history. First, the effective preconsolidation stress (σ_p') is evaluated from the DMT contact pressure, p_0 (Mayne & Bachus, 1989):

$$\sigma_p' \approx 0.509(p_0 - u_0) \quad (7)$$

where u_0 = hydrostatic pore water pressure. The effective overburden stress (σ_{vo}') is calculated based on cumulative unit weights from mass densities (Eq. 2) and u_0. Overconsolidation ratios ($OCR = \sigma_p'/\sigma_{vo}'$) for each test depth are computed

Note: For Material Index (ID) reference: Gayduck, Alexandra and Guskov, Igor. Development of Soil Classification by Material Index (ID). GEOINGSERVICE LLC, MOSCOW, RUSSIA.

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83463
Client:	Schnabel Engineering	Longitude:	-75.48399
Sounding ID:	D-2	Elevation (ft):	
Date:	19-Jun-2018	Ground Water Depth (ft):	-11.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{v0} (psf)	σ_{v0}' (psf)	I_D	K_D	E_D (ksf)	K_0	OCR[3]	OCR[4]	ϕ'[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
5.00	1.15	2.25		0.15	0.58	1.23	1.63		1025.71	96.11	1185.77	160.06	0.53	9.66	28.54	1.80	4.92	11.66		2.46	252.06	154.58	70.32
6.00	2.60	4.10		0.15	0.58	2.66	3.48		1089.82	105.09	1290.87	201.05	0.38	22.22	58.97	2.95	11.31	42.80		3.26	897.40	446.83	192.03
7.00	2.55	4.05	1.80	0.15	0.58	2.61	3.43	1.90	1153.92	104.89	1395.77	241.85	0.40	17.78	58.97	2.60	9.05	30.22		3.04	816.69	429.98	179.57
8.00	2.70	4.15		0.15	0.58	2.76	3.53		1218.03	104.84	1500.62	282.59	0.35	16.12	55.17	2.45	8.20	25.92		2.95	844.03	455.42	162.85
9.00	2.80	4.35		0.15	0.58	2.86	3.73		1282.13	105.68	1606.30	324.17	0.39	14.46	62.78	2.30	7.36	21.90		2.85	845.73	468.85	178.88
10.00	2.95	4.45		0.15	0.58	3.01	3.83		1346.23	105.62	1711.94	365.70	0.34	13.52	58.97	2.21	6.88	19.70		2.79	876.66	494.29	164.26
11.00	3.05	4.60		0.15	0.58	3.11	3.98		1410.34	106.10	1818.05	407.71	0.36	12.47	62.78	2.11	6.35	17.37		2.71	883.36	508.24	170.05
12.00	3.15	4.70		0.15	0.58	3.21	4.08		1474.44	106.25	1924.31	449.86	0.35	11.62	62.78	2.02	5.91	15.56		2.64	892.68	522.72	165.87
13.00	2.75	4.15		0.15	0.58	2.82	3.53		1538.55	104.22	2028.54	489.99	0.34	8.86	51.36	1.70	4.51	10.20		2.38	693.21	434.33	122.06
14.00	2.70	4.20	1.90	0.15	0.58	2.76	3.58	2.00	1602.65	104.72	2133.27	530.62	0.41	7.85	58.97	1.58	3.99	8.44		2.25	644.72	416.43	132.79
15.00	2.40	3.70		0.15	0.58	2.47	3.08		1666.76	102.27	2235.55	568.79	0.36	6.14	43.76	1.34	3.13	5.76		2.00	508.91	349.46	87.54
16.50	2.35	10.40		0.15	0.58	2.08	9.78		1762.91	114.42	2407.19	644.28	6.20	4.02	557.40				36.05	1.71			952.13
17.50	2.10	8.35		0.15	0.58	1.92	7.73		1827.02	111.88	2519.08	692.06	5.53	3.17	420.43				34.78	1.50			631.04
18.00	1.75	5.75		0.15	0.58	1.69	5.13		1859.07	107.50	2572.83	713.76	4.32	2.33	249.21				33.08	1.23			307.67
19.00	2.25	8.40		0.15	0.58	2.08	7.78		1923.17	112.33	2685.17	762.00	4.92	3.17	412.82				34.79	1.50			620.53
20.00	1.80	8.35		0.15	0.58	1.61	7.73		1987.28	109.58	2794.76	807.48	9.31	1.70	443.26				31.25	0.96			425.91
21.00	2.50	12.40		0.15	0.58	2.14	11.78		2051.38	115.33	2910.10	858.71	8.31	2.82	698.18				34.15	1.40			977.59
22.00	2.75	10.00	0.75	0.15	0.58	2.52	9.38	0.85	2115.49	114.89	3025.00	909.51	4.53	3.47	496.53				35.27	1.58			784.77
23.00	3.15	11.20		0.15	0.58	2.88	10.58		2179.59	116.70	3141.71	962.11	4.18	3.99	557.40				36.02	1.70			949.23
24.00	4.55	6.00		0.15	0.58	4.61	5.38		2243.70	107.41	3249.13	1005.43	0.22	7.35	55.17	1.51	3.74	7.62		2.18	1125.96	739.23	120.53
25.00	4.60	6.20		0.15	0.58	4.66	5.58		2307.80	108.45	3357.58	1049.78	0.26	7.07	66.58	1.47	3.60	7.16		2.14	1118.52	741.70	142.75
26.00	4.90	6.75		0.15	0.58	4.94	6.13		2371.91	110.20	3467.79	1095.89	0.31	7.26	85.61	1.50	3.69	7.47		2.17	1207.48	795.33	185.89
27.00	5.00	6.85		0.15	0.58	5.04	6.23		2436.01	110.30	3578.10	1142.09	0.30	7.09	85.61	1.48	3.61	7.20		2.15	1222.33	809.81	183.85
28.00	5.35	7.35	3.95	0.15	0.58	5.39	6.73	4.05	2500.11	111.42	3689.53	1189.42	0.32	7.36	97.02	1.51	3.74	7.63		2.19	1332.81	874.93	212.02
29.00	5.30	16.60		0.15	0.58	4.87	15.98		2564.22	122.99	3812.54	1248.32	3.05	6.10	804.72				38.17	2.07			1665.82
30.00	4.30	13.60		0.15	0.58	3.97	12.98		2628.32	119.93	3932.47	1304.15	3.32	4.34	652.52				36.46	1.78			1158.80
31.00	5.85	17.80		0.15	0.58	5.39	17.18		2692.43	124.09	4056.57	1364.15	2.87	6.28	854.18				38.31	2.09			1786.65
32.00	2.90	12.00		0.15	0.58	2.58	11.38		2756.53	115.29	4171.87	1415.34	6.97	1.86	637.30				31.79	1.04			662.59
33.00	5.90	14.80		0.15	0.58	5.59	14.18		2820.64	122.35	4294.23	1473.59	2.02	6.01	622.09				38.10	2.03			1260.00
34.00	4.25	8.20		0.15	0.58	4.19	7.58		2884.74	114.40	4408.64	1523.90	1.21	3.85	245.41					1.56			382.55
35.00	9.40	13.40		0.15	0.58	9.34	12.78		2948.85	120.59	4529.24	1580.39	0.43	10.47	249.21	1.89	5.33	13.23		2.54	2753.92	1655.03	633.93
36.00	9.35	12.60	6.10	0.15	0.58	9.32	11.98	6.20	3012.95	119.00	4648.24	1635.29	0.34	10.07	192.14	1.85	5.12	12.44		2.51	2711.92	1646.01	481.54
37.00	9.50	13.00		0.15	0.58	9.46	12.38		3077.05	119.64	4767.89	1690.84	0.36	9.87	211.17	1.82	5.02	12.06		2.49	2735.01	1668.32	525.01
38.00	10.20	13.60		0.15	0.58	10.17	12.98		3141.16	119.91	4887.81	1746.65	0.32	10.36	203.56	1.88	5.27	13.01		2.53	3002.11	1809.15	515.67
39.00	9.75	13.20		0.15	0.58	9.71	12.58		3205.26	119.67	5007.49	1802.23	0.35	9.48	207.36	1.78	4.82	11.33		2.45	2772.47	1708.23	507.02
40.00	9.00	12.00		0.15	0.58	8.99	11.38		3269.37	118.02	5125.52	1856.15	0.32	8.35	173.12	1.64	4.25	9.29		2.32	2436.99	1549.88	400.80
41.00	7.90	10.40		0.15	0.58	7.91	9.78		3333.47	115.63	5241.16	1907.69	0.30	6.91	135.07	1.45	3.52	6.92		2.12	1978.31	1318.95	286.58
42.00	8.45	11.40	6.00	0.15	0.58	8.44	10.78	6.10	3397.58	117.39	5358.56	1960.98	0.34	7.26	169.31	1.50	3.69	7.46		2.17	2159.80	1422.71	367.60
43.00	8.70	11.60		0.15	0.58	8.69	10.98		3461.68	117.44	5476.01	2014.33	0.32	7.29	165.51	1.50	3.71	7.53		2.18	2233.03	1469.04	360.22
44.00	9.10	12.20		0.15	0.58	9.08	11.58		3525.78	118.25	5594.27	2068.49	0.34	7.46	180.73	1.53	3.80	7.80		2.20	2360.80	1544.08	397.66
45.00	9.25	12.20		0.15	0.58	9.24	11.58		3589.89	117.97	5712.25	2122.36	0.31	7.40	169.31	1.52	3.77	7.70		2.19	2396.07	1570.56	371.03
46.00	8.95	12.00		0.15	0.58	8.93	11.38		3653.99	117.96	5830.22	2176.23	0.34	6.89	176.92	1.45	3.51	6.89		2.12	2248.99	1500.45	374.88
47.00	9.20	12.40		0.15	0.58	9.18	11.78		3718.10	118.50	5948.73	2230.63	0.35	6.92	188.34	1.45	3.52	6.94		2.12	2317.82	1544.69	399.91
48.00	9.45	12.60		0.15	0.58	9.43	11.98		3782.20	118.55	6067.29	2285.09	0.33	6.96	184.53	1.46	3.54	7.00		2.13	2390.57	1591.02	392.86
49.00	9.00	11.60	6.90	0.15	0.58	9.01	10.98	7.00	3846.31	116.68	6183.98	2337.68	0.27	6.40	142.68	1.38	3.26	6.14		2.04	2201.59	1496.36	291.46
50.00	8.40	11.20		0.15	0.58	8.40	10.58		3910.41	116.73	6300.72	2390.31	0.33	5.70	157.90	1.27	2.90	5.12		1.92	1947.44	1362.55	303.79
51.00	8.15	10.40		0.15	0.58	8.17	9.78		3974.52	114.72	6415.44	2440.93	0.26	5.37	116.05	1.22	2.73	4.66		1.86	1843.74	1309.67	216.06
52.00	9.15	12.20		0.15	0.58	9.13	11.58		4038.62	117.97	6533.43	2494.81	0.34	6.03	176.92	1.32	3.07	5.59		1.98	2179.46	1503.76	350.51
53.00	8.10	10.80		0.15	0.58	8.10	10.18		4102.72	116.08	6649.52	2546.79	0.34	5.03	150.29	1.17	2.56	4.22		1.80	1775.72	1281.71	269.96
54.00	7.85	10.60		0.15	0.58	7.85	9.98		4166.83	115.95	6765.48	2598.65	0.36	4.70	154.09	1.11	2.39	3.80		1.73	1665.47	1222.56	266.15
55.00	8.50	11.60		0.15	0.58	8.48	10.98		4230.93	117.46	6882.95	2652.01	0.39	5.08	180.73	1.17	2.59	4.29		1.81	1872.64	1348.25	326.51

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83463
Client:	Schnabel Engineering	Longitude:	-75.48399
Sounding ID:	D-2	Elevation (ft):	
Date:	19-Jun-2018	Ground Water Depth (ft):	-11.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{v0} (psf)	σ_{v0}' (psf)	I_D	K_D	E_D (ksf)	K_0	OCR[3]	OCR[4]	ϕ'[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
56.00	8.90	12.60	4.80	0.15	0.58	8.85	11.98	4.90	4295.04	119.09	7002.05	2707.01	0.46	5.24	226.39	1.20	2.67	4.50		1.84	1986.26	1419.12	416.12
57.00	9.35	15.00		0.15	0.58	9.20	14.38		4359.14	122.41	7124.47	2765.33	0.73	5.37	374.77	1.22	2.74	4.67		1.87	2093.35	1486.33	700.37
58.00	7.30	20.00		0.15	0.58	6.80	19.38		4423.25	125.32	7249.80	2826.55	2.68	3.46	911.25				35.26	1.56			1418.36
59.00	9.15	14.00		0.15	0.58	9.04	13.38		4487.35	121.14	7370.95	2883.60	0.63	4.99	313.90	1.16	2.54	4.17		1.79	1991.31	1440.09	561.76
60.00	8.85	19.40		0.15	0.58	8.46	18.78		4551.46	125.92	7496.88	2945.43	1.64	4.45	747.64					1.73			1290.22
61.00	7.60	16.40		0.15	0.58	7.30	15.78		4615.56	123.39	7620.28	3004.72	1.67	3.54	614.48					1.51			925.77
62.00	7.65	12.20		0.15	0.58	7.56	11.58		4679.66	119.13	7739.42	3059.75	0.76	3.63	291.07	0.91	1.85	2.53		1.47	1418.13	1110.71	428.35
63.00	6.90	12.40		0.15	0.58	6.76	11.78		4743.77	119.44	7858.87	3115.10	1.12	3.01	363.36	0.79	1.53	1.89		1.31	1142.54	937.74	475.97
64.00	8.75	17.40	2.10	0.15	0.58	8.45	16.78	2.20	4807.87	124.45	7983.33	3175.45	1.35	4.05	603.06					1.62			975.13
65.00	9.05	13.60		0.15	0.58	8.96	12.98		4871.98	120.44	8103.78	3231.80	0.61	4.28	291.07	1.04	2.18	3.28		1.63	1841.39	1383.88	474.74
66.00	7.80	14.60		0.15	0.58	7.60	13.98		4936.08	121.82	8225.61	3289.53	1.22	3.32	462.28					1.42			654.15
67.00	6.40	12.00		0.15	0.58	6.26	11.38		5000.19	118.67	8344.29	3344.10	1.33	2.41	370.97					1.11			411.64
68.00	11.20	27.40	2.10	0.15	0.58	10.53	26.78	2.20	5064.29	130.47	8474.76	3410.47	2.01	4.96	1177.59				37.14	1.85			2173.57

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83991
Client:	Schnabel Engineering	Longitude:	-75.47855
Sounding ID:	D-3	Elevation (ft):	
Date:	20-Jun-2018	Ground Water Depth (ft):	-13.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{v0} (psf)	σ_{v0}' (psf)	I_D	K_D	E_D (ksf)	K_0	OCR[3]	OCR[4]	ϕ'[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
4.00	1.80	2.90		0.18	0.50	1.90	2.35		1089.69	99.78	1232.42	142.73	0.32	20.22	32.34	2.80	10.29	36.94		3.17	566.17	288.64	102.41
5.00	2.05	3.30		0.18	0.50	2.15	2.75		1153.80	102.02	1334.45	180.65	0.38	18.43	43.76	2.65	9.38	31.95		3.08	637.93	332.87	134.71
6.00	1.90	3.05		0.18	0.50	2.00	2.50		1217.90	100.46	1434.92	217.02	0.35	13.65	36.15	2.22	6.95	20.00		2.79	526.57	296.18	101.01
7.00	2.00	3.10	1.40	0.18	0.50	2.10	2.55	1.53	1282.00	100.15	1535.08	253.08	0.30	12.30	32.34	2.09	6.26	17.00		2.70	538.99	311.18	87.18
8.00	2.35	3.55		0.18	0.50	2.45	3.00		1346.11	102.19	1637.28	291.18	0.31	12.94	39.95	2.15	6.59	18.41		2.74	661.10	376.82	109.63
9.00	2.35	3.40		0.18	0.50	2.46	2.85		1410.21	100.42	1737.71	327.50	0.22	11.36	28.54	1.99	5.78	15.02		2.62	631.65	371.98	74.78
10.00	2.00	3.15		0.18	0.50	2.10	2.60		1474.32	100.38	1838.11	363.79	0.36	8.01	36.15	1.60	4.08	8.71		2.27	453.50	291.42	82.15
11.00	2.15	3.25		0.18	0.50	2.25	2.70		1538.42	100.25	1938.36	399.94	0.29	7.92	32.34	1.59	4.03	8.56		2.26	491.73	316.86	73.13
12.00	2.35	3.70		0.18	0.50	2.44	3.15		1602.53	103.10	2041.46	438.94	0.42	7.96	51.36	1.59	4.05	8.63		2.27	543.27	349.61	116.43
13.00	2.65	3.95		0.18	0.50	2.74	3.40		1666.63	103.48	2144.95	478.32	0.34	8.50	47.56	1.66	4.32	9.55		2.33	641.76	406.38	110.96
14.00	3.05	4.45	2.30	0.18	0.50	3.14	3.90	2.43	1730.74	105.15	2250.10	519.37	0.33	9.29	55.17	1.76	4.73	10.98		2.42	779.12	482.47	133.76
15.00	2.70	4.00		0.18	0.50	2.79	3.45		1794.84	103.45	2353.56	558.72	0.34	7.23	47.56	1.49	3.68	7.43		2.17	612.80	404.00	103.10
16.00	3.25	4.75		0.18	0.50	3.33	4.20		1858.94	106.12	2459.69	600.74	0.35	8.50	62.78	1.66	4.32	9.55		2.33	805.98	510.37	146.46
17.00	3.10	4.40		0.18	0.50	3.19	3.85		1923.05	104.28	2563.98	640.93	0.29	7.41	47.56	1.52	3.77	7.71		2.19	724.41	474.72	104.27
18.00	3.35	4.75		0.18	0.50	3.44	4.20		1987.15	105.53	2669.52	682.37	0.31	7.61	55.17	1.55	3.87	8.05		2.22	798.17	519.48	122.50
19.00	3.20	4.80		0.18	0.50	3.28	4.25		2051.26	106.40	2775.94	724.68	0.42	6.62	70.39	1.41	3.37	6.47		2.08	711.64	479.66	146.20
20.00	3.70	5.10		0.18	0.50	3.79	4.55		2115.36	106.12	2882.06	766.70	0.27	7.56	55.17	1.54	3.85	7.96		2.21	889.28	579.76	122.12
21.00	3.85	5.45		0.18	0.50	3.93	4.90		2179.47	107.62	2989.69	810.23	0.34	7.44	70.39	1.52	3.79	7.76		2.20	920.47	602.59	154.61
22.00	3.75	5.20	2.80	0.18	0.50	3.84	4.65	2.93	2243.57	106.44	3096.14	852.57	0.29	6.77	58.97	1.43	3.44	6.69		2.10	860.58	576.86	123.82
23.00	3.70	5.10		0.18	0.50	3.79	4.55		2307.67	105.94	3202.09	894.41	0.28	6.27	55.17	1.36	3.19	5.94		2.02	820.35	560.53	111.50
24.00	2.85	8.65		0.18	0.50	2.72	8.10		2371.78	113.78	3315.87	944.10	3.40	3.50	389.99				35.33	1.59			619.58
25.00	3.15	9.00		0.18	0.50	3.02	8.45		2435.88	114.72	3430.61	994.72	2.94	3.88	393.80				35.87	1.67			659.51
26.00	2.60	4.95		0.18	0.50	2.64	4.40		2499.99	107.10	3537.71	1037.72	1.22	2.91	127.46					1.28			163.58
27.00	2.70	9.05		0.18	0.50	2.54	8.50		2564.09	113.30	3651.01	1086.92	4.54	2.52	431.85				33.53	1.30			563.21
28.00	3.00	9.00		0.18	0.50	2.86	8.45		2628.20	114.06	3765.08	1136.88	3.49	2.94	405.21				34.38	1.44			582.16
29.00	2.75	6.05	1.10	0.18	0.50	2.74	5.50	1.23	2692.30	109.57	3874.66	1182.36	1.89	2.57	199.75				33.63	1.22			244.07
30.00	3.85	6.90		0.18	0.50	3.86	6.35		2756.41	112.10	3986.76	1230.36	0.98	4.31	180.73	1.04	2.19	3.31		1.66	705.86	529.75	299.53
31.00	2.75	4.60		0.18	0.50	2.82	4.05		2820.51	105.29	4092.06	1271.55	0.84	2.41	89.41	0.65	1.23	1.34		1.06	352.73	306.14	95.04
32.00	3.85	5.60		0.18	0.50	3.92	5.05		2884.61	107.75	4199.82	1315.20	0.44	4.03	81.80	0.99	2.05	2.99		1.57	695.43	530.51	128.39
33.25	3.00	5.90		0.18	0.50	3.01	5.35		2964.75	109.17	4336.29	1371.54	1.47	2.43	169.31					1.13			191.13
34.00	3.35	7.85		0.18	0.50	3.28	7.30		3012.82	112.97	4421.02	1408.20	2.18	2.73	291.07				33.97	1.30			379.36
35.00	5.05	12.20	0.60	0.18	0.50	4.85	11.65	0.73	3076.93	119.56	4540.59	1463.67	2.01	4.82	492.72				36.99	1.82			896.35
36.00	5.25	13.20		0.18	0.50	5.01	12.65		3141.03	120.48	4661.09	1520.06	2.18	4.82	553.60				36.99	1.83			1011.33
37.00	4.60	12.00		0.18	0.50	4.39	11.45		3205.14	118.78	4779.88	1574.74	2.47	3.79	511.75				35.74	1.62			830.53
38.00	4.70	10.60		0.18	0.50	4.56	10.05		3269.24	117.58	4897.47	1628.23	1.83	3.85	397.60				35.82	1.60			635.05
39.00	5.20	15.00		0.18	0.50	4.87	14.45		3333.35	121.44	5018.92	1685.57	2.93	4.06	694.38				36.10	1.71			1188.60
40.00	5.25	13.00		0.18	0.50	5.02	12.45		3397.45	120.12	5139.05	1741.60	2.19	4.07	538.38				36.12	1.67			900.08
41.00	5.65	14.20		0.18	0.50	5.38	13.65		3461.55	121.33	5260.38	1798.83	2.22	4.32	599.26				36.43	1.73			1036.18
42.00	4.80	12.40		0.18	0.50	4.58	11.85		3525.66	119.03	5379.42	1853.77	2.52	3.26	526.97				34.93	1.49			785.26
43.00	5.55	15.00		0.18	0.50	5.24	14.45		3589.76	121.64	5501.07	1911.31	2.62	3.84	667.74				35.82	1.65			1098.96
44.00	6.30	14.60	0.75	0.18	0.50	6.04	14.05	0.88	3653.87	122.00	5623.08	1969.21	1.86	4.55	580.23				36.70	1.76			1020.46
45.00	6.40	13.40		0.18	0.50	6.21	12.85		3717.97	121.05	5744.13	2026.16	1.50	4.56	481.31					1.74			838.54
46.00	6.55	15.60		0.18	0.50	6.26	15.05		3782.08	122.78	5866.93	2084.85	1.98	4.45	637.30				36.59	1.74			1111.14
47.00	5.90	15.40		0.18	0.50	5.58	14.85		3846.18	122.05	5988.99	2142.81	2.48	3.65	671.55				35.54	1.59			1067.46
48.00	5.85	15.80		0.18	0.50	5.51	15.25		3910.29	122.18	6111.18	2200.89	2.68	3.45	705.79				35.25	1.55			1096.82
49.00	5.85	13.80	0.80	0.18	0.50	5.61	13.25	0.93	3974.39	120.82	6232.01	2257.62	2.06	3.43	553.60				35.21	1.51			833.29
50.00	5.95	14.80		0.18	0.50	5.67	14.25		4038.49	121.57	6353.59	2315.09	2.30	3.37	622.09				35.11	1.50			936.19
51.00	5.95	12.00		0.18	0.50	5.81	11.45		4102.60	119.22	6472.81	2370.21	1.47	3.39	409.02					1.45			593.56
52.00	5.70	13.20		0.18	0.50	5.48	12.65		4166.70	120.07	6592.89	2426.19	2.05	3.00	519.36				34.49	1.38			717.26
53.00	7.25	17.20		0.18	0.50	6.91	16.65		4230.81	123.99	6716.89	2486.09	1.99	4.10	705.79				36.16	1.67			1177.32
54.00	9.35	19.40		0.18	0.50	9.01	18.85		4294.91	126.27	6843.17	2548.26	1.42	5.70	713.40					1.95			1393.33

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83991
Client:	Schnabel Engineering	Longitude:	-75.47855
Sounding ID:	D-3	Elevation (ft):	
Date:	20-Jun-2018	Ground Water Depth (ft):	-13.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{v0} (psf)	σ_{v0}' (psf)	I_D	K_D	E_D (ksf)	K_0	OCR[3]	OCR[4]	ϕ'[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
55.00	8.50	23.00		0.18	0.50	7.93	22.45		4359.02	127.64	6970.82	2611.80	2.48	4.68	1052.03				36.84	1.81			1908.38
57.00	8.25	34.60		0.18	0.50	7.09	34.05		4487.22	130.55	7231.93	2744.71	5.45	3.76	1953.77				35.70	1.65			3224.95

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

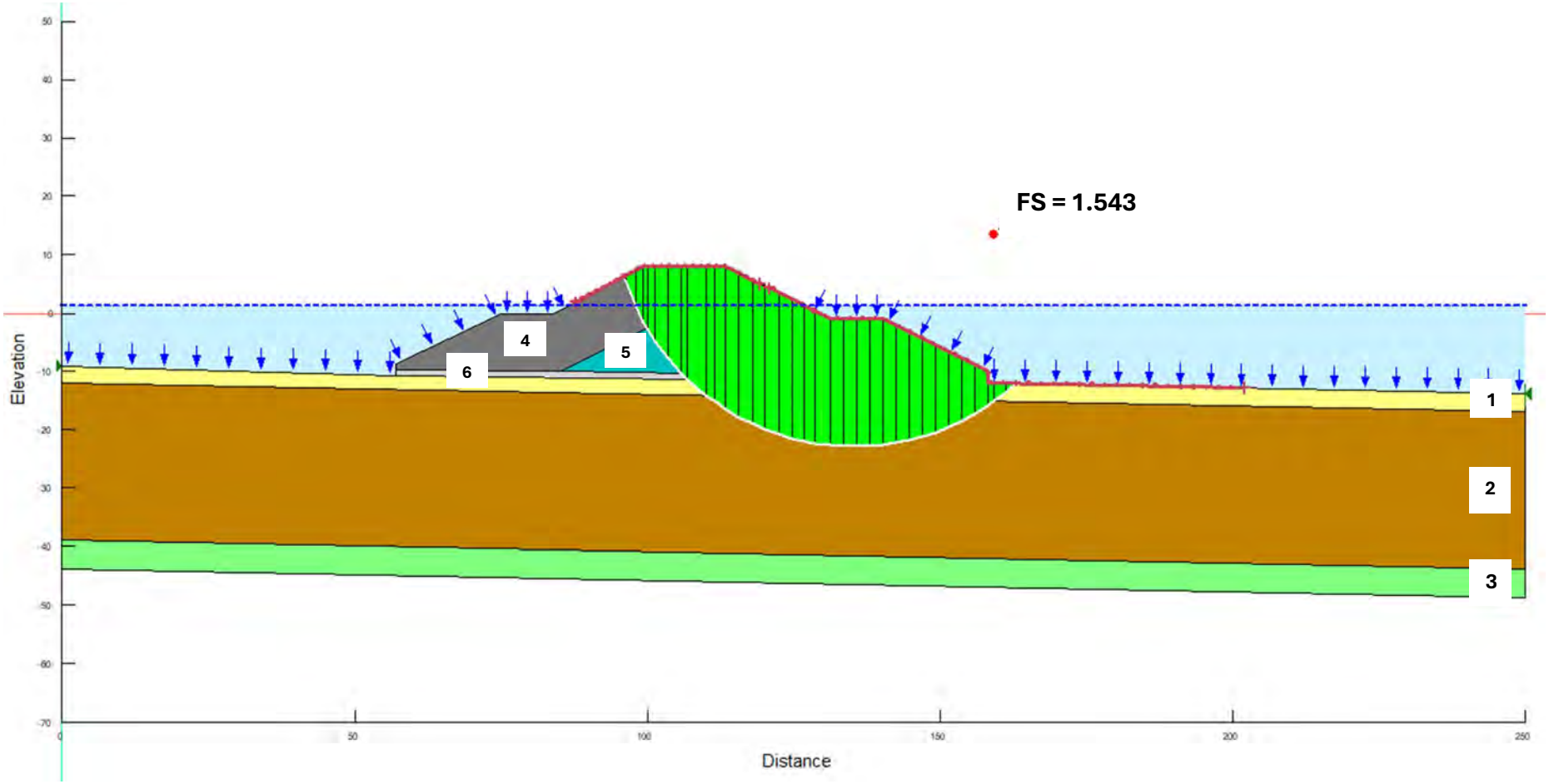
BREAKWATER STRUCTURE

SLOPE STABILITY ANALYSIS

NASA WALLOPS FLIGHT FACILITY SHORELINE PROTECTION PROJECT
SLOPE STABILITY ANALYSIS GEOSTUDIO 2024.2.1
UNDRAINED CONDITION, END OF CONSTRUCTION, SPENCER ANALYSIS, INCLUDES 1-FOOT CONSTRUCTION TOLERANCE
SLOPES 2H:1V; CREST ELEVATION +8 FEET; PIEZOMETRIC LINE MHW = +1.31

Material Number	Soil Type (USCS) or Material	Moist Unit Weight (pcf)	Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)
1 (Yellow)	SP-SM	106		30	0
2 (Brown)	CH	104		0	300 top to 675 max
3 (Green)	SC	112		34	0
4 (Dark Gray)	Armor Stone Type II		132	40	0
5 (Blue)	Class III Stone		132	40	0
6 (Light Gray)	12” Marine Mattress #2 Stone		125	34	0

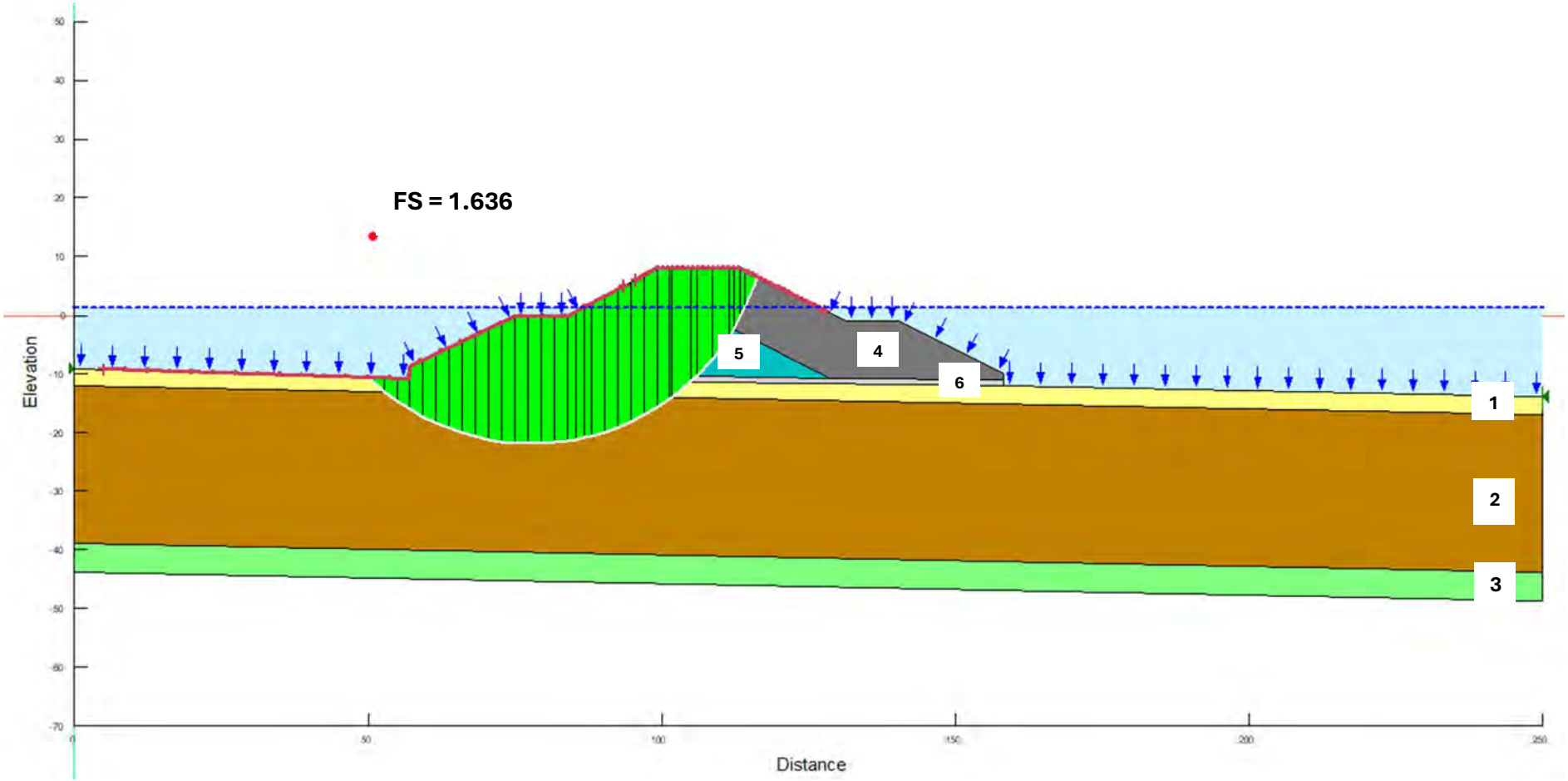
NOTE: MOHR COULOMB MATERAL MODEL FOR ALL MATERIALS EXCEPT NUMBER 2 (CH) WHICH IS: S = f(depth). Slip surface direction of movement left to right.



NASA WALLOPS FLIGHT FACILITY SHORELINE PROTECTION PROJECT
SLOPE STABILITY ANALYSIS GEOSTUDIO 2024.2.1
UNDRAINED CONDITION, END OF CONSTRUCTION, SPENCER ANALYSIS, INCLUDES 1-FOOT CONSTRUCTION TOLERANCE
SLOPES 2H:1V; CREST ELEVATION +8 FEET; PIEZOMETRIC LINE MHW = +1.31

Material Number	Soil Type (USCS) or Material	Moist Unit Weight (pcf)	Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)
1 (Yellow)	SP-SM	106		30	0
2 (Brown)	CH	104		0	300 top to 675 max
3 (Green)	SC	112		34	0
4 (Dark Gray)	Armor Stone Type II		132	40	0
5 (Blue)	Class III Stone		132	40	0
6 (Light Gray)	12” Marine Mattress #2 Stone		125	34	0

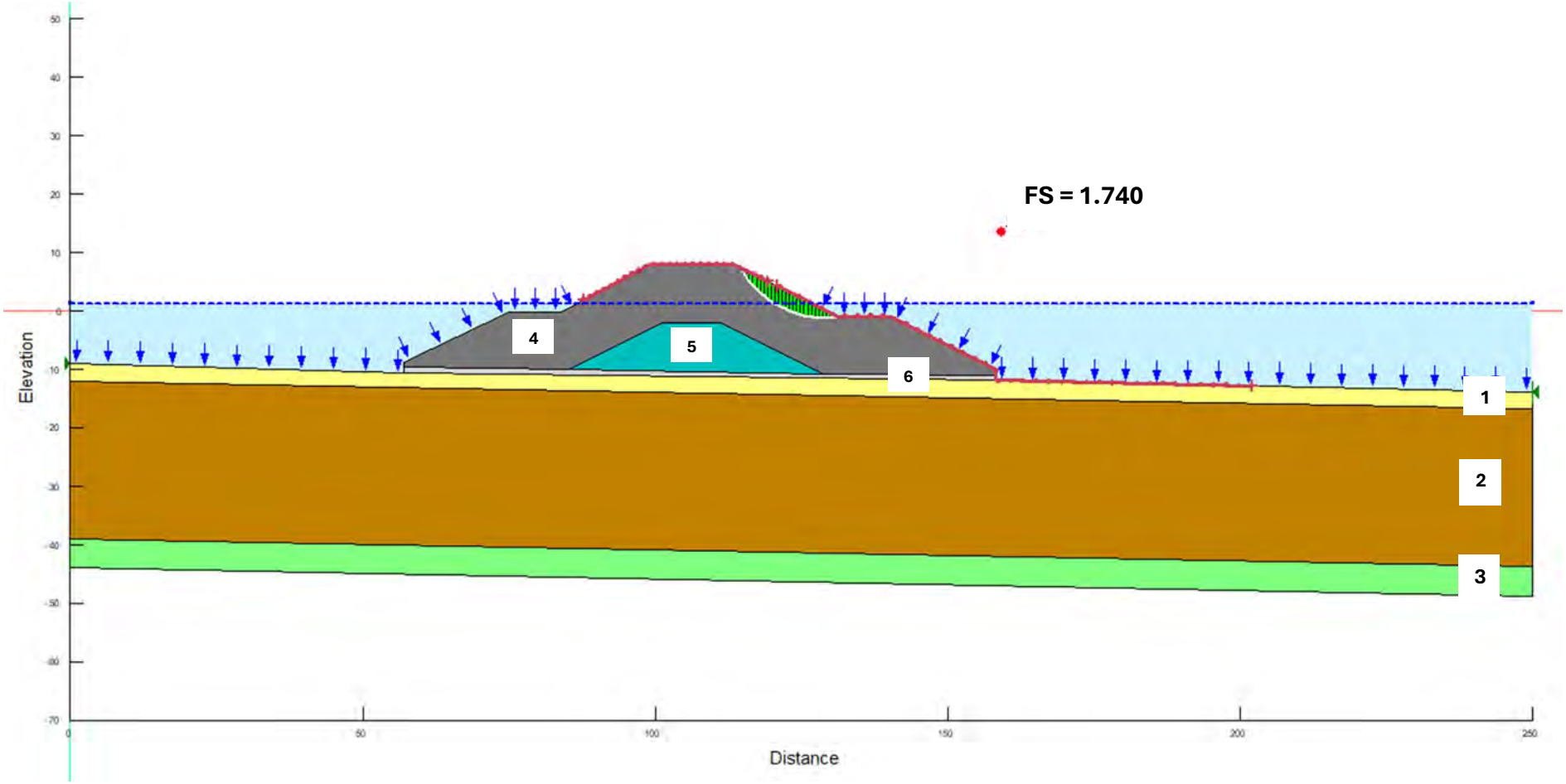
NOTE: MOHR COULOMB MATERAL MODEL FOR ALL MATERIALS EXCEPT NUMBER 2 (CH) WHICH IS: S = f(depth). Slip surface direction of movement right to left.



NASA WALLOPS FLIGHT FACILITY SHORELINE PROTECTION PROJECT
SLOPE STABILITY ANALYSIS GEOSTUDIO 2024.2.1
UNDRAINED CONDITION, END OF CONSTRUCTION, SPENCER ANALYSIS, INCLUDES 1-FOOT CONSTRUCTION TOLERANCE
SLOPES 2H:1V; CREST ELEVATION +8 FEET; PIEZOMETRIC LINE MHW = +1.31

Material Number	Soil Type (USCS) or Material	Moist Unit Weight (pcf)	Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)
1 (Yellow)	SP-SM	106		30	0
2 (Brown)	CH	104		0	600
3 (Green)	SC	112		34	0
4 (Dark Gray)	Armor Stone Type II		132	40	0
5 (Blue)	Class III Stone		132	40	0
6 (Light Gray)	12” Marine Mattress #2 Stone		125	34	0

NOTE: MOHR COULOMB MATERAL MODEL FOR ALL MATERIALS EXCEPT NUMBER 2 (CH) WHICH IS: S = f(depth). Slip surface direction of movement left to right.



NASA WALLOPS FLIGHT FACILITY SHORELINE PROTECTION PROJECT

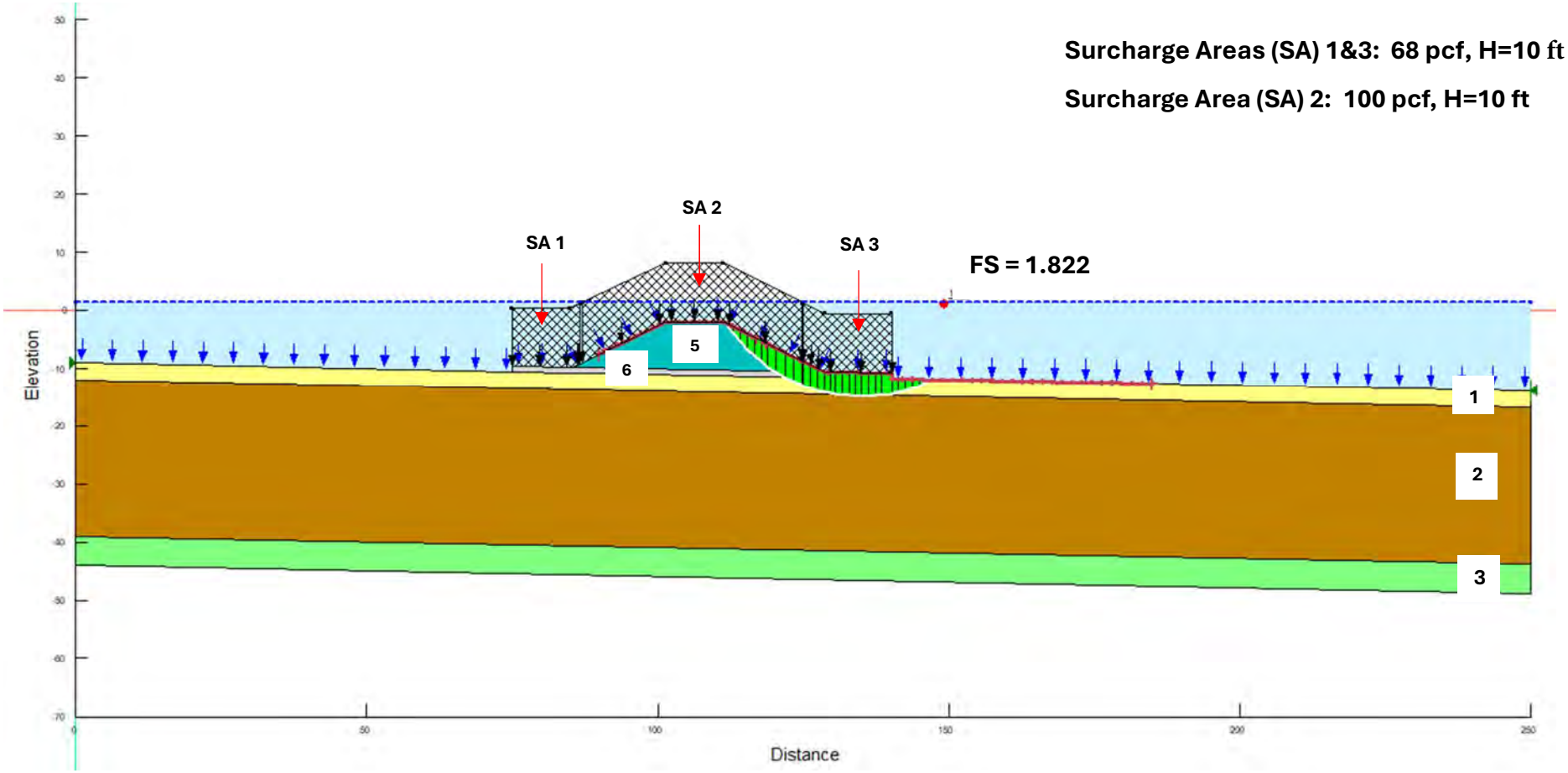
SLOPE STABILITY ANALYSIS GEOSTUDIO 2024.2.1

UNDRAINED CONDITION, END OF CONSTRUCTION, SPENCER ANALYSIS, INCLUDES 1-FOOT CONSTRUCTION TOLERANCE, SURCHARGE CONDITION

SLOPES 2H:1V; CREST ELEVATION +8 FEET; PIEZOMETRIC LINE MHW = +1.31

Material Number	Soil Type (USCS) or Material	Moist Unit Weight (pcf)	Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)
1 (Yellow)	SP-SM	106		30	0
2 (Brown)	CH	104		0	300 top to 675 max
3 (Green)	SC	112		34	0
Black Hatch Regions	Armor Stone Type II	-	-	-	-
5 (Blue)	Class III Stone		132	40	0
6 (Light Gray)	12” Marine Mattress #2 Stone		125	34	0

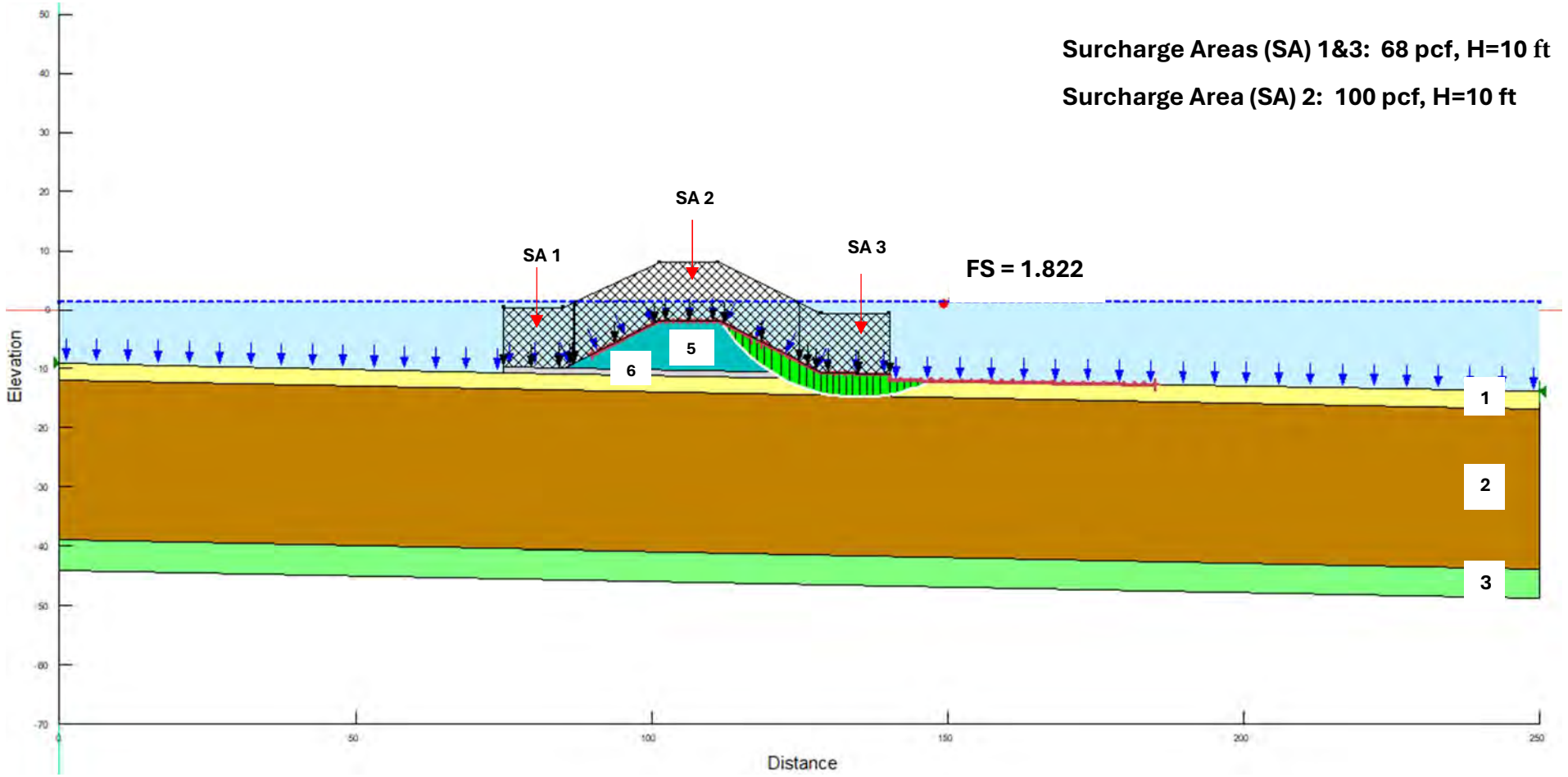
NOTE: MOHR COULOMB MATERAL MODEL FOR ALL MATERIALS EXCEPT ARMOR STONE SURCHARGE LOAD. Slip surface direction of movement left to right.



NASA WALLOPS FLIGHT FACILITY SHORELINE PROTECTION PROJECT
SLOPE STABILITY ANALYSIS GEOSTUDIO 2024.2.1
UNDRAINED CONDITION, END OF CONSTRUCTION, SPENCER ANALYSIS, INCLUDES 1-FOOT CONSTRUCTION TOLERANCE, SURCHARGE CONDITION
SLOPES 2H:1V; CREST ELEVATION +8 FEET; PIEZOMETRIC LINE MHW = +1.31

Material Number	Soil Type (USCS) or Material	Moist Unit Weight (pcf)	Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)
1 (Yellow)	SP-SM	106		30	0
2 (Brown)	CH	104		0	600
3 (Green)	SC	112		34	0
Black Hatch Regions	Armor Stone Type II	-	-	-	-
5 (Blue)	Class III Stone		132	40	0
6 (Light Gray)	12” Marine Mattress #2 Stone		125	34	0

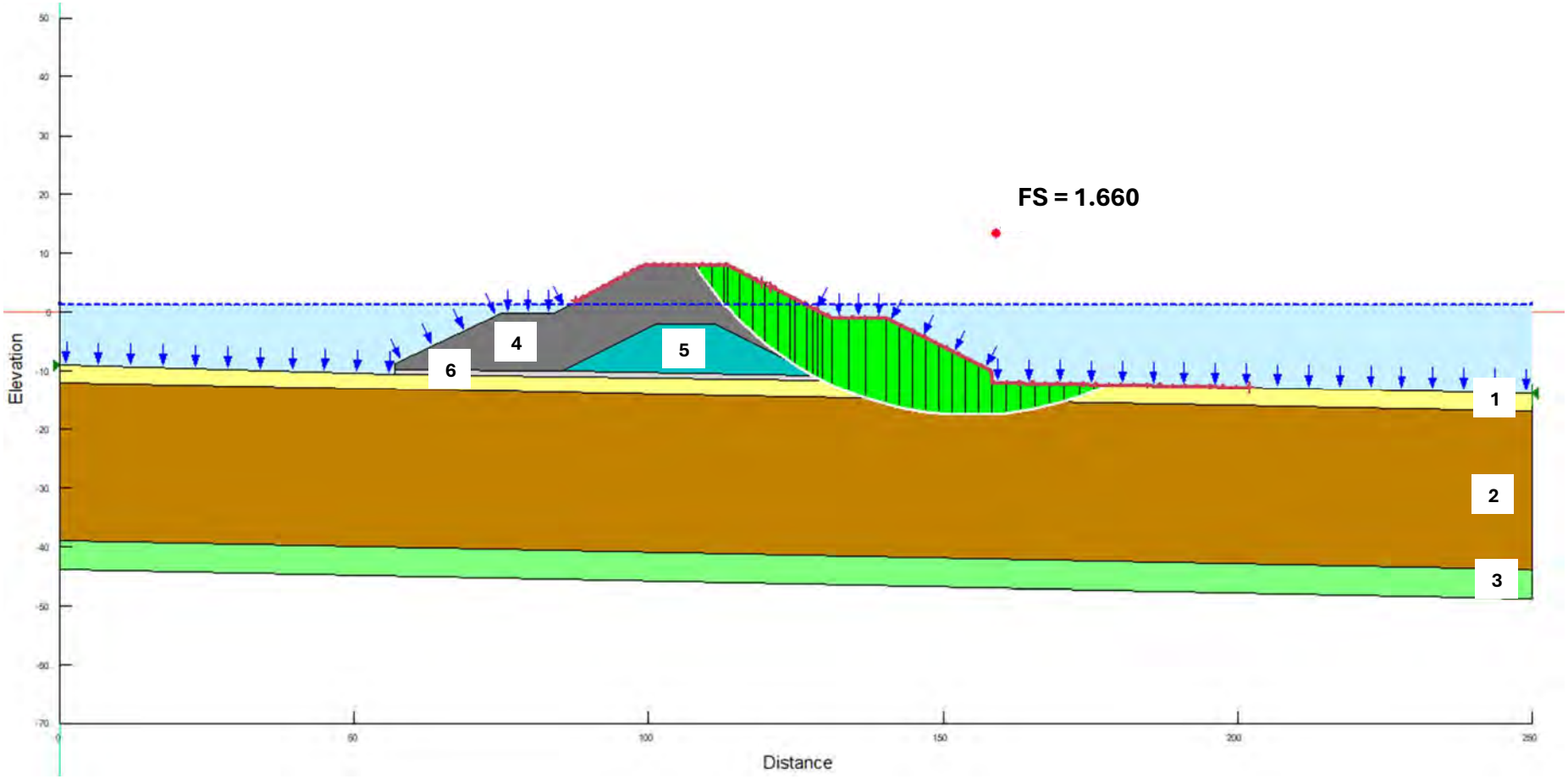
NOTE: MOHR COULOMB MATERAL MODEL FOR ALL MATERIALS EXCEPT ARMOR STONE SURCHARGE LOAD. Slip surface direction of movement left to right.



NASA WALLOPS FLIGHT FACILITY SHORELINE PROTECTION PROJECT
SLOPE STABILITY ANALYSIS GEOSTUDIO 2024.2.1
DRAINED CONDITION, LONG TERM, SPENCER ANALYSIS, INCLUDES 1-FOOT CONSTRUCTION TOLERANCE
SLOPES 2H:1V; CREST ELEVATION +8 FEET; PIEZOMETRIC LINE MHW = +1.31

Material Number	Soil Type (USCS) or Material	Moist Unit Weight (pcf)	Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)
1 (Yellow)	SP-SM	106		30	0
2 (Brown)	CH	104		25	0
3 (Green)	SC	112		34	0
4 (Dark Gray)	Armor Stone Type II		132	40	0
5 (Blue)	Class III Stone		132	40	0
6 (Light Gray)	12” Marine Mattress #2 Stone		125	34	0

NOTE: MOHR COULOMB MATERAL MODEL FOR ALL MATERIALS. Slip surface direction of movement left to right.



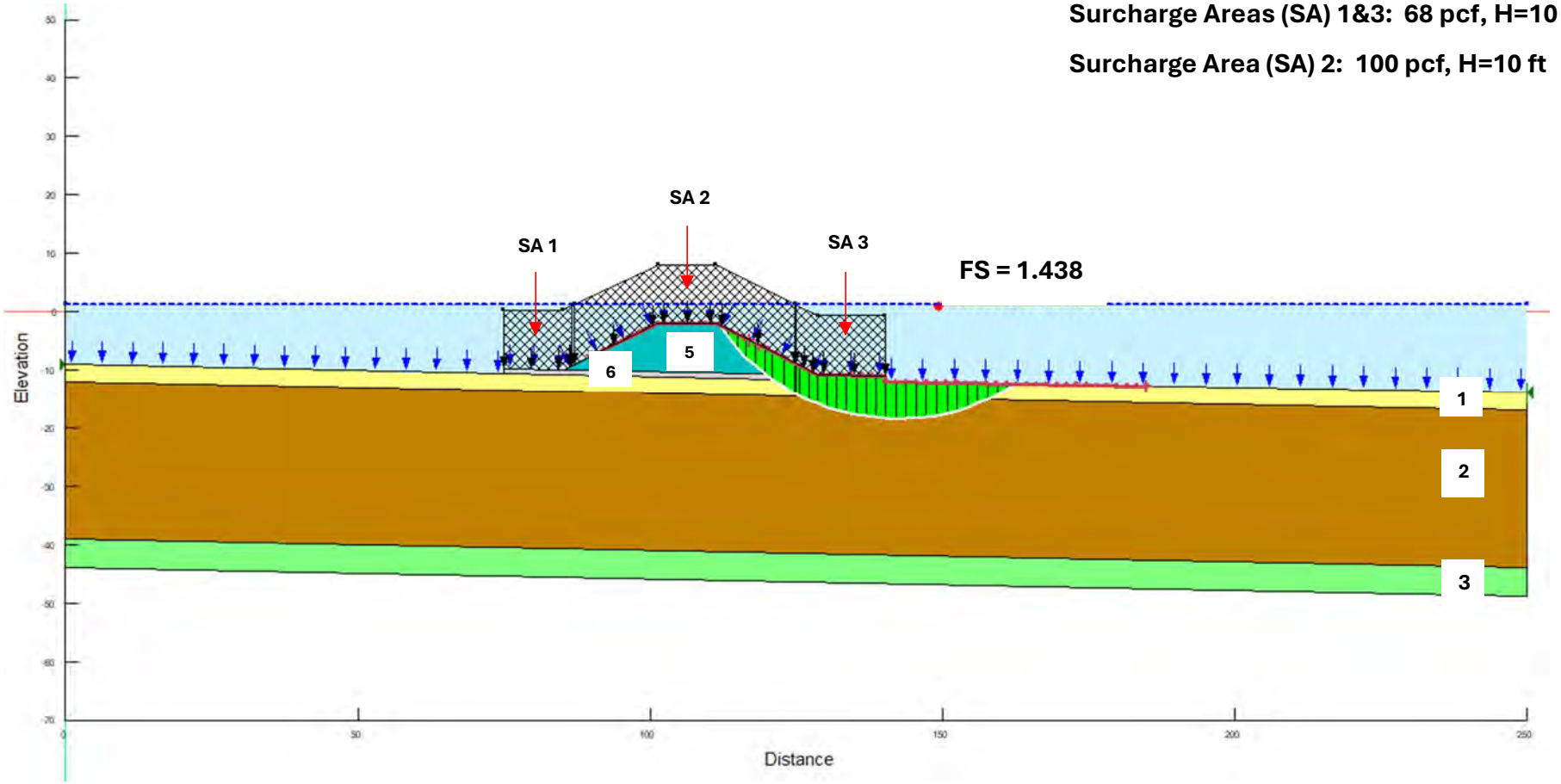
NASA WALLOPS FLIGHT FACILITY SHORELINE PROTECTION PROJECT
SLOPE STABILITY ANALYSIS GEOSTUDIO 2024.2.1
DRAINED CONDITION, LONG TERM, SPENCER ANALYSIS, INCLUDES 1-FOOT CONSTRUCTION TOLERANCE, SURCHARGE CONDITION
SLOPES 2H:1V; CREST ELEVATION +8 FEET; PIEZOMETRIC LINE MHW = +1.31

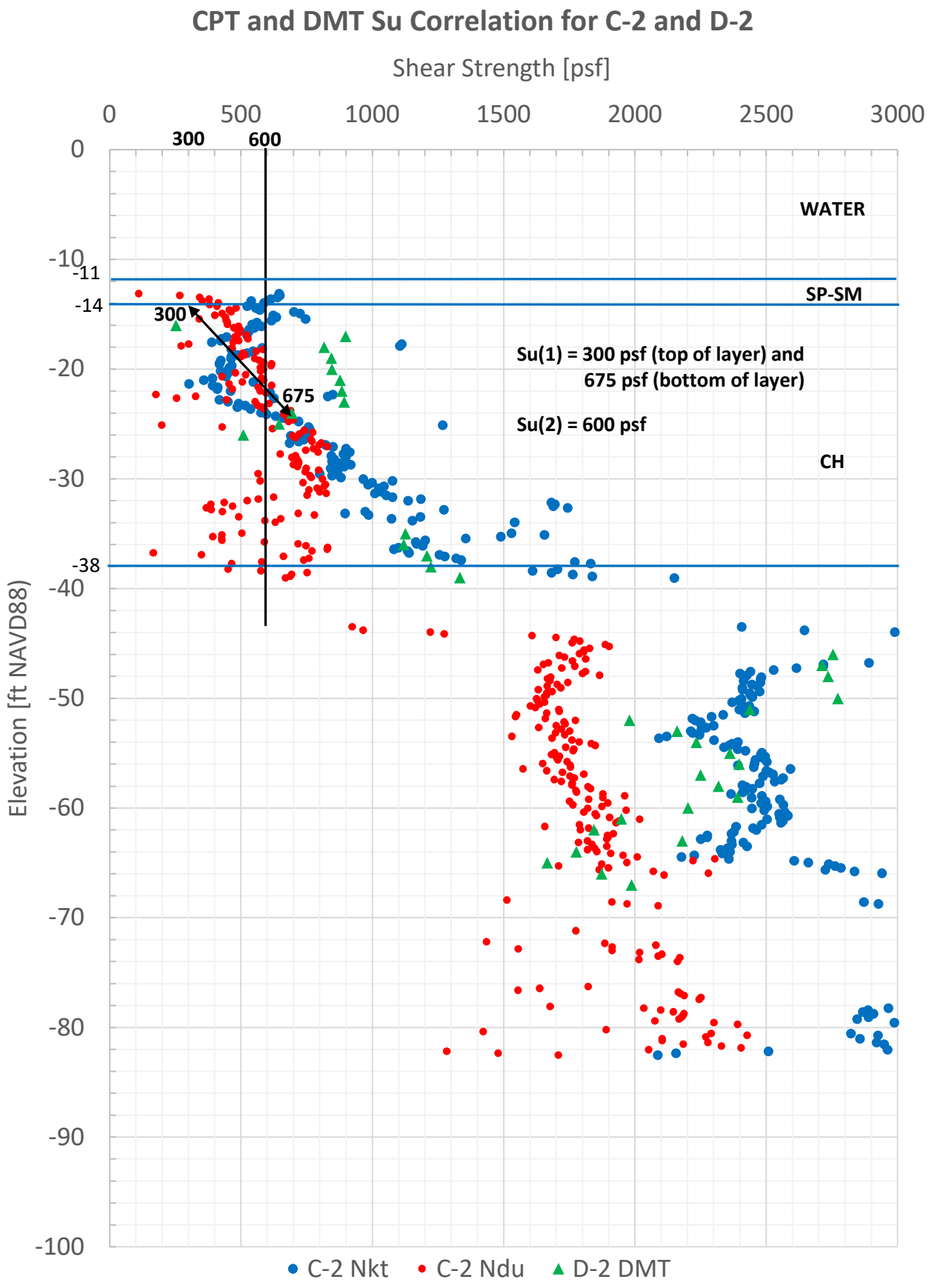
Material Number	Soil Type (USCS) or Material	Moist Unit Weight (pcf)	Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (psf)
1 (Yellow)	SP-SM	106		30	0
2 (Brown)	CH	104		25	0
3 (Green)	SC	112		34	0
Black Hatch Regions	Armor Stone Type II	-	-	-	-
5 (Blue)	Class III Stone		132	40	0
6 (Light Gray)	12” Marine Mattress #2 Stone		125	34	0

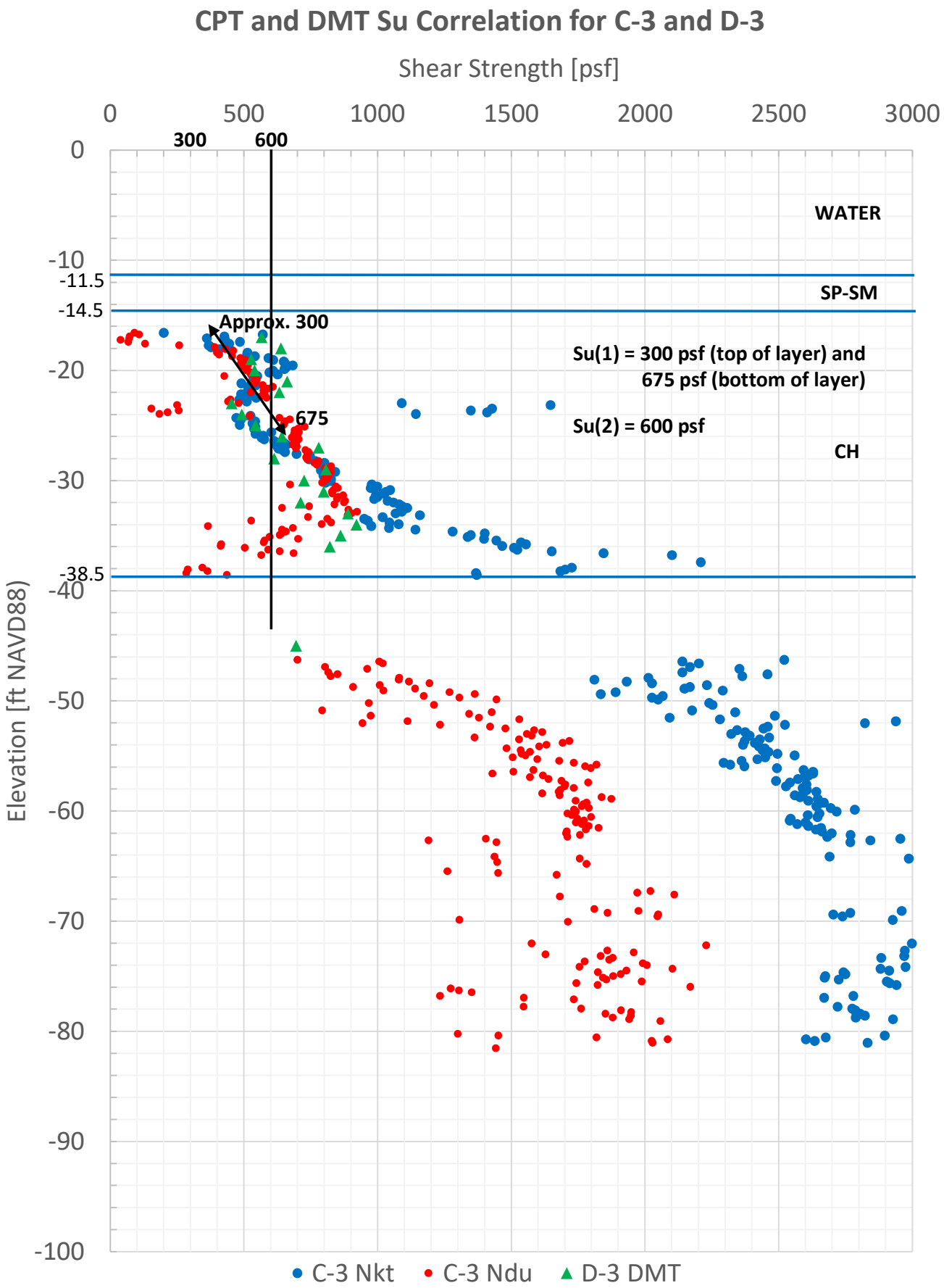
NOTE: MOHR COULOMB MATERAL MODEL FOR ALL MATERIALS EXCEPT ARMOR STONE SURCHARGE LOAD. Slip surface direction of movement left to right.

Surcharge Areas (SA) 1&3: 68 pcf, H=10 ft

Surcharge Area (SA) 2: 100 pcf, H=10 ft

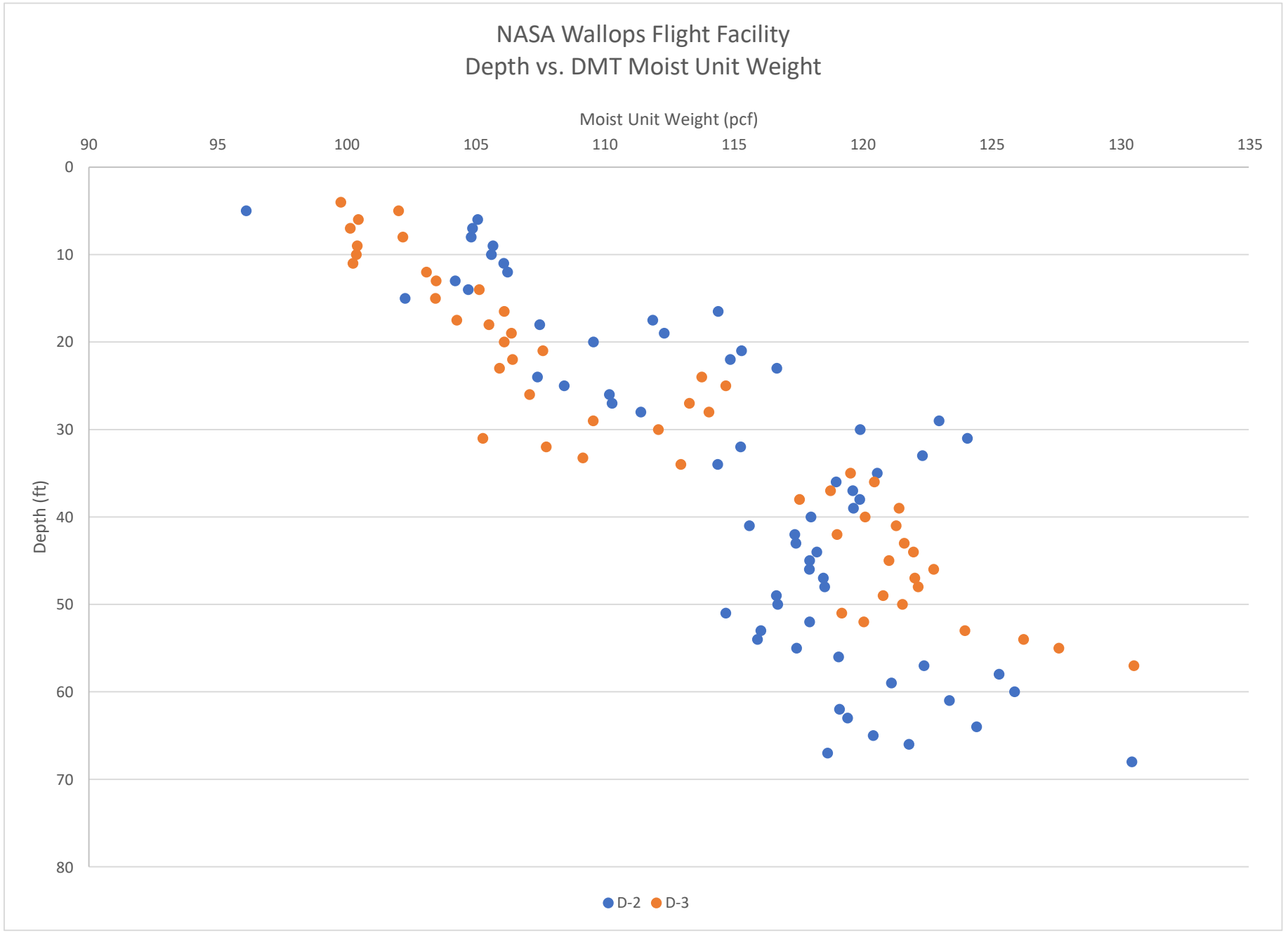



CPT and DMT Su Correlation for C-2 and D-2
Shear Strength [psf]
0
500
1000
1500
2000
2500
3000
300
600
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-11
-14
-38
WATER
SP-SM
CH
300
675
Su(1) = 300 psf (top of layer) and
675 psf (bottom of layer)
Su(2) = 600 psf
Elevation [ft NAVD88)
C-2 Nkt
C-2 Ndu
D-2 DMT


CPT and DMT Su Correlation for C-3 and D-3
Shear Strength [psf]
0
500
1000
1500
2000
2500
3000
300
600
0
-10
-11.5
-14.5
-20
-30
-38.5
-40
-50
-60
-70
-80
-90
-100
Elevation [ft NAVD88)
WATER
SP-SM
CH
Approx. 300
675
Su(1) = 300 psf (top of layer) and
675 psf (bottom of layer)
Su(2) = 600 psf
C-3 Nkt
C-3 Ndu
D-3 DMT

Total Unit Weight

Depth (ft)	D-2 (pcf)	D-3 (pcf)
0		
1		
2		
3		
4		99.78
5	96.11	102.02
6	105.09	100.46
7	104.89	100.15
8	104.84	102.19
9	105.68	100.42
10	105.62	100.38
11	106.1	100.25
12	106.25	103.1
13	104.22	103.48
14	104.72	105.15
15	102.27	103.45
16.5	114.42	106.12
17.5	111.88	104.28
18	107.5	105.53
19	112.33	106.4
20	109.58	106.12
21	115.33	107.62
22	114.89	106.44
23	116.7	105.94
24	107.41	113.78
25	108.45	114.72
26	110.2	107.1
27	110.3	113.3
28	111.42	114.06
29	122.99	109.57
30	119.93	112.1
31	124.09	105.29
32	115.29	107.75
33	122.35	
33.25		109.17
34	114.4	112.97
35	120.59	119.56
36	119	120.48
37	119.64	118.78
38	119.91	117.58
39	119.67	121.44
40	118.02	120.12
41	115.63	121.33
42	117.39	119.03
43	117.44	121.64
44	118.25	122
45	117.97	121.05
46	117.96	122.78
47	118.5	122.05
48	118.55	122.18
49	116.68	120.82
50	116.73	121.57
51	114.72	119.22
52	117.97	120.07
53	116.08	123.99
54	115.95	126.27
55	117.46	127.64
56	119.09	
57	122.41	130.55
58	125.32	
59	121.14	
60	125.92	
61	123.39	
62	119.13	
63	119.44	
64	124.45	
65	120.44	
66	121.82	
67	118.67	
68	130.47	


NASA Wallops Flight Facility
Depth vs. DMT Moist Unit Weight
Moist Unit Weight (pcf)
90
95
100
105
110
115
120
125
130
135
Depth (ft)
0
10
20
30
40
50
60
70
80
D-2
D-3

Stratigraphy

DMTs did not start until 4-5 feet bgs, so use boring B-2 for first strata from 0-3 feet bgs

Data Source	USCS/Material	Elevation Range (ft)	Depth Range (ft)	Total Unit Weight (pcf)	Phi Angle (degrees)	Undrained Shear Strength (tsf)	Undrained Shear Strength (psf)	PI	*Phi Angle (degrees)	Assumed Drain Shear Strength (tsf)	Assumed Drained Shear Strength (psf)
B-2	SP-SM	-11 to -14	0 to 3	106	30	0	0		30	0	0
D-2 and D-3	CH	-14 to -38	3 to 27	104	0		300 (top) and 675 max, and 600	27	25	0	0
D-2 and D-3	SC	-38 to -43	27 to 32	112	34	0	0		34	0	0
	Type II Stone			132	40						
	Class III Stone			132	40						
	Marine Mattress			125	34						

*EM 1110-2-1913 Design and Construction of Levees, 31 March 1978, Figure 3-2 page 3-7. Mississippi River Soil Data.

Interpolated Values:
SPT B-2, Loose 4-10, B-2 N=8, EM 1110-1-1905 31 July 2025, Table 3-6, page 49 of 408, peak friction angle is 30 degrees

Unit weights (Virginia Tech Reference)
Emperical Values for unit weight granular soils, (from Bowels, Foundation Analysis)
SP-SM: N=8, saturated unit weight for N value 4-10 is 90-115 pcf , 4/6 = 0.66 * 25 = 16.66 + 90 = 106.66 pcf

Su Values:
C-2 and D-2 and C-3 and D-3 each plotted as a set. CPT Ndu values best fit DMT data. Two interpretations for GeoStudio undrained condition: 1) 300 top of layer to 675 bottom of layer, 2) 600 psf

LL-PL =PI
55-28 = 27

For drained condition:
No PI data available in the geotechnical report for drained condition CH, OH, and CH layer. Soil layers removed. Failure circles do not pass through deeper soil strata.

All stone: unit weight from riprap-VDOT reference STD & SPEC 3.19 RIPRAP, includes assumption of 25%, generally porosity is typically EM 1110-2-1100 (Part VI) Table VI-5-51
Specification requires highest unit weight to be 175 pcf, therefore 175 pcf x 0.75 (assuming conservative 25% porosity)=132 pcf, unit weight for rock embankments typically 130-140 pcf
Angle of Internal Friction 40 to 45 degrees (assuming 40 degrees)

PI vs Phi

(1) Ref: EM 1110-2-1913 "Design & Construction of Levees" 31 March 1978 Figure 3-2 page 3-7. Mississippi River Soil Data

(2) Ref: EM 1110-2-2504 "Design of Sheet Pile Walls" 31 March 1994 Figure 3-4 page 3-7

(3) Ref: Ladd et al, 1977

PI	Phi (1)	Phi (2)	Phi (3)	
1				
2	>34	35	36	g
3		35		
4		35		
5	>34	**34**	**35**	g
6		34		
7	34	34	34	g
8	33	33		
9	33	33	34	g
10	**32**	**33**	**34**	g
11	32	32		
12	31	32	33	g
13	31	32		
14	30	31	32.5	
15	**30**	**31**	**32**	g
16	29	31	32	g
17	29	31	32	g
18	28.5	31		
19	28	30	31	g
20	**28**	**30**	**31**	g
21	27	30	31	g
22	27	30		
23	~~26~~ 27	29	31	g
24	26	29		
25	**26**	**29**	**30**	g
26	26	29	30	
27	25	29	30	
28	25	29		
29	24	28	29.5	
30	**24**	**28**	**29**	g

PI	Phi (1)	Phi (2)	Phi (3)	
31	23	28		
32	23	28		
33	23	28	29	g
34	23	27		
35	**22**	**27**	**28**	
36	22	27		
37	22	27		
38	22	27	28	
39	22	26	27	g
40	**21**	**26**	**27**	g
41		26	27	
42		26	27	
43		26		
44		26	26.5	
45	**21**	**25**	**26**	g
46		25	26.5	
47		25		
48	20	25		
49		25		
50	**20**	**25**	**26**	g
51		25	25.5	
		24		
55		**24**	**25**	
56		24		
58		24		
59		24		
60		**23**	**24**	

Revised 9/14/1999

GEOTECHNICAL INFO .COM

Career Development and Resources for Geotechnical Engineers

Soil Unit Weight

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Learning and training resources for geotechnical engineers.

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Tips for earning more respect and more money. Market yourself.

Unit Weight of Soil

Unit weight of a soil mass is the ratio of the total weight of soil to the total volume of soil.

Unit Weight, γ, is usually determined in the laboratory by measuring the weight and volume of a relatively undisturbed soil sample obtained from a brass ring. Measuring unit weight of soil in the field may consist of a sand cone test, rubber balloon or nuclear densiometer.

Empirical values for γ, of granular soils based on the standard penetration number, (from Bowels, *Foundation Analysis*).

SPT Penetration, N-Value (blows/ foot)	γ (lb/ft^3)
0 - 4	70 - 100
4 - 10	90 - 115
10 - 30	110 - 130
30 - 50	110 - 140
>50	130 - 150

Empirical values for γ, of cohesive soils based on the standard penetration number, (from Bowels, *Foundation Analysis*).

SPT Penetration, N-Value (blows/ foot)	γ_{sat} (lb/ft^3)
0 - 4	100 - 120
4 - 8	110 - 130
8 - 32	120 - 140

Typical Soil Characteristics (from Lindeburg, *Civil Engineering Reference Manual for the PE Exam, 8th ed.*)

Soil Type	γ (lb/ft^3)	γ_{sat} (lb/ft^3)
Sand, loose and uniform	90	118
Sand, dense and uniform	109	130
sand, loose and well graded	99	124
Sand, dense and well graded	116	135
glacial clay, soft	76	110
glacial clay, stiff	106	125

Typical Values of Soil Index Properties (from *NAVFAC 7.01*)

Soil Type	γ (lb/ft^3)	γ_{sub} (lb/ft^3)
Sand; clean, uniform,		

Technical Resources

- Bearing Capacity
- Cold Weather Engineering
- Compaction
- Dams
- Earthquake Engineering
- Earthwork
- Excavation
- Erosion Control
- Field Testing
- Foundations
- Geophysics
- Geosynthetics
- Laboratory Testing
- Materials
- Grouting
- Instrumentation
- Landfills
- Pavement Analysis
- Quality Assurance/ Control
- Reconnaissance
- Retaining Walls
- Seepage
- Settlement Analysis
- Slope Stability
- Soil Stabilization
- Subsurface Investigations
- Tunneling

Other Geotechnical Links

Other Geotechnical Resources

- Geotechnical Forum
- Geotechnical Glossary
- Publications
- Software
- Geotechnical Training
- Career Development
- Geotechnical Societies and Institutes
- Teaching Resources
- Services and Supplies
- Other Quality Geotechnical Websites
- Engineering

fine or medium	84 - 136	52 - 73
Silt; uniform, inorganic	81 - 136	51 - 73
Silty Sand	88 - 142	54 - 79
Sand; Well-graded	86 - 148	53 - 86
Silty Sand and Gravel	90 - 155	56 - 92
Sandy or Silty Clay	100 - 147	38 - 85
Silty Clay with Gravel; uniform	115 - 151	53 - 89
Well-graded Gravel, Sand, Silt and Clay	125 - 156	62 - 94
Clay	94 - 133	31 - 71
Colloidal Clay	71 - 128	8 - 66
Organic Silt	87 - 131	25 - 69
Organic Clay	81 - 125	18 - 62

- Marketing Average Salaries

Typical Soil Characteristics (from Lindeburg, *Civil Engineering Reference Manual for the PE Exam, 8th ed.*)

Soil Type	γ (lb/ft^3)	γ_{sat} (lb/ft^3)
Sand, loose and uniform	90	118
Sand, dense and uniform	109	130
sand, loose and well graded	99	124
Sand, dense and well graded	116	135
glacial clay, soft	76	110
glacial clay, stiff	106	125

Other soil and soil related properties are listed below:

Angle of Internal Friction
Bearing Capacity Factors
Cohesion
External Friction Angle
Factor of Safety
Lateral Earth Pressure Coefficients
Modulus of Vertical Subgrade Reaction
Soil Unit Weights
Young's Modulus or modulus of elasticity

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a method specification. Because of the nature of the material, compaction testing is generally not feasible. The specification allows for a broad range of material and properties such that the internal friction angle and unit weight can vary considerably based on the amount and type of rock in the fill. Rock excavated from cuts consisting of siltstone, sandstone and claysto ring the compaction process, resulting in less coarse material. A , failure may occur through the rock fragments rather than arc s of materials, the strength parameters may resemble those of earth embankments. For existing embankments, the soft rock may continue to weather with time, if the embankment materials continue to become wet. For embankments constructed of sound rock, the strength parameters may be much higher. For compacted earth embankments with sound rock, internal friction angles of up to 45 degrees may be reasonable. Unit weights for rock embankments generally range from 130 to 140 pcf.

Note the difference of unit weights below.

Quarry Spalls and Rip Rap – Quarry spalls, light loose rip rap and heavy loose rip rap created from shot rock are often used as fill material below the water table or in shear keys in slope stability and landslide mitigation applications. WSDOT Standard Specification Section 9-13 provides minimum requirements for degradation and specific gravity for these materials. Therefore sound rock must be used for these applications. For design purposes, typical values of 105 to 120 pcf for the unit weight (this considers the large amount of void space due to the coarse open gradation of this type of material) and internal angles of friction of about 40 to 45 degrees should be used.

assuming 165 pcf, this is 27 to 36% voids

Wood Fiber – Wood fiber fills have been used by WSDOT for over 30 years in fill heights up to about 40 feet. The wood fiber has generally been used as light-weight fill material over soft soil to improve embankment stability. Wood fiber has also been used in emergency repair because rain and wet weather does not affect the placement and compaction of the embankment. Only fresh wood fiber should be used to prolong the life of the fill, and the maximum particle size should be 6 inches or less. The wood fiber is generally compacted in lifts of about 12 inches with two passes of a track dozer. Presumptive design values of 50 pcf for unit weight and an internal angle of friction of about 40 degrees may be used for the design of the wood fiber fills (Allen et al., 1993).

To mitigate the effects of leachate, the amount of water entering the wood should be minimized. Generally topsoil caps of about 2 feet in thickness are used. The pavement section should be a minimum of 2 feet (a thicker section may be needed depending on the depth of wood fiber fill). Wood fiber fill will experience creep settlement for several years and some pavement distress should be expected during that period. Additional information on the properties and durability of wood fiber fill is provided in Kilian and Ferry (1993).

Geofoam – Geofoam has been used as lightweight fill on WSDOT projects since 1995. Geofoam ranges in unit weight from about 1 to 2 pcf. Geofoam constructed from expanded polystyrene (EPS) is manufactured according to ASTM standards for minimum density (ASTM C 303), compressive strength (ASTM D 1621) and water absorption (ASTM C 272). Type I and II are generally used in highway applications. Bales of recycled industrial polystyrene waste are also available. These bales have been used to construct temporary haul roads over soft soil. However, these bales should not be used in permanent applications.

Table VI-5-51
Layer Coefficient and Porosity for Various Armor Units

Armor Unit	n	Placement	Layer Coefficient k_Δ	Porosity P (percent)
Quarrystone (smooth)[1]	2	Random	1.02	38
Quarrystone (rough)[2]	2	Random	1.00	37
Quarrystone (rough)[2]	∃3	Random	1.00	40
Quarrystone (parallepiped)[3]	2	Special	--	27
Quarrystone[4]	Graded	Random	--	37
Cube (modified)[1]	2	Random	1.10	47
Tetrapod[1]	2	Random	1.04	50
Tribar[1]	2	Random	1.02	54
Tribar[1]	1	Uniform	1.13	47
dolos[5]	2	Random	0.94	56
Core-Loc[6] Vol. < 5 m^3 5 < Vol. < 12 m^3 12 < Vol. < 22m^3	1	Random	1.51	60 63 64
Accropod[7] Vol. < 5 m^3 5 < Vol. < 12 m^3 12 < Vol. < 22m^3	1	Random	1.51	57 59 62

[1] Hudson (1974)
[2] Carver and Davidson (1983)
[3] Layer thickness is twice the average long dimension of the parallelepiped stones. Porosity is estimated from tests on one layer of uniformly placed modified cubes (Hudson 1974).
[4] The minimum layer thickness should be twice the cubic dimension of the W_{50} riprap. Check to determine that the graded layer thickness is ∃1.25 the cubic dimension of the W_{max} riprap (see Equations VI-5-119 and VI-5-120).
[5] Carver and Davidson (1977)
[6] Turk and Melby (1997)
[7] Accropod informational brochure

BREAKWATER STRUCTURE

SEISMIC SITE CLASSIFICATION

NASA Wallops | Seismic Site Class | 12/5/25

ASCE 7-16 Ch 4 and Table 20.3-1 of ASCE 7-16

Boring Location B-2

0'-2.8' SP-SM

2.8'-27' CH PI = LL - PL = 55 - 28 = 27, MC = 34.3%

27'-32' SC

32'-34' CH

34'-42' OH

42'-58.5' CH

DMT Locations D-2 & D-3, values of undrained shear strength range from 260 psf to 675 psf

Site Class E soft clay soil (CH) 2.8'-27'

- Profile more than 10 ft ✓
- PI > 20 ✓
- MC = 34.3% (but is saturated offshore environment)
- $\bar{s}_u$ 260 psf - 675 psf ✓
- $\bar{N}$ < 15 ✓ (WOH pretty consistent to 27')

* Does not meet Site Class F Requirements

∴ Site Classification is E

No threat to human life in the event of failure therefore:

Risk Category I

IBC 2024 Table 1604.5 - Risk Category of Buildings & Other Structures

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: **B-2**
Contract Number: 18C13074
Sheet: 1 of 2

Contractor: Fishbume Drilling, Inc.
Chesapeake, Virginia
Contractor Foreman: J. Raasio
Schnabel Representative: E. Bradshaw
Equipment: CME-55 (Track)
Method: 3-7/8" O.D. Tri-cone Roller Bit

Hammer Type: Auto Hammer (140 lb)
Dates Started: 6/10/18 **Finished:** 6/10/18
Location: See Location Plan

Ground Surface Elevation: -11± (ft) **Total Depth:** 58.5 ft

Groundwater Observations

Date	Time	Depth	Casing	Caved

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND WITH SILT, fine to medium grained sand; wet, brown and gray, contains shell fragments	SP-SM		A1		S-01, SPT 2+4+4+1 REC=16", 67%		QUATERNARY DEPOSITS
2.8	FAT CLAY; wet, bluish gray, contains organic matter		-13.8			S-02, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
					5	S-03, SPT WOH/24" REC=24", 100%	MC = 47.1% PP <0.25 tsf	
						S-04, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
						S-05, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
					10			
	Change: dark brown	CH		A2		S-06, SPT 1+1+1+1 REC=24", 100%	PP = 0.50 tsf	
					15	UD-1, UNDIST REC=21", 88%	LL = 55 PL = 28 MC = 34.3% % Passing #200 = 99.4	
	Change: gray					S-07, SPT WOH/24" REC=24", 100%	PP = 0.50 tsf PP <0.25 tsf	
					20			
						S-08, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
					25			
27.0	CLAYEY SAND, fine to medium grained sand; wet, gray, contains shell fragments	SC	-38.0	A1		S-09, SPT 6+5+6+5 REC=24", 100%		
					30			
32.0	FAT CLAY; wet, dark gray, contains organic matter	CH	-43.0	A2		S-10, SPT WOH+2+4+5 REC=24", 100%	PP = 0.50 tsf	
34.0	ORGANIC CLAY; wet, dark brown	OH	-45.0	A3			MC = 187.1%	

(continued)

TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/6/18

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: B-2
Contract Number: 18C13074
Sheet: 2 of 2

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Change: brownish gray	OH		A3	40	S-11, SPT 1+1+1+2 REC=24", 100%	MC = 85.5% PP = 1.00 tsf	
42.0	FAT CLAY WITH SAND; wet, greenish gray, contains organic matter		-53.0					
					45	S-12, SPT WOH+1+2+2 REC=24", 100%	PP = 1.00 tsf	
		CH		A2	50	S-13, SPT WOH+2+2+2 REC=24", 100%	MC = 41.4% PP = 1.50 tsf	
					55	S-14, SPT 1+1+1+3 REC=24", 100%	PP = 1.00 tsf	
						S-15, SPT WOH+1+2+4 REC=24", 100%	PP = 0.50 tsf	
58.5			-69.5					

Bottom of Boring at 58.5 ft.
Boring terminated at selected depth.
Boring backfilled with cuttings upon completion.
11 ft of water at boring location.

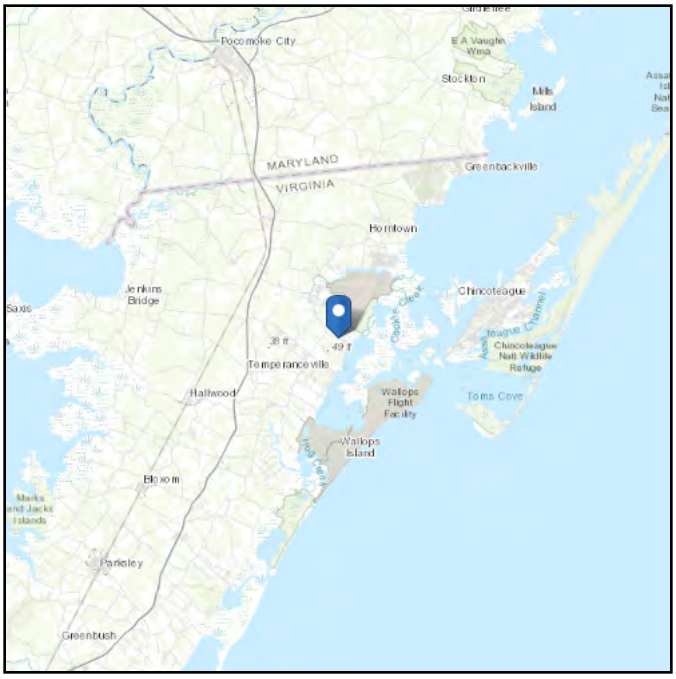
TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/6/18

ASCE Hazards Report

Address:
Nasa Wallops Flight Facility - Wallops Island
,

Standard:	ASCE/SEI 7-16	**Latitude:**	37.911881
Risk Category:	I	**Longitude:**	-75.48454
Soil Class:	E - Soft Clay Soil	**Elevation:**	35.5886329301748 ft (NAVD 88)





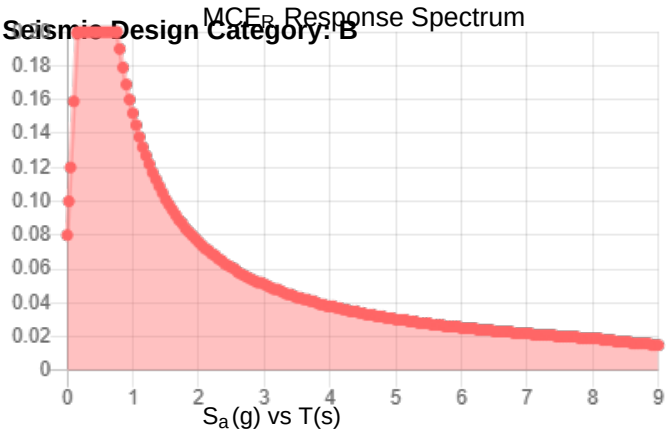
Seismic

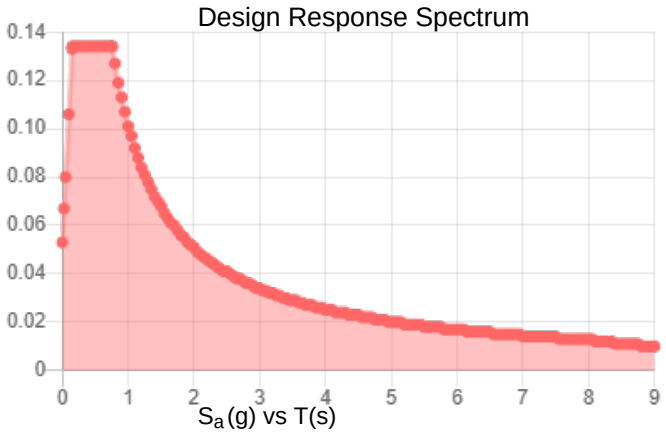
Site Soil Class: E - Soft Clay Soil

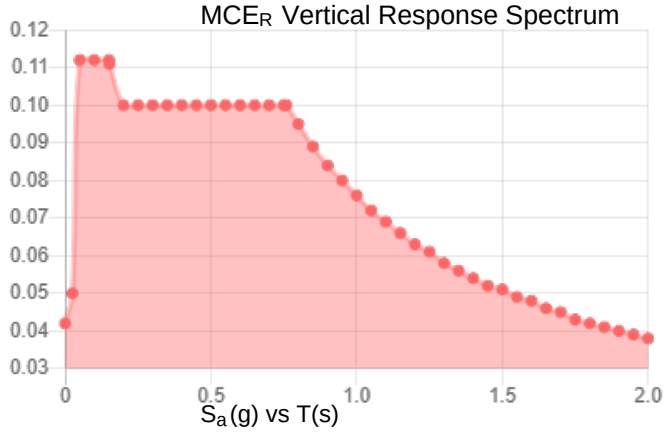
Results:

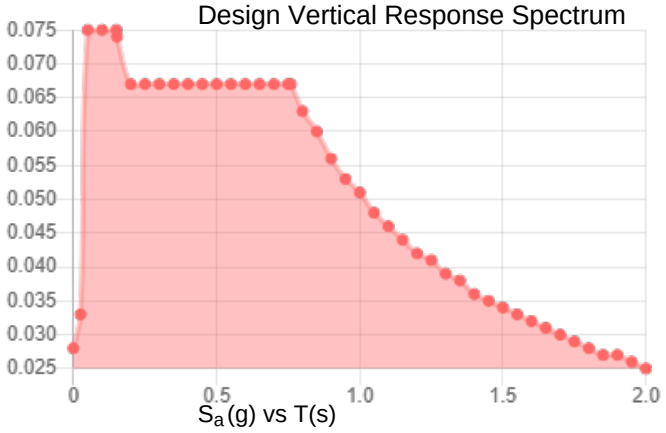
S_S :	0.083	S_{D1} :	0.101
S_1 :	0.036	T_L :	8
F_a :	2.4	PGA :	0.039
F_v :	4.2	PGA_M :	0.095
S_{MS} :	0.2	F_{PGA} :	2.4
S_{M1} :	0.152	I_e :	1
S_{DS} :	0.134	C_v :	0.7

Seismic Design Category: B









Data Accessed: Sun Dec 07 2025

Date Source:

USGS Seismic Design Maps based on ASCE/SEI 7-16 and ASCE/SEI 7-16 Table 1.5-2. Additional data for site-specific ground motion procedures in accordance with ASCE/SEI 7-16 Ch. 21 are available from USGS.

The ASCE Hazard Tool is provided for your convenience, for informational purposes only, and is provided “as is” and without warranties of any kind. The location data included herein has been obtained from information developed, produced, and maintained by third party providers; or has been extrapolated from maps incorporated in the ASCE standard. While ASCE has made every effort to use data obtained from reliable sources or methodologies, ASCE does not make any representations or warranties as to the accuracy, completeness, reliability, currency, or quality of any data provided herein. Any third-party links provided by this Tool should not be construed as an endorsement, affiliation, relationship, or sponsorship of such third-party content by or from ASCE.

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Announcement
ASCE 7-22 is now available.

Wallops Island Flight Facility Shoreline Protection Project

Wallops Island, Virginia, USA

Latitude, Longitude: 37.8815432, -75.437386



Date	12/7/2025, 10:26:15 AM
Design Code Reference Document	ASCE7-16
Risk Category	I
Site Class	E

Type	Value	Description
S_S	0.082	MCE_R ground motion. (for 0.2 second period)
S_1	0.036	MCE_R ground motion. (for 1.0s period)
S_{MS}	0.196	Site-modified spectral acceleration value
S_{M1}	0.151	Site-modified spectral acceleration value
S_{DS}	0.131	Numeric seismic design value at 0.2 second SA
S_{D1}	0.101	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	B	Seismic design category
F_a	2.4	Site amplification factor at 0.2 second
F_v	4.2	Site amplification factor at 1.0 second
PGA	0.038	MCE_G peak ground acceleration
F_{PGA}	2.4	Site amplification factor at PGA
PGA_M	0.092	Site modified peak ground acceleration
T_L	8	Long-period transition period in seconds
SsRT	0.082	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	0.087	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.036	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.04	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.6	Factored deterministic acceleration value. (1.0 second)

Type	Value	Description
PGAd	0.5	Factored deterministic acceleration value. (Peak Ground Acceleration)
PGA_{UH}	0.038	Uniform-hazard (2% probability of exceedance in 50 years) Peak Ground Acceleration
C_{RS}	0.936	Mapped value of the risk coefficient at short periods
C_{R1}	0.907	Mapped value of the risk coefficient at a period of 1 s
C_V	0.7	Vertical coefficient

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APPENDIX C

2018 SCHNABEL ENGINEERING GEOTECHNICAL REPORT

REVISION NO. 1
GEOTECHNICAL ENGINEERING REPORT

Wallops Island Breakwaters
Wallops Island, Virginia

Schnabel Reference 18C13074
August 21, 2018

Prepared For: U.S. Army Corps of Engineers



Schnabel ENGINEERING

Schnabel ENGINEERING

August 21, 2018

Mr. Julio Altuna
NCAC & IIES PM
U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, VA 23510-1096

Subject: **Project 18C13074, Revision No. 1, Geotechnical Engineering Report, Wallops Island Breakwaters, Wallops Island, Virginia**

Dear Mr. Altuna:

SCHNABEL ENGINEERING, LLC (Schnabel) is pleased to submit our revised geotechnical engineering report for this project. This study was performed in accordance with our revised proposal dated April 26, 2018, as authorized by the USACE on May 22, 2018.

PROJECT AND SITE DESCRIPTION

The project site is located offshore of the NASA Facility located on the northern portion of Wallops Island. The project site is approximately 3 miles long and the seafloor is at about El -6 to -11.

We understand proposed construction consists of five to eight detached breakwaters at Wallops Island. The exact number and location of the breakwaters is still under consideration. However, we understand the breakwaters are anticipated to be approximately 300 to 1,000 feet offshore and will be built of a 12" maritime mattress below a section of VDOT Class II riprap with a six foot cover of VDOT Type I riprap. The top of the breakwaters will be at EL 5, with a top width of 10 ft. Exact breakwater lengths were not available at the writing of this report, but proposed breakwater limits are approximately 3 miles apart and span the majority of the developed beachfront.

We obtained the site information from the Spring 2018 Survey received from USACE on July 2, 2018. We obtained the project information from USACE on July 2, 2018. A Site Vicinity Map is included as Figure 1.

SUBSURFACE EXPLORATION AND LABORATORY TESTING PROGRAM

We performed a subsurface exploration and field testing program to identify the subsurface stratigraphy underlying the site and to evaluate the geotechnical properties of the materials encountered. This program included test borings, and cone penetration test (CPT) and dilatometer test (DMT) soundings. Exploration methods used are discussed below. The appendices contain the results of our exploration.

Subsurface Exploration Methods

Test Borings

Our subcontractor, Fishburne Drilling, Inc., drilled 5 test borings under our observation between June 10 and June 14, 2018. The Standard Penetration Test (SPT) was performed at selected depths in the borings. Appendix A includes specific observations, remarks, and logs for the borings; classification criteria; drilling methods; and sampling protocols. Figure 2, included at the end of this report, indicates the approximate test boring locations. We will retain soil samples up to 45 days beyond the issuance of this report, unless you request other disposition.

The SPT samples were obtained using a hydraulically driven automatic trip hammer (ATH). Most correlations with SPT data are based on N-values collected with a safety hammer. The energy applied to the split-spoon sampler using the ATH is about 33 percent greater than that applied using the safety hammer, resulting in lower N-values. The hammer blows shown on the boring logs are uncorrected for the higher energy. However, we correct SPT N values for the higher energy when using N values in our analyses.

In Situ Testing

In addition to the SPTs performed in the test borings, we conducted in-situ cone penetrometer (CPT) and dilatometer (DMT) tests to further establish the geotechnical properties of the materials encountered at the site. Our subcontractor, ConeTec, Inc. performed 7 CPTs and 8 DMTs on the site. A detailed description of the CPT and DMT equipment, test methods and results are in Appendix C. Figure 2 indicates the approximate CPT and DMT locations. CPeT-IT software was used to interpret the CPT results. This data is also provided in Appendix C.

Soil Laboratory Testing

Our laboratory performed tests on selected samples collected during the subsurface exploration. The testing aided in the classification of materials encountered in the subsurface exploration and provided data for use in the development of recommendations for the settlement of the breakwater structures. We performed gradation analyses, Atterberg Limits, and moisture content analyses on selected samples. We also performed three one-dimensional consolidation tests on samples of fine-grained soil encountered. The results of the laboratory tests are included in Appendix B and are summarized for each stratum in the Site Geology and Subsurface Conditions section of this report. Selected test results are also shown on the boring logs in Appendix A.

SITE GEOLOGY AND SUBSURFACE CONDITIONS

Site Geology

We reviewed existing geologic data and information in our files. Based on this review, the geologic stratigraphy consists of Quaternary-age alluvial and intertidal deposits overlaying the Yorktown Formation. The Yorktown Formation is a late Pliocene age deposit. It typically consists of silty sands and clayey sands containing shell fragments. These soils are preconsolidated and exhibit high strength and

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low compressibility. Yorktown Formation soils are sensitive to disturbance and exhibit higher strengths than would be indicated by Standard Penetration Test data.

Generalized Subsurface Stratigraphy

We characterized the following generalized subsurface stratigraphy based on the exploration and laboratory test data included in the appendices.

Stratum A: Quaternary Deposits

From the top of the mudline to about El -39.5 to -57, the borings encountered Quaternary deposits. However, at locations B-2, C-2, C-3, D-2, and D-3 where the deposits were encountered to maximum depth of El -75.5 in Boring B-2, these deposits consist of three interlayered soil types coarse-grained (A1), fine-grained (A2), and organic (A3).

Stratum A1: Coarse-Grained Quaternary Deposits

The coarse-grained Quaternary-age deposits were typically encountered at the mudline to about El -42.5 to -57. However, at locations B-2, C-2, D-2, and D-3 the coarse-grained deposits were encountered to the maximum depth of exploration El -79.5. These soils were also interlayered with the soils of Stratum A2 and A3.

These soils consist of CLAYEY SAND (SC), SILTY SAND (SM), POORLY-GRADED SAND WITH SILT (SP-SM), or POORLY-GRADED GRAVEL WITH SILT AND SAND (GP-GM) with varying amounts of organic matter and shell fragments. The natural moisture contents measured were about 25 and 28 percent. Based on the Standard Penetration Tests performed, this stratum is generally loose to medium dense: N = 3 to 29. However, very loose soils were encountered about three feet below the mudline in B-3.

CPT testing performed in Stratum A1 indicated cone tip resistances of about 6 to 100 tsf. Correlations with the CPT data indicated angles of internal friction of about 33 to 40 degrees for this stratum. DMT testing performed in Stratum A1 resulted in dilatometer moduli of about 150 to 3200 tsf. Correlations with the dilatometer data indicate angles of internal friction of about 32 to 40 degrees for this stratum.

Stratum A2: Fine-Grained Quaternary Deposits

The fine-grained Quaternary-age deposits were typically encountered below the upper layer of Stratum A1 to about El -38 to -51. However, at locations B-2, C-2, C-3 and D-2 these fine-grained soils were encountered to a maximum depth of El -82.5. These soils were also interlayered with the soils of Stratum A1 and A3.

The fine-grained Quaternary deposits consist of FAT CLAY (CH) and LEAN CLAY WITH SAND (CL) with varying amounts of sand, shell fragments, and organic matter. These soils were generally of moderate to high plasticity having Liquid Limits between 31 and 55, and Plasticity Indices of 12 to 32. The natural moisture contents measured were between about 26 and 55 percent. Based on the Standard Penetration Tests performed, this stratum is generally very soft to medium stiff: N = 0 to 6.

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CPT testing performed in Stratum A2 indicated cone tip resistances of about 2 to 31 tsf. Correlations with the CPT data indicated undrained shear strengths of 0.34 to 1.56 tsf for this stratum. DMT testing performed in Stratum A2 resulted in dilatometer moduli of about 30 to 700 tsf. Correlations with the dilatometer data indicate undrained shear strengths of about 150 to 1800 psf and overconsolidation ratios of about 1.25 to 6 for this stratum.

We performed two one-dimensional consolidation tests on samples of Stratum A2 soils. The results of these tests are summarized in Tables 1 and 2.

Table 1: Consolidation Test Results, Pc'-Po', Cεr and Cεc – Stratum A2

Boring	Sample EL (ft)	USCS Class	Moisture Content (%)	Natural Wet Density (pcf)	P_c' (ksf)	$P_c'-P_o'$ (ksf)	Cεr	Cεc
B-1	-18	CH	55.4	103.5	1.5	1.2	0.016	0.26
B-2	-27	CH	34.3	114.6	3.2	2.3	0.012	0.15

Table 2: Consolidation Test Results, Cv and Cα – Stratum A2

Boring	Sample EL (ft)	C_v at $P'<0.8P_c'$ (ft^2/day)	C_v at $P'>P_c'$ (ft^2/day)	Cα at $P'<0.8P_c'$	Cα at $P' > P_c'$
B-1	-18	0.959	0.289	0.0006	0.0085
B-2	-27	2.002	0.621	0.0006	0.0045

Stratum A3: Organic Quaternary Deposits

The organic soils of the Quaternary deposits were interlayered with Strata A1 and A2 in Borings B-1, B-2, and B-4 from about El -26.5 to -53. The organic soils consisted of ORGANIC CLAY and ORGANIC SILT (OH, OL) with varying amounts of sand. It is possible that some of the fine-grained layers shown in the CPTs and DMTs are part of Stratum A3, but the difference between the Stratum A2 and A3 soils is not apparent in the tests. These soils were generally of high plasticity having Liquid Limits between 47 and 154, and Plasticity Indices of 19 to 57. The natural moisture contents measured were between about 33 and 187 percent. Based on the Standard Penetration Tests performed, this stratum is generally very soft to medium stiff: N = 2 to 4.

We performed a one-dimensional consolidation test on samples of Stratum A3 soils. The results of this test is summarized in Tables 3 and 4.

Table 3: Consolidation Test Results, Pc'-Po', Cεr and Cεc – Stratum A3

Boring	Sample EL (ft)	USCS Class	Moisture Content (%)	Natural Wet Density (pcf)	P_c' (ksf)	$P_c'-P_o'$ (ksf)	Cεr	Cεc
B-4	-37	OL	33.8	116.9	3.7	2.1	0.009	0.15

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Table 4: Consolidation Test Results, Cv and Cα – Stratum A3

Boring	Sample EL (ft)	c_v at P'<0.8P_c' (ft^2/day)	c_v at P'>P_c' (ft^2/day)	Cα at P'<0.8P_c'	Cα at P' > P_c'
B-4	-37	1.844	0.531	0.0005	0.0045

Stratum B: Yorktown Formation

Stratum B1: Coarse-Grained Yorktown Formation

Interlayered with Stratum B2 and below the Quaternary deposits, Borings B-1, B-3, and B-5 encountered the coarse-grained soils of the Yorktown Formation between about EL -49 to -70 consisting of CLAYEY SAND (SC) and SILTY SAND (SM) with varying amounts of shell fragments. The natural moisture contents measured were between about 23 and 30 percent. Based on the Standard Penetration Tests performed, this stratum is generally loose to medium dense: N = 4 to 17. However, a dense layer of this stratum was encountered at about EL -68 in Boring B-3.

CPT testing performed in Stratum B1 indicated cone tip resistances of about 13 to 104 tsf. Correlations with the CPT data indicated angles of internal friction of about 32 to 38 degrees for this stratum. DMT testing performed in Stratum B1 resulted in dilatometer moduli of about 250 to 2800 tsf. Correlations with the dilatometer data indicate angles of internal friction of about 30 to 38 degrees for this stratum.

Stratum B2: Fine-Grained Yorktown Formation

Interlayered with Stratum B1 and below the Quaternary deposits, Borings B-4 and B-5 encountered the fine-grained soils of the Yorktown Formation between about EL -54 and -78.5 consisting of FAT CLAY (CH) with varying amounts of sand and shell fragments. Based on the Standard Penetration Tests performed, this stratum is generally soft to stiff: N = 3 to 7.

CPT testing performed in Stratum B2 indicated cone tip resistances of about 27 to 30 tsf. Correlations with the CPT data indicated undrained shear strengths of 1.8 tsf for this stratum. DMT testing performed in Stratum B2 resulted in dilatometer moduli of about 185 to 1300 tsf. Correlations with the dilatometer data indicate undrained shear strengths of about 800 to 3000 psf and overconsolidation ratios of about 1.5 to 4.5 for this stratum.

GEOTECHNICAL RECOMMENDATIONS

We based our geotechnical engineering analysis on the information developed from our subsurface exploration and soil laboratory testing, along with the project description and site plans furnished to our office. The following sections of the report provide our detailed recommendations.

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Breakwater Settlement

The soils beneath the proposed breakwaters are expected to settle under the weight of the structures. We recommend that additional stone be placed during construction to maintain the desired crest elevation of El +5. The expected maximum settlements are shown in Table 5. These settlements are based on a design life of 50 years.

Table 5: Summary of Expected Maximum Settlements

Breakwater Structure	Applicable Borings & Soundings	Elastic Settlement (in)	Primary Consolidation Settlement (in)	Secondary Consolidation Settlement (in)	Total Settlement (in)
1	C-1, B-1, D-1	1.1	7.0	2.7	10.8
2	C-2, D-2, C-3, B-2, D-3	0.6	9.1	6.6	16.3
3	C-4, B-3, D-4	1.1	6.8	2.4	10.3
4	C-5, D-5, B-4, D-6, C-6	0.8	1.5	2.5	4.8
5	D-7, C-7, B-5, D-8	1.2	1.2	3.4	5.8

We recommend a net allowable soil bearing pressure of 2,000 psf for the Breakwaters. This bearing pressure provides a factor of safety against general bearing capacity failure of at least 3.0.

Breakwater Slopes

We evaluated the slope stability of the 5 breakwater structures listed above using the computer program Slope/W in GeoStudio 2016. The results of the analyses are included in Appendix D. Based on the analyses, we recommend that breakwater slopes be constructed to at 1.5H:1V or flatter. Based on the schematic provided, there is a 6 ft high vertical face on the ocean side of the breakwater. We recommend that this be built as a slope as described above. Slopes constructed as listed above had calculated factors of safety greater than 1.3.

GENERAL SPECIFICATION RECOMMENDATIONS

An allowance should be established to account for possible additional costs that may be required to construct the breakwaters as recommended in this report. Additional costs may be incurred for a variety of reasons including variation of soil between borings, etc.

This report may be made available to prospective bidders for informational purposes. We recommend that the project specifications contain the following statement:

> *Schnabel Engineering, LLC has prepared this geotechnical engineering report for this project. This report is for informational purposes only and is not part of the contract documents. The opinions expressed represent the Geotechnical Engineer's interpretation of the subsurface conditions, tests, and the results of analyses performed. Should the data contained in this report not be adequate for the Contractor's purposes, the Contractor may make, before bidding,*

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independent exploration, tests and analyses. This report may be examined by bidders at the office of the Owner, or copies may be obtained from the Owner at nominal charge.

Additional data and reports prepared by others that could have an impact upon the Contractor's bid should also be made available to prospective bidders for informational purposes.

LIMITATIONS

We based the analyses and recommendations submitted in this report on the information revealed by our exploration. We attempted to provide for normal contingencies, but the possibility remains that unexpected conditions may be encountered during construction.

This report has been prepared to aid in the evaluation of this site and to assist in the design of the project. It is intended for use concerning this specific project. We based our recommendations on information on the site and proposed construction as described in this report. Substantial changes in locations or grades should be brought to our attention so we can modify our recommendations as needed. We would appreciate an opportunity to review the plans and specifications as they pertain to the recommendations contained in this report, and to submit our comments to you based on this review.

We have endeavored to complete the services identified herein in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality and under similar conditions as this project. No other representation, express or implied, is included or intended, and no warranty or guarantee is included or intended in this report, or other instrument of service.

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We appreciate the opportunity to be of service for this project. Please call us if you have any questions regarding this report.

Sincerely,

SCHNABEL ENGINEERING, LLC

Ethan J. Bradshaw, EIT
Senior Staff Engineer

Kevin D. Pocta, PE
Project Engineer



James J. Seli, PE
Principal



EJB:KDP:JJS:dah

Figures
Appendix A: Subsurface Exploration Data
Appendix B: Soil Laboratory Test Data
Appendix C: In Situ Test Results
Appendix D: Calculations

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FIGURES

Figure 1: Site Vicinity Map
Figures 2A & 2B: Location Plans

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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

NOT TO SCALE

Schnabel ENGINEERING

WALLOPS ISLAND BREAKWATERS
WALLOPS ISLAND, VIRGINIA

PROJECT NO. 18C13074

SITE VICINITY MAP

FIGURE 1

6/21/2018. This Map was Created In Schnabel Engineerings Site Vicinity Map Application

arcgis

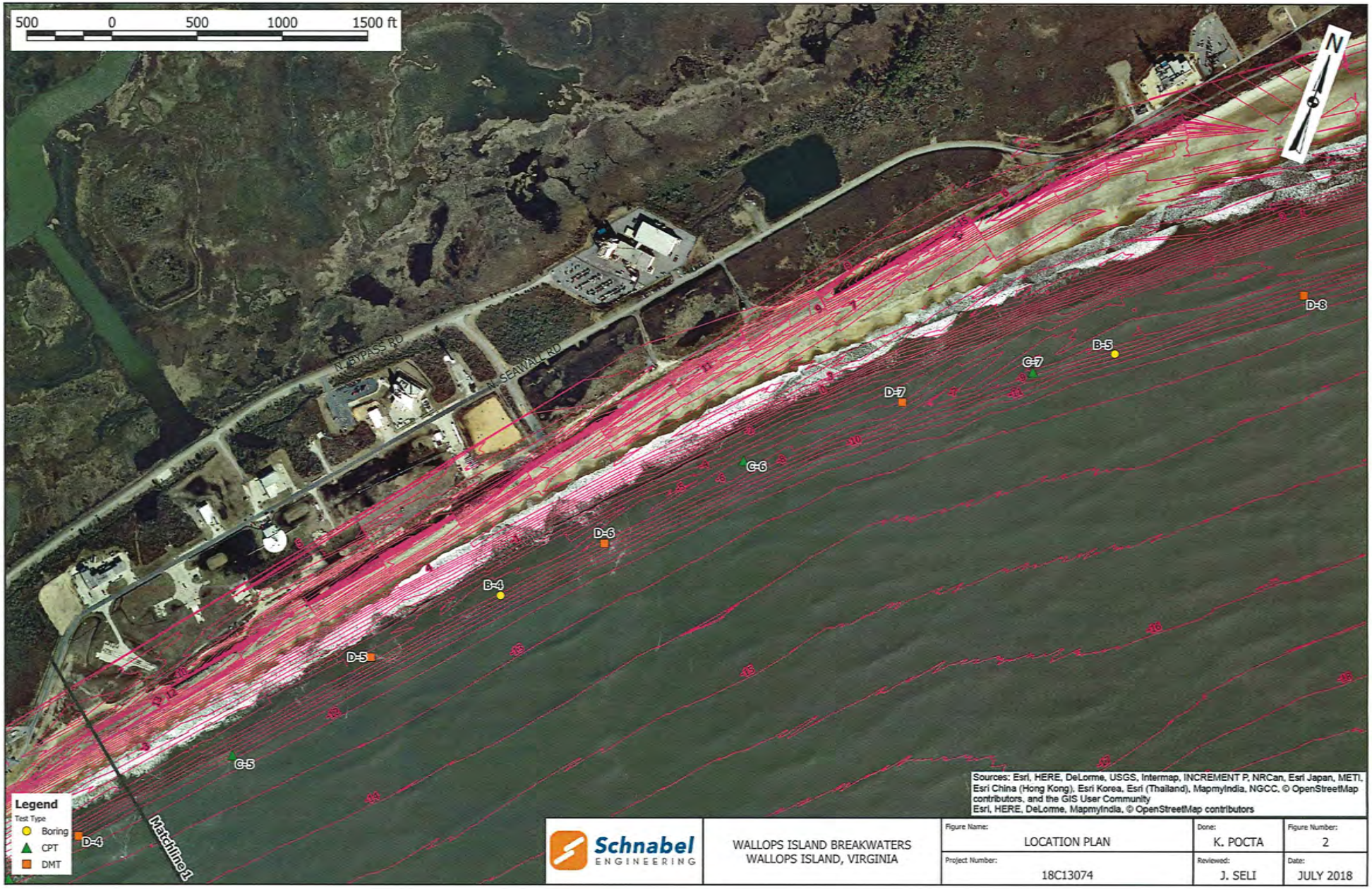
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Schnabel ENGINEERING

WALLOPS ISLAND BREAKWATERS
WALLOPS ISLAND, VIRGINIA

Figure Name:	Done:	Figure Number:
LOCATION PLAN	K. POCTA	2
Project Number:	**Reviewed:**	**Date:**
18C13074	J. SELI	JULY 2018



Schnabel ENGINEERING

WALLOPS ISLAND BREAKWATERS
WALLOPS ISLAND, VIRGINIA

Figure Name:	Done:	Figure Number:
LOCATION PLAN	K. POCTA	2
Project Number:	**Reviewed:**	**Date:**
18C13074	J. SELI	JULY 2018

APPENDIX A

SUBSURFACE EXPLORATION DATA

Subsurface Exploration Procedures
General Notes for Subsurface Exploration Logs
Identification of Soil
Boring Logs, B-1 through B-5

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SUBSURFACE EXPLORATION PROCEDURES

Test Borings – Mud Rotary

Drillers advanced the borings using mud rotary drilling techniques. The boring is advanced with a drill string consisting of a 3⅞-inch diameter tri-cone roller bit attached to A-sized drilled rods. Bentonite drilling fluid is pumped through the drill rods to flush cuttings to the surface. The borehole remains full of drilling fluid to maintain the sides of the borehole. At the designated depth, the drillers removed the drill string and performed the Standard Penetration Test (SPT). Water level data is indicated on the logs.

Standard Penetration Test Results

The numbers in the Sampling Data column of the boring logs represent Standard Penetration Test (SPT) results. Each number represents the blows needed to drive a 2-inch O.D., 1⅜-inch I.D. split-spoon sampler 6 inches, using a 140-pound hammer falling 30 inches. The sampler is typically driven a total of 18 or 24 inches. The first 6 inches are considered a seating interval. The total of the number of blows for the second and third 6-inch intervals is the SPT "N value." The SPT is performed according to ASTM D1586.

The SPT samples were obtained using a hydraulically driven automatic trip hammer (ATH). Most correlations with SPT data are based on N-values collected with a safety hammer. The energy applied to the split-spoon sampler using the ATH is about 33 percent greater than that applied using the safety hammer, resulting in lower N-values. The hammer blows shown on the boring logs are uncorrected for the higher energy. However, we correct SPT N values for the higher energy when using N values in our analyses.

Soil Classification Criteria

The group symbols on the logs represent the Unified Soil Classification System Group Symbols (ASTM D2487) based on visual observation and limited laboratory testing of the samples. Criteria for visual identification of soil samples are included in this appendix. Some variation can be expected between samples visually classified and samples classified in the laboratory.

Pocket Penetrometer Results

The values following "PP=" in the sampling data column of the logs represent pocket penetrometer readings. Pocket penetrometer readings provide an estimate of the unconfined compressive strength of fine-grained soils.

Boring and Sounding Locations and Elevations

Boring and sounding locations were located using sub-meter GPS equipment. Approximate locations are shown on Figures 2A and 2B. Elevations at the boring and sounding locations were obtained from the bathymetric survey provided by USACE on July 2, 2018, and are indicated on the boring/sounding logs. Locations and elevations should be considered no more accurate than the methods used to determine them.

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GENERAL NOTES FOR SUBSURFACE EXPLORATION LOGS

1. Numbers in sampling data column next to Standard Penetration Test (SPT) symbols indicate blows required to drive a 2-inch O.D., 1⅜-inch I.D. sampling spoon 6 inches using a 140 pound hammer falling 30 inches. The Standard Penetration Test (SPT) N value is the number of blows required to drive the sampler 12 inches, after a 6 inch seating interval. The Standard Penetration Test is performed in general accordance with ASTM D1586.
2. Visual classification of soil is in accordance with terminology set forth in "Identification of Soil." The ASTM D2487 group symbols (e.g., CL) shown in the classification column are based on visual observations.
3. Estimated water levels indicated on the logs are only estimates from available data and may vary with precipitation, porosity of the soil, site topography, tidal action, and other factors.
4. The logs and related information depict subsurface conditions only at the specific locations and at the particular time when drilled or excavated. Soil conditions at other locations may differ from conditions occurring at these locations. Also, the passage of time may result in a change in the subsurface soil and water level conditions at the subsurface exploration location.
5. The stratification lines represent the approximate boundary between soil and rock types as obtained from the subsurface exploration. Some variation may also be expected vertically between samples taken. The soil profile, water level observations and penetration resistances presented on these logs have been made with reasonable care and accuracy and must be considered only an approximate representation of subsurface conditions to be encountered at the particular location.
6. Key to symbols and abbreviations:



S-1, SPT	Sample No., Standard Penetration Test
5+10+1	Number of blows in each 6-inch increment



UD-1, UNDIST	Sample No., 2" or 3" Undisturbed Tube Sample
Rec=24", 100%	Recovery in inches, Percent Recovery

LL	Liquid Limit
MC	Moisture Content (percent)
PL	Plastic Limit
PP	Pocket Penetrometer Reading (tsf)
%Passing#200	Percent by weight passing a No. 200 Sieve

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IDENTIFICATION OF SOIL

I. DEFINITION OF SOIL GROUP NAMES (ASTM D2487)

			SYMBOL	GROUP NAME
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels – More than 50% of coarse fraction retained on No. 4 sieve Coarse, ¾" to 3" Fine, No. 4 to ¾"	Clean Gravels Less than 5% fines	GW	WELL GRADED GRAVEL
			GP	POORLY GRADED GRAVEL
		Gravels with fines More than 12% fines	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	Sands – 50% or more of coarse Fraction passes No. 4 sieve Coarse, No. 10 to No. 4 Medium, No. 40 to No. 10 Fine, No. 200 to No. 40	Clean Sands Less than 5% fines	SW	WELL GRADED SAND
			SP	POORLY GRADED SAND
		Sands with fines More than 12% fines	SM	SILTY SAND
			SC	CLAYEY SAND
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays – Liquid Limit less than 50 Low to medium plasticity	Inorganic	CL	LEAN CLAY
			ML	SILT
		Organic	OL	ORGANIC CLAY
				ORGANIC SILT
	Silts and Clays – Liquid Limit 50 or more Medium to high plasticity	Inorganic	CH	FAT CLAY
			MH	ELASTIC SILT
		Organic	OH	ORGANIC CLAY
				ORGANIC SILT
Highly Organic Soils	Primarily organic matter, dark in color and organic odor		PT	PEAT

II. DEFINITION OF SOIL COMPONENT PROPORTIONS (ASTM D2487)

			Examples
Adjective Form	GRAVELLY SANDY	>30% to <50% coarse grained component in a fine-grained soil	GRAVELLY LEAN CLAY
	CLAYEY SILTY	>12% to <50% fine grained component in a coarse-grained soil	SILTY SAND
"With"	WITH GRAVEL WITH SAND	>15% to <30% coarse grained component in a fine-grained soil	FAT CLAY WITH GRAVEL
	WITH GRAVEL WITH SAND	>15% to <50% coarse grained component in a coarse-grained soil	POORLY GRADED GRAVEL WITH SAND
	WITH SILT WITH CLAY	>5% to <12% fine grained component in a coarse-grained soil	POORLY GRADED SAND WITH SILT

III. GLOSSARY OF MISCELLANEOUS TERMS

SYMBOLS ..... Unified Soil Classification Symbols are shown above as group symbols. A dual symbol "-" indicates the soil belongs to two groups. A borderline symbol "/" indicates the soil belongs to two possible groups.

FILL..... Man-made deposit containing soil, rock and often foreign matter.

PROBABLE FILL..... Soils which contain no visually detected foreign matter but which are suspect with regard to origin.

DISINTEGRATED ROCK (DR)..... Residual materials with a standard penetration resistance (SPT) between 60 blows per foot and refusal. Refusal is defined as a SPT of 100 blows for 2" or less penetration.

PARTIALLY WEATHERED ROCK (PWR)..... Residual materials with a standard penetration resistance (SPT) between 100 blows per foot and refusal. Refusal is defined as a SPT of 100 blows for 2" or less penetration.

BOULDERS & COBBLES..... Boulders are considered rounded pieces of rock larger than 12 inches, while cobbles range from 3 to 12 inch size.

LENSES..... 0 to ½ inch seam within a material in a test pit.

LAYERS..... ½ to 12 inch seam within a material in a test pit.

POCKET..... Discontinuous body within a material in a test pit.

MOISTURE CONDITIONS..... Wet, moist or dry to indicate visual appearance of specimen.

COLOR..... Overall color, with modifiers such as light to dark or variation in coloration.

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: **B-1**
Contract Number: 18C13074
Sheet: 1 of 2

Contractor: Fishbume Drilling, Inc.
Chesapeake, Virginia
Contractor Foreman: J. Raasio
Schnabel Representative: E. Bradshaw
Equipment: CME-55 (Track)
Method: 3-7/8" O.D. Tri-cone Roller Bit

Hammer Type: Auto Hammer (140 lb)
Dates Started: 6/10/18 **Finished:** 6/10/18
Location: See Location Plan

Ground Surface Elevation: -11± (ft) **Total Depth:** 58.5 ft

Groundwater Observations

Date	Time	Depth	Casing	Caved

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND WITH SILT, fine to medium grained sand; wet, brown and gray, contains shell fragments	SP-SM		A1		S-01, SPT 2+3+4+5 REC=13", 54%		QUATERNARY DEPOSITS
						S-02, SPT 2+2+1+1 REC=11", 46%		
4.0	FAT CLAY; wet, bluish gray, contains shell fragments		-15.0		5	S-03, SPT WOH/24" REC=20", 83%	PP <0.25 tsf	
					UD	UD-1, UNDIST REC=15", 63%	LL = 54 PL = 22 MC = 55.4% % Passing #200 = 98.0	
		CH		A2	10	S-04, SPT WOH/24" REC=24", 100%	PP <0.25 tsf PP <0.25 tsf	
					15	S-05, SPT WOH/24" REC=24", 100%	MC = 39.0% PP <0.25 tsf	
15.0	ORGANIC SILT WITH SAND; wet, dark brown and gray, contains shell fragments		-26.0					
					20	S-06, SPT WOH/12"+2+2 REC=24", 100%	PP = 0.50 tsf	
		OH		A3				
					25	S-07, SPT 1+2+2+2 REC=24", 100%	LL = 130 PL = 83 MC = 73.9% % Passing #200 = 82.4 PP = 1.00 tsf	
27.0	SILTY SAND, fine to medium grained sand; wet, dark gray		-38.0					
		SM			30	S-08, SPT 5+5+7+10 REC=21", 88%	MC = 24.8%	
				A1				
32.0	POORLY GRADED GRAVEL WITH SILT AND SAND, fine gravel; wet, gray	GP-GM	-43.0					
33.5	SILTY SAND, fine to medium grained sand; wet, bluish gray, contains shell	SM	-44.5			S-09, SPT 8+8+4+2 REC=14", 58%		

(continued)

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: B-1
Contract Number: 18C13074
Sheet: 2 of 2

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	fragments	SM		A1	40	S-10, SPT 1+2+2+2 REC=21", 88%		
					45	S-11, SPT 1+2+2+2 REC=19", 79%		
47.0	CLAYEY SAND, fine to medium grained sand; wet, bluish gray, contains shell fragments	SC	-58.0	B1	50	S-12, SPT 2+3+5+5 REC=24", 100%	MC = 26.8%	YORKTOWN FORMATION
					55	S-13, SPT 4+4+4+6 REC=24", 100%		
58.5			-69.5			S-14, SPT 8+8+9+9 REC=17", 71%		

Bottom of Boring at 58.5 ft.
Boring terminated at selected depth.
Boring backfilled with cuttings upon completion.
11 ft of water at boring location.

TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/5/18

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: **B-2**
Contract Number: 18C13074
Sheet: 1 of 2

Contractor: Fishbume Drilling, Inc.
Chesapeake, Virginia
Contractor Foreman: J. Raasio
Schnabel Representative: E. Bradshaw
Equipment: CME-55 (Track)
Method: 3-7/8" O.D. Tri-cone Roller Bit

Hammer Type: Auto Hammer (140 lb)
Dates Started: 6/10/18 **Finished:** 6/10/18
Location: See Location Plan

Ground Surface Elevation: -11± (ft) **Total Depth:** 58.5 ft

Groundwater Observations

Date	Time	Depth	Casing	Caved

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND WITH SILT, fine to medium grained sand; wet, brown and gray, contains shell fragments	SP-SM		A1		S-01, SPT 2+4+4+1 REC=16", 67%		QUATERNARY DEPOSITS
2.8	FAT CLAY; wet, bluish gray, contains organic matter		-13.8			S-02, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
					5	S-03, SPT WOH/24" REC=24", 100%	MC = 47.1% PP <0.25 tsf	
						S-04, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
						S-05, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
					10			
	Change: dark brown	CH		A2		S-06, SPT 1+1+1+1 REC=24", 100%	PP = 0.50 tsf	
					15	UD-1, UNDIST REC=21", 88%	LL = 55 PL = 28 MC = 34.3% % Passing #200 = 99.4	
	Change: gray					S-07, SPT WOH/24" REC=24", 100%	PP = 0.50 tsf PP <0.25 tsf	
					20			
						S-08, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
					25			
27.0	CLAYEY SAND, fine to medium grained sand; wet, gray, contains shell fragments	SC	-38.0	A1		S-09, SPT 6+5+6+5 REC=24", 100%		
					30			
32.0	FAT CLAY; wet, dark gray, contains organic matter	CH	-43.0	A2		S-10, SPT WOH+2+4+5 REC=24", 100%	PP = 0.50 tsf	
34.0	ORGANIC CLAY; wet, dark brown	OH	-45.0	A3			MC = 187.1%	

(continued)

TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/6/18

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: B-2
Contract Number: 18C13074
Sheet: 2 of 2

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Change: brownish gray	OH		A3	40	S-11, SPT 1+1+1+2 REC=24", 100%	MC = 85.5% PP = 1.00 tsf	
42.0	FAT CLAY WITH SAND; wet, greenish gray, contains organic matter		-53.0					
					45	S-12, SPT WOH+1+2+2 REC=24", 100%	PP = 1.00 tsf	
		CH		A2	50	S-13, SPT WOH+2+2+2 REC=24", 100%	MC = 41.4% PP = 1.50 tsf	
					55	S-14, SPT 1+1+1+3 REC=24", 100%	PP = 1.00 tsf	
						S-15, SPT WOH+1+2+4 REC=24", 100%	PP = 0.50 tsf	
58.5			-69.5					

Bottom of Boring at 58.5 ft.
Boring terminated at selected depth.
Boring backfilled with cuttings upon completion.
11 ft of water at boring location.

TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/6/18

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: B-3
Contract Number: 18C13074
Sheet: 1 of 2

Contractor: Fishbume Drilling, Inc.
Chesapeake, Virginia
Contractor Foreman: J. Raasio
Schnabel Representative: E. Bradshaw
Equipment: CME-55 (Track)
Method: 3-7/8" O.D. Tri-cone Roller Bit

Hammer Type: Auto Hammer (140 lb)
Dates Started: 6/10/18 **Finished:** 6/10/18
Location: See Location Plan

Ground Surface Elevation: -11± (ft) **Total Depth:** 58.0 ft

Groundwater Observations

Date	Time	Depth	Casing	Caved

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND WITH SILT, fine to coarse grained sand; wet, brown, contains shell fragments	SP-SM		A1		S-01, SPT 2+3+2+3 REC=18", 75%		QUATERNARY DEPOSITS
						S-02, SPT 1+2+WOH+1 REC=15", 63%		
4.0	LEAN CLAY; wet, bluish gray, contains organic matter, and shell fragments		-15.0		5	S-03, SPT WOR+WOH/12"+WOH REC=24", 100%	PP <0.25 tsf	
	Change: no organic matter					S-04, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
					10	S-05, SPT WOH/24" REC=24", 100%	LL = 31 PL = 19 MC = 32.2% % Passing #200 = 85.2 PP <0.25 tsf	
					15	S-06, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
		CL		A2				
					20	S-07, SPT WOH/24" REC=24", 100%	PP <0.25 tsf	
	Change: contains organic matter				25	S-08, SPT WOH+2+2+3 REC=24", 100%	MC = 33.7% PP = 1.00 tsf	
27.0	SILTY SAND, fine to medium grained sand; wet, gray		-38.0					
					30	S-09, SPT 7+7+9+2 REC=24", 100%		
		SM		A1				
						S-10, SPT 2+3+3+3 REC=24", 100%		

(continued)

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: B-3
Contract Number: 18C13074
Sheet: 2 of 2

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
		SM		A1				
37.0	CLAYEY SAND, fine to coarse grained sand; wet, greenish gray, contains shell fragments		-48.0					YORKTOWN FORMATION
					40	S-11, SPT 2+2+3+3 REC=24", 100%	MC = 28.0%	
					45	S-12, SPT 2+3+2+4 REC=24", 100%		
		SC		B1				
					50	S-13, SPT 3+4+6+7 REC=24", 100%		
					55	S-14, SPT 4+3+3+4 REC=24", 100%		
						S-15, SPT 7+13+10+12 REC=24", 100%		
58.0			-69.0					

Bottom of Boring at 58.0 ft.
Boring terminated at selected depth.
Boring backfilled with cuttings upon completion.
11 ft of water at boring location.

TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/6/18

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: B-4
Contract Number: 18C13074
Sheet: 1 of 2

Contractor: Fishburne Drilling, Inc.
Chesapeake, Virginia
Contractor Foreman: J. Raasio
Schnabel Representative: E. Bradshaw
Equipment: CME-55 (Track)
Method: 3-7/8" O.D. Tri-cone Roller Bit

Hammer Type: Auto Hammer (140 lb)
Dates Started: 6/14/18 **Finished:** 6/14/18
Location: See Location Plan

Ground Surface Elevation: -7± (ft) **Total Depth:** 70.0 ft

Groundwater Observations

Date	Time	Depth	Casing	Caved

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND WITH SILT, fine to medium grained sand; wet, grayish brown, contains shell fragments	SP-SM				S-01, SPT 2+3+4 REC=7", 39% S-02, SPT 7+8+10+8 REC=17", 71% S-03, SPT 4+5+6+8 REC=11", 46%	MC = 29.9%	QUATERNARY DEPOSITS
5.5	SILTY SAND, fine to medium grained sand; wet, gray, contains shell fragments	SM	-12.0	A1	5	S-04, SPT 13+14+15+13 REC=15", 63% S-05, SPT 3+6+2+1 REC=9", 38%		
11.5	SANDY FAT CLAY; wet, bluish gray	CH	-18.0	A2	10	S-06, SPT WOH/18" REC=24", 133%	MC = 31.2% PP = 0.25 tsf	
					15	UD-1, UNDIST REC=22", 92%	PP = 0.25 tsf	
	Change: contains shell fragments				20	S-07, SPT WOH/24" REC=12", 50%	PP = 0.25 tsf	
26.5	ORGANIC SILT; wet, gray	OL	-33.0	A3	25	S-08, SPT 2+3+4+4 REC=22", 92%	PP = 2.50 tsf	
					30	UD-2, UNDIST REC=19.5", 81%	LL = 47 PL = 28 MC = 32.8% % Passing #200 = 99.5 PP = 0.25 tsf	
33.0	ORGANIC SILT WITH SAND; wet, dark brown and black	OH	-39.5			S-09, SPT 1+1+2 REC=12", 67%	LL = 154 PL = 97	

(continued)

TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/6/18

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: **B-4**
Contract Number: 18C13074
Sheet: 2 of 2

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
		OH		A3			MC = 93.5%	
36.5	CLAYEY SAND, fine to medium grained sand; wet, greenish gray, contains shell fragments	SC	-43.0			S-10, SPT 2+3+4+7 REC=21", 88%	% Passing #200 = 77.8 MC = 30.4%	YORKTOWN FORMATION
41.5	SILTY SAND, fine to medium grained sand; wet, greenish gray, contains shell fragments	SM	-48.0			S-11, SPT 6+8+13+17 REC=21", 88% S-12, SPT 7+10+15+15 REC=22", 92%		
51.5	CLAYEY SAND, fine to medium grained sand; wet, greenish gray, contains shell fragments	SC	-58.0	B1		S-13, SPT 5+5+9+11 REC=24", 100% S-14, SPT 4+8+8+11 REC=22", 92% S-15, SPT 6+7+9+12 REC=24", 100%	MC = 27.4%	
67.0	FAT CLAY WITH SAND; wet, greenish gray, contains shell fragments	CH	-73.5	B2		S-16, SPT 2+3+4+4 REC=24", 100%		
70.0			-76.5					

Bottom of Boring at 70.0 ft.
Boring terminated at selected depth.
Boring backfilled with cuttings upon completion.
6.5 ft of water at boring location.

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: **B-5**
Contract Number: 18C13074
Sheet: 1 of 2

Contractor: Fishburne Drilling, Inc.
Chesapeake, Virginia
Contractor Foreman: J. Raasio
Schnabel Representative: E. Bradshaw
Equipment: CME-55 (Track)
Method: 3-7/8" O.D. Tri-cone Roller Bit

Hammer Type: Auto Hammer (140 lb)
Dates Started: 6/14/18 **Finished:** 6/14/18
Location: See Location Plan

Ground Surface Elevation: -9± (ft) **Total Depth:** 70.0 ft

Groundwater Observations

Date	Time	Depth	Casing	Caved

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND WITH SILT, fine to medium grained sand; wet, brown, contains shell fragments					S-01, SPT 6+4+2+4 REC=20", 83%		QUATERNARY DEPOSITS
						S-02, SPT 2+2+2+1 REC=13", 54%		
	Change: dark bluish gray	SP-SM		A1	5	S-03, SPT 3+6+10+11 REC=15", 63%		
						S-04, SPT 9+9+13+14 REC=16", 67%		
	Change: gray					S-05, SPT 7+8+3+2 REC=11", 46%	MC = 28.4%	
12.0					10			
	FAT CLAY; wet, bluish gray, contains shell fragments		-21.0			S-06, SPT WOR/12"+WOH/12" REC=24", 100%	PP = 0.25 tsf	
					15			
	Change: brown and gray					S-07, SPT 2+2+4+4 REC=20", 83%	MC = 30.4% PP = 2.50 tsf	
		CH			20			
	Change: greenish gray			A2		S-08, SPT WOH/24" REC=24", 100%	PP = 0.25 tsf	
					25			
28.0	SANDY FAT CLAY; greenish gray, contains shell fragments		-37.0			S-09, SPT 2+1+1+1 REC=24", 100%	PP = 0.50 tsf	
					30	UD-1, UNDIST REC=22.5", 94%		
		CH						
	Change: contains shell fragments					S-10, SPT WOH+1+WOH+1 REC=12", 50%	MC = 26.0% PP = 0.50 tsf	

(continued)

TEST BORING LOG 18C13074.GPJ SCHNABEL DATA TEMPLATE 2008_07_06.GDT 7/6/18

Schnabel ENGINEERING **TEST BORING LOG**

Project: Wallops Island Breakwaters
Wallops Island, Virginia

Boring Number: **B-5**
Contract Number: 18C13074
Sheet: 2 of 2

DEPTH (ft)	MATERIAL DESCRIPTION	SYMBOL	ELEV (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
		CH		A2	40	S-11, SPT 1+1+2+2 REC=24", 100%	PP = 1.25 tsf	
42.0	CLAYEY SAND, fine to medium grained sand; wet, greenish gray, contains shell fragments	SC	-51.0	B1	45	S-12, SPT 1+2+2+2 REC=24", 100%	MC = 22.9%	YORKTOWN FORMATION
47.0	SANDY FAT CLAY; wet, greenish gray	CH	-56.0	B2	50	S-13, SPT 1+1+2+2 REC=24", 100%	PP = 1.00 tsf	
					55	S-14, SPT 1+1+2+2 REC=24", 100%	PP = 1.00 tsf	
					60	S-15, SPT 1+1+2+2 REC=24", 100%	PP = 1.00 tsf	
					65	S-16, SPT 1+2+2+4 REC=24", 100%	PP = 1.25 tsf	
70.0			-79.0		70	S-17, SPT 2+2+4+4 REC=24", 100%	PP = 1.50 tsf	

Bottom of Boring at 70.0 ft.
Boring terminated at selected depth.
Boring backfilled with cuttings upon completion.
9 ft of water at boring location.

APPENDIX B

SOIL LABORATORY TEST DATA

Summary of Laboratory Tests
Atterberg Limits
Gradation Curves
Consolidation Test Curves

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Summary Of Laboratory Tests

Project Number: 18C13074

Boring No.	Sample Depth ft / Elevation ft	Sample Type	Description of Soil Specimen	Testing Laboratory	Stratum	Natural Moisture (%)	Wet Natural Density (pcf)	Liquid Limit	Plastic Limit	Plasticity Index	Oven Dry Liquid Limit	% Passing No. 200 Sieve	% Passing No. 40 Sieve	% Retained No. 4 Sieve
B-1	6.0 - 8.0 -17.0 - -19.0	Tube	FAT CLAY (CH), gray	RICH	A2	55.4	103.5	54	22	32	--	98.0	99.5	--
B-1	23.0 - 25.0 -34.0 - -36.0	Jar	ORGANIC SILT WITH SAND (OH), gray	RICH	A3	73.9	--	130	83	47	57	82.4	94.2	0.0
B-2	15.0 - 17.0 -26.0 - -28.0	Tube	FAT CLAY (CH), gray	RICH	A2	34.3	114.6	55	28	27	46	99.4	99.9	--
B-3	8.0 - 10.0 -19.0 - -21.0	Jar	LEAN CLAY WITH SAND (CL), contains mica, gray	RICH	A2	32.2	--	31	19	12	--	85.2	99.9	--
B-4	29.5 - 31.5 -36.0 - -38.0	Tube	ORGANIC SILT (OL), gray	RICH	A3	32.8	116.9	47	28	19	35	99.5	99.9	--
B-4	33.0 - 34.5 -39.5 - -41.0	Jar	ORGANIC SILT WITH SAND (OH), dark brown and black	RICH	A3	93.5	--	154	97	57	63	77.8	88.2	0.0

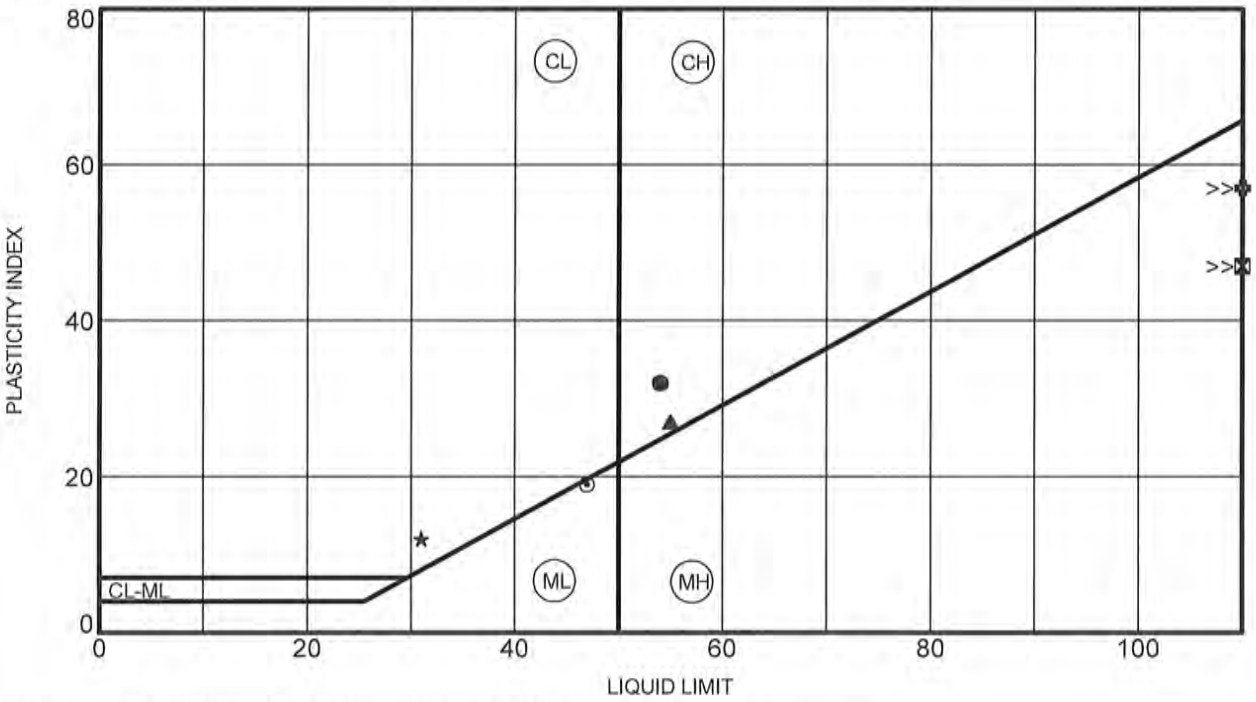
Notes:
1. Soil tests in general accordance with ASTM standards.
2. Soil classifications are in general accordance with ASTM D2487(as applicable), based on testing indicated and visual classification.
3. Key to abbreviations: NP=Non-Plastic; -- indicates no test performed

Schnabel ENGINEERING

Project: Wallops Island Breakwaters

Wallops Island, VA

DYNAMIC LAB SUMMARY 18C13074.GPJ SCHNABEL DATA TEMPLATE 2010 02 25.GDT 7/6/18



PLOTTED DATA REPRESENTS SOIL PASSING NO. 40 SIEVE

	Specimen		LL	PL	PI	Fines	Oven Dry Liquid Limit	Testing Lab	Description
●	B-1	6.0 ft	54	22	32	98		RICH	FAT CLAY (CH), gray
⊠	B-1	23.0 ft	130	83	47	82	57.0	RICH	ORGANIC SILT WITH SAND (OH), gray
▲	B-2	15.0 ft	55	28	27	99	46.0	RICH	FAT CLAY (CH), gray
★	B-3	8.0 ft	31	19	12	85		RICH	LEAN CLAY WITH SAND (CL), contains mica, gray
⊙	B-4	29.5 ft	47	28	19	100	35.0	RICH	ORGANIC SILT (OL), gray
✿	B-4	33.0 ft	154	97	57	78	63.0	RICH	ORGANIC SILT WITH SAND (OH), dark brown and black

NOTE: An organic clay or silt is a soil that would be classified as a clay or silt, respectively, except that its oven dried liquid limit is less than 75% of its liquid limit value.

Schnabel ENGINEERING

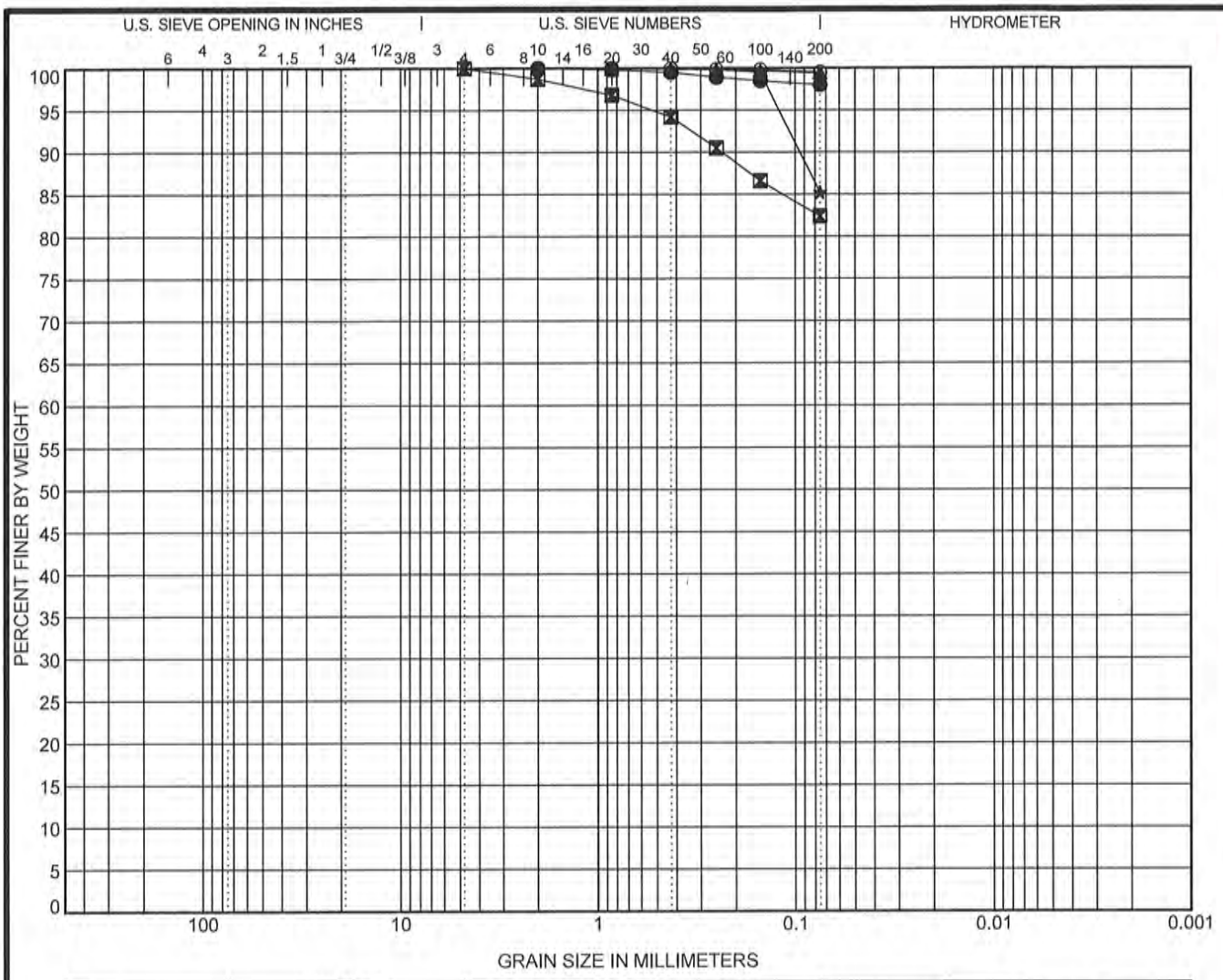
ATTERBERG LIMITS

Project: Wallops Island Breakwaters

Wallops Island, VA

Contract: 18C13074

ATTERBERG_LIMITS_18C13074.GPJ SCHNABEL_DATA_TEMPLATE 2008_04_22.GDT 7/6/18



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen		Sample Description	LL	PL	PI		
●	B-1	6.0 ft	FAT CLAY (CH), gray	54	22	32		
⊠	B-1	23.0 ft	ORGANIC SILT WITH SAND (OH), gray	130	83	47		
▲	B-2	15.0 ft	FAT CLAY (CH), gray	55	28	27		
★	B-3	8.0 ft	LEAN CLAY WITH SAND (CL), contains mica, gray	31	19	12		
⊙	B-4	29.5 ft	ORGANIC SILT (OL), gray	47	28	19		

	Specimen		Test Method	Testing Lab	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	B-1	6.0 ft	ASTM D422	RICH	2	--	--	--	0.0	2.0	98.0	
⊠	B-1	23.0 ft	ASTM D422	RICH	4.75	--	--	--	0.0	17.6	82.4	
▲	B-2	15.0 ft	ASTM D422	RICH	2	--	--	--	0.0	0.6	99.4	
★	B-3	8.0 ft	ASTM D422	RICH	2	--	--	--	0.0	14.8	85.2	
⊙	B-4	29.5 ft	ASTM D422	RICH	0.85	--	--	--	0.0	0.5	99.5	

Schnabel ENGINEERING

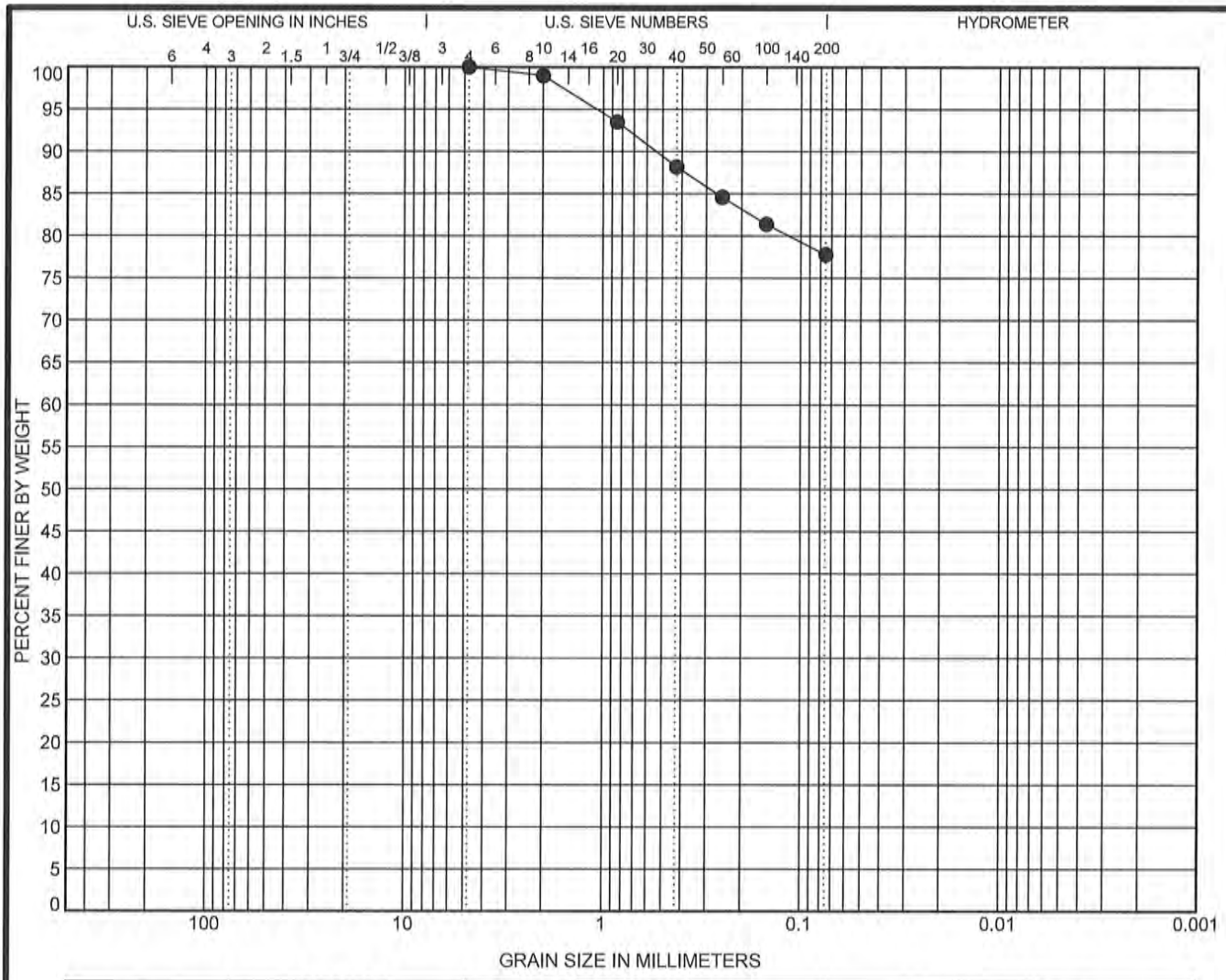
GRADATION CURVES

Project: Wallops Island Breakwaters

Wallops Island, VA

Contract: 18C13074

SIEVE 5 SHEET 18C13074.GPJ SCHNABEL DATA TEMPLATE 2010 02 25.GDT 7/6/18



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen	Sample Description	LL	PL	PI
● B-4 33.0 ft	ORGANIC SILT WITH SAND (OH), dark brown and black	154	97	57

Specimen	Test Method	Testing Lab	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● B-4 33.0 ft	ASTM D422	RICH	4.75	--	--	--	0.0	22.2	77.8	

Schnabel ENGINEERING

GRADATION CURVES

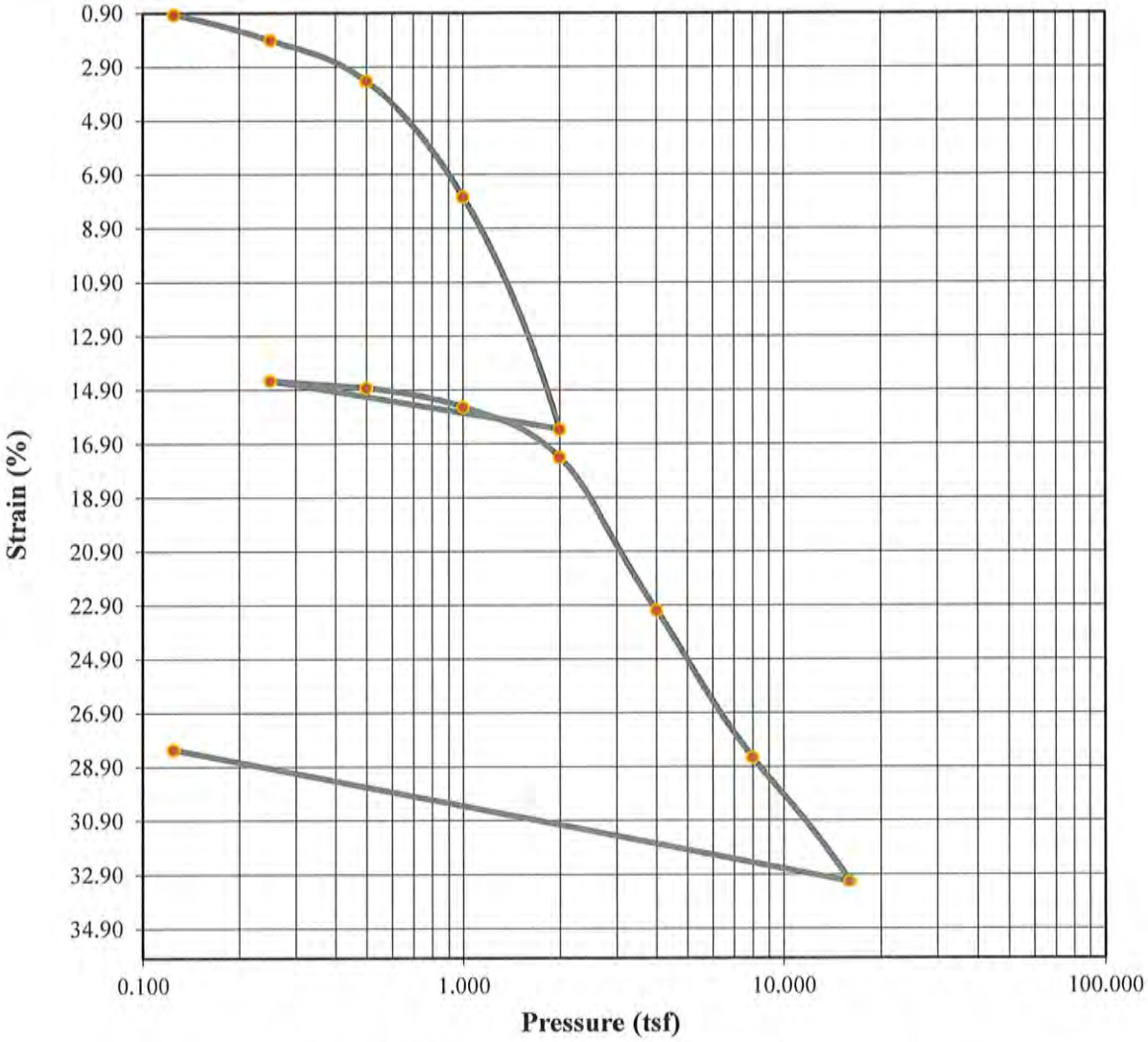
Project: Wallops Island Breakwaters

Wallops Island, VA

Contract: 18C13074

SIEVE 5 SHEET 18C13074.GPJ SCHNABEL DATA TEMPLATE 2010 02 25.GDT 7/6/18

Consolidation Test
Test Results



	Before	After				
Moisture (%):	55.32	32.42	**Liquid Limits:**	54	**Test Date:**	6-19-18
Dry Density (pcf):	65.85	90.53	**Plastic Limits:**	22		
Saturation (%):	96.22	102.44	**Plasticity Index (%):**	32		
Void Ratio:	1.5379	0.8211	**Specific Gravity:**	2.680	Assumed	

Sample Description: FAT CLAY (CH), gray

Project Number: 18C13074 **Depth:** 6'-8'

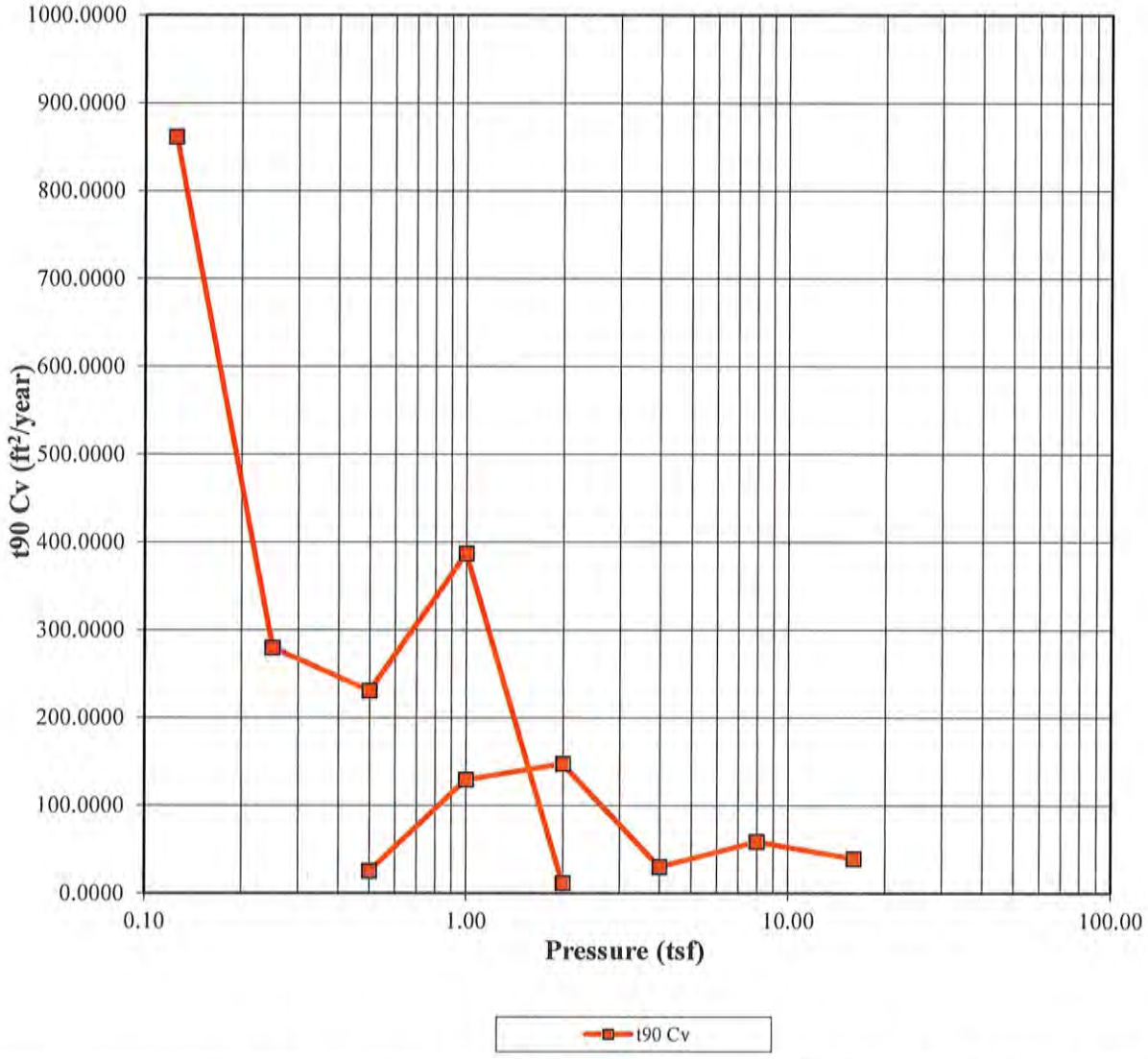
Sample Number: B-1 **Boring Number:** B-1

Project: Wallops Island Breakwaters

Location: Wallops Island, VA

Remarks:

Consolidation Test
Test Results



	Before	After				
Moisture (%):	55.32	32.42	**Liquid Limits:**	54	**Test Date:**	6-19-18
Dry Density (pcf):	65.85	90.53	**Plastic Limits:**	22		
Saturation (%):	96.22	102.44	**Plasticity Index (%):**	32		
Void Ratio:	1.5379	0.8211	**Specific Gravity:**	2.680	Assumed	
Soil Description:	FAT CLAY (CH), gray					
Project Number:	18C13074		**Depth:** 6'-8'		**Remarks:**	
Sample Number:	B-1		**Boring Number:** B-1			
Project:	Wallops Island Breakwaters					
Client:						
Location:	Wallops Island, VA					

Consolidation Test Results
Summary

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

Sample Description: FAT CLAY (CH), gray
Remarks:

Test Number:
Test Date: 6-19-18

Index	Load Sequence (tsf)	Cummulative Change in Height (in)	Specimen Height (in)	Height of Void (in)	Vertical Strain (%)	Void Ratio	t90 Fitting Time (min)	t50 Fitting Time (min)	t90 Cv (ft2/year)	t50 Cv (ft2/year)
0	0.000	0.0000	1.0090	0.6112	0.00	1.5363	0.000	0.000	0.000	0.000
1	0.125	0.0097	0.9993	0.6015	0.96	1.5119	0.897	* 0.4984	861.328	360.174
2	0.250	0.0193	0.9897	0.5919	1.91	1.4878	2.709	* 1.5050	279.786	116.996
3	0.500	0.0346	0.9744	0.5766	3.43	1.4493	3.182	* 1.7676	230.910	96.558
4	1.000	0.0780	0.9310	0.5332	7.73	1.3402	1.732	* 0.9623	387.227	161.915
5	2.000	0.1651	0.8439	0.4461	16.36	1.1213	47.863	* 26.5903	11.514	4.815
6	0.250	0.1468	0.8622	0.4644	14.55	1.1673	0.000	0.000	0.000	0.000
7	0.500	0.1495	0.8595	0.4617	14.82	1.1605	22.880	* 12.7110	24.984	10.447
8	1.000	0.1567	0.8523	0.4545	15.53	1.1424	4.353	* 2.4181	129.140	54.002
9	2.000	0.1756	0.8334	0.4356	17.40	1.0949	3.643	* 2.0237	147.541	61.696
10	4.000	0.2329	0.7761	0.3783	23.08	0.9509	15.529	* 8.6274	30.013	12.550
11	8.000	0.2881	0.7209	0.3231	28.55	0.8121	6.857	* 3.8097	58.644	24.522
12	16.000	0.3346	0.6744	0.2766	33.16	0.6952	8.958	* 4.9766	39.288	16.429
13	0.125	0.2850	0.7240	0.3262	28.25	0.8199	0.000	0.000	0.000	0.000

Predicted value indicated with *

Tested By: RG

Checked By: DS

Consolidation Test
Consolidation Specimen Information

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

Sample Description: FAT CLAY (CH), gray
Remarks:

Test Number:
Liquid Limit: 54.0000
Plastic Limit: 22.0000
Specific Gravity: 2.6800 Assumed

Initial Void Ratio: 1.5379
Plasticity Index (%): 32.0000
Weight of Ring (g): 111.6700

Initial Height (in): 1.0090
Initial Diameter (in): 2.5000

Parameters	Initial Specimen	Final Specimen
Moist Weight + Container (g)	218.65	314.20
Dry Soil + Container (g)	173.00	286.90
Weight of Container (g)	90.70	202.70
Moisture Content (%)	55.32	32.42
Void Ratio	1.5379	0.8211
Saturation (%)	96.22	102.44
Dry Density (pcf)	65.85	90.53

Tested By: RG

Checked By: DS

Consolidation Test Results
(Sequence 1) Load 0.125 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

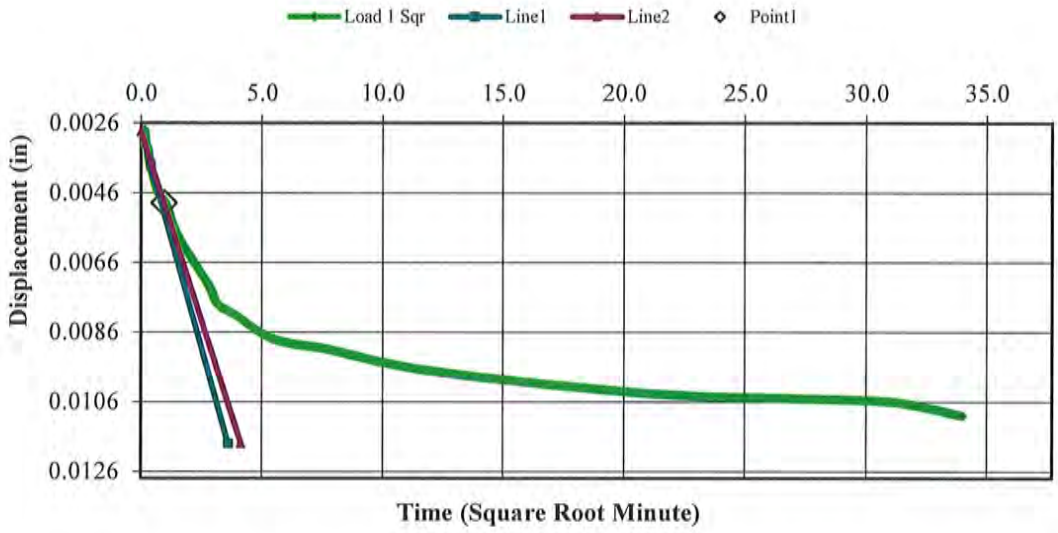
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0013	0.0000	0.0000	1.5379
1	00:00:01	0.0028	0.0015	0.1487	1.5341
2	00:00:02	0.0032	0.0019	0.1883	1.5331
3	00:00:03	0.0033	0.0020	0.1982	1.5329
4	00:00:04	0.0033	0.0020	0.1982	1.5329
5	00:00:05	0.0034	0.0021	0.2081	1.5326
6	00:00:06	0.0036	0.0023	0.2279	1.5321
7	00:00:12	0.0040	0.0027	0.2676	1.5311
8	00:00:15	0.0041	0.0028	0.2775	1.5309
9	00:00:30	0.0046	0.0033	0.3271	1.5296
10	00:01:00	0.0049	0.0036	0.3568	1.5288
11	00:02:00	0.0057	0.0044	0.4361	1.5268
12	00:04:01	0.0064	0.0051	0.5055	1.5251
13	00:08:01	0.0073	0.0060	0.5946	1.5228
14	00:10:01	0.0078	0.0065	0.6442	1.5216
15	00:15:02	0.0081	0.0068	0.6739	1.5208
16	00:30:03	0.0088	0.0075	0.7433	1.5190
17	01:00:06	0.0091	0.0078	0.7730	1.5183
18	02:00:12	0.0096	0.0083	0.8226	1.5170
19	04:00:24	0.0100	0.0087	0.8622	1.5160
20	08:00:47	0.0104	0.0091	0.9019	1.5150
21	12:01:11	0.0105	0.0092	0.9118	1.5148
22	16:01:35	0.0106	0.0093	0.9217	1.5145
23	19:16:07	0.0110	0.0097	0.9613	1.5135

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 1) Load 0.125 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 2) Load 0.250 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

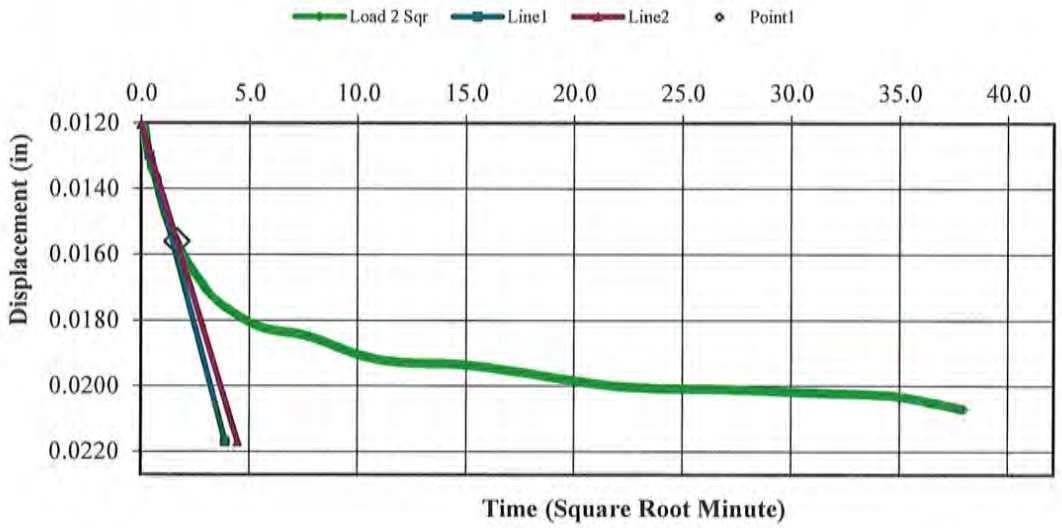
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0110	0.0097	0.9613	1.5135
1	00:00:01	0.0121	0.0107	1.0605	1.5110
2	00:00:02	0.0123	0.0109	1.0803	1.5105
3	00:00:03	0.0126	0.0112	1.1100	1.5097
4	00:00:04	0.0127	0.0113	1.1199	1.5095
5	00:00:05	0.0128	0.0114	1.1298	1.5092
6	00:00:06	0.0129	0.0115	1.1397	1.5090
7	00:00:12	0.0131	0.0117	1.1596	1.5085
8	00:00:15	0.0134	0.0120	1.1893	1.5077
9	00:00:30	0.0137	0.0123	1.2190	1.5070
10	00:01:00	0.0145	0.0131	1.2983	1.5050
11	00:02:00	0.0153	0.0139	1.3776	1.5029
12	00:04:00	0.0161	0.0147	1.4569	1.5009
13	00:08:01	0.0169	0.0155	1.5362	1.4989
14	00:10:01	0.0172	0.0158	1.5659	1.4982
15	00:15:01	0.0176	0.0162	1.6056	1.4972
16	00:30:03	0.0182	0.0168	1.6650	1.4956
17	01:00:06	0.0185	0.0171	1.6947	1.4949
18	02:00:13	0.0192	0.0178	1.7641	1.4931
19	04:00:31	0.0194	0.0180	1.7839	1.4926
20	08:00:35	0.0200	0.0186	1.8434	1.4911
21	12:00:32	0.0201	0.0187	1.8533	1.4909
22	16:00:29	0.0202	0.0188	1.8632	1.4906
23	20:00:25	0.0203	0.0189	1.8731	1.4904
24	23:59:59	0.0207	0.0193	1.9128	1.4894

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 2) Load 0.250 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 3) Load 0.500 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

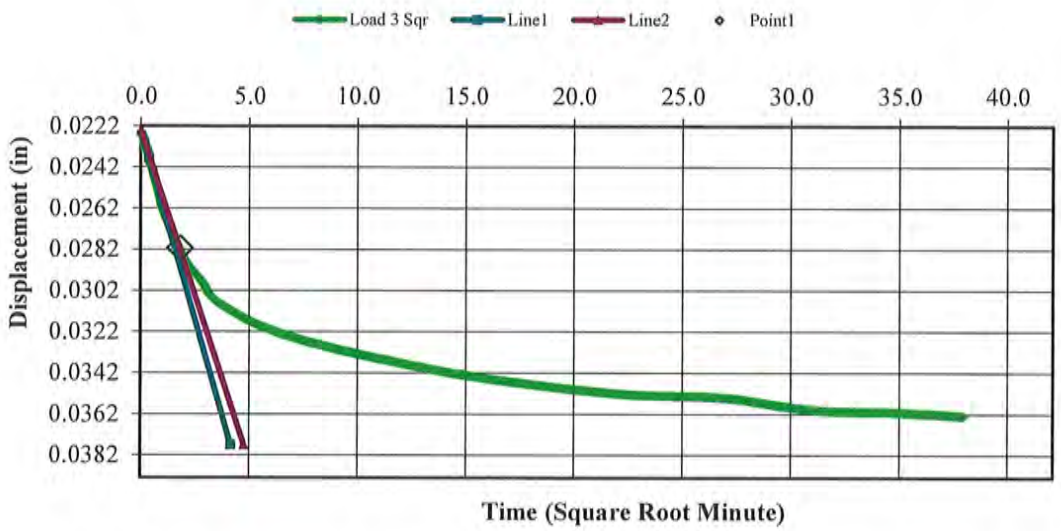
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0207	0.0193	1.9128	1.4894
1	00:00:00	0.0225	0.0208	2.0614	1.4856
2	00:00:01	0.0229	0.0212	2.1011	1.4846
3	00:00:02	0.0232	0.0215	2.1308	1.4838
4	00:00:03	0.0233	0.0216	2.1407	1.4836
5	00:00:04	0.0233	0.0216	2.1407	1.4836
6	00:00:05	0.0234	0.0217	2.1506	1.4833
7	00:00:11	0.0241	0.0224	2.2200	1.4816
8	00:00:14	0.0242	0.0225	2.2299	1.4813
9	00:00:29	0.0250	0.0233	2.3092	1.4793
10	00:00:59	0.0262	0.0245	2.4281	1.4763
11	00:01:59	0.0273	0.0256	2.5372	1.4735
12	00:03:59	0.0287	0.0270	2.6759	1.4700
13	00:07:59	0.0298	0.0281	2.7849	1.4672
14	00:09:59	0.0304	0.0287	2.8444	1.4657
15	00:14:59	0.0310	0.0293	2.9039	1.4642
16	00:29:59	0.0319	0.0302	2.9931	1.4619
17	00:59:59	0.0327	0.0310	3.0723	1.4599
18	01:59:58	0.0335	0.0318	3.1516	1.4579
19	04:00:05	0.0344	0.0327	3.2408	1.4557
20	08:00:22	0.0352	0.0335	3.3201	1.4536
21	12:00:39	0.0354	0.0337	3.3399	1.4531
22	16:00:55	0.0360	0.0343	3.3994	1.4516
23	20:01:12	0.0361	0.0344	3.4093	1.4514
24	23:59:59	0.0363	0.0346	3.4291	1.4509

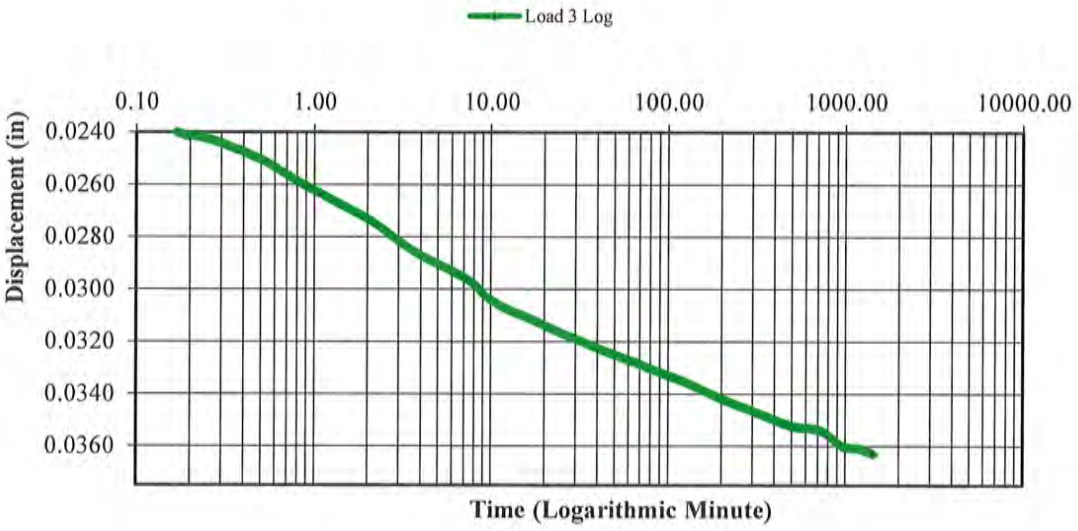
Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 3) Load 0.500 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 4) Load 1.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

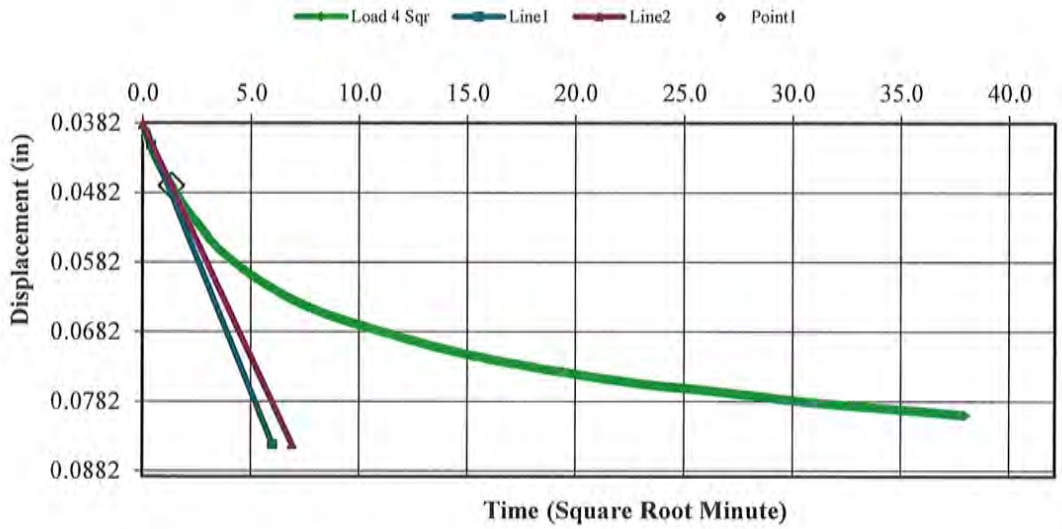
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0363	0.0346	3.4291	1.4509
1	00:00:01	0.0393	0.0371	3.6769	1.4446
2	00:00:02	0.0400	0.0378	3.7463	1.4428
3	00:00:03	0.0402	0.0380	3.7661	1.4423
4	00:00:04	0.0406	0.0384	3.8057	1.4413
5	00:00:05	0.0408	0.0386	3.8256	1.4408
6	00:00:06	0.0409	0.0387	3.8355	1.4406
7	00:00:12	0.0418	0.0396	3.9247	1.4383
8	00:00:15	0.0424	0.0402	3.9841	1.4368
9	00:00:30	0.0437	0.0415	4.1130	1.4335
10	00:01:00	0.0455	0.0433	4.2914	1.4290
11	00:02:00	0.0478	0.0456	4.5193	1.4232
12	00:04:00	0.0505	0.0483	4.7869	1.4164
13	00:08:01	0.0538	0.0516	5.1140	1.4081
14	00:10:01	0.0552	0.0530	5.2527	1.4046
15	00:15:01	0.0573	0.0551	5.4609	1.3993
16	00:30:02	0.0610	0.0588	5.8276	1.3900
17	01:00:04	0.0648	0.0626	6.2042	1.3804
18	02:00:08	0.0681	0.0659	6.5312	1.3721
19	04:00:17	0.0718	0.0696	6.8979	1.3628
20	08:00:34	0.0752	0.0730	7.2349	1.3543
21	12:00:50	0.0769	0.0747	7.4034	1.3500
22	16:01:07	0.0784	0.0762	7.5520	1.3462
23	20:01:23	0.0793	0.0771	7.6412	1.3440
24	24:00:00	0.0802	0.0780	7.7304	1.3417

Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 4) Load 1.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 5) Load 2.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

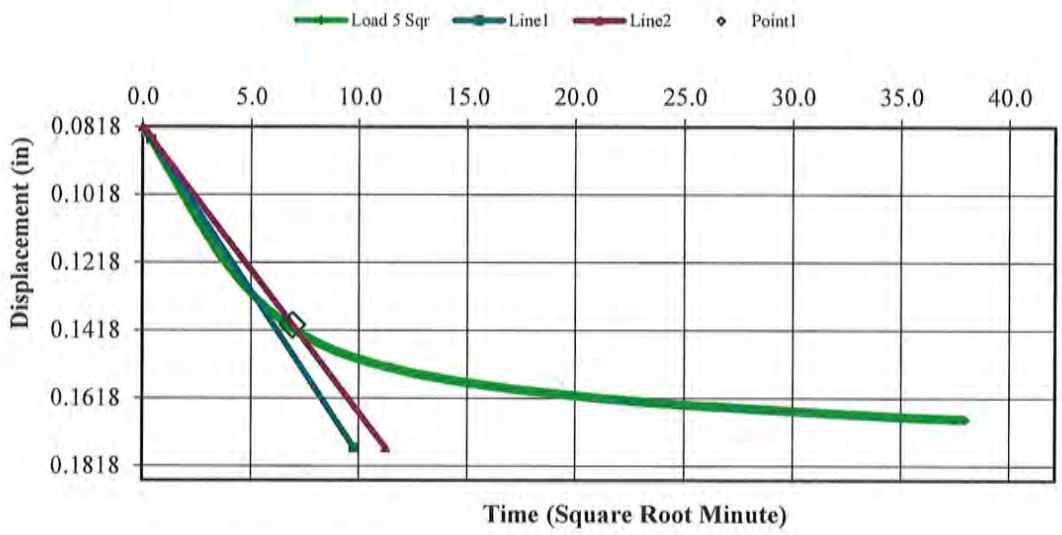
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0802	0.0780	7.7304	1.3417
1	00:00:01	0.0831	0.0802	7.9485	1.3362
2	00:00:02	0.0837	0.0808	8.0079	1.3347
3	00:00:03	0.0841	0.0812	8.0476	1.3337
4	00:00:04	0.0845	0.0816	8.0872	1.3327
5	00:00:05	0.0848	0.0819	8.1169	1.3319
6	00:00:06	0.0849	0.0820	8.1269	1.3317
7	00:00:12	0.0863	0.0834	8.2656	1.3281
8	00:00:15	0.0866	0.0837	8.2953	1.3274
9	00:00:30	0.0889	0.0860	8.5233	1.3216
10	00:01:00	0.0922	0.0893	8.8503	1.3133
11	00:02:00	0.0969	0.0940	9.3162	1.3015
12	00:04:00	0.1034	0.1005	9.9604	1.2851
13	00:08:00	0.1122	0.1093	10.8325	1.2630
14	00:10:00	0.1156	0.1127	11.1695	1.2544
15	00:15:01	0.1223	0.1194	11.8335	1.2376
16	00:30:02	0.1339	0.1310	12.9832	1.2084
17	01:00:04	0.1445	0.1416	14.0337	1.1817
18	02:00:08	0.1521	0.1492	14.7869	1.1626
19	04:00:16	0.1577	0.1548	15.3419	1.1485
20	08:00:33	0.1622	0.1593	15.7879	1.1372
21	12:00:49	0.1644	0.1615	16.0059	1.1317
22	16:01:06	0.1659	0.1630	16.1546	1.1279
23	20:01:22	0.1672	0.1643	16.2834	1.1246
24	23:59:59	0.1680	0.1651	16.3627	1.1226

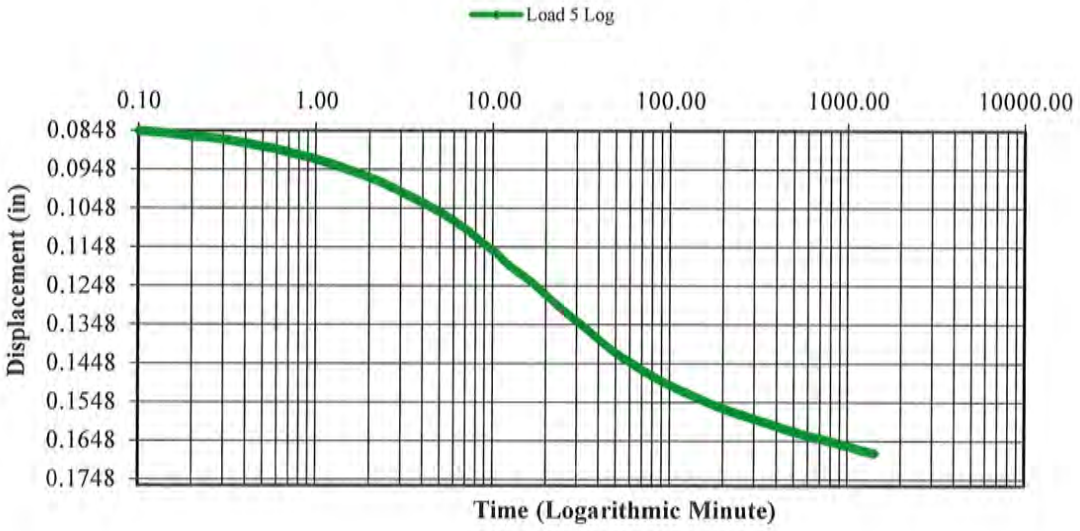
Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 5) Load 2.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 6) Rebound 0.250 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

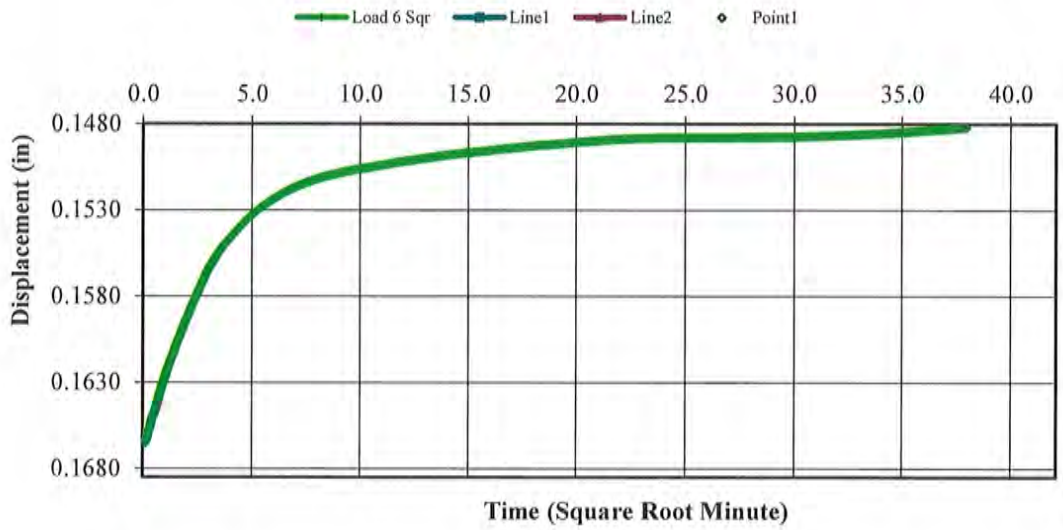
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1680	0.1651	16.3627	1.1226
1	00:00:01	0.1665	0.1651	16.3627	1.1226
2	00:00:02	0.1663	0.1649	16.3429	1.1231
3	00:00:03	0.1661	0.1647	16.3231	1.1236
4	00:00:04	0.1658	0.1644	16.2934	1.1244
5	00:00:05	0.1657	0.1643	16.2834	1.1246
6	00:00:06	0.1657	0.1643	16.2834	1.1246
7	00:00:12	0.1650	0.1636	16.2141	1.1264
8	00:00:15	0.1649	0.1635	16.2042	1.1267
9	00:00:30	0.1640	0.1626	16.1150	1.1289
10	00:01:00	0.1627	0.1613	15.9861	1.1322
11	00:02:00	0.1612	0.1598	15.8375	1.1360
12	00:04:00	0.1593	0.1579	15.6492	1.1407
13	00:08:00	0.1569	0.1555	15.4113	1.1468
14	00:10:00	0.1561	0.1547	15.3320	1.1488
15	00:15:01	0.1548	0.1534	15.2032	1.1521
16	00:30:02	0.1528	0.1514	15.0050	1.1571
17	01:00:04	0.1513	0.1499	14.8563	1.1609
18	02:00:08	0.1504	0.1490	14.7671	1.1631
19	04:00:16	0.1496	0.1482	14.6878	1.1651
20	08:00:33	0.1489	0.1475	14.6184	1.1669
21	12:00:49	0.1488	0.1474	14.6085	1.1672
22	16:01:06	0.1487	0.1473	14.5986	1.1674
23	20:01:22	0.1485	0.1471	14.5788	1.1679
24	23:59:59	0.1482	0.1468	14.5491	1.1687

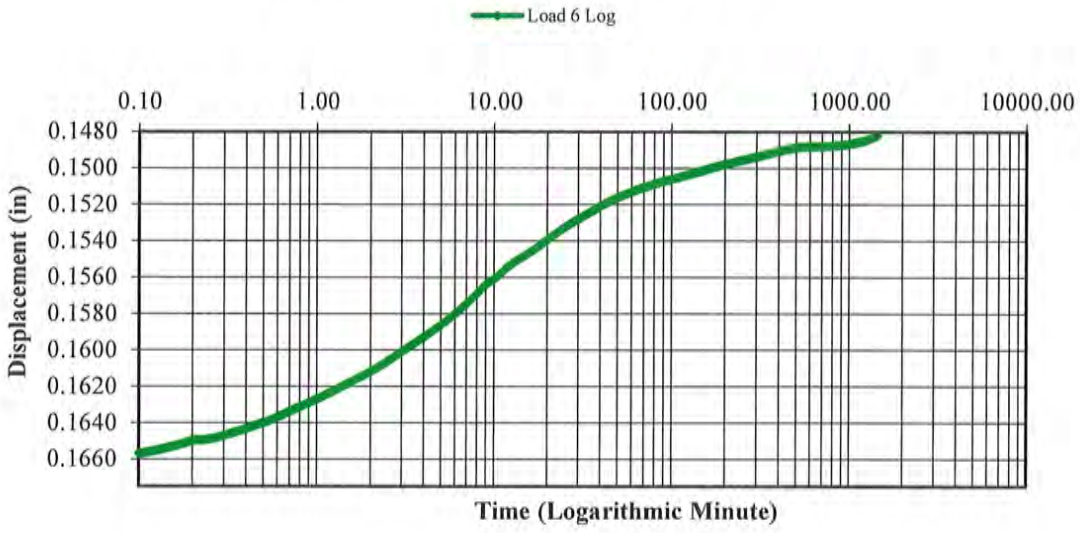
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 6) Rebound 0.250 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 7) Load 0.500 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

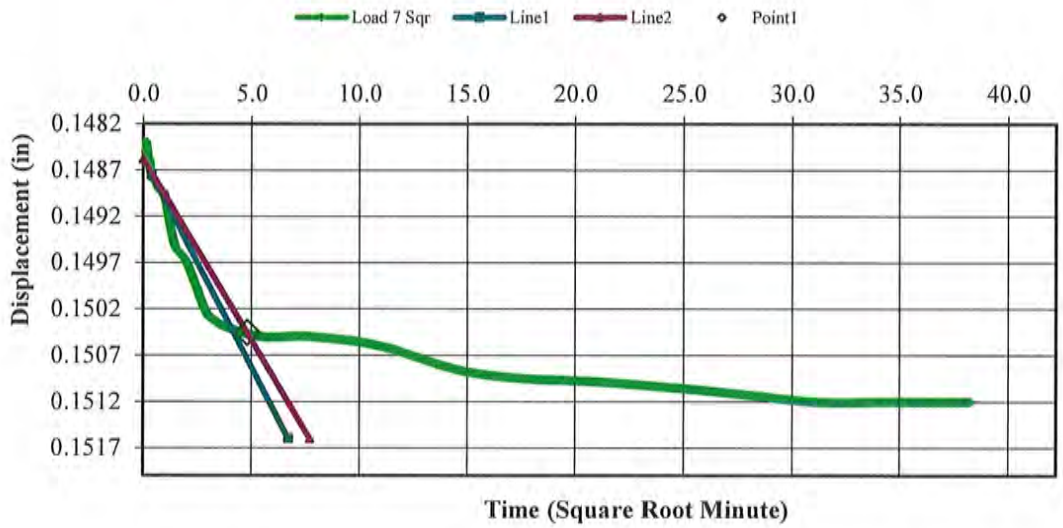
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1482	0.1468	14.5491	1.1687
1	00:00:01	0.1484	0.1467	14.5391	1.1689
2	00:00:02	0.1485	0.1468	14.5491	1.1687
3	00:00:03	0.1486	0.1469	14.5590	1.1684
4	00:00:04	0.1486	0.1469	14.5590	1.1684
5	00:00:05	0.1486	0.1469	14.5590	1.1684
6	00:00:06	0.1487	0.1470	14.5689	1.1682
7	00:00:12	0.1488	0.1471	14.5788	1.1679
8	00:00:15	0.1488	0.1471	14.5788	1.1679
9	00:00:30	0.1489	0.1472	14.5887	1.1677
10	00:01:00	0.1490	0.1473	14.5986	1.1674
11	00:02:01	0.1495	0.1478	14.6482	1.1661
12	00:04:01	0.1497	0.1480	14.6680	1.1656
13	00:08:01	0.1502	0.1485	14.7175	1.1644
14	00:10:01	0.1503	0.1486	14.7275	1.1641
15	00:15:01	0.1504	0.1487	14.7374	1.1639
16	00:30:02	0.1505	0.1488	14.7473	1.1636
17	01:00:05	0.1505	0.1488	14.7473	1.1636
18	02:00:09	0.1506	0.1489	14.7572	1.1634
19	04:00:17	0.1509	0.1492	14.7869	1.1626
20	08:00:33	0.1510	0.1493	14.7968	1.1624
21	12:00:50	0.1511	0.1494	14.8067	1.1621
22	16:01:06	0.1512	0.1495	14.8166	1.1619
23	20:01:23	0.1512	0.1495	14.8166	1.1619
24	24:01:39	0.1512	0.1495	14.8166	1.1619
25	24:08:12	0.1512	0.1495	14.8166	1.1619

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 7) Load 0.500 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 8) Load 1.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

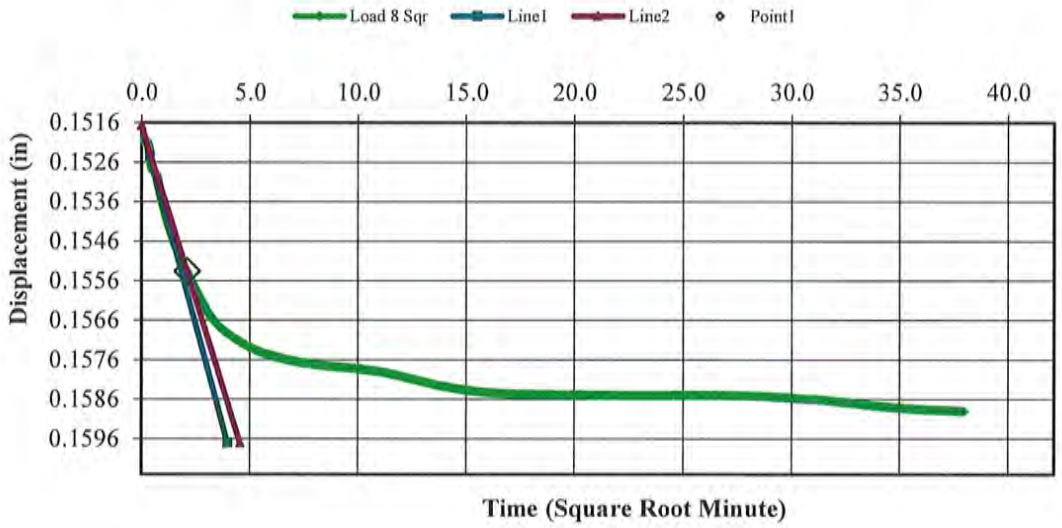
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1512	0.1495	14.8166	1.1619
1	00:00:01	0.1520	0.1498	14.8464	1.1611
2	00:00:02	0.1521	0.1499	14.8563	1.1609
3	00:00:03	0.1521	0.1499	14.8563	1.1609
4	00:00:04	0.1521	0.1499	14.8563	1.1609
5	00:00:05	0.1522	0.1500	14.8662	1.1606
6	00:00:06	0.1522	0.1500	14.8662	1.1606
7	00:00:12	0.1527	0.1505	14.9158	1.1594
8	00:00:15	0.1528	0.1506	14.9257	1.1591
9	00:00:30	0.1530	0.1508	14.9455	1.1586
10	00:01:00	0.1537	0.1515	15.0149	1.1568
11	00:02:00	0.1545	0.1523	15.0942	1.1548
12	00:04:00	0.1553	0.1531	15.1734	1.1528
13	00:08:00	0.1562	0.1540	15.2626	1.1506
14	00:10:00	0.1565	0.1543	15.2924	1.1498
15	00:15:01	0.1569	0.1547	15.3320	1.1488
16	00:30:02	0.1574	0.1552	15.3816	1.1475
17	01:00:04	0.1577	0.1555	15.4113	1.1468
18	02:00:08	0.1579	0.1557	15.4311	1.1463
19	04:00:16	0.1584	0.1562	15.4807	1.1450
20	08:00:33	0.1585	0.1563	15.4906	1.1448
21	12:00:49	0.1585	0.1563	15.4906	1.1448
22	16:01:05	0.1586	0.1564	15.5005	1.1445
23	20:01:22	0.1588	0.1566	15.5203	1.1440
24	23:59:59	0.1589	0.1567	15.5302	1.1438

Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 8) Load 1.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 9) Load 2.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

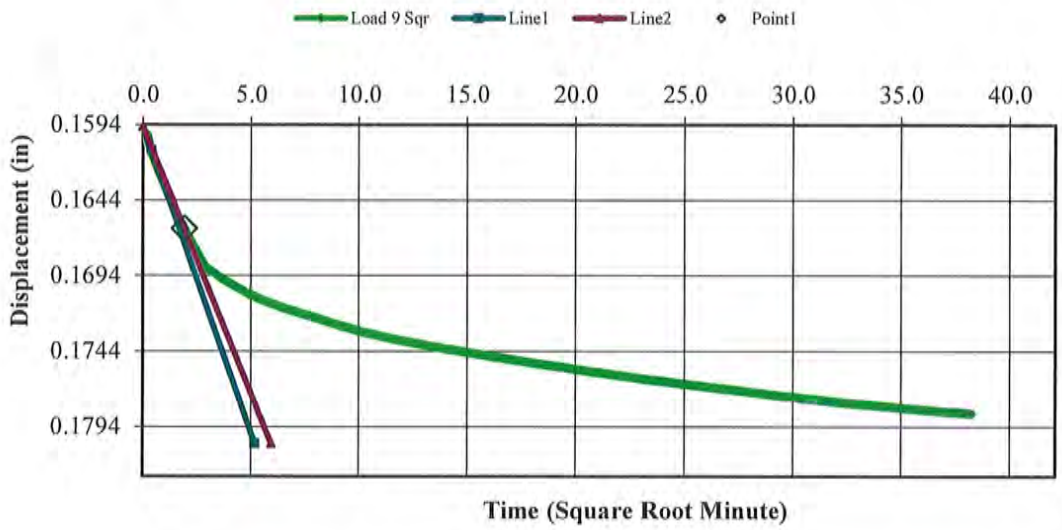
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1589	0.1567	15.5302	1.1438
1	00:00:01	0.1600	0.1571	15.5699	1.1428
2	00:00:02	0.1601	0.1572	15.5798	1.1425
3	00:00:03	0.1604	0.1575	15.6095	1.1417
4	00:00:04	0.1606	0.1577	15.6293	1.1412
5	00:00:05	0.1608	0.1579	15.6492	1.1407
6	00:00:06	0.1608	0.1579	15.6492	1.1407
7	00:00:12	0.1614	0.1585	15.7086	1.1392
8	00:00:15	0.1616	0.1587	15.7284	1.1387
9	00:00:30	0.1624	0.1595	15.8077	1.1367
10	00:01:00	0.1634	0.1605	15.9068	1.1342
11	00:02:00	0.1649	0.1620	16.0555	1.1304
12	00:04:01	0.1666	0.1637	16.2240	1.1262
13	00:08:01	0.1687	0.1658	16.4321	1.1209
14	00:10:01	0.1691	0.1662	16.4718	1.1199
15	00:15:01	0.1698	0.1669	16.5411	1.1181
16	00:30:02	0.1710	0.1681	16.6601	1.1151
17	01:00:04	0.1721	0.1692	16.7691	1.1123
18	02:00:08	0.1734	0.1705	16.8979	1.1091
19	04:00:17	0.1746	0.1717	17.0168	1.1060
20	08:00:33	0.1760	0.1731	17.1556	1.1025
21	12:00:50	0.1769	0.1740	17.2448	1.1002
22	16:01:06	0.1776	0.1747	17.3142	1.0985
23	20:01:22	0.1781	0.1752	17.3637	1.0972
24	24:01:39	0.1785	0.1756	17.4034	1.0962
25	24:01:39	0.1785	0.1756	17.4034	1.0962

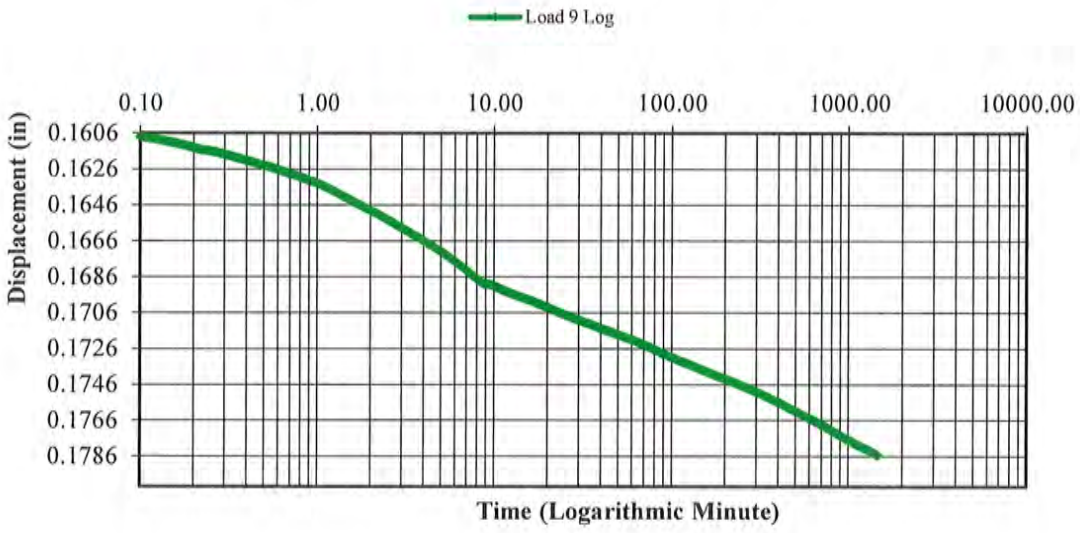
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 9) Load 2.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 10) Load 4.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

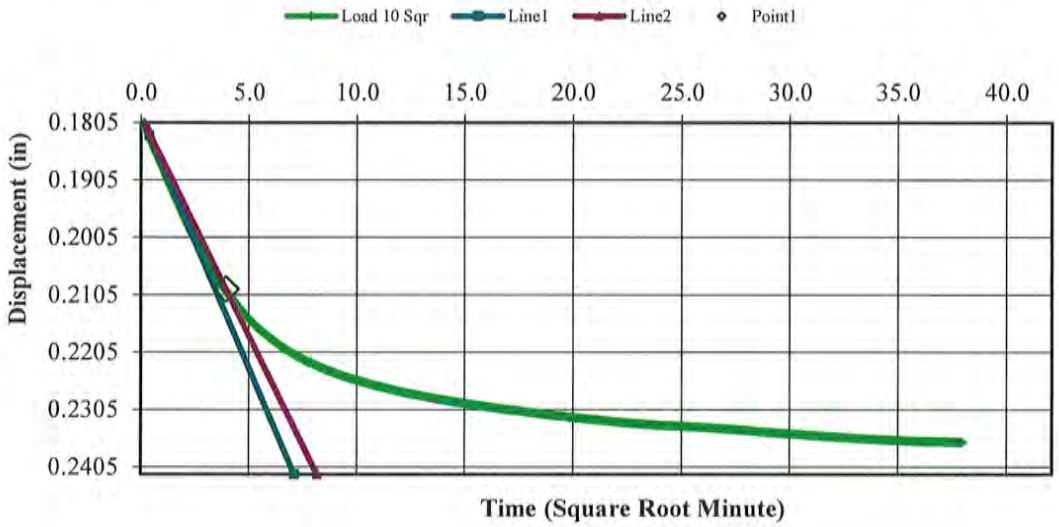
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1785	0.1756	17.4034	1.0962
1	00:00:01	0.1806	0.1773	17.5719	1.0919
2	00:00:02	0.1809	0.1776	17.6016	1.0912
3	00:00:03	0.1814	0.1781	17.6511	1.0899
4	00:00:04	0.1816	0.1783	17.6710	1.0894
5	00:00:05	0.1818	0.1785	17.6908	1.0889
6	00:00:06	0.1822	0.1789	17.7304	1.0879
7	00:00:12	0.1833	0.1800	17.8394	1.0852
8	00:00:15	0.1838	0.1805	17.8890	1.0839
9	00:00:30	0.1856	0.1823	18.0674	1.0794
10	00:01:00	0.1881	0.1848	18.3152	1.0731
11	00:02:00	0.1919	0.1886	18.6918	1.0635
12	00:04:00	0.1968	0.1935	19.1774	1.0512
13	00:08:01	0.2032	0.1999	19.8117	1.0351
14	00:10:01	0.2054	0.2021	20.0297	1.0296
15	00:15:01	0.2096	0.2063	20.4460	1.0190
16	00:30:02	0.2165	0.2132	21.1298	1.0016
17	01:00:04	0.2222	0.2189	21.6947	0.9873
18	02:00:08	0.2264	0.2231	22.1110	0.9767
19	04:00:17	0.2297	0.2264	22.4381	0.9684
20	08:00:33	0.2326	0.2293	22.7255	0.9612
21	12:00:49	0.2338	0.2305	22.8444	0.9581
22	16:01:06	0.2350	0.2317	22.9633	0.9551
23	20:01:22	0.2358	0.2325	23.0426	0.9531
24	24:00:01	0.2362	0.2329	23.0823	0.9521

Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 10) Load 4.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 11) Load 8.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

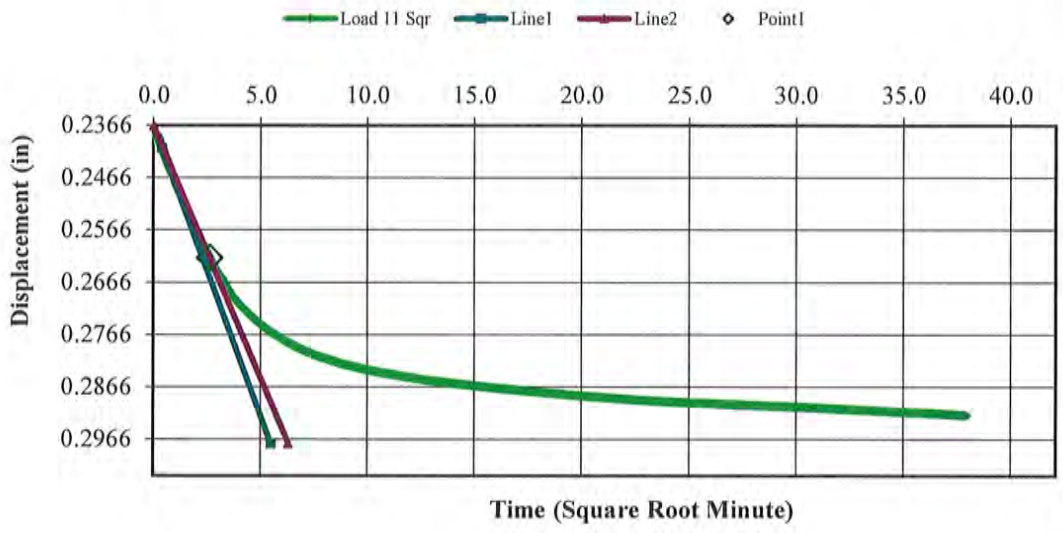
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.2362	0.2329	23.0823	0.9521
1	00:00:01	0.2384	0.2345	23.2408	0.9481
2	00:00:02	0.2390	0.2351	23.3003	0.9466
3	00:00:03	0.2393	0.2354	23.3300	0.9458
4	00:00:04	0.2398	0.2359	23.3796	0.9446
5	00:00:05	0.2401	0.2362	23.4093	0.9438
6	00:00:06	0.2403	0.2364	23.4291	0.9433
7	00:00:12	0.2417	0.2378	23.5679	0.9398
8	00:00:15	0.2424	0.2385	23.6373	0.9380
9	00:00:30	0.2445	0.2406	23.8454	0.9327
10	00:01:00	0.2474	0.2435	24.1328	0.9254
11	00:02:00	0.2515	0.2476	24.5391	0.9151
12	00:04:00	0.2569	0.2530	25.0743	0.9015
13	00:08:00	0.2638	0.2599	25.7582	0.8842
14	00:10:00	0.2659	0.2620	25.9663	0.8789
15	00:15:01	0.2702	0.2663	26.3925	0.8681
16	00:30:02	0.2761	0.2722	26.9772	0.8532
17	01:00:04	0.2808	0.2769	27.4430	0.8414
18	02:00:08	0.2841	0.2802	27.7701	0.8331
19	04:00:16	0.2866	0.2827	28.0178	0.8268
20	08:00:32	0.2889	0.2850	28.2458	0.8211
21	12:00:49	0.2899	0.2860	28.3449	0.8185
22	16:01:05	0.2906	0.2867	28.4143	0.8168
23	20:01:22	0.2913	0.2874	28.4836	0.8150
24	23:58:43	0.2920	0.2881	28.5530	0.8133

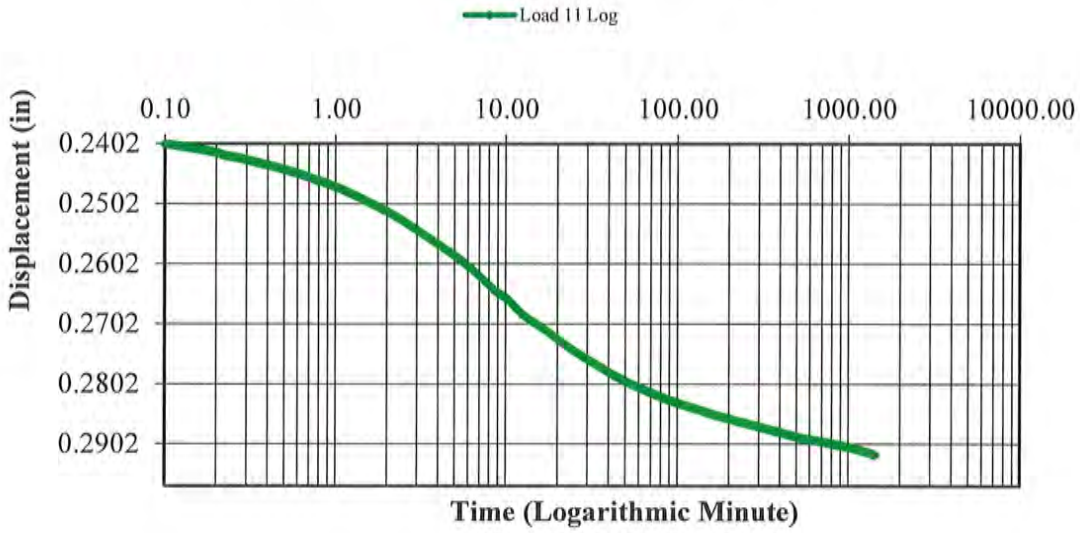
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 11) Load 8.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 12) Load 16.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

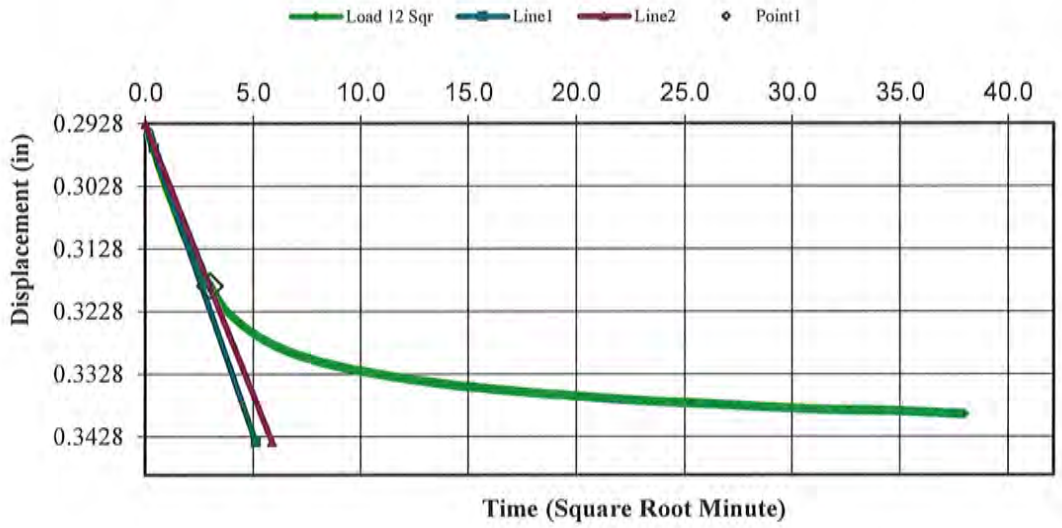
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.2920	0.2881	28.5530	0.8133
1	00:00:01	0.2939	0.2893	28.6719	0.8102
2	00:00:02	0.2945	0.2899	28.7314	0.8087
3	00:00:03	0.2951	0.2905	28.7909	0.8072
4	00:00:04	0.2953	0.2907	28.8107	0.8067
5	00:00:05	0.2958	0.2912	28.8603	0.8055
6	00:00:06	0.2960	0.2914	28.8801	0.8050
7	00:00:12	0.2974	0.2928	29.0188	0.8014
8	00:00:15	0.2978	0.2932	29.0585	0.8004
9	00:00:30	0.3000	0.2954	29.2765	0.7949
10	00:01:00	0.3030	0.2984	29.5738	0.7873
11	00:02:00	0.3069	0.3023	29.9604	0.7775
12	00:04:00	0.3120	0.3074	30.4658	0.7647
13	00:08:00	0.3177	0.3131	31.0307	0.7504
14	00:10:01	0.3198	0.3152	31.2388	0.7451
15	00:15:01	0.3231	0.3185	31.5659	0.7368
16	00:30:02	0.3273	0.3227	31.9822	0.7262
17	01:00:04	0.3305	0.3259	32.2993	0.7182
18	02:00:08	0.3329	0.3283	32.5372	0.7121
19	04:00:16	0.3350	0.3304	32.7453	0.7069
20	08:00:33	0.3368	0.3322	32.9237	0.7023
21	12:00:49	0.3377	0.3331	33.0129	0.7001
22	16:01:06	0.3384	0.3338	33.0823	0.6983
23	20:01:22	0.3387	0.3341	33.1120	0.6976
24	23:59:59	0.3392	0.3346	33.1615	0.6963

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 12) Load 16.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 13) Rebound 0.125 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6-19-18
Test Number:

Sample Number: B-1
Boring Number: B-1
Depth: 6'-8'
Sample Type: Undisturbed

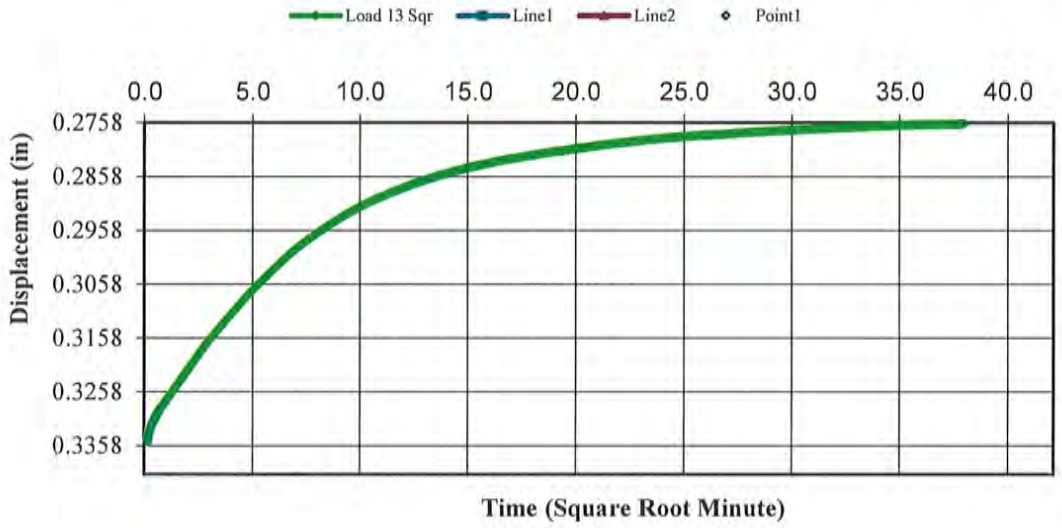
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.3392	0.3346	33.1615	0.6963
1	00:00:01	0.3351	0.3338	33.0823	0.6983
2	00:00:02	0.3337	0.3324	32.9435	0.7018
3	00:00:03	0.3330	0.3317	32.8741	0.7036
4	00:00:04	0.3328	0.3315	32.8543	0.7041
5	00:00:05	0.3323	0.3310	32.8048	0.7054
6	00:00:06	0.3321	0.3308	32.7849	0.7059
7	00:00:12	0.3310	0.3297	32.6759	0.7086
8	00:00:15	0.3305	0.3292	32.6264	0.7099
9	00:00:30	0.3290	0.3277	32.4777	0.7137
10	00:01:00	0.3273	0.3260	32.3092	0.7179
11	00:02:00	0.3249	0.3236	32.0714	0.7240
12	00:04:00	0.3216	0.3203	31.7443	0.7323
13	00:08:01	0.3169	0.3156	31.2785	0.7441
14	00:10:01	0.3153	0.3140	31.1199	0.7481
15	00:15:01	0.3119	0.3106	30.7830	0.7567
16	00:30:02	0.3049	0.3036	30.0892	0.7743
17	01:00:04	0.2970	0.2957	29.3062	0.7941
18	02:00:08	0.2896	0.2883	28.5728	0.8128
19	04:00:17	0.2837	0.2824	27.9881	0.8276
20	08:00:33	0.2796	0.2783	27.5818	0.8379
21	12:00:50	0.2779	0.2766	27.4133	0.8422
22	16:01:06	0.2770	0.2757	27.3241	0.8444
23	20:01:23	0.2763	0.2750	27.2547	0.8462
24	23:59:59	0.2760	0.2747	27.2250	0.8470

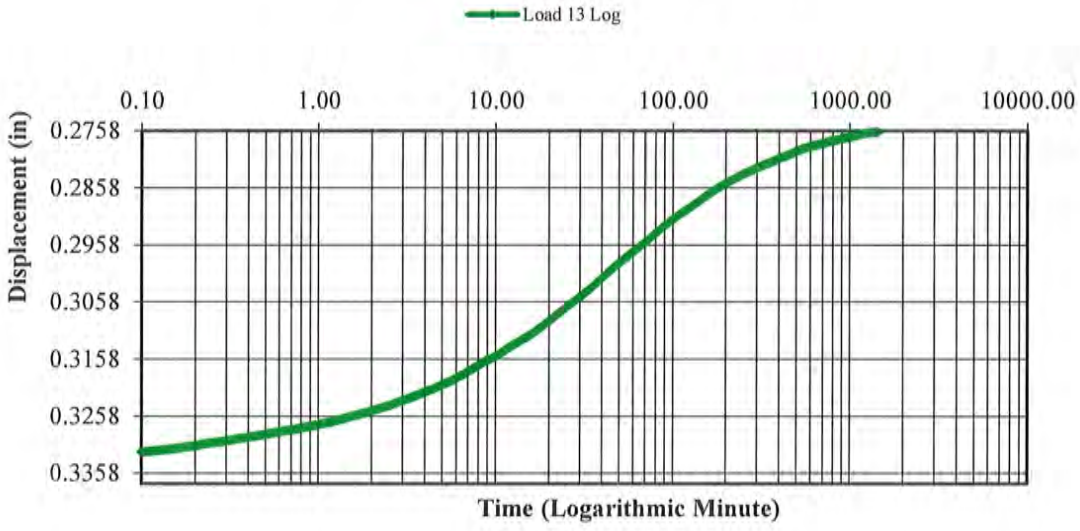
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 13) Rebound 0.125 tsf

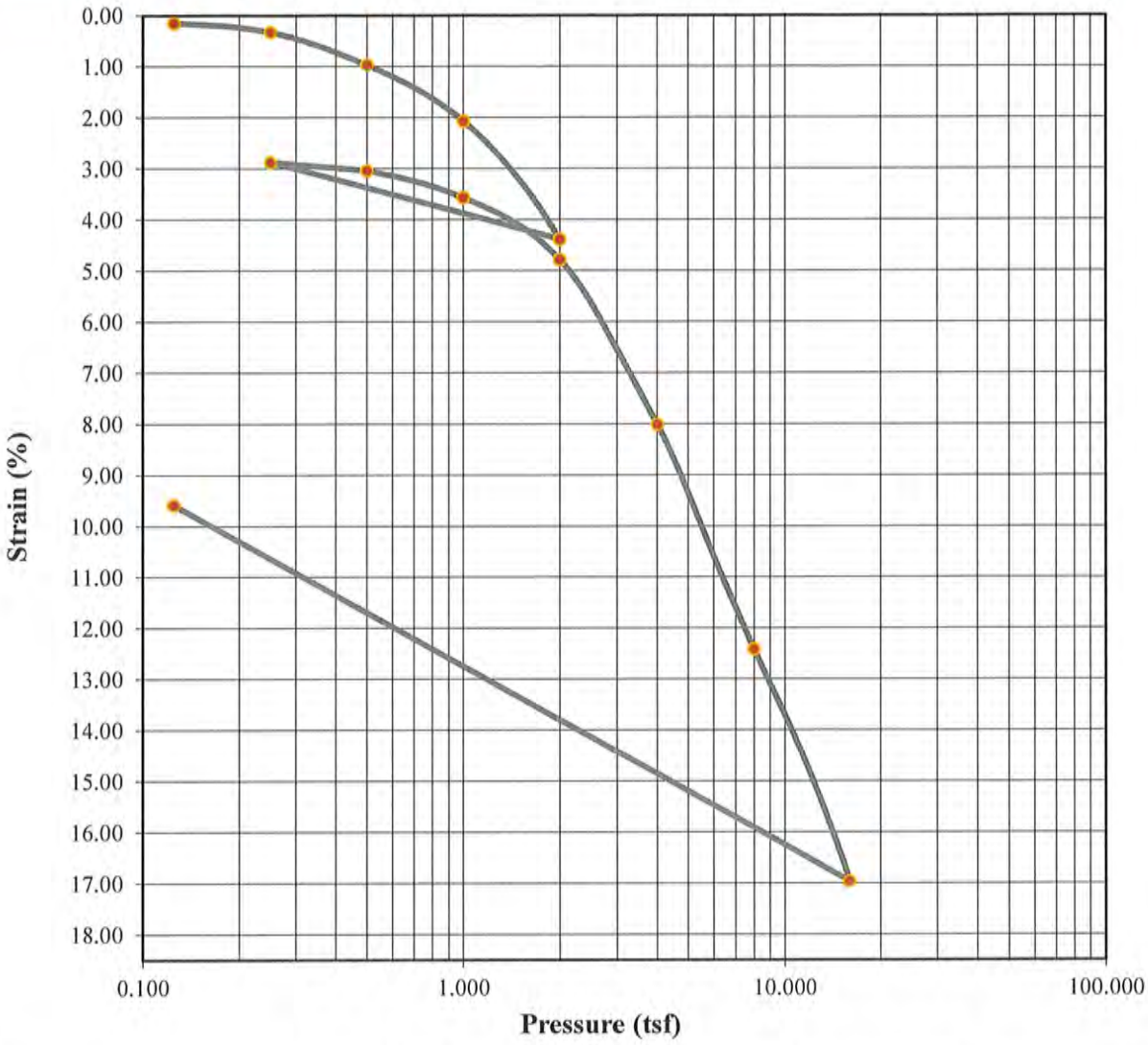
Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



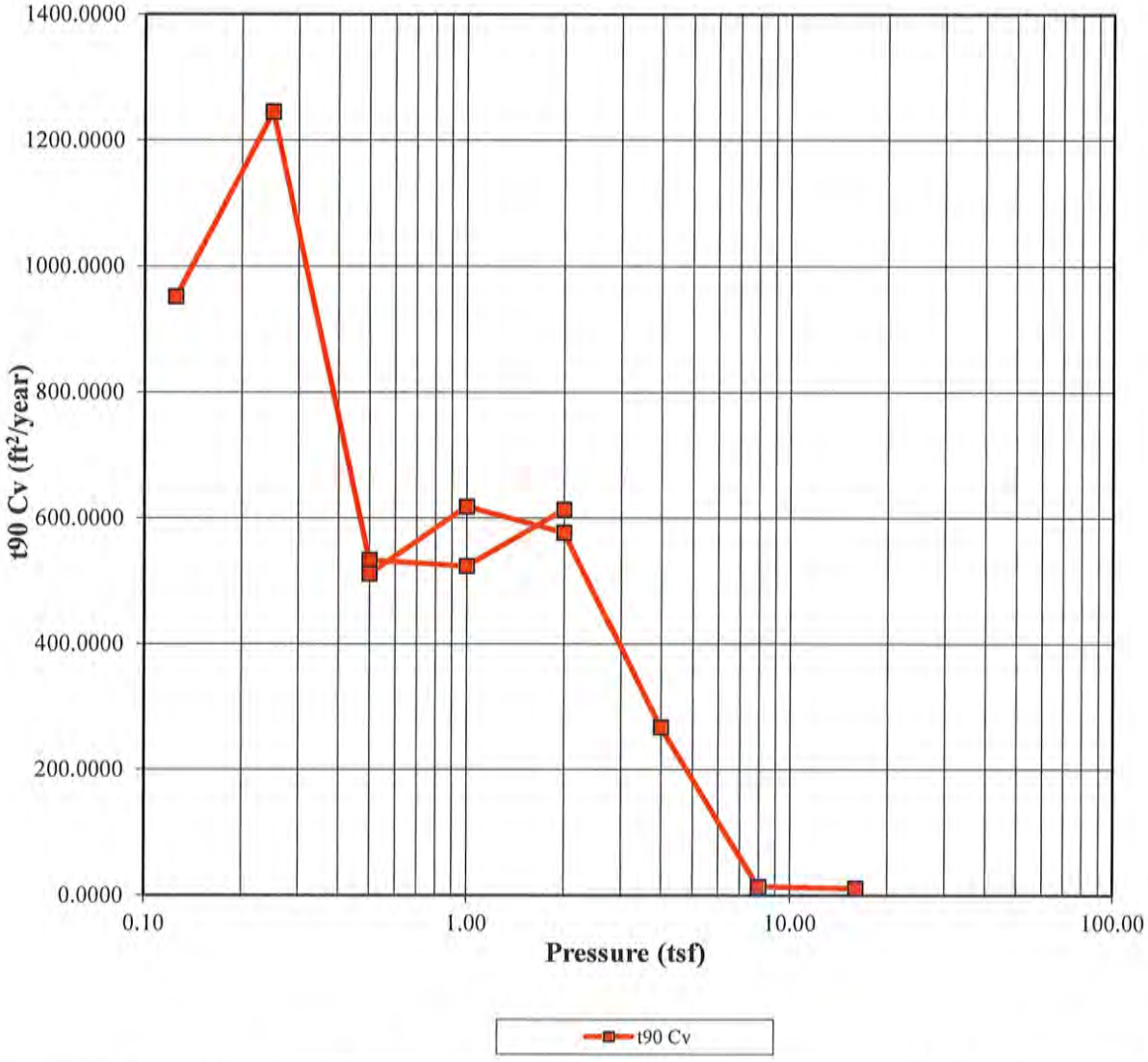
Consolidation Test
Test Results



	Before	After				
Moisture (%):	34.26	30.15	**Liquid Limits:**	55	**Test Date:**	6/20/18
Dry Density (pcf):	85.67	93.69	**Plastic Limits:**	28		
Saturation (%):	96.36	102.83	**Plasticity Index (%):**	27		
Void Ratio:	0.9506	0.7636	**Specific Gravity:**	2.680	Assumed	

Sample Description:	FAT CLAY (CH), gray		
Project Number:	18C13074	**Depth:** 15'-17'	**Remarks:**
Sample Number:	B-2	**Boring Number:** B-2	
Project:	Wallops Island Breakwaters		
Location:	Wallops Island, VA		

Consolidation Test
Test Results



	Before	After				
Moisture (%):	34.26	30.15	**Liquid Limits:**	55	**Test Date:**	6/20/18
Dry Density (pcf):	85.67	93.69	**Plastic Limits:**	28		
Saturation (%):	96.36	102.83	**Plasticity Index (%):**	27		
Void Ratio:	0.9506	0.7636	**Specific Gravity:**	2.680	Assumed	

Soil Description:	FAT CLAY (CH), gray		
Project Number:	18C13074	**Depth:** 15'-17'	**Remarks:**
Sample Number:	B-2	**Boring Number:** B-2	
Project:	Wallops Island Breakwaters		
Client:			
Location:	Wallops Island, VA		

Consolidation Test Results
Summary

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

Sample Description: FAT CLAY (CH), gray
Remarks:

Test Number:
Test Date: 6/20/18

Index	Load Sequence (tsf)	Cummulative Change in Height (in)	Specimen Height (in)	Height of Void (in)	Vertical Strain (%)	Void Ratio	t90 Fitting Time (min)	t50 Fitting Time (min)	t90 Cv (ft2/year)	t50 Cv (ft2/year)
0	0.000	0.0000	1.0035	0.4887	0.00	0.9494	0.000	0.000	0.000	0.000
1	0.125	0.0015	1.0020	0.4872	0.15	0.9465	0.816	*0.4534	951.926	398.064
2	0.250	0.0033	1.0002	0.4854	0.33	0.9430	0.622	*0.3453	1245.412	520.806
3	0.500	0.0097	0.9938	0.4790	0.97	0.9305	1.433	*0.7960	533.355	223.041
4	1.000	0.0208	0.9827	0.4679	2.07	0.9090	1.427	*0.7927	523.698	218.994
5	2.000	0.0440	0.9595	0.4447	4.38	0.8639	1.161	*0.6450	613.562	256.584
6	0.250	0.0288	0.9747	0.4599	2.87	0.8934	0.000	0.000	0.000	0.000
7	0.500	0.0305	0.9730	0.4582	3.04	0.8901	1.433	*0.7960	511.273	213.802
8	1.000	0.0358	0.9677	0.4529	3.57	0.8798	1.172	*0.6510	618.375	258.583
9	2.000	0.0480	0.9555	0.4407	4.78	0.8561	1.224	*0.6802	577.013	241.281
10	4.000	0.0804	0.9231	0.4083	8.01	0.7932	2.467	*1.3705	267.291	111.768
11	8.000	0.1245	0.8790	0.3642	12.41	0.7075	42.711	*23.7285	13.998	5.853
12	16.000	0.1702	0.8333	0.3185	16.96	0.6188	47.736	*26.5198	11.256	4.707
13	0.125	0.0962	0.9073	0.3925	9.59	0.7625	0.000	0.000	0.000	0.000

Predicted value indicated with *

Tested By: RG

Checked By: DS

Consolidation Test
Consolidation Specimen Information

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

Sample Description: FAT CLAY (CH), gray
Remarks:

Test Number:
Liquid Limit: 55.0000
Plastic Limit: 28.0000
Specific Gravity: 2.6800 Assumed

Initial Void Ratio: 0.9506
Plasticity Index (%): 27.0000
Weight of Ring (g): 110.5500

Initial Height (in): 1.0035
Initial Diameter (in): 2.5000

Parameters	Initial Specimen	Final Specimen
Moist Weight + Container (g)	354.85	340.40
Dry Soil + Container (g)	315.25	307.90
Weight of Container (g)	199.40	200.10
Moisture Content (%)	34.26	30.15
Void Ratio	0.9506	0.7636
Saturation (%)	96.36	102.83
Dry Density (pcf)	85.67	93.69

Tested By: RG

Checked By: DS

Consolidation Test Results
(Sequence 1) Load 0.125 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

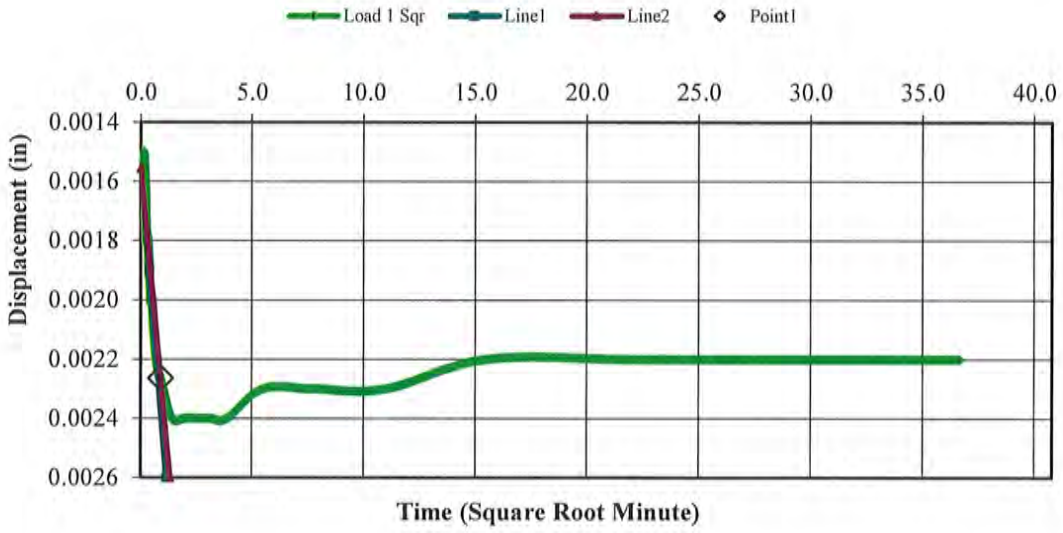
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0007	0.0000	0.0000	0.9506
1	00:00:01	0.0015	0.0008	0.0797	0.9490
2	00:00:02	0.0016	0.0009	0.0897	0.9488
3	00:00:03	0.0017	0.0010	0.0997	0.9486
4	00:00:04	0.0018	0.0011	0.1096	0.9484
5	00:00:05	0.0018	0.0011	0.1096	0.9484
6	00:00:06	0.0018	0.0011	0.1096	0.9484
7	00:00:12	0.0020	0.0013	0.1295	0.9481
8	00:00:15	0.0020	0.0013	0.1295	0.9481
9	00:00:30	0.0022	0.0015	0.1495	0.9477
10	00:01:00	0.0023	0.0016	0.1594	0.9475
11	00:02:00	0.0024	0.0017	0.1694	0.9473
12	00:04:00	0.0024	0.0017	0.1694	0.9473
13	00:08:01	0.0024	0.0017	0.1694	0.9473
14	00:10:01	0.0024	0.0017	0.1694	0.9473
15	00:15:02	0.0024	0.0017	0.1694	0.9473
16	00:30:04	0.0023	0.0016	0.1594	0.9475
17	01:00:09	0.0023	0.0016	0.1594	0.9475
18	02:00:18	0.0023	0.0016	0.1594	0.9475
19	04:00:28	0.0022	0.0015	0.1495	0.9477
20	08:00:24	0.0022	0.0015	0.1495	0.9477
21	12:00:21	0.0022	0.0015	0.1495	0.9477
22	16:00:17	0.0022	0.0015	0.1495	0.9477
23	20:00:14	0.0022	0.0015	0.1495	0.9477
24	22:23:03	0.0022	0.0015	0.1495	0.9477

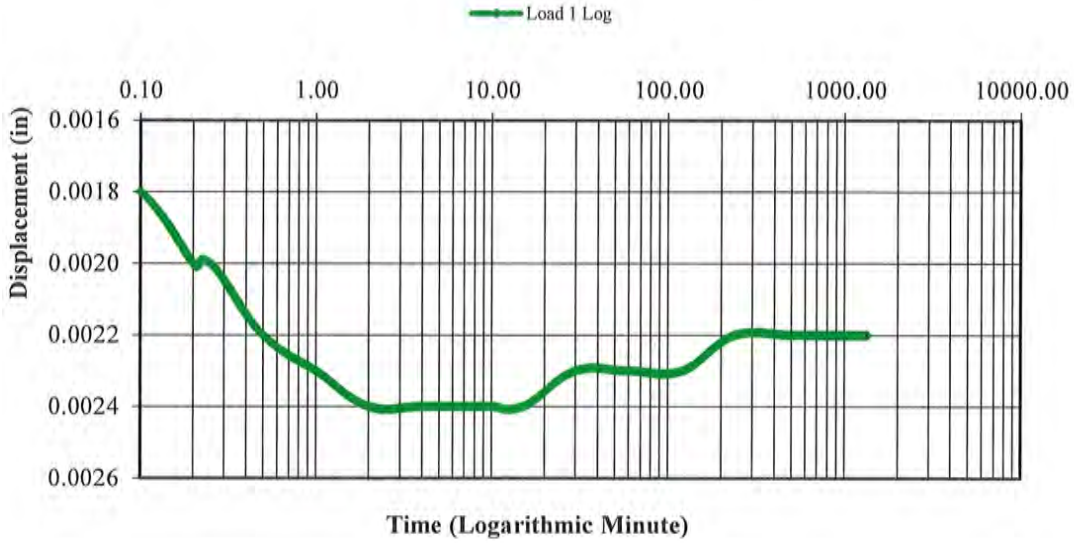
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 1) Load 0.125 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 2) Load 0.250 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

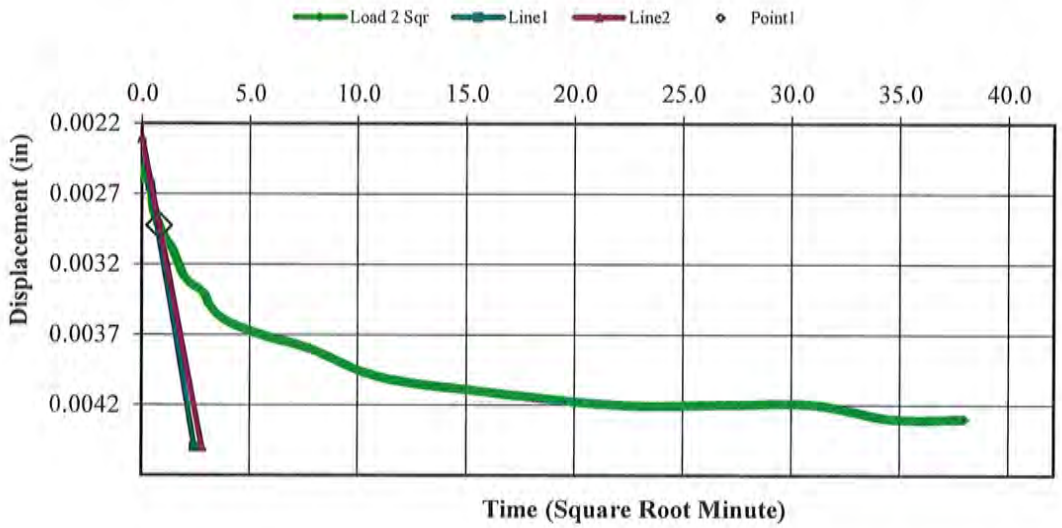
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0022	0.0015	0.1495	0.9477
1	00:00:01	0.0025	0.0015	0.1495	0.9477
2	00:00:02	0.0026	0.0016	0.1594	0.9475
3	00:00:03	0.0026	0.0016	0.1594	0.9475
4	00:00:04	0.0026	0.0016	0.1594	0.9475
5	00:00:05	0.0026	0.0016	0.1594	0.9475
6	00:00:06	0.0026	0.0016	0.1594	0.9475
7	00:00:12	0.0027	0.0017	0.1694	0.9473
8	00:00:15	0.0028	0.0018	0.1794	0.9471
9	00:00:30	0.0029	0.0019	0.1893	0.9469
10	00:01:00	0.0030	0.0020	0.1993	0.9467
11	00:01:59	0.0031	0.0021	0.2093	0.9465
12	00:03:59	0.0033	0.0023	0.2292	0.9461
13	00:07:59	0.0034	0.0024	0.2392	0.9459
14	00:09:59	0.0035	0.0025	0.2491	0.9457
15	00:14:59	0.0036	0.0026	0.2591	0.9455
16	00:29:59	0.0037	0.0027	0.2691	0.9453
17	00:59:59	0.0038	0.0028	0.2790	0.9451
18	01:59:58	0.0040	0.0030	0.2990	0.9448
19	04:00:06	0.0041	0.0031	0.3089	0.9446
20	08:00:23	0.0042	0.0032	0.3189	0.9444
21	12:00:39	0.0042	0.0032	0.3189	0.9444
22	16:00:56	0.0042	0.0032	0.3189	0.9444
23	20:01:13	0.0043	0.0033	0.3288	0.9442
24	24:01:18	0.0043	0.0033	0.3288	0.9442

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 2) Load 0.250 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 3) Load 0.500 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0043	0.0033	0.3288	0.9442
1	00:00:01	0.0054	0.0040	0.3986	0.9428
2	00:00:02	0.0056	0.0042	0.4185	0.9424
3	00:00:03	0.0057	0.0043	0.4285	0.9422
4	00:00:04	0.0058	0.0044	0.4385	0.9420
5	00:00:05	0.0059	0.0045	0.4484	0.9418
6	00:00:06	0.0060	0.0046	0.4584	0.9416
7	00:00:12	0.0062	0.0048	0.4783	0.9413
8	00:00:15	0.0063	0.0049	0.4883	0.9411
9	00:00:30	0.0067	0.0053	0.5282	0.9403
10	00:01:00	0.0071	0.0057	0.5680	0.9395
11	00:02:00	0.0075	0.0061	0.6079	0.9387
12	00:04:00	0.0081	0.0067	0.6677	0.9376
13	00:08:01	0.0086	0.0072	0.7175	0.9366
14	00:10:01	0.0088	0.0074	0.7374	0.9362
15	00:15:01	0.0091	0.0077	0.7673	0.9356
16	00:30:02	0.0096	0.0082	0.8171	0.9346
17	01:00:04	0.0101	0.0087	0.8670	0.9337
18	02:00:08	0.0104	0.0090	0.8969	0.9331
19	04:00:17	0.0106	0.0092	0.9168	0.9327
20	08:00:34	0.0109	0.0095	0.9467	0.9321
21	12:00:50	0.0109	0.0095	0.9467	0.9321
22	16:01:07	0.0110	0.0096	0.9567	0.9319
23	20:01:23	0.0110	0.0096	0.9567	0.9319
24	24:00:01	0.0111	0.0097	0.9666	0.9317

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 3) Load 0.500 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 4) Load 1.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

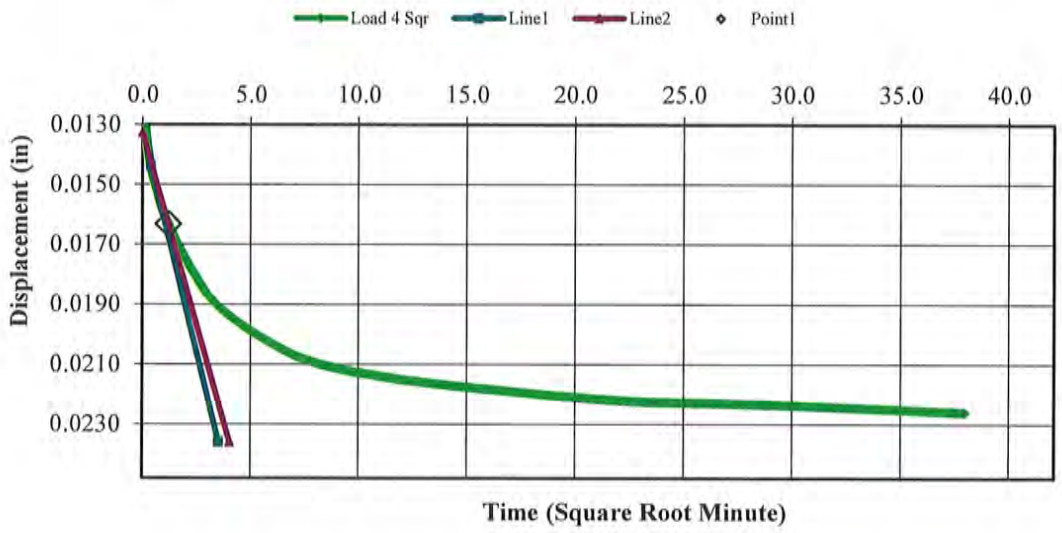
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0111	0.0097	0.9666	0.9317
1	00:00:01	0.0131	0.0113	1.1261	0.9286
2	00:00:02	0.0135	0.0117	1.1659	0.9278
3	00:00:03	0.0138	0.0120	1.1958	0.9273
4	00:00:04	0.0139	0.0121	1.2058	0.9271
5	00:00:05	0.0141	0.0123	1.2257	0.9267
6	00:00:06	0.0142	0.0124	1.2357	0.9265
7	00:00:12	0.0146	0.0128	1.2755	0.9257
8	00:00:15	0.0148	0.0130	1.2955	0.9253
9	00:00:30	0.0153	0.0135	1.3453	0.9243
10	00:01:00	0.0160	0.0142	1.4150	0.9230
11	00:02:00	0.0167	0.0149	1.4848	0.9216
12	00:04:00	0.0175	0.0157	1.5645	0.9201
13	00:08:00	0.0185	0.0167	1.6642	0.9181
14	00:10:01	0.0188	0.0170	1.6941	0.9175
15	00:15:01	0.0193	0.0175	1.7439	0.9166
16	00:30:02	0.0201	0.0183	1.8236	0.9150
17	01:00:04	0.0209	0.0191	1.9033	0.9135
18	02:00:08	0.0214	0.0196	1.9532	0.9125
19	04:00:16	0.0218	0.0200	1.9930	0.9117
20	08:00:33	0.0222	0.0204	2.0329	0.9109
21	12:00:49	0.0223	0.0205	2.0429	0.9107
22	16:01:06	0.0224	0.0206	2.0528	0.9105
23	20:01:22	0.0225	0.0207	2.0628	0.9103
24	23:59:59	0.0226	0.0208	2.0727	0.9102

Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 4) Load 1.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 5) Load 2.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

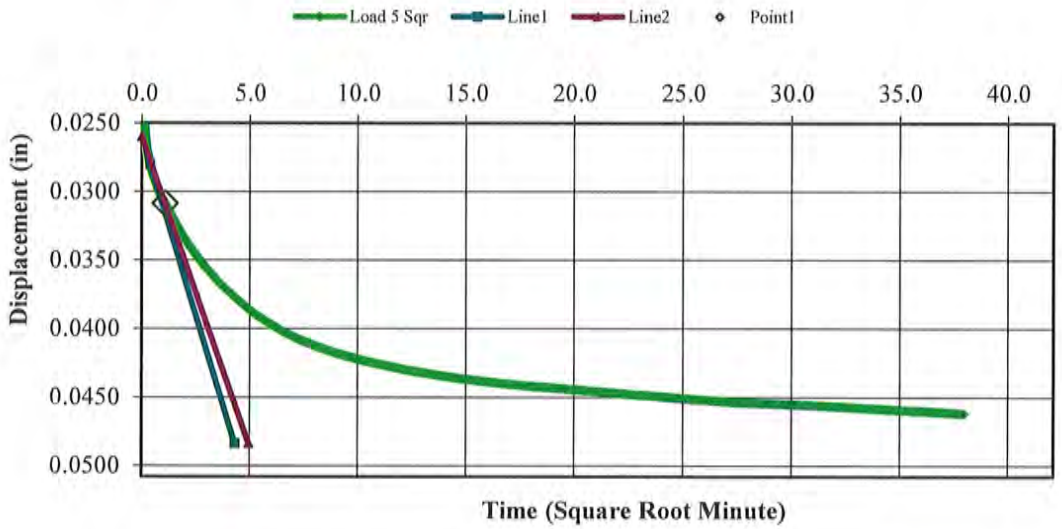
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0226	0.0208	2.0727	0.9102
1	00:00:01	0.0252	0.0230	2.2920	0.9059
2	00:00:02	0.0263	0.0241	2.4016	0.9037
3	00:00:03	0.0269	0.0247	2.4614	0.9026
4	00:00:04	0.0272	0.0250	2.4913	0.9020
5	00:00:05	0.0274	0.0252	2.5112	0.9016
6	00:00:06	0.0276	0.0254	2.5311	0.9012
7	00:00:12	0.0284	0.0262	2.6109	0.8997
8	00:00:15	0.0287	0.0265	2.6408	0.8991
9	00:00:30	0.0296	0.0274	2.7304	0.8973
10	00:01:00	0.0307	0.0285	2.8401	0.8952
11	00:02:00	0.0319	0.0297	2.9596	0.8929
12	00:04:01	0.0335	0.0313	3.1191	0.8897
13	00:08:01	0.0353	0.0331	3.2985	0.8862
14	00:10:01	0.0359	0.0337	3.3582	0.8851
15	00:15:01	0.0371	0.0349	3.4778	0.8827
16	00:30:02	0.0392	0.0370	3.6871	0.8787
17	01:00:04	0.0411	0.0389	3.8764	0.8750
18	02:00:08	0.0426	0.0404	4.0259	0.8721
19	04:00:17	0.0438	0.0416	4.1455	0.8697
20	08:00:33	0.0447	0.0425	4.2352	0.8680
21	12:00:50	0.0453	0.0431	4.2950	0.8668
22	16:01:06	0.0456	0.0434	4.3249	0.8662
23	20:01:23	0.0459	0.0437	4.3548	0.8656
24	24:00:00	0.0462	0.0440	4.3847	0.8651

Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 5) Load 2.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 6) Rebound 0.250 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0462	0.0440	4.3847	0.8651
1	00:00:01	0.0439	0.0429	4.2750	0.8672
2	00:00:02	0.0436	0.0426	4.2451	0.8678
3	00:00:03	0.0434	0.0424	4.2252	0.8682
4	00:00:04	0.0433	0.0423	4.2152	0.8684
5	00:00:05	0.0431	0.0421	4.1953	0.8687
6	00:00:06	0.0430	0.0420	4.1854	0.8689
7	00:00:12	0.0426	0.0416	4.1455	0.8697
8	00:00:15	0.0425	0.0415	4.1355	0.8699
9	00:00:30	0.0419	0.0409	4.0757	0.8711
10	00:01:00	0.0412	0.0402	4.0060	0.8724
11	00:02:00	0.0403	0.0393	3.9163	0.8742
12	00:04:01	0.0391	0.0381	3.7967	0.8765
13	00:08:01	0.0376	0.0366	3.6472	0.8794
14	00:10:01	0.0370	0.0360	3.5874	0.8806
15	00:15:01	0.0359	0.0349	3.4778	0.8827
16	00:30:02	0.0340	0.0330	3.2885	0.8864
17	01:00:04	0.0323	0.0313	3.1191	0.8897
18	02:00:09	0.0312	0.0302	3.0095	0.8919
19	04:00:17	0.0306	0.0296	2.9497	0.8930
20	08:00:33	0.0302	0.0292	2.9098	0.8938
21	12:00:50	0.0301	0.0291	2.8999	0.8940
22	16:01:06	0.0300	0.0290	2.8899	0.8942
23	20:01:22	0.0300	0.0290	2.8899	0.8942
24	24:01:39	0.0299	0.0289	2.8799	0.8944
25	24:06:31	0.0298	0.0288	2.8700	0.8946

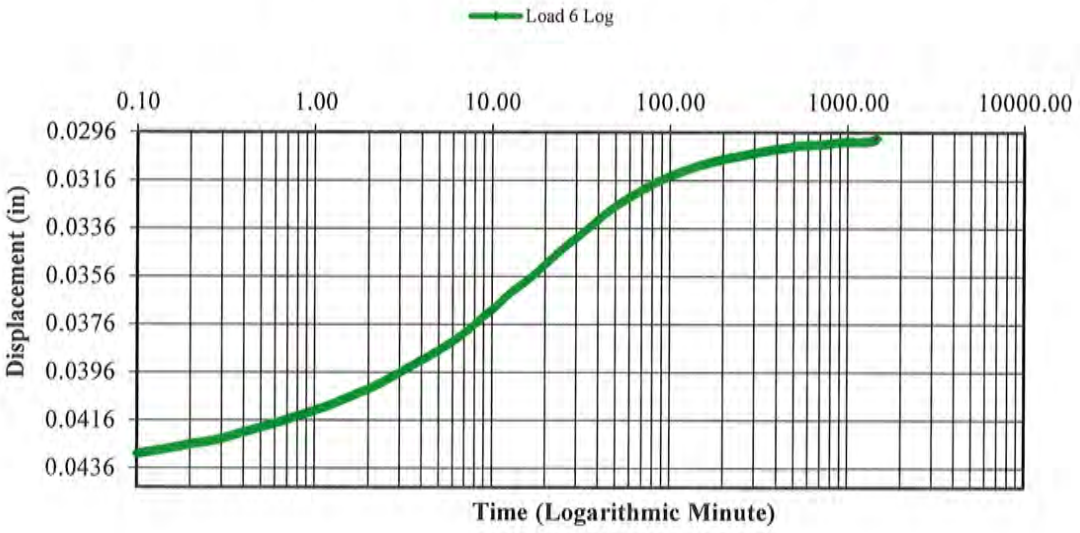
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 6) Rebound 0.250 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 7) Load 0.500 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

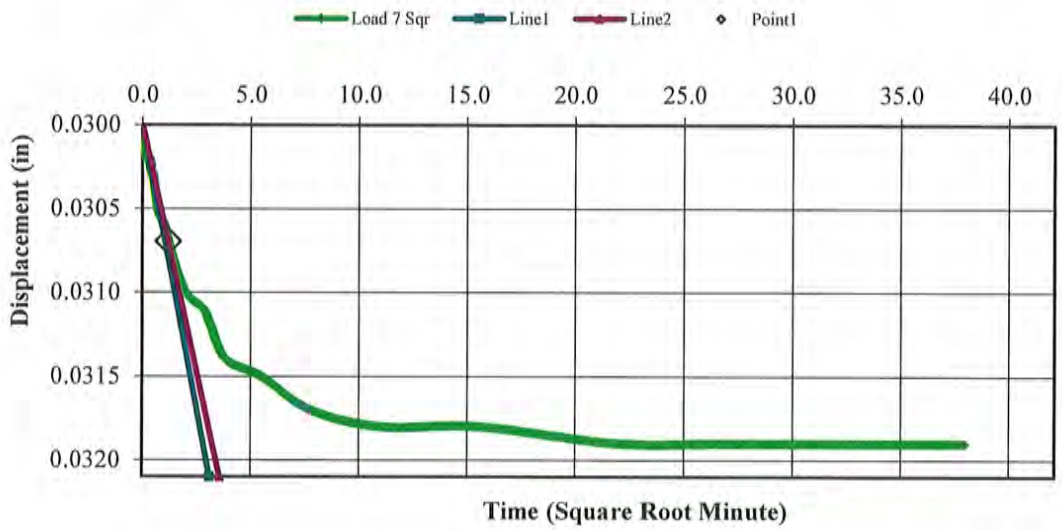
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0298	0.0288	2.8700	0.8946
1	00:00:01	0.0301	0.0287	2.8600	0.8948
2	00:00:02	0.0302	0.0288	2.8700	0.8946
3	00:00:03	0.0302	0.0288	2.8700	0.8946
4	00:00:04	0.0302	0.0288	2.8700	0.8946
5	00:00:05	0.0302	0.0288	2.8700	0.8946
6	00:00:06	0.0302	0.0288	2.8700	0.8946
7	00:00:12	0.0303	0.0289	2.8799	0.8944
8	00:00:15	0.0303	0.0289	2.8799	0.8944
9	00:00:30	0.0305	0.0291	2.8999	0.8940
10	00:01:00	0.0306	0.0292	2.9098	0.8938
11	00:02:00	0.0308	0.0294	2.9297	0.8934
12	00:04:00	0.0310	0.0296	2.9497	0.8930
13	00:08:01	0.0311	0.0297	2.9596	0.8929
14	00:10:01	0.0312	0.0298	2.9696	0.8927
15	00:15:01	0.0314	0.0300	2.9895	0.8923
16	00:30:02	0.0315	0.0301	2.9995	0.8921
17	01:00:04	0.0317	0.0303	3.0194	0.8917
18	02:00:09	0.0318	0.0304	3.0294	0.8915
19	04:00:17	0.0318	0.0304	3.0294	0.8915
20	08:00:33	0.0319	0.0305	3.0394	0.8913
21	12:00:49	0.0319	0.0305	3.0394	0.8913
22	16:01:06	0.0319	0.0305	3.0394	0.8913
23	20:01:22	0.0319	0.0305	3.0394	0.8913
24	23:59:59	0.0319	0.0305	3.0394	0.8913

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 7) Load 0.500 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 8) Load 1.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

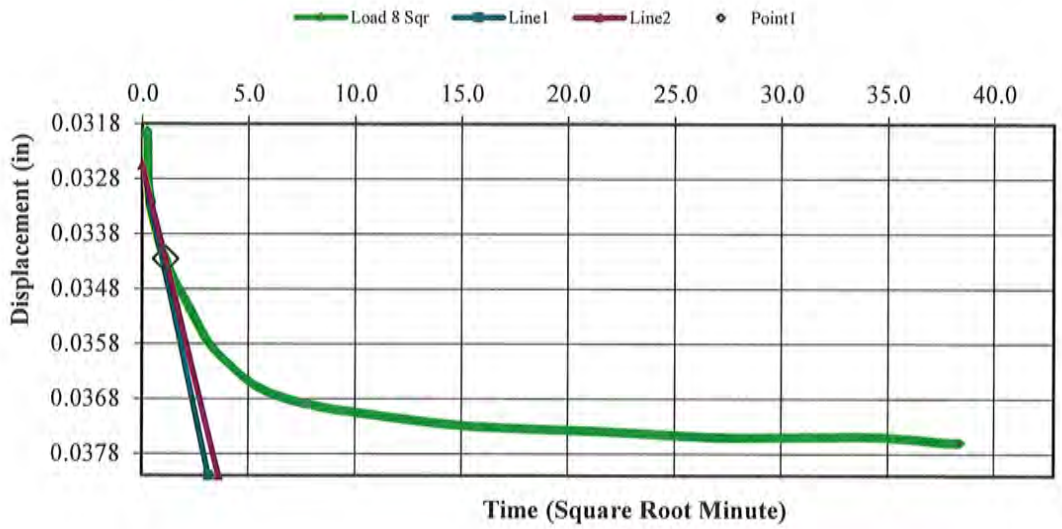
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0319	0.0305	3.0394	0.8913
1	00:00:01	0.0320	0.0302	3.0095	0.8919
2	00:00:02	0.0320	0.0302	3.0095	0.8919
3	00:00:03	0.0320	0.0302	3.0095	0.8919
4	00:00:04	0.0328	0.0310	3.0892	0.8903
5	00:00:05	0.0330	0.0312	3.1091	0.8899
6	00:00:06	0.0331	0.0313	3.1191	0.8897
7	00:00:12	0.0334	0.0316	3.1490	0.8892
8	00:00:15	0.0335	0.0317	3.1589	0.8890
9	00:00:30	0.0338	0.0320	3.1888	0.8884
10	00:01:00	0.0342	0.0324	3.2287	0.8876
11	00:02:00	0.0346	0.0328	3.2686	0.8868
12	00:04:00	0.0350	0.0332	3.3084	0.8860
13	00:08:00	0.0356	0.0338	3.3682	0.8849
14	00:10:00	0.0358	0.0340	3.3881	0.8845
15	00:15:01	0.0361	0.0343	3.4180	0.8839
16	00:30:02	0.0366	0.0348	3.4679	0.8829
17	01:00:04	0.0369	0.0351	3.4978	0.8824
18	02:00:08	0.0371	0.0353	3.5177	0.8820
19	04:00:16	0.0373	0.0355	3.5376	0.8816
20	08:00:32	0.0374	0.0356	3.5476	0.8814
21	12:00:49	0.0375	0.0357	3.5575	0.8812
22	16:01:05	0.0375	0.0357	3.5575	0.8812
23	20:01:22	0.0375	0.0357	3.5575	0.8812
24	24:01:38	0.0376	0.0358	3.5675	0.8810
25	24:01:38	0.0376	0.0358	3.5675	0.8810
26	24:35:48	0.0376	0.0358	3.5675	0.8810

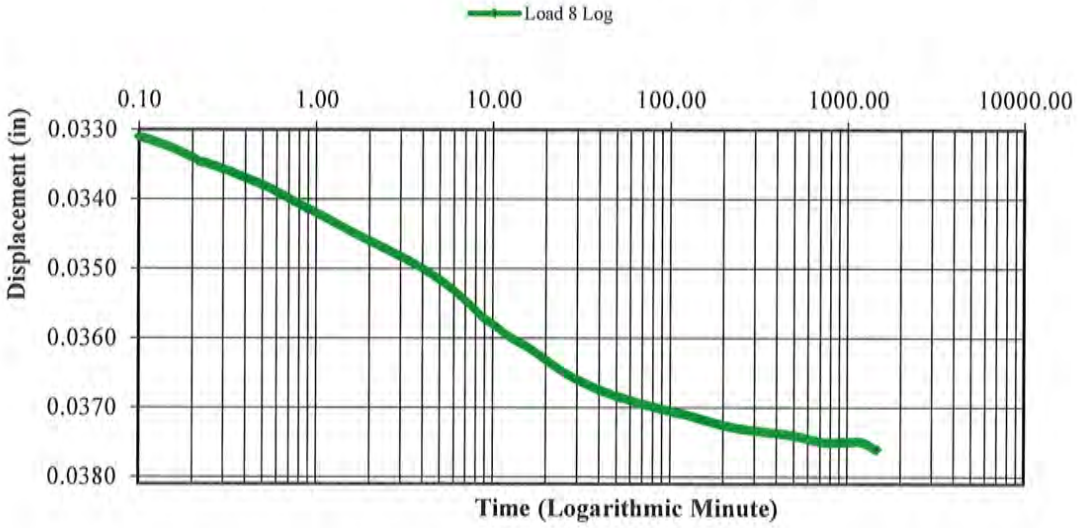
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 8) Load 1.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 9) Load 2.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

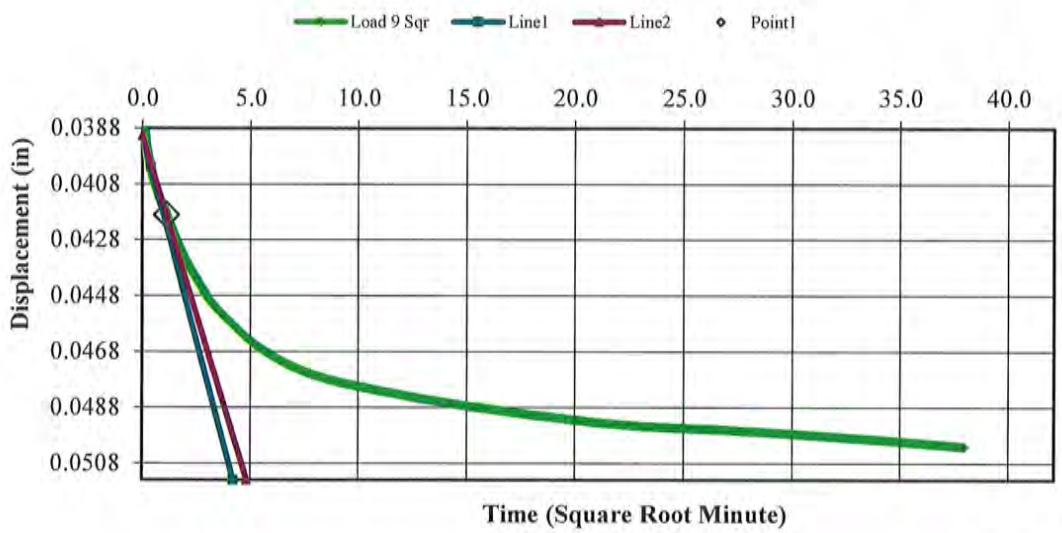
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0376	0.0358	3.5675	0.8810
1	00:00:01	0.0389	0.0367	3.6572	0.8792
2	00:00:02	0.0394	0.0372	3.7070	0.8783
3	00:00:03	0.0396	0.0374	3.7270	0.8779
4	00:00:04	0.0398	0.0376	3.7469	0.8775
5	00:00:05	0.0399	0.0377	3.7569	0.8773
6	00:00:06	0.0400	0.0378	3.7668	0.8771
7	00:00:12	0.0404	0.0382	3.8067	0.8763
8	00:00:15	0.0406	0.0384	3.8266	0.8759
9	00:00:30	0.0411	0.0389	3.8764	0.8750
10	00:01:00	0.0417	0.0395	3.9362	0.8738
11	00:02:00	0.0425	0.0403	4.0159	0.8722
12	00:04:00	0.0435	0.0413	4.1156	0.8703
13	00:08:00	0.0446	0.0424	4.2252	0.8682
14	00:10:00	0.0450	0.0428	4.2651	0.8674
15	00:15:01	0.0456	0.0434	4.3249	0.8662
16	00:30:02	0.0467	0.0445	4.4345	0.8641
17	01:00:04	0.0476	0.0454	4.5242	0.8623
18	02:00:08	0.0482	0.0460	4.5840	0.8612
19	04:00:16	0.0488	0.0466	4.6437	0.8600
20	08:00:33	0.0494	0.0472	4.7035	0.8588
21	12:00:49	0.0496	0.0474	4.7235	0.8584
22	16:01:05	0.0498	0.0476	4.7434	0.8581
23	20:01:22	0.0500	0.0478	4.7633	0.8577
24	23:59:59	0.0502	0.0480	4.7833	0.8573

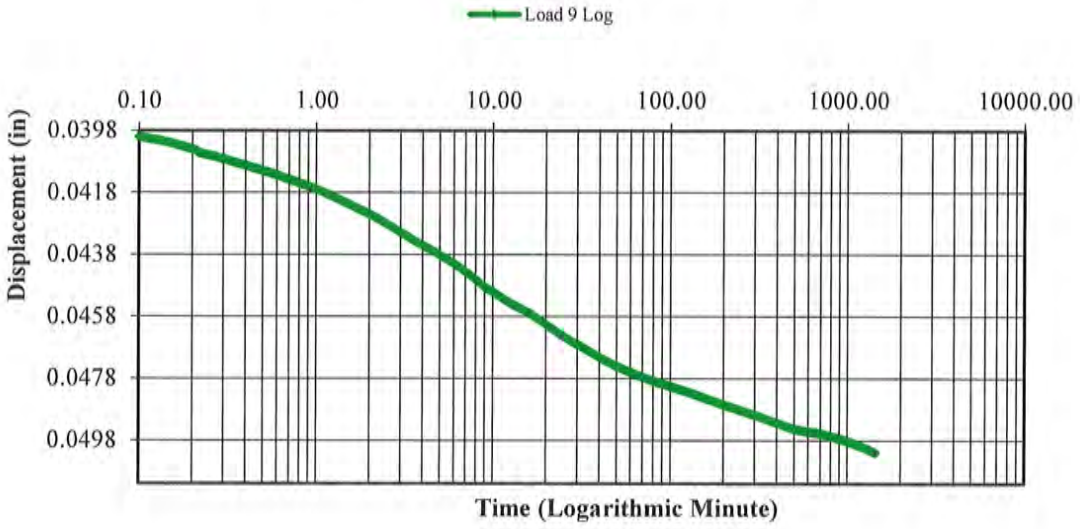
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 9) Load 2.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 10) Load 4.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

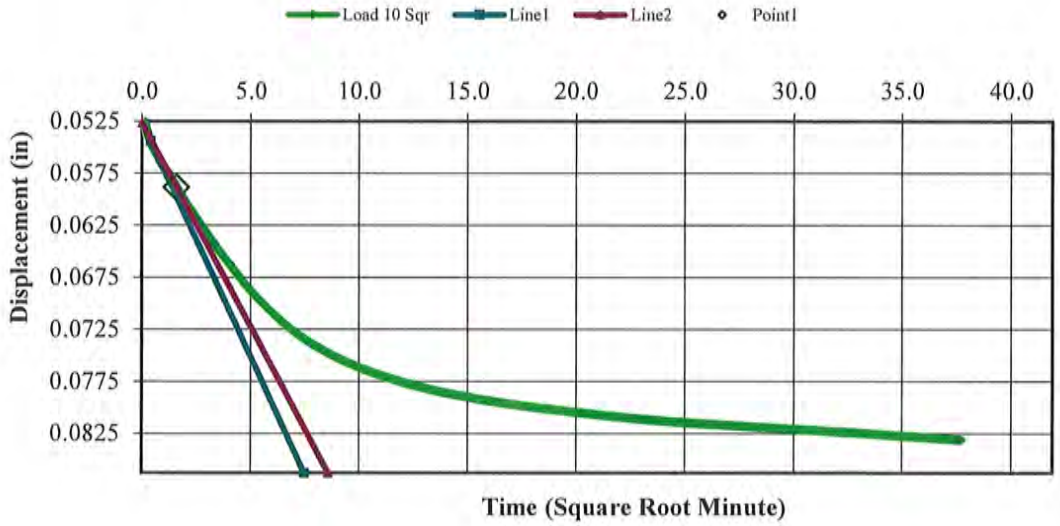
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0502	0.0480	4.7833	0.8573
1	00:00:01	0.0526	0.0499	4.9726	0.8536
2	00:00:02	0.0532	0.0505	5.0324	0.8524
3	00:00:03	0.0535	0.0508	5.0623	0.8518
4	00:00:04	0.0538	0.0511	5.0922	0.8513
5	00:00:05	0.0540	0.0513	5.1121	0.8509
6	00:00:06	0.0541	0.0514	5.1221	0.8507
7	00:00:12	0.0547	0.0520	5.1819	0.8495
8	00:00:15	0.0550	0.0523	5.2118	0.8489
9	00:00:30	0.0558	0.0531	5.2915	0.8474
10	00:01:00	0.0569	0.0542	5.4011	0.8452
11	00:02:00	0.0583	0.0556	5.5406	0.8425
12	00:04:00	0.0603	0.0576	5.7399	0.8386
13	00:08:01	0.0629	0.0602	5.9990	0.8336
14	00:10:01	0.0639	0.0612	6.0987	0.8316
15	00:15:01	0.0659	0.0632	6.2980	0.8277
16	00:30:02	0.0699	0.0672	6.6966	0.8200
17	01:00:04	0.0738	0.0711	7.0852	0.8124
18	02:00:08	0.0769	0.0742	7.3941	0.8064
19	04:00:16	0.0792	0.0765	7.6233	0.8019
20	08:00:33	0.0809	0.0782	7.7927	0.7986
21	12:00:49	0.0817	0.0790	7.8724	0.7970
22	16:01:06	0.0822	0.0795	7.9223	0.7961
23	20:01:22	0.0827	0.0800	7.9721	0.7951
24	23:41:54	0.0831	0.0804	8.0120	0.7943

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 10) Load 4.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 11) Load 8.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

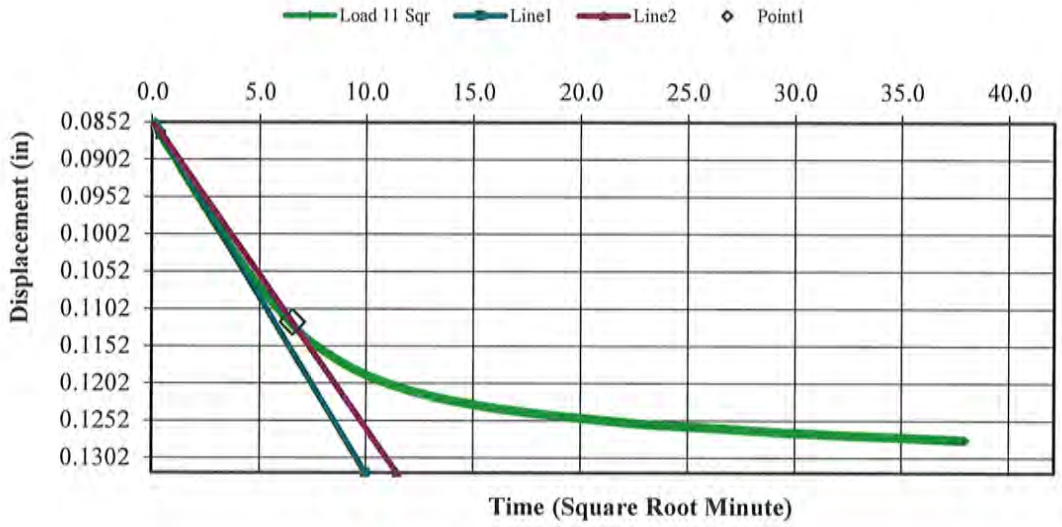
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0831	0.0804	8.0120	0.7943
1	00:00:01	0.0853	0.0820	8.1714	0.7912
2	00:00:02	0.0858	0.0825	8.2212	0.7902
3	00:00:03	0.0860	0.0827	8.2412	0.7898
4	00:00:04	0.0862	0.0829	8.2611	0.7894
5	00:00:05	0.0864	0.0831	8.2810	0.7891
6	00:00:06	0.0866	0.0833	8.3009	0.7887
7	00:00:12	0.0872	0.0839	8.3607	0.7875
8	00:00:15	0.0874	0.0841	8.3807	0.7871
9	00:00:30	0.0885	0.0852	8.4903	0.7850
10	00:01:00	0.0898	0.0865	8.6198	0.7824
11	00:02:00	0.0918	0.0885	8.8191	0.7786
12	00:04:01	0.0945	0.0912	9.0882	0.7733
13	00:08:01	0.0983	0.0950	9.4669	0.7659
14	00:10:01	0.0998	0.0965	9.6163	0.7630
15	00:15:01	0.1029	0.0996	9.9253	0.7570
16	00:30:02	0.1091	0.1058	10.5431	0.7449
17	01:00:04	0.1154	0.1121	11.1709	0.7327
18	02:00:09	0.1202	0.1169	11.6492	0.7234
19	04:00:17	0.1233	0.1200	11.9581	0.7173
20	08:00:33	0.1254	0.1221	12.1674	0.7132
21	12:00:50	0.1263	0.1230	12.2571	0.7115
22	16:01:06	0.1270	0.1237	12.3269	0.7101
23	20:01:22	0.1274	0.1241	12.3667	0.7094
24	24:00:00	0.1278	0.1245	12.4066	0.7086

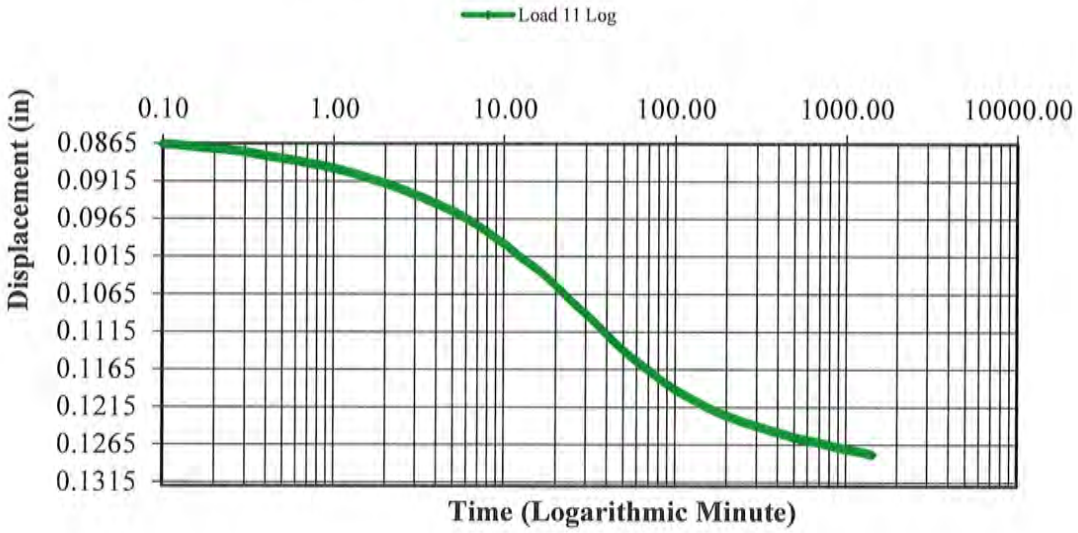
Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 11) Load 8.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 12) Load 16.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

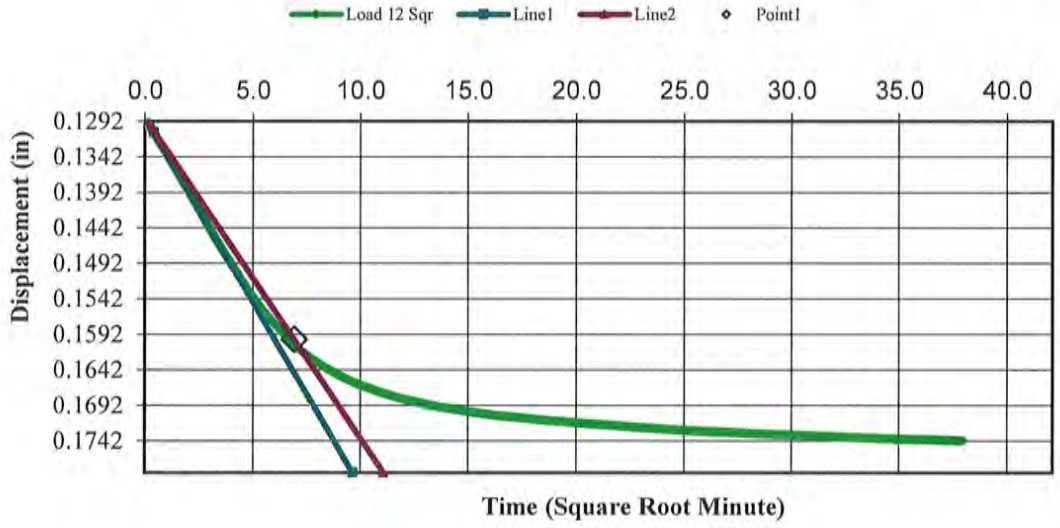
Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1278	0.1245	12.4066	0.7086
1	00:00:01	0.1294	0.1254	12.4963	0.7068
2	00:00:02	0.1297	0.1257	12.5262	0.7062
3	00:00:03	0.1299	0.1259	12.5461	0.7059
4	00:00:04	0.1301	0.1261	12.5660	0.7055
5	00:00:05	0.1303	0.1263	12.5859	0.7051
6	00:00:06	0.1304	0.1264	12.5959	0.7049
7	00:00:12	0.1311	0.1271	12.6657	0.7035
8	00:00:15	0.1314	0.1274	12.6956	0.7029
9	00:00:30	0.1324	0.1284	12.7952	0.7010
10	00:01:00	0.1339	0.1299	12.9447	0.6981
11	00:02:00	0.1361	0.1321	13.1639	0.6938
12	00:04:00	0.1391	0.1351	13.4629	0.6880
13	00:08:00	0.1435	0.1395	13.9013	0.6794
14	00:10:00	0.1453	0.1413	14.0807	0.6759
15	00:15:01	0.1488	0.1448	14.4295	0.6691
16	00:30:02	0.1559	0.1519	15.1370	0.6553
17	01:00:04	0.1627	0.1587	15.8146	0.6421
18	02:00:08	0.1674	0.1634	16.2830	0.6330
19	04:00:16	0.1703	0.1663	16.5720	0.6273
20	08:00:33	0.1721	0.1681	16.7514	0.6238
21	12:00:49	0.1730	0.1690	16.8411	0.6221
22	16:01:06	0.1735	0.1695	16.8909	0.6211
23	20:01:22	0.1739	0.1699	16.9307	0.6203
24	24:00:00	0.1742	0.1702	16.9606	0.6198

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 12) Load 16.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 13) Rebound 0.125 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-2
Boring Number: B-2
Depth: 15'-17'
Sample Type: Undisturbed

Soil Description: FAT CLAY (CH), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1742	0.1702	16.9606	0.6198
1	00:00:01	0.1714	0.1707	17.0105	0.6188
2	00:00:02	0.1703	0.1696	16.9008	0.6209
3	00:00:03	0.1700	0.1693	16.8710	0.6215
4	00:00:04	0.1697	0.1690	16.8411	0.6221
5	00:00:05	0.1695	0.1688	16.8211	0.6225
6	00:00:06	0.1693	0.1686	16.8012	0.6229
7	00:00:12	0.1685	0.1678	16.7215	0.6244
8	00:00:15	0.1682	0.1675	16.6916	0.6250
9	00:00:30	0.1669	0.1662	16.5620	0.6275
10	00:01:00	0.1652	0.1645	16.3926	0.6308
11	00:02:00	0.1630	0.1623	16.1734	0.6351
12	00:04:00	0.1598	0.1591	15.8545	0.6413
13	00:08:01	0.1554	0.1547	15.4160	0.6499
14	00:10:01	0.1536	0.1529	15.2367	0.6534
15	00:15:01	0.1499	0.1492	14.8680	0.6606
16	00:30:00	0.1421	0.1414	14.0907	0.6757
17	01:00:00	0.1322	0.1315	13.1041	0.6950
18	01:59:59	0.1211	0.1204	11.9980	0.7166
19	03:59:57	0.1099	0.1092	10.8819	0.7383
20	07:59:53	0.1005	0.0998	9.9452	0.7566
21	11:59:50	0.0966	0.0959	9.5566	0.7642
22	15:59:46	0.0946	0.0939	9.3573	0.7681
23	19:59:42	0.0935	0.0928	9.2476	0.7702
24	23:59:38	0.0927	0.0920	9.1679	0.7718
25	23:59:50	0.0927	0.0920	9.1679	0.7718

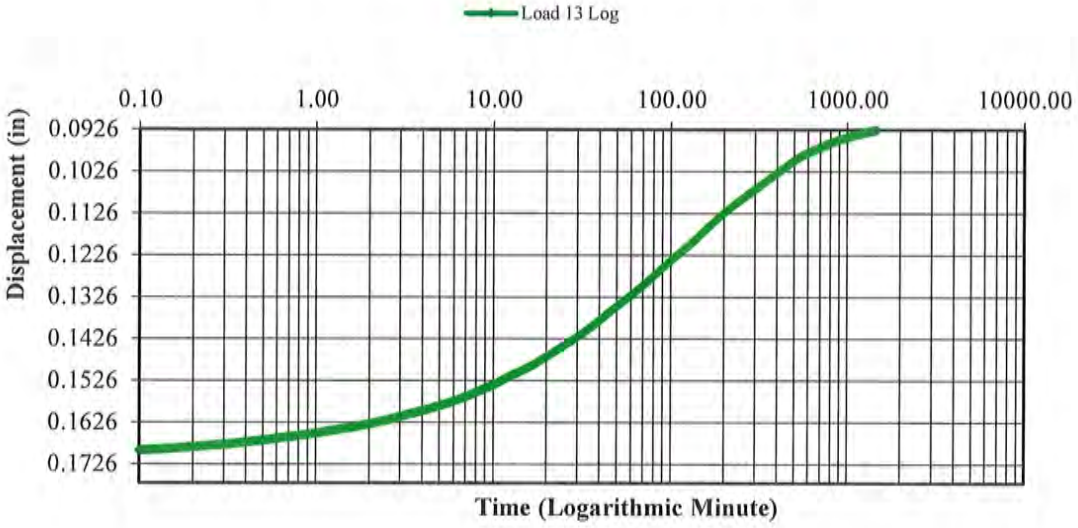
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 13) Rebound 0.125 tsf

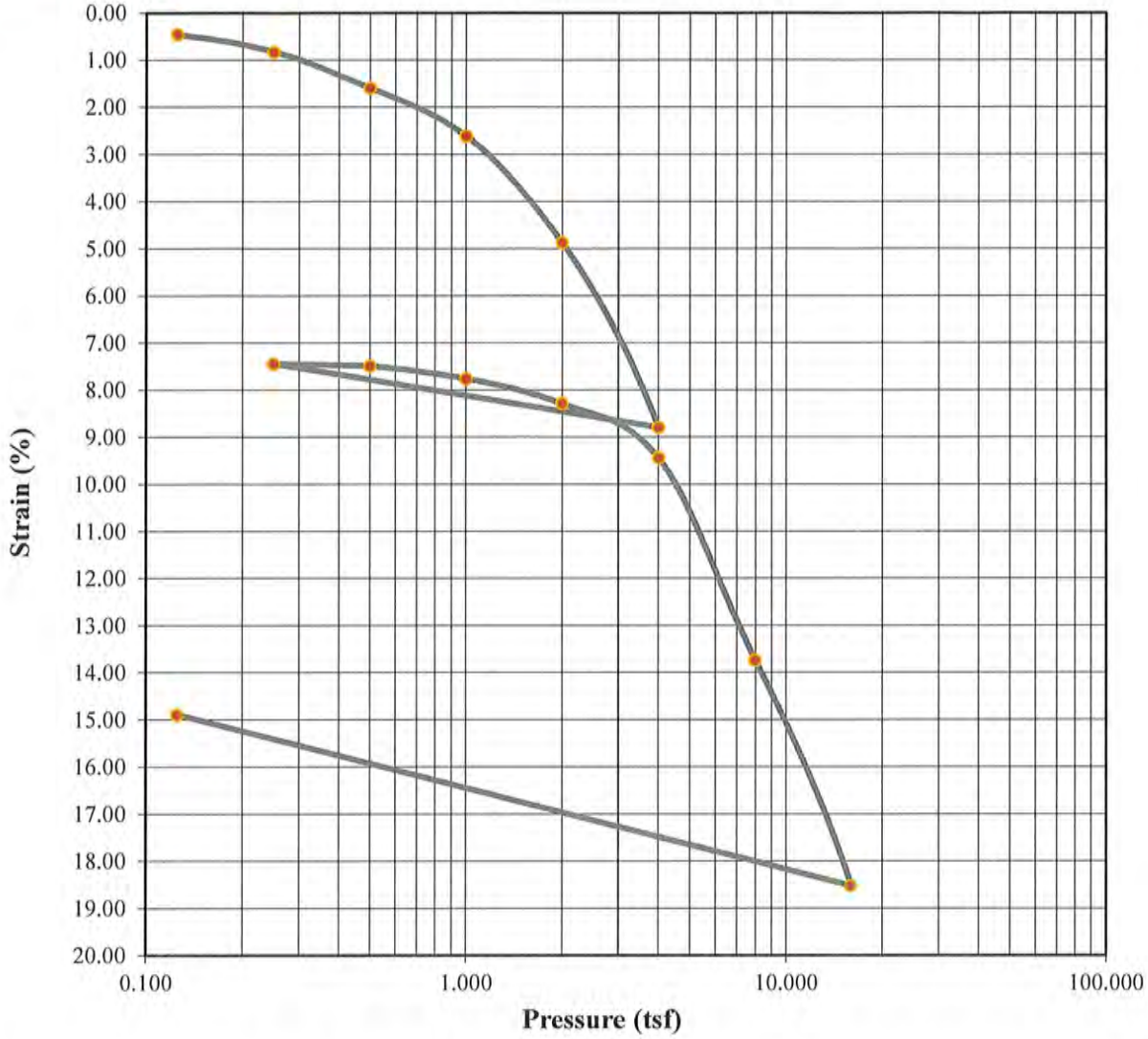
Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



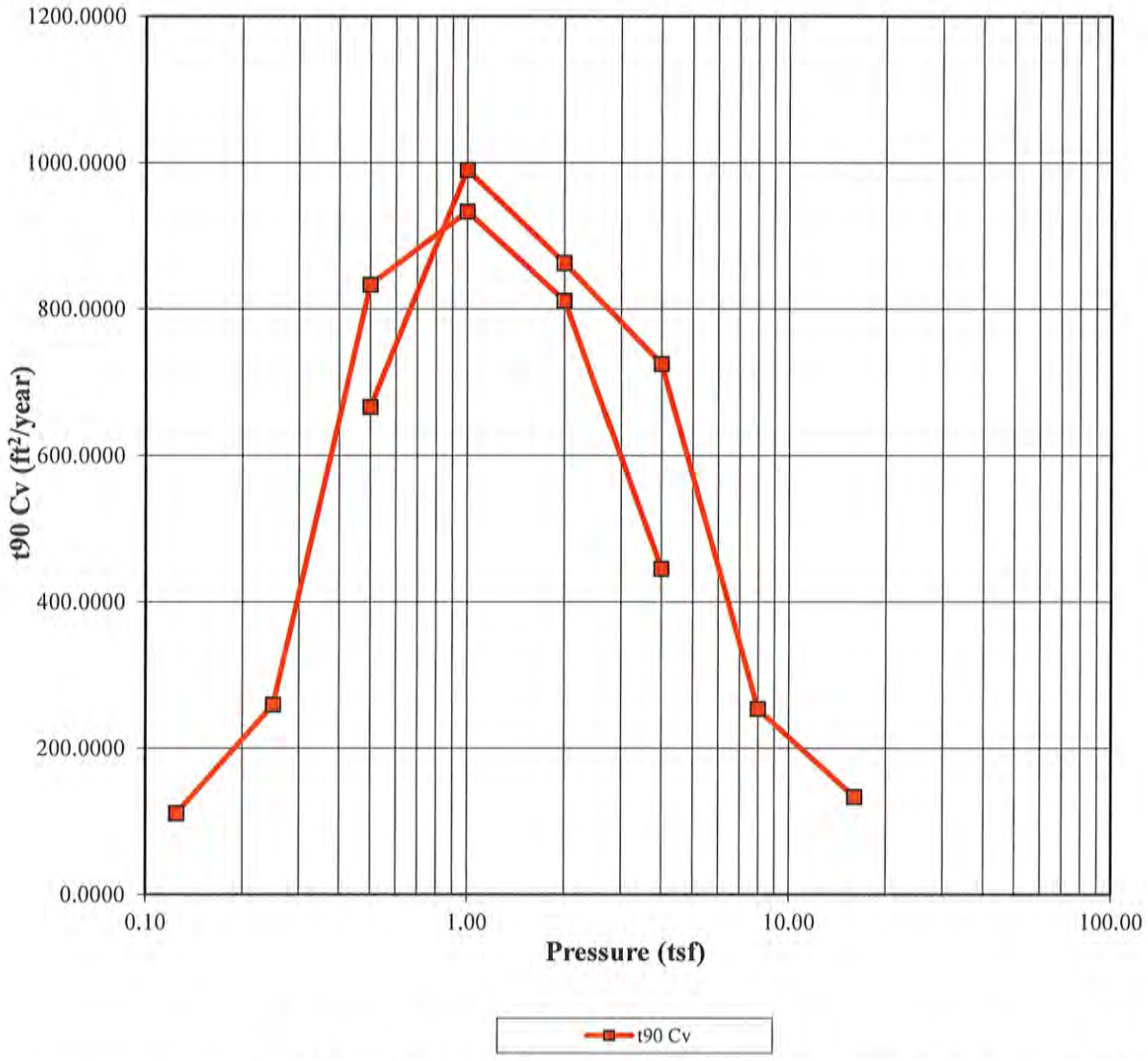
Consolidation Test
Test Results



	Before	After				
Moisture (%):	33.23	26.53	**Liquid Limits:**	47	**Test Date:**	6/20/18
Dry Density (pcf):	86.75	100.10	**Plastic Limits:**	28		
Saturation (%):	95.90	105.91	**Plasticity Index (%):**	19		
Void Ratio:	0.9265	0.6396	**Specific Gravity:**	2.680	Assumed	

Sample Description:	ORGANIC SILT (OL), gray		
Project Number:	18C13074	**Depth:** 29.5'-31.5'	**Remarks:**
Sample Number:	B-4	**Boring Number:** B-4	
Project:	Wallops Island Breakwaters		
Location:	Wallops Island, VA		

Consolidation Test
Test Results



	Before	After				
Moisture (%):	33.23	26.53	**Liquid Limits:**	47	**Test Date:**	6/20/18
Dry Density (pcf):	86.75	100.10	**Plastic Limits:**	28		
Saturation (%):	95.90	105.91	**Plasticity Index (%):**	19		
Void Ratio:	0.9265	0.6396	**Specific Gravity:**	2.680	Assumed	

Soil Description:	ORGANIC SILT (OL), gray		
Project Number:	18C13074	**Depth:** 29.5'-31.5'	**Remarks:**
Sample Number:	B-4	**Boring Number:** B-4	
Project:	Wallops Island Breakwaters		
Client:			
Location:	Wallops Island, VA		

Consolidation Test Results
Summary

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

Sample Description: ORGANIC SILT (OL), gray
Remarks:

Test Number:
Test Date: 6/20/18

Index	Load Sequence (tsf)	Cummulative Change in Height (in)	Specimen Height (in)	Height of Void (in)	Vertical Strain (%)	Void Ratio	t90 Fitting Time (min)	t50 Fitting Time (min)	t90 Cv (ft2/year)	t50 Cv (ft2/year)
0	0.000	0.0000	1.0065	0.4837	0.00	0.9252	0.000	0.000	0.000	0.000
1	0.125	0.0046	1.0019	0.4791	0.46	0.9164	7.001	* 3.8892	110.954	46.397
2	0.250	0.0083	0.9982	0.4754	0.82	0.9093	2.970	* 1.6498	259.636	108.568
3	0.500	0.0160	0.9905	0.4677	1.59	0.8946	0.911	* 0.5060	833.580	348.544
4	1.000	0.0263	0.9802	0.4574	2.61	0.8749	0.796	* 0.4423	933.731	390.491
5	2.000	0.0490	0.9575	0.4347	4.87	0.8315	0.874	* 0.4856	811.681	339.389
6	4.000	0.0885	0.9180	0.3952	8.79	0.7559	1.463	* 0.8126	445.821	186.426
7	0.250	0.0749	0.9316	0.4088	7.44	0.7819	0.000	0.000	0.000	0.000
8	0.500	0.0754	0.9311	0.4083	7.49	0.7810	1.006	* 0.5591	666.565	278.742
9	1.000	0.0781	0.9284	0.4056	7.76	0.7758	0.674	* 0.3742	990.204	414.062
10	2.000	0.0834	0.9231	0.4003	8.29	0.7657	0.764	* 0.4244	863.213	360.928
11	4.000	0.0950	0.9115	0.3887	9.44	0.7435	0.886	* 0.4923	725.558	303.377
12	8.000	0.1382	0.8683	0.3455	13.73	0.6609	2.297	* 1.2763	253.941	106.191
13	16.000	0.1864	0.8201	0.2973	18.52	0.5687	3.894	* 2.1631	133.661	55.893
14	0.125	0.1499	0.8566	0.3338	14.89	0.6385	0.000	0.000	0.000	0.000

Predicted value indicated with *

Tested By: RG

Checked By: DS

Consolidation Test
Consolidation Specimen Information

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

Sample Description: ORGANIC SILT (OL), gray
Remarks:

Test Number:
Liquid Limit: 47.0000
Plastic Limit: 28.0000
Specific Gravity: 2.6800 Assumed

Initial Void Ratio: 0.9265
Plasticity Index (%): 19.0000
Weight of Ring (g): 111.1700

Initial Height (in): 1.0065
Initial Diameter (in): 2.5000

Parameters	Initial Specimen	Final Specimen
Moist Weight + Container (g)	338.60	336.80
Dry Soil + Container (g)	302.80	307.70
Weight of Container (g)	195.05	198.00
Moisture Content (%)	33.23	26.53
Void Ratio	0.9265	0.6396
Saturation (%)	95.90	105.91
Dry Density (pcf)	86.75	100.10

Tested By: RG

Checked By: DS

Consolidation Test Results
(Sequence 1) Load 0.125 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

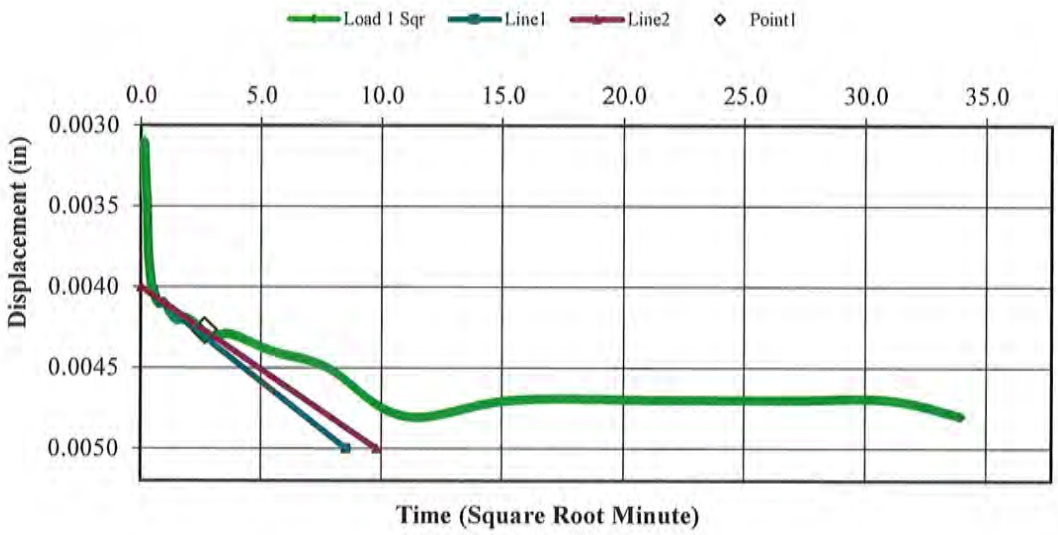
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0002	0.0000	0.0000	0.9265
1	00:00:01	0.0031	0.0029	0.2881	0.9210
2	00:00:02	0.0033	0.0031	0.3080	0.9206
3	00:00:03	0.0034	0.0032	0.3179	0.9204
4	00:00:04	0.0035	0.0033	0.3279	0.9202
5	00:00:05	0.0037	0.0035	0.3477	0.9198
6	00:00:06	0.0038	0.0036	0.3577	0.9196
7	00:00:12	0.0040	0.0038	0.3775	0.9192
8	00:00:15	0.0040	0.0038	0.3775	0.9192
9	00:00:30	0.0041	0.0039	0.3875	0.9190
10	00:00:59	0.0041	0.0039	0.3875	0.9190
11	00:01:59	0.0042	0.0040	0.3974	0.9188
12	00:03:59	0.0042	0.0040	0.3974	0.9188
13	00:07:59	0.0043	0.0041	0.4074	0.9187
14	00:09:59	0.0043	0.0041	0.4074	0.9187
15	00:14:59	0.0043	0.0041	0.4074	0.9187
16	00:29:59	0.0044	0.0042	0.4173	0.9185
17	00:59:59	0.0045	0.0043	0.4272	0.9183
18	01:59:58	0.0048	0.0046	0.4570	0.9177
19	03:59:56	0.0047	0.0045	0.4471	0.9179
20	07:59:53	0.0047	0.0045	0.4471	0.9179
21	11:59:49	0.0047	0.0045	0.4471	0.9179
22	15:59:46	0.0047	0.0045	0.4471	0.9179
23	19:11:52	0.0048	0.0046	0.4570	0.9177

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 1) Load 0.125 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 2) Load 0.250 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

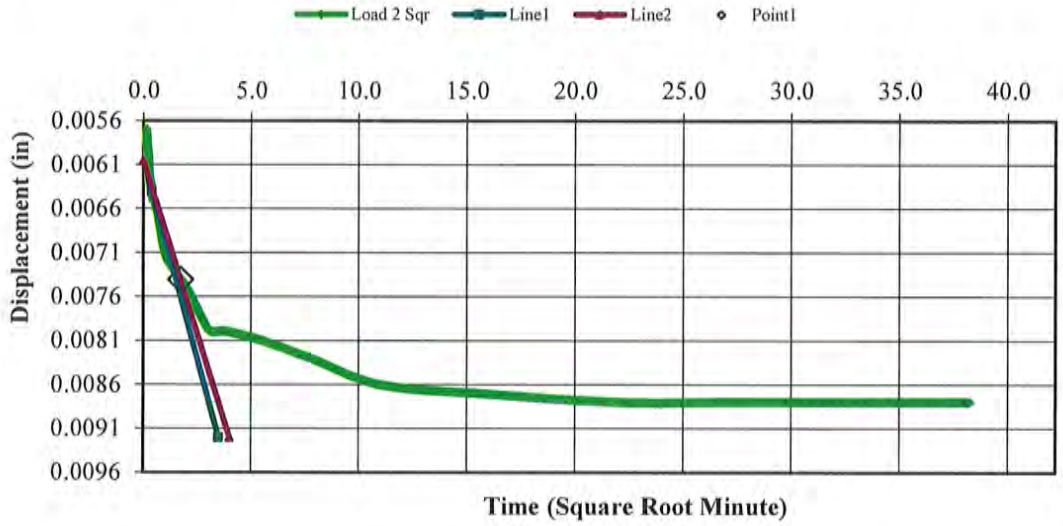
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0048	0.0046	0.4570	0.9177
1	00:00:01	0.0057	0.0052	0.5166	0.9165
2	00:00:02	0.0059	0.0054	0.5365	0.9162
3	00:00:03	0.0060	0.0055	0.5464	0.9160
4	00:00:04	0.0062	0.0057	0.5663	0.9156
5	00:00:05	0.0063	0.0058	0.5763	0.9154
6	00:00:06	0.0063	0.0058	0.5763	0.9154
7	00:00:12	0.0065	0.0060	0.5961	0.9150
8	00:00:15	0.0065	0.0060	0.5961	0.9150
9	00:00:30	0.0067	0.0062	0.6160	0.9146
10	00:01:00	0.0071	0.0066	0.6557	0.9139
11	00:02:00	0.0073	0.0068	0.6756	0.9135
12	00:04:00	0.0075	0.0070	0.6955	0.9131
13	00:08:00	0.0079	0.0074	0.7352	0.9123
14	00:10:00	0.0080	0.0075	0.7452	0.9121
15	00:15:00	0.0080	0.0075	0.7452	0.9121
16	00:30:00	0.0081	0.0076	0.7551	0.9120
17	00:59:59	0.0083	0.0078	0.7750	0.9116
18	01:59:59	0.0086	0.0081	0.8048	0.9110
19	04:00:07	0.0087	0.0082	0.8147	0.9108
20	08:00:24	0.0088	0.0083	0.8246	0.9106
21	12:00:40	0.0088	0.0083	0.8246	0.9106
22	16:00:57	0.0088	0.0083	0.8246	0.9106
23	20:01:13	0.0088	0.0083	0.8246	0.9106
24	24:01:30	0.0088	0.0083	0.8246	0.9106
25	24:04:00	0.0088	0.0083	0.8246	0.9106

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 2) Load 0.250 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 3) Load 0.500 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

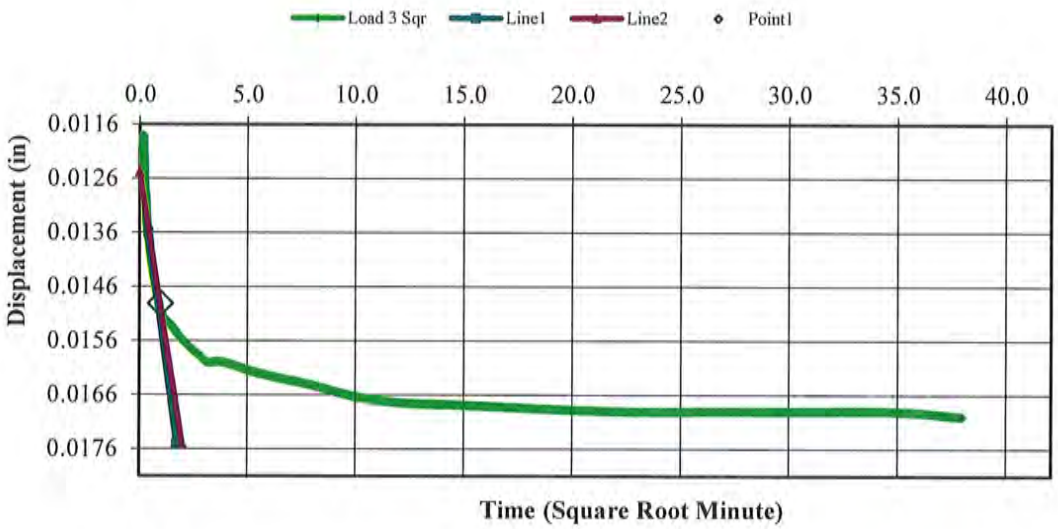
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0088	0.0083	0.8246	0.9106
1	00:00:01	0.0118	0.0108	1.0730	0.9058
2	00:00:02	0.0123	0.0113	1.1227	0.9049
3	00:00:03	0.0128	0.0118	1.1724	0.9039
4	00:00:04	0.0129	0.0119	1.1823	0.9037
5	00:00:05	0.0131	0.0121	1.2022	0.9033
6	00:00:06	0.0134	0.0124	1.2320	0.9028
7	00:00:12	0.0138	0.0128	1.2717	0.9020
8	00:00:15	0.0140	0.0130	1.2916	0.9016
9	00:00:30	0.0145	0.0135	1.3413	0.9007
10	00:01:00	0.0151	0.0141	1.4009	0.8995
11	00:02:01	0.0153	0.0143	1.4208	0.8991
12	00:04:01	0.0156	0.0146	1.4506	0.8986
13	00:08:01	0.0159	0.0149	1.4804	0.8980
14	00:10:01	0.0160	0.0150	1.4903	0.8978
15	00:15:01	0.0160	0.0150	1.4903	0.8978
16	00:30:02	0.0162	0.0152	1.5102	0.8974
17	01:00:05	0.0164	0.0154	1.5301	0.8970
18	02:00:09	0.0167	0.0157	1.5599	0.8965
19	04:00:17	0.0168	0.0158	1.5698	0.8963
20	08:00:34	0.0169	0.0159	1.5797	0.8961
21	12:00:51	0.0169	0.0159	1.5797	0.8961
22	16:01:07	0.0169	0.0159	1.5797	0.8961
23	20:01:23	0.0169	0.0159	1.5797	0.8961
24	24:01:14	0.0170	0.0160	1.5897	0.8959

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 3) Load 0.500 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 4) Load 1.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

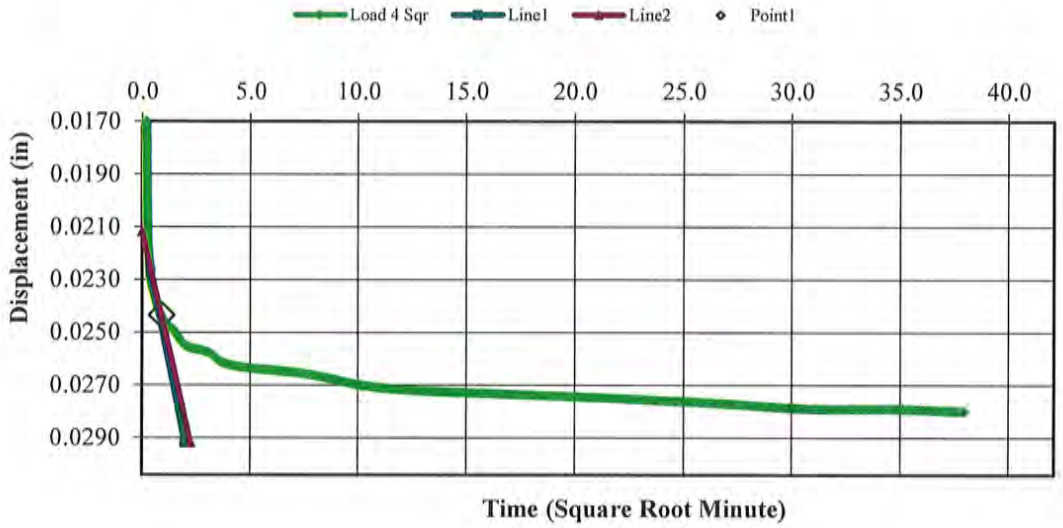
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0170	0.0160	1.5897	0.8959
1	00:00:01	0.0171	0.0154	1.5301	0.8970
2	00:00:02	0.0171	0.0154	1.5301	0.8970
3	00:00:03	0.0200	0.0183	1.8182	0.8915
4	00:00:04	0.0216	0.0199	1.9771	0.8884
5	00:00:05	0.0219	0.0202	2.0070	0.8878
6	00:00:06	0.0223	0.0206	2.0467	0.8871
7	00:00:12	0.0232	0.0215	2.1361	0.8854
8	00:00:15	0.0233	0.0216	2.1461	0.8852
9	00:00:30	0.0240	0.0223	2.2156	0.8838
10	00:01:00	0.0246	0.0229	2.2752	0.8827
11	00:02:00	0.0249	0.0232	2.3050	0.8821
12	00:04:00	0.0255	0.0238	2.3646	0.8809
13	00:08:01	0.0257	0.0240	2.3845	0.8806
14	00:10:01	0.0258	0.0241	2.3944	0.8804
15	00:15:01	0.0262	0.0245	2.4342	0.8796
16	00:30:02	0.0264	0.0247	2.4540	0.8792
17	01:00:04	0.0266	0.0249	2.4739	0.8788
18	02:00:08	0.0271	0.0254	2.5236	0.8779
19	04:00:17	0.0273	0.0256	2.5435	0.8775
20	08:00:33	0.0275	0.0258	2.5633	0.8771
21	12:00:50	0.0277	0.0260	2.5832	0.8767
22	16:01:06	0.0279	0.0262	2.6031	0.8764
23	20:01:22	0.0279	0.0262	2.6031	0.8764
24	24:00:02	0.0280	0.0263	2.6130	0.8762

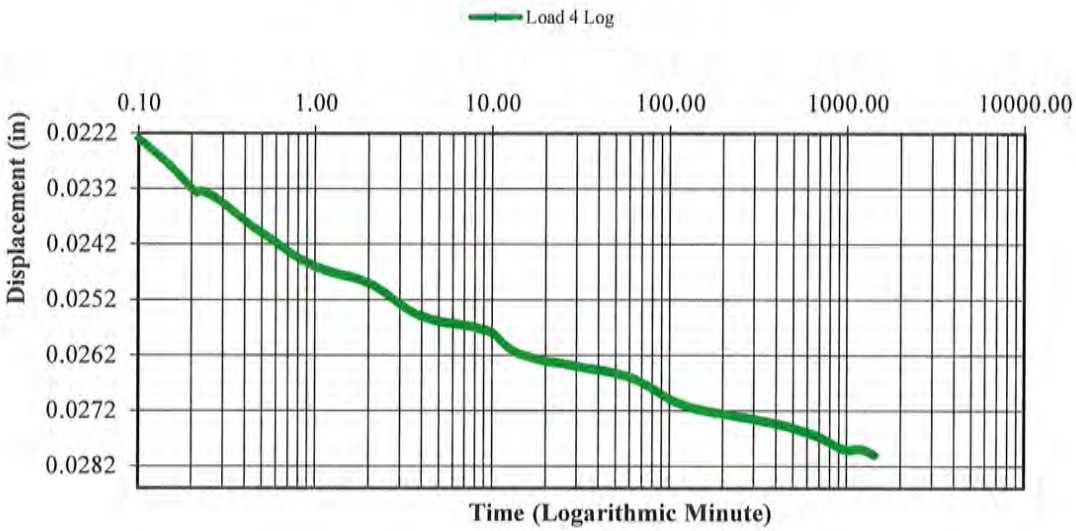
Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 4) Load 1.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 5) Load 2.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

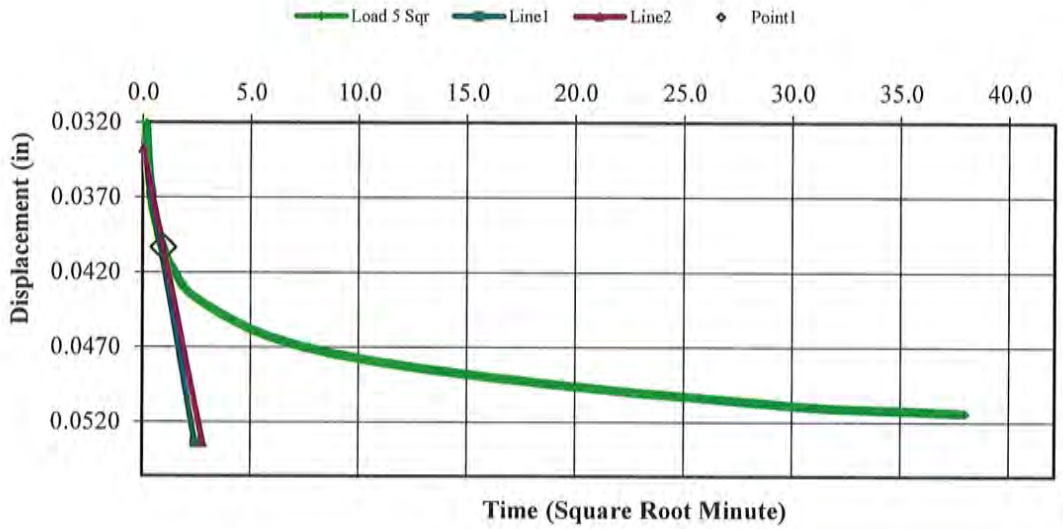
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0280	0.0263	2.6130	0.8762
1	00:00:01	0.0321	0.0297	2.9508	0.8697
2	00:00:02	0.0336	0.0312	3.0999	0.8668
3	00:00:03	0.0346	0.0322	3.1992	0.8649
4	00:00:04	0.0353	0.0329	3.2688	0.8635
5	00:00:05	0.0359	0.0335	3.3284	0.8624
6	00:00:06	0.0361	0.0337	3.3482	0.8620
7	00:00:12	0.0376	0.0352	3.4973	0.8591
8	00:00:15	0.0380	0.0356	3.5370	0.8584
9	00:00:30	0.0393	0.0369	3.6662	0.8559
10	00:01:00	0.0408	0.0384	3.8152	0.8530
11	00:02:00	0.0419	0.0395	3.9245	0.8509
12	00:04:00	0.0432	0.0408	4.0537	0.8484
13	00:08:00	0.0441	0.0417	4.1431	0.8467
14	00:10:00	0.0444	0.0420	4.1729	0.8461
15	00:15:01	0.0450	0.0426	4.2325	0.8450
16	00:30:02	0.0461	0.0437	4.3418	0.8429
17	01:00:04	0.0471	0.0447	4.4411	0.8409
18	02:00:08	0.0480	0.0456	4.5306	0.8392
19	04:00:16	0.0489	0.0465	4.6200	0.8375
20	08:00:32	0.0499	0.0475	4.7193	0.8356
21	12:00:49	0.0505	0.0481	4.7789	0.8344
22	16:01:05	0.0510	0.0486	4.8286	0.8335
23	20:01:22	0.0512	0.0488	4.8485	0.8331
24	23:59:59	0.0514	0.0490	4.8684	0.8327

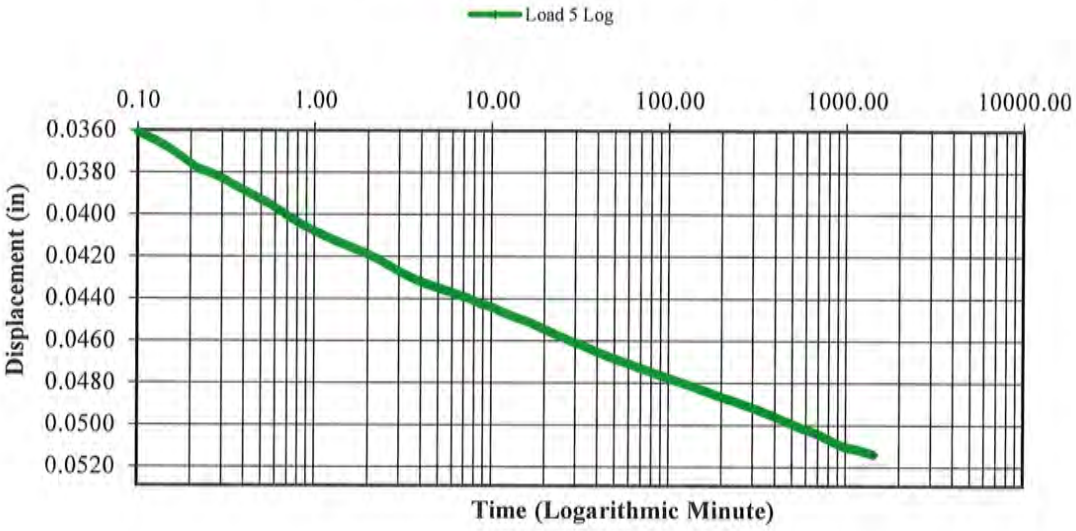
Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 5) Load 2.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 6) Load 4.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

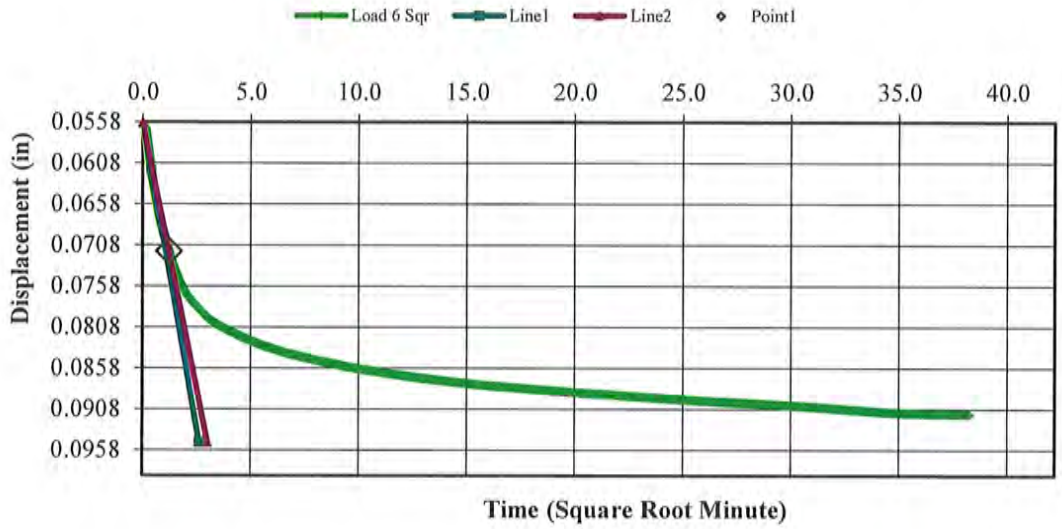
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0514	0.0490	4.8684	0.8327
1	00:00:01	0.0566	0.0537	5.3353	0.8237
2	00:00:02	0.0578	0.0549	5.4545	0.8214
3	00:00:03	0.0586	0.0557	5.5340	0.8199
4	00:00:04	0.0593	0.0564	5.6036	0.8185
5	00:00:05	0.0600	0.0571	5.6731	0.8172
6	00:00:06	0.0606	0.0577	5.7327	0.8161
7	00:00:12	0.0626	0.0597	5.9314	0.8122
8	00:00:15	0.0634	0.0605	6.0109	0.8107
9	00:00:30	0.0664	0.0635	6.3090	0.8050
10	00:01:00	0.0697	0.0668	6.6369	0.7986
11	00:02:00	0.0734	0.0705	7.0045	0.7916
12	00:04:00	0.0767	0.0738	7.3323	0.7852
13	00:08:00	0.0792	0.0763	7.5807	0.7805
14	00:10:00	0.0800	0.0771	7.6602	0.7789
15	00:15:01	0.0811	0.0782	7.7695	0.7768
16	00:30:02	0.0830	0.0801	7.9583	0.7732
17	01:00:04	0.0847	0.0818	8.1272	0.7699
18	02:00:08	0.0863	0.0834	8.2861	0.7669
19	04:00:16	0.0878	0.0849	8.4352	0.7640
20	08:00:33	0.0891	0.0862	8.5643	0.7615
21	12:00:49	0.0899	0.0870	8.6438	0.7600
22	16:01:05	0.0905	0.0876	8.7034	0.7588
23	20:01:22	0.0912	0.0883	8.7730	0.7575
24	24:01:38	0.0914	0.0885	8.7928	0.7571
25	24:04:40	0.0914	0.0885	8.7928	0.7571

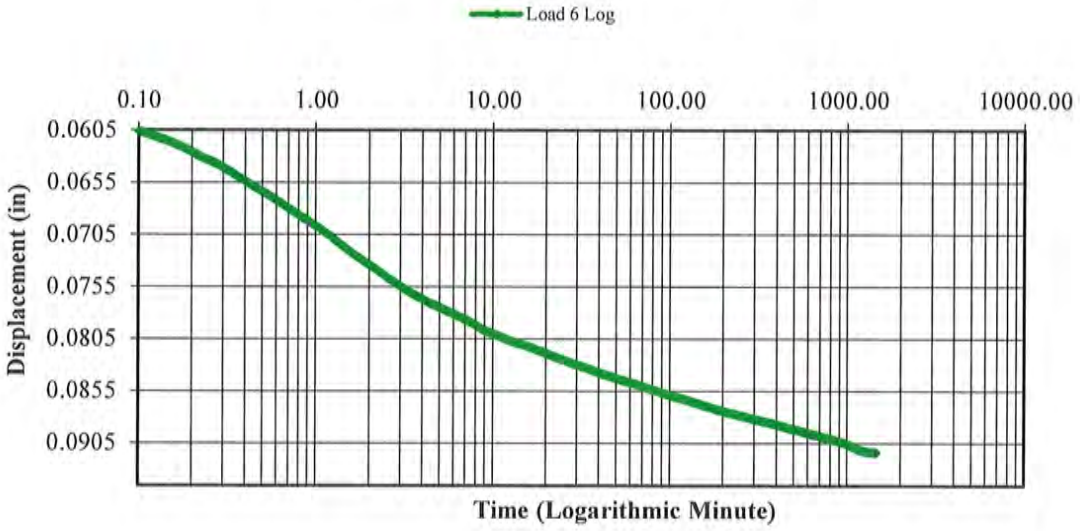
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 6) Load 4.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 7) Rebound 0.250 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

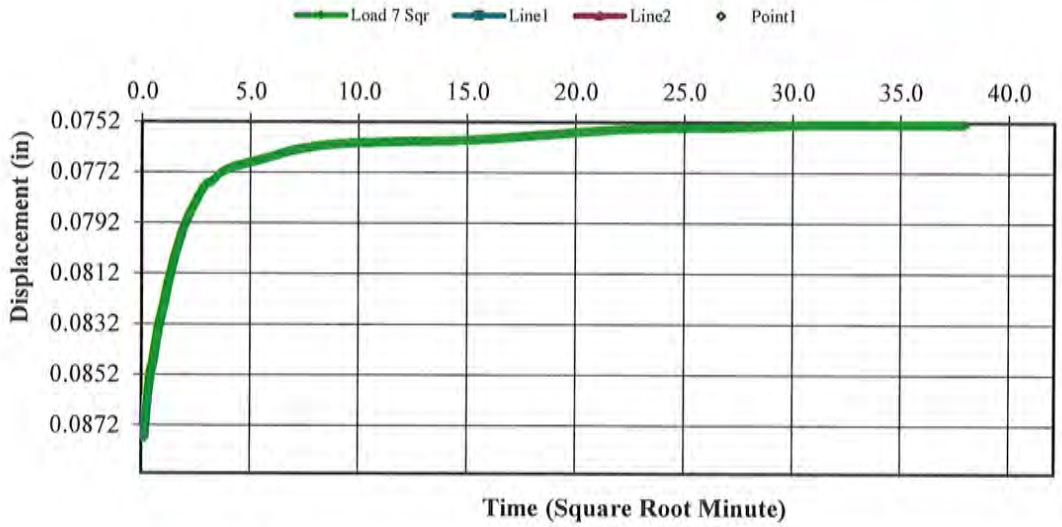
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0914	0.0885	8.7928	0.7571
1	00:00:01	0.0877	0.0873	8.6736	0.7594
2	00:00:02	0.0870	0.0866	8.6041	0.7607
3	00:00:03	0.0865	0.0861	8.5544	0.7617
4	00:00:04	0.0863	0.0859	8.5345	0.7621
5	00:00:05	0.0859	0.0855	8.4948	0.7629
6	00:00:06	0.0857	0.0853	8.4749	0.7632
7	00:00:12	0.0849	0.0845	8.3954	0.7648
8	00:00:15	0.0848	0.0844	8.3855	0.7650
9	00:00:30	0.0836	0.0832	8.2663	0.7673
10	00:01:00	0.0824	0.0820	8.1470	0.7695
11	00:02:00	0.0808	0.0804	7.9881	0.7726
12	00:04:00	0.0792	0.0788	7.8291	0.7757
13	00:08:01	0.0778	0.0774	7.6900	0.7784
14	00:10:01	0.0776	0.0772	7.6701	0.7787
15	00:15:01	0.0771	0.0767	7.6205	0.7797
16	00:30:02	0.0767	0.0763	7.5807	0.7805
17	01:00:04	0.0762	0.0758	7.5310	0.7814
18	02:00:08	0.0760	0.0756	7.5112	0.7818
19	04:00:16	0.0759	0.0755	7.5012	0.7820
20	08:00:33	0.0755	0.0751	7.4615	0.7828
21	12:00:49	0.0754	0.0750	7.4516	0.7829
22	16:01:06	0.0753	0.0749	7.4416	0.7831
23	20:01:22	0.0753	0.0749	7.4416	0.7831
24	24:00:45	0.0753	0.0749	7.4416	0.7831

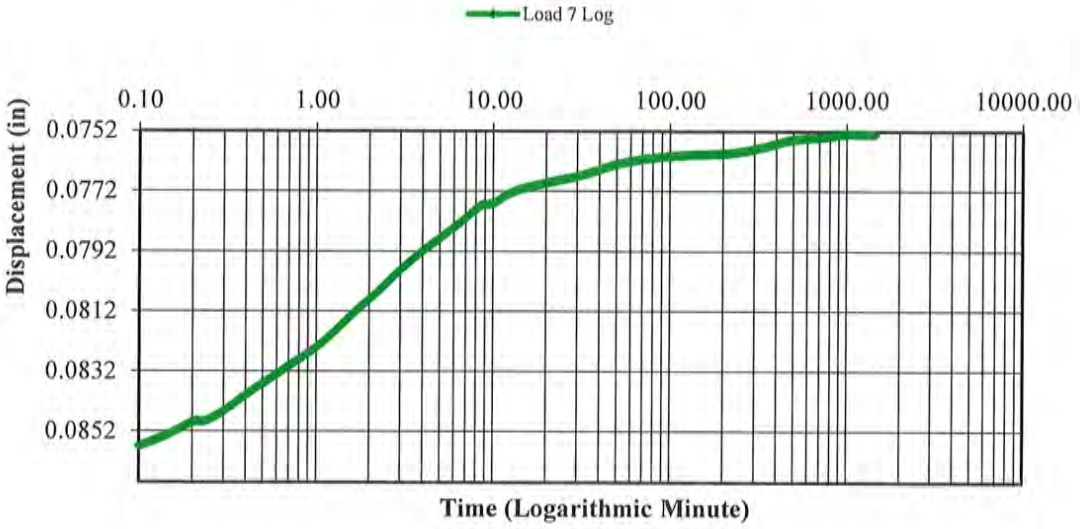
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 7) Rebound 0.250 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 8) Load 0.500 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0753	0.0749	7.4416	0.7831
1	00:00:01	0.0755	0.0746	7.4118	0.7837
2	00:00:02	0.0755	0.0746	7.4118	0.7837
3	00:00:03	0.0756	0.0747	7.4218	0.7835
4	00:00:04	0.0756	0.0747	7.4218	0.7835
5	00:00:05	0.0756	0.0747	7.4218	0.7835
6	00:00:06	0.0757	0.0748	7.4317	0.7833
7	00:00:12	0.0758	0.0749	7.4416	0.7831
8	00:00:15	0.0758	0.0749	7.4416	0.7831
9	00:00:30	0.0759	0.0750	7.4516	0.7829
10	00:01:00	0.0760	0.0751	7.4615	0.7828
11	00:02:00	0.0760	0.0751	7.4615	0.7828
12	00:04:00	0.0761	0.0752	7.4714	0.7826
13	00:08:00	0.0761	0.0752	7.4714	0.7826
14	00:10:00	0.0761	0.0752	7.4714	0.7826
15	00:15:01	0.0761	0.0752	7.4714	0.7826
16	00:30:02	0.0761	0.0752	7.4714	0.7826
17	01:00:04	0.0762	0.0753	7.4814	0.7824
18	02:00:08	0.0762	0.0753	7.4814	0.7824
19	04:00:16	0.0762	0.0753	7.4814	0.7824
20	08:00:32	0.0763	0.0754	7.4913	0.7822
21	12:00:49	0.0763	0.0754	7.4913	0.7822
22	16:01:05	0.0763	0.0754	7.4913	0.7822
23	20:01:22	0.0763	0.0754	7.4913	0.7822
24	24:01:38	0.0763	0.0754	7.4913	0.7822
25	24:36:12	0.0763	0.0754	7.4913	0.7822

Tested By: **Checked By:**

Consolidation Test Results
(Sequence 8) Load 0.500 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 9) Load 1.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

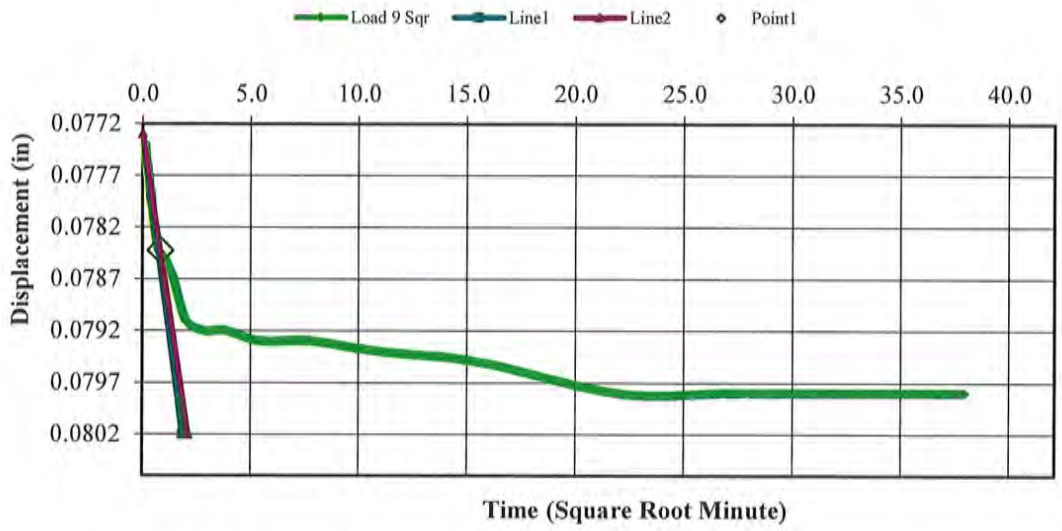
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0763	0.0754	7.4913	0.7822
1	00:00:01	0.0774	0.0757	7.5211	0.7816
2	00:00:02	0.0776	0.0759	7.5410	0.7812
3	00:00:03	0.0776	0.0759	7.5410	0.7812
4	00:00:04	0.0777	0.0760	7.5509	0.7810
5	00:00:05	0.0777	0.0760	7.5509	0.7810
6	00:00:06	0.0778	0.0761	7.5609	0.7808
7	00:00:12	0.0780	0.0763	7.5807	0.7805
8	00:00:15	0.0781	0.0764	7.5907	0.7803
9	00:00:30	0.0784	0.0767	7.6205	0.7797
10	00:01:00	0.0785	0.0768	7.6304	0.7795
11	00:02:00	0.0787	0.0770	7.6503	0.7791
12	00:04:00	0.0791	0.0774	7.6900	0.7784
13	00:08:01	0.0792	0.0775	7.6999	0.7782
14	00:10:01	0.0792	0.0775	7.6999	0.7782
15	00:15:01	0.0792	0.0775	7.6999	0.7782
16	00:30:02	0.0793	0.0776	7.7099	0.7780
17	01:00:04	0.0793	0.0776	7.7099	0.7780
18	02:00:08	0.0794	0.0777	7.7198	0.7778
19	04:00:16	0.0795	0.0778	7.7298	0.7776
20	08:00:33	0.0798	0.0781	7.7596	0.7770
21	12:00:49	0.0798	0.0781	7.7596	0.7770
22	16:01:06	0.0798	0.0781	7.7596	0.7770
23	20:01:22	0.0798	0.0781	7.7596	0.7770
24	24:00:01	0.0798	0.0781	7.7596	0.7770

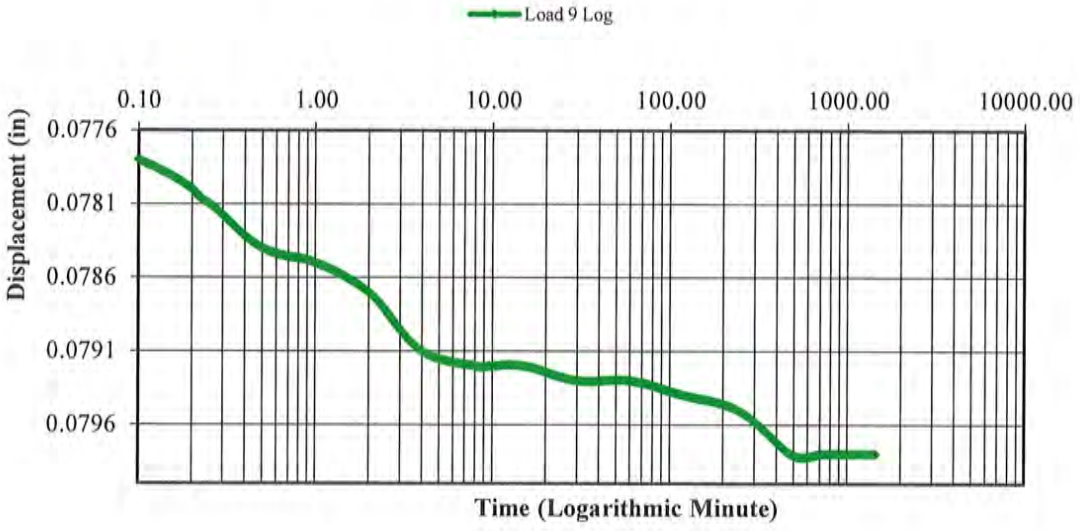
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 9) Load 1.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 10) Load 2.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

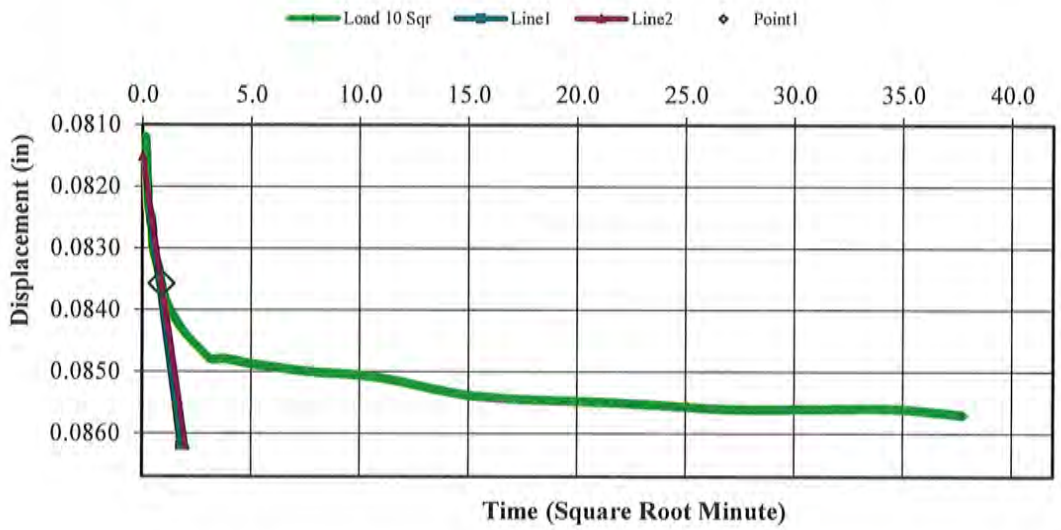
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0798	0.0781	7.7596	0.7770
1	00:00:01	0.0812	0.0789	7.8390	0.7755
2	00:00:02	0.0817	0.0794	7.8887	0.7745
3	00:00:03	0.0820	0.0797	7.9185	0.7740
4	00:00:04	0.0823	0.0800	7.9483	0.7734
5	00:00:05	0.0824	0.0801	7.9583	0.7732
6	00:00:06	0.0824	0.0801	7.9583	0.7732
7	00:00:12	0.0827	0.0804	7.9881	0.7726
8	00:00:15	0.0830	0.0807	8.0179	0.7720
9	00:00:30	0.0833	0.0810	8.0477	0.7715
10	00:01:00	0.0838	0.0815	8.0974	0.7705
11	00:02:00	0.0841	0.0818	8.1272	0.7699
12	00:04:00	0.0844	0.0821	8.1570	0.7694
13	00:08:00	0.0847	0.0824	8.1868	0.7688
14	00:10:00	0.0848	0.0825	8.1967	0.7686
15	00:15:01	0.0848	0.0825	8.1967	0.7686
16	00:30:02	0.0849	0.0826	8.2067	0.7684
17	01:00:04	0.0850	0.0827	8.2166	0.7682
18	02:00:08	0.0851	0.0828	8.2265	0.7680
19	04:00:16	0.0854	0.0831	8.2563	0.7674
20	08:00:32	0.0855	0.0832	8.2663	0.7673
21	12:00:49	0.0856	0.0833	8.2762	0.7671
22	16:01:05	0.0856	0.0833	8.2762	0.7671
23	20:01:22	0.0856	0.0833	8.2762	0.7671
24	23:45:36	0.0857	0.0834	8.2861	0.7669

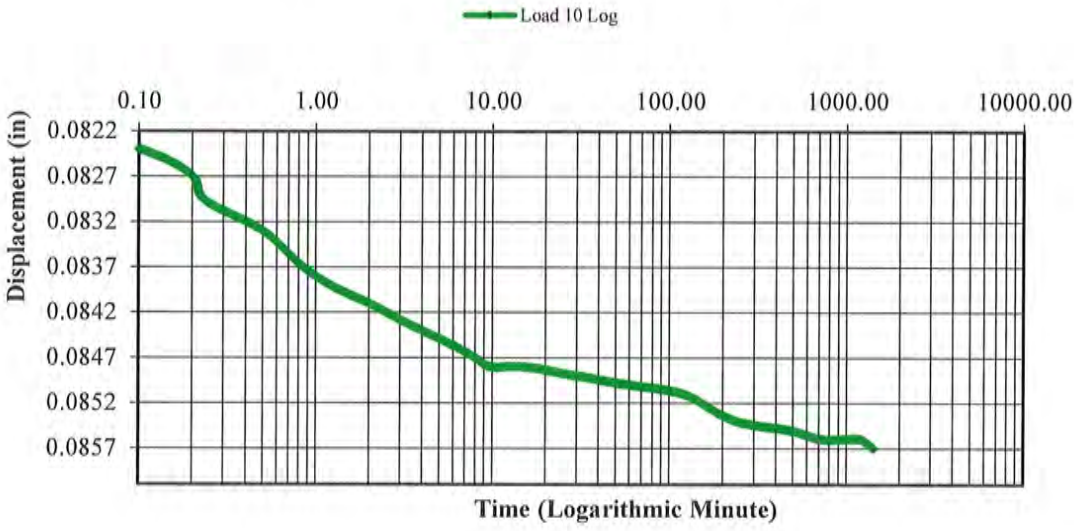
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 10) Load 2.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 11) Load 4.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

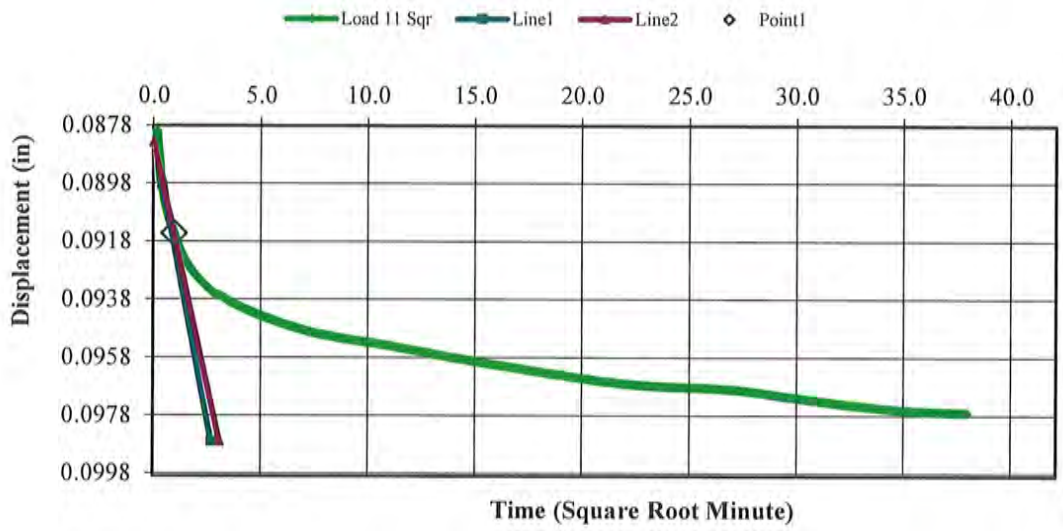
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0857	0.0834	8.2861	0.7669
1	00:00:01	0.0880	0.0853	8.4749	0.7632
2	00:00:02	0.0886	0.0859	8.5345	0.7621
3	00:00:03	0.0889	0.0862	8.5643	0.7615
4	00:00:04	0.0891	0.0864	8.5842	0.7611
5	00:00:05	0.0895	0.0868	8.6239	0.7604
6	00:00:06	0.0896	0.0869	8.6339	0.7602
7	00:00:12	0.0901	0.0874	8.6836	0.7592
8	00:00:15	0.0904	0.0877	8.7134	0.7586
9	00:00:30	0.0910	0.0883	8.7730	0.7575
10	00:01:00	0.0917	0.0890	8.8425	0.7562
11	00:02:00	0.0924	0.0897	8.9121	0.7548
12	00:04:00	0.0930	0.0903	8.9717	0.7537
13	00:08:00	0.0936	0.0909	9.0313	0.7525
14	00:10:00	0.0937	0.0910	9.0412	0.7523
15	00:15:01	0.0940	0.0913	9.0710	0.7517
16	00:30:02	0.0945	0.0918	9.1207	0.7508
17	01:00:04	0.0950	0.0923	9.1704	0.7498
18	02:00:08	0.0954	0.0927	9.2101	0.7491
19	04:00:16	0.0960	0.0933	9.2697	0.7479
20	08:00:33	0.0967	0.0940	9.3393	0.7466
21	12:00:49	0.0969	0.0942	9.3592	0.7462
22	16:01:05	0.0973	0.0946	9.3989	0.7454
23	20:01:22	0.0976	0.0949	9.4287	0.7449
24	24:00:00	0.0977	0.0950	9.4386	0.7447

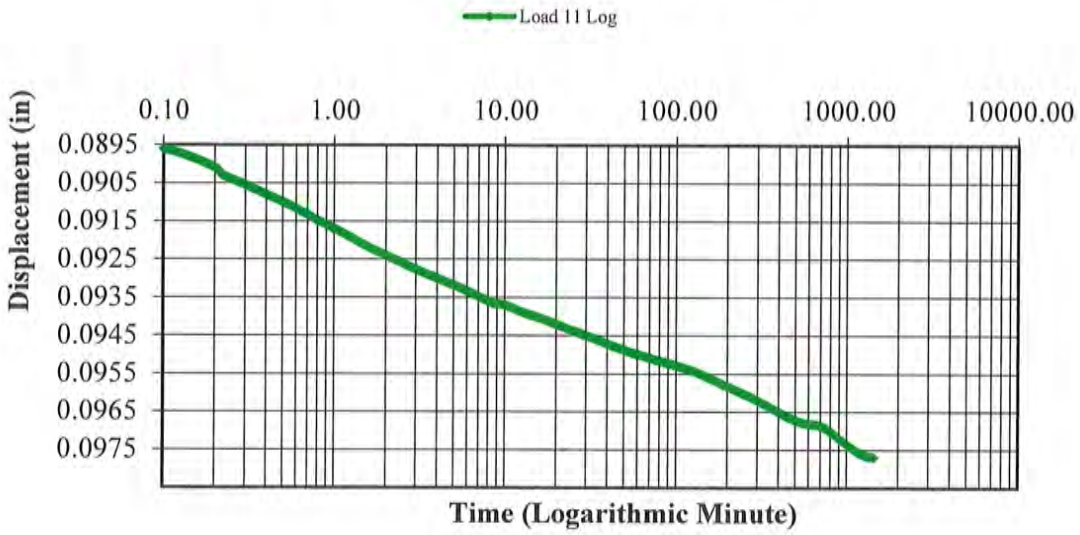
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 11) Load 4.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 12) Load 8.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

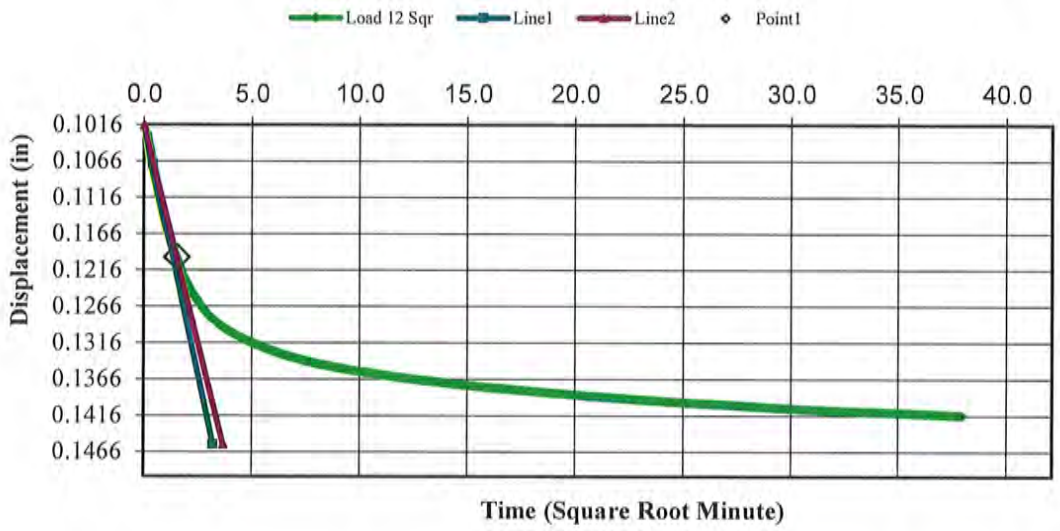
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.0977	0.0950	9.4386	0.7447
1	00:00:01	0.1029	0.0995	9.8857	0.7361
2	00:00:02	0.1040	0.1006	9.9950	0.7339
3	00:00:03	0.1046	0.1012	10.0546	0.7328
4	00:00:04	0.1050	0.1016	10.0944	0.7320
5	00:00:05	0.1056	0.1022	10.1540	0.7309
6	00:00:06	0.1060	0.1026	10.1937	0.7301
7	00:00:12	0.1079	0.1045	10.3825	0.7265
8	00:00:15	0.1087	0.1053	10.4620	0.7250
9	00:00:30	0.1113	0.1079	10.7203	0.7200
10	00:01:00	0.1151	0.1117	11.0979	0.7127
11	00:02:00	0.1193	0.1159	11.5152	0.7047
12	00:04:00	0.1236	0.1202	11.9424	0.6964
13	00:08:01	0.1273	0.1239	12.3100	0.6894
14	00:10:01	0.1283	0.1249	12.4093	0.6874
15	00:15:01	0.1299	0.1265	12.5683	0.6844
16	00:30:02	0.1322	0.1288	12.7968	0.6800
17	01:00:04	0.1343	0.1309	13.0055	0.6760
18	02:00:08	0.1360	0.1326	13.1744	0.6727
19	04:00:16	0.1376	0.1342	13.3333	0.6696
20	08:00:33	0.1392	0.1358	13.4923	0.6666
21	12:00:49	0.1401	0.1367	13.5817	0.6649
22	16:01:06	0.1408	0.1374	13.6513	0.6635
23	20:01:22	0.1412	0.1378	13.6910	0.6627
24	23:59:59	0.1416	0.1382	13.7307	0.6620

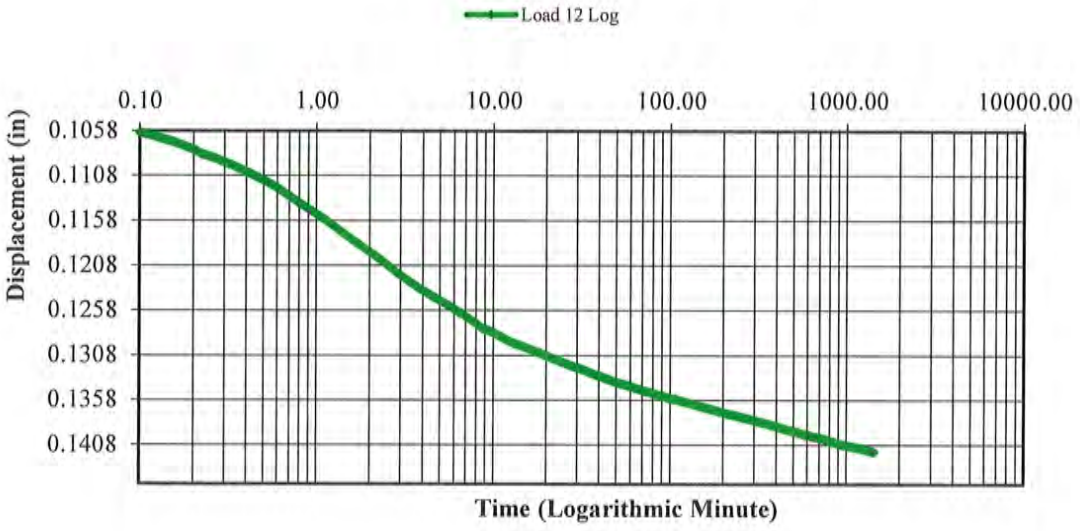
Tested By: RG
Checked By: DS

Consolidation Test Results
(Sequence 12) Load 8.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 13) Load 16.000 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

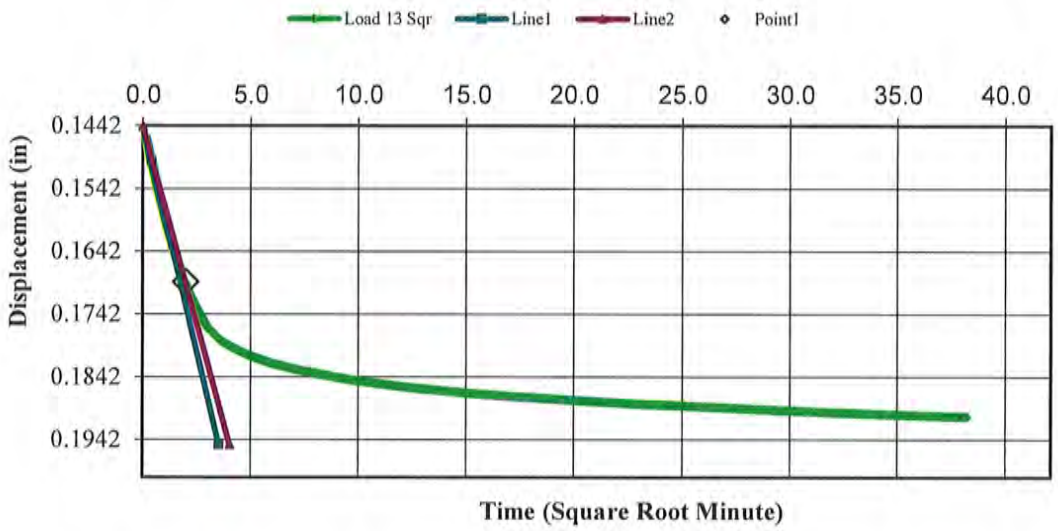
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1416	0.1382	13.7307	0.6620
1	00:00:01	0.1460	0.1419	14.0984	0.6549
2	00:00:02	0.1470	0.1429	14.1977	0.6530
3	00:00:03	0.1475	0.1434	14.2474	0.6520
4	00:00:04	0.1480	0.1439	14.2971	0.6511
5	00:00:05	0.1485	0.1444	14.3467	0.6501
6	00:00:06	0.1489	0.1448	14.3865	0.6493
7	00:00:12	0.1507	0.1466	14.5653	0.6459
8	00:00:15	0.1515	0.1474	14.6448	0.6444
9	00:00:30	0.1545	0.1504	14.9429	0.6386
10	00:01:00	0.1586	0.1545	15.3502	0.6308
11	00:02:00	0.1640	0.1599	15.8867	0.6204
12	00:04:00	0.1698	0.1657	16.4630	0.6093
13	00:08:00	0.1754	0.1713	17.0194	0.5986
14	00:10:00	0.1769	0.1728	17.1684	0.5958
15	00:15:00	0.1790	0.1749	17.3770	0.5917
16	00:30:00	0.1815	0.1774	17.6254	0.5869
17	00:59:59	0.1835	0.1794	17.8241	0.5831
18	01:59:58	0.1853	0.1812	18.0030	0.5797
19	03:59:56	0.1869	0.1828	18.1619	0.5766
20	07:59:52	0.1883	0.1842	18.3010	0.5739
21	11:59:49	0.1891	0.1850	18.3805	0.5724
22	15:59:45	0.1897	0.1856	18.4401	0.5713
23	19:59:41	0.1902	0.1861	18.4898	0.5703
24	23:59:38	0.1905	0.1864	18.5196	0.5697
25	23:59:50	0.1905	0.1864	18.5196	0.5697

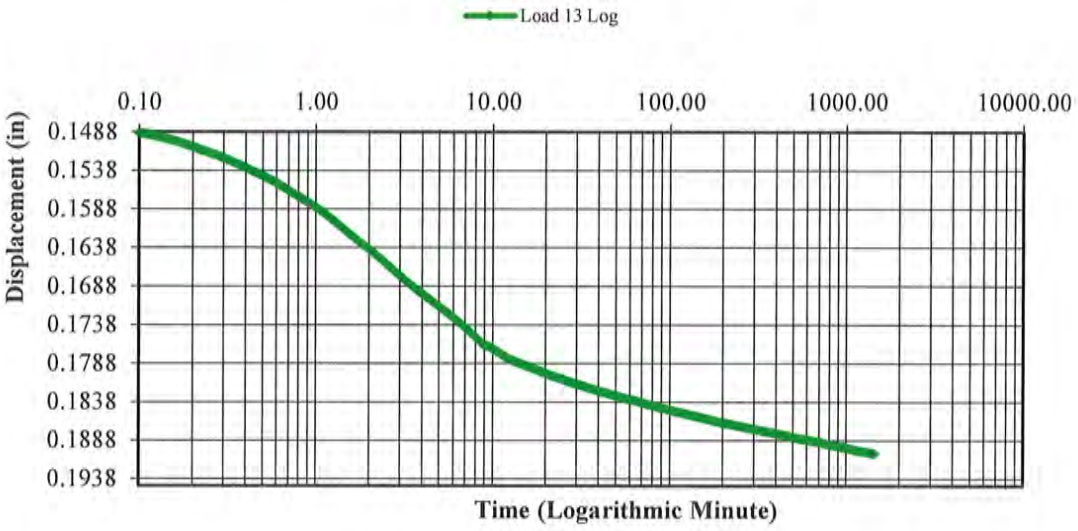
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 13) Load 16.000 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



Consolidation Test Results
(Sequence 14) Rebound 0.125 tsf

Project: Wallops Island Breakwaters
Location: Wallops Island, VA
Job Number: 18C13074

Project Number: 18C13074
Test Date: 6/20/18
Test Number:

Sample Number: B-4
Boring Number: B-4
Depth: 29.5'-31.5'
Sample Type: Undisturbed

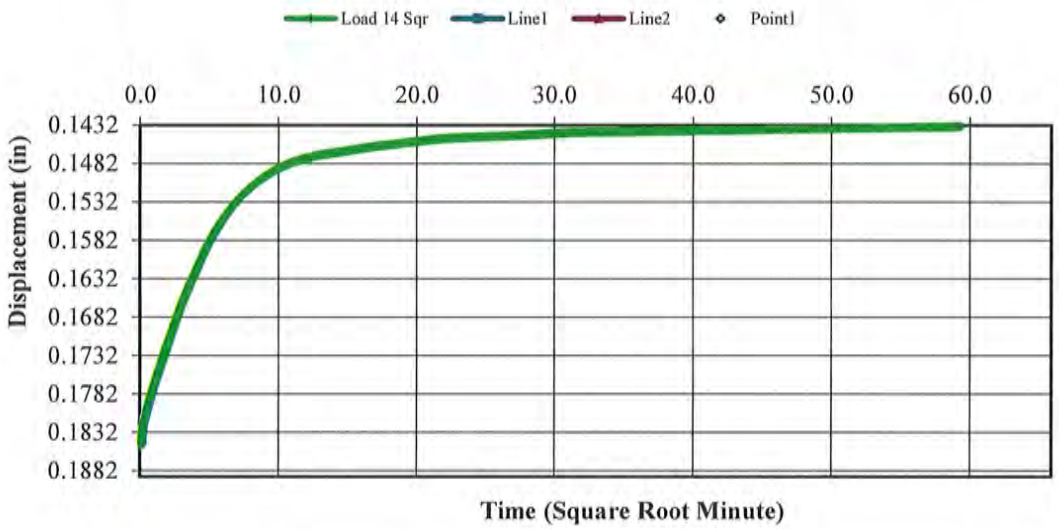
Soil Description: ORGANIC SILT (OL), gray
Remarks:

Index	Time	Displacement (in)	Settlement (in)	Axial Strain (%)	Void Ratio
0	00:00:00	0.1905	0.1864	18.5196	0.5697
1	00:00:01	0.1848	0.1846	18.3408	0.5732
2	00:00:02	0.1833	0.1831	18.1918	0.5760
3	00:00:03	0.1827	0.1825	18.1321	0.5772
4	00:00:04	0.1824	0.1822	18.1023	0.5778
5	00:00:05	0.1820	0.1818	18.0626	0.5785
6	00:00:06	0.1817	0.1815	18.0328	0.5791
7	00:00:12	0.1808	0.1806	17.9434	0.5808
8	00:00:15	0.1803	0.1801	17.8937	0.5818
9	00:00:30	0.1791	0.1789	17.7745	0.5841
10	00:01:00	0.1772	0.1770	17.5857	0.5877
11	00:02:00	0.1749	0.1747	17.3572	0.5921
12	00:04:00	0.1716	0.1714	17.0293	0.5984
13	00:08:00	0.1673	0.1671	16.6021	0.6067
14	00:10:00	0.1658	0.1656	16.4531	0.6095
15	00:15:00	0.1628	0.1626	16.1550	0.6153
16	00:30:00	0.1569	0.1567	15.5688	0.6266
17	01:00:02	0.1517	0.1515	15.0522	0.6365
18	02:00:05	0.1481	0.1479	14.6945	0.6434
19	04:00:13	0.1464	0.1462	14.5256	0.6467
20	08:00:28	0.1450	0.1448	14.3865	0.6493
21	12:00:43	0.1446	0.1444	14.3467	0.6501
22	16:00:58	0.1442	0.1440	14.3070	0.6509
23	20:01:13	0.1441	0.1439	14.2971	0.6511
24	24:01:28	0.1440	0.1438	14.2871	0.6513
25	58:33:53	0.1434	0.1432	14.2275	0.6524

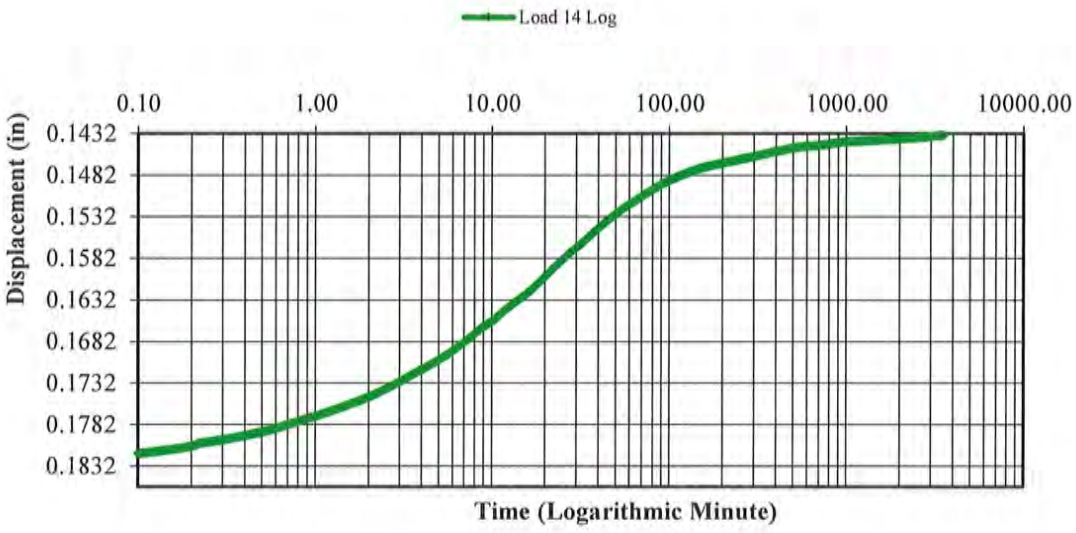
Tested By: **Checked By:**

Consolidation Test Results
(Sequence 14) Rebound 0.125 tsf

Consolidation Graph (Squareroot Time)



Consolidation Graph (Logarithmic Time)



APPENDIX C

IN SITU TEST RESULTS

ConeTec Report – Wallops Island Breakwaters
Data Interpretation for CPT Logs C-1 and C-7

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PRESENTATION OF SITE INVESTIGATION RESULTS

Wallops Island Break Waters – Wallops Island, VA

Prepared for:

Schnabel Engineering

ConeTec Job No: 18-54025

Project Start Date: 15-Jun-2018
Project End Date: 24-Jun-2018
Report Date: 03-Jul-2018



Prepared by:

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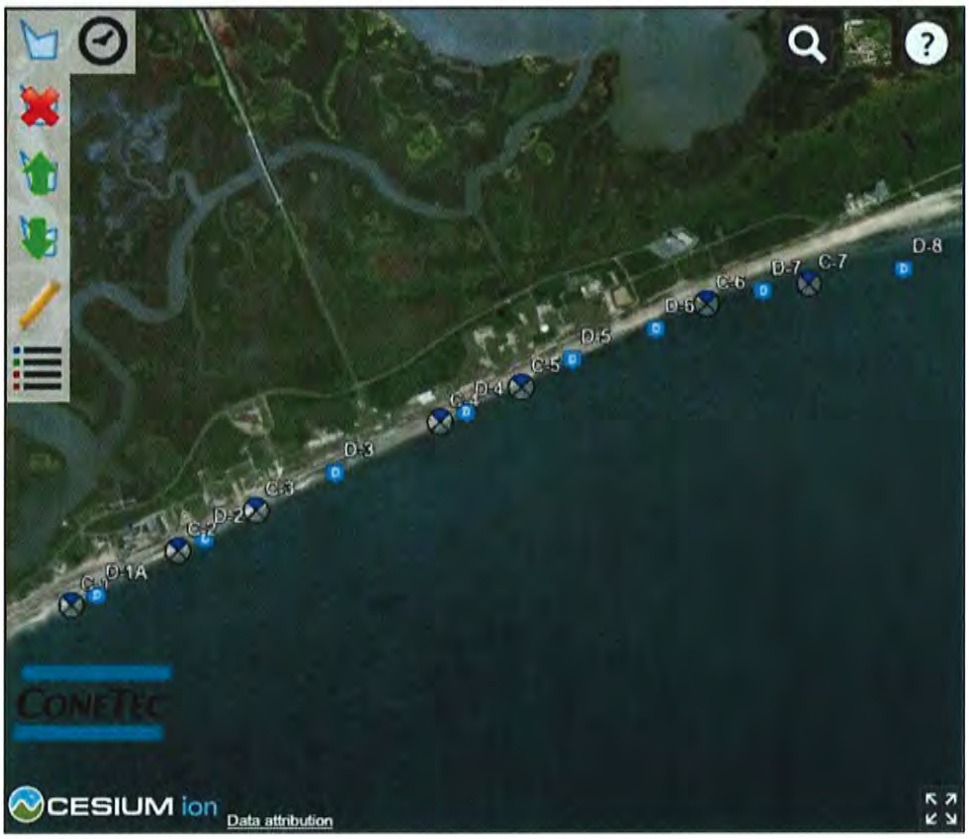
Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec Inc. for Schnabel Engineering off the coast of Wallops Island, VA for the NASA Wallops Flight Facility. The program consisted of seven cone penetration tests (CPTu) and nine flat plate dilatometer tests (DMT) at locations selected and numbered under the direction of Schnabel Engineering personnel. The purpose of the program was to evaluate existing site conditions.

Project Information

Project	
Client	Schnabel Engineering
Project	Wallops Island Break Waters
ConeTec project number	18-54025

A map from Cesium including the CPTu and DMT test locations is presented below.



Rig Description	Deployment System	Test Type
Client Provided Barge	Portable Ramset	CPTu, DMT

Coordinates		
Test Type	Collection Method	EPSG Number
CPTu, DMT	Handheld GPS	4326

Cone Penetration Test (CPT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Phreatic surface determination	The assumed phreatic surface was based on the initial water depth reading taken during test setup.

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm^2)	Sleeve Area (cm^2)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
367T1500F15U500	AD367	15	225	1500	15	500
Cone AD367 was used for all CPT soundings.						

Interpretation Tables	
Additional information	The Normalized Soil Behaviour Type (SBT Qtn) classification chart (Robertson, 2009) was used to classify the soil for this project. A detailed set of CPT interpretations were generated and are provided in Excel format files in the release folder. The CPT interpretations are based on values of corrected tip (q_t), sleeve friction (f_s) and pore pressure (u_2) measured every 5.0 cm. Soils were classified as either drained or undrained based on the Normalized Soil Behaviour Type (SBT Qtn) classification chart (Robertson, 2009). The unit weight of water was assumed to be 64.1 pcf due to testing in the Atlantic Ocean.

Flat Plate Dilatometer Test (DMT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Phreatic surface determination	The assumed phreatic surface was based on the initial water depth reading taken during test setup.
Additional comments	The unit weight of water was assumed to be 64.1 pcf due to testing in the Atlantic Ocean.

Limitations

This report has been prepared for the exclusive use of Schnabel Engineering (Client) for the project titled "Wallops Island Break Waters". The report's contents may not be relied upon by any other party without the express written permission of ConeTec Inc. (ConeTec). ConeTec has provided site investigation services, prepared the factual data reporting, and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to ConeTec by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.

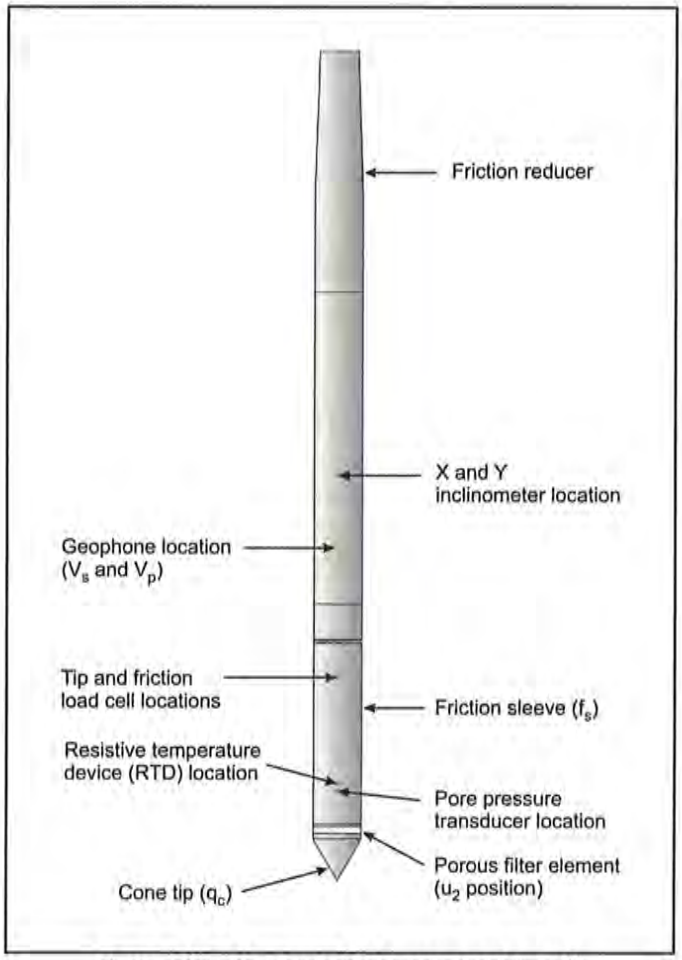


Figure CPTu. Piezocone Penetrometer (15 cm^2)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording intervals are either 2.5 cm or 5.0 cm depending on project requirements; custom recording intervals are possible. The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with either glycerin or silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 1.5 inches are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil or glycerin under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson (1990) and Robertson (2009). It should be noted that it is not always possible to accurately identify a soil type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behavior type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al, 1986:

$$q_t = q_c + (1\text{-}a) \bullet u_2$$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (Rf) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high

friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of interpretation files were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the interpretation methods used is also included in the data release folder.

For additional information on CPTu interpretations, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

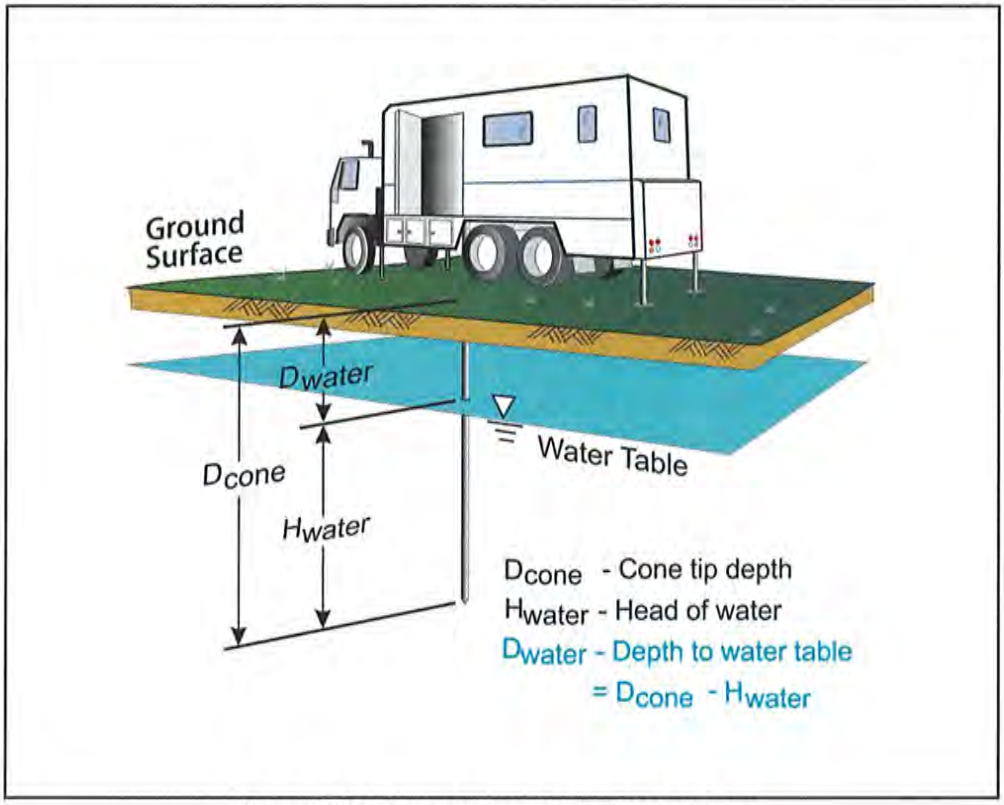


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behavior.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

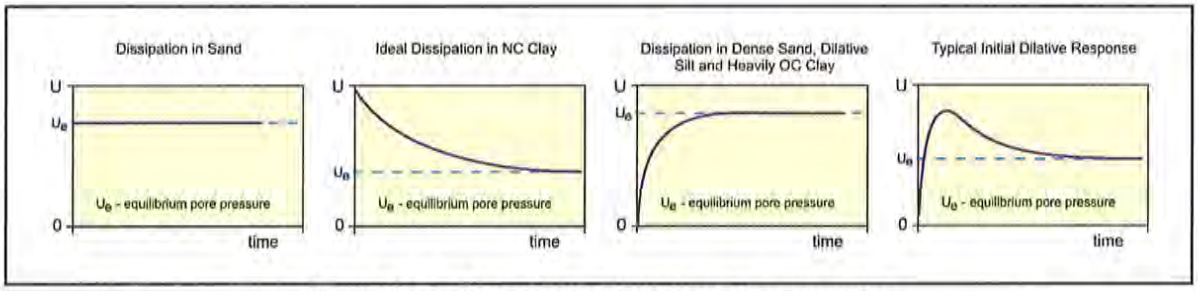


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve of Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100}. In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100}. A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

T* is the dimensionless time factor (Table Time Factor)
a is the radius of the cone
I_r is the rigidity index
t is the time at the degree of consolidation

Table Time Factor. T* versus degree of dissipation (Teh and Houlsby, 1991)

Degree of Dissipation (%)	20	30	40	50	60	70	80
T* (u_2)	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50}, dissipation tests must be taken to a pressure less than u_{50}. The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100}. To estimate u_{50}, both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby, 1991), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50}. In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r, the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50}, other methods should be applied to confirm the results for c_h.

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

ASTM D5778-12, 2012, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM, West Conshohocken, US.

Burns, S.E. and Mayne, P.W., 1998, "Monotonic and dilatory pore pressure decay during piezocone tests", Canadian Geotechnical Journal 26 (4): 1063-1073.

Burns, S.E. and Mayne, P.W., 2002, "Analytical cavity expansion-critical state model cone dissipation in fine-grained soils", Soils & Foundations, Vol. 42(2): 131-137.

Jones, G.A. and Van Zyl, D.J.A., 1981, "The piezometer probe: a useful investigation tool", Proceedings, 10th International Conference on Soil Mechanics and Foundation Engineering, Vol. 3, Stockholm: 489-495.

Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, "Cone Penetration Testing in Geotechnical Practice", Blackie Academic and Professional.

Mayne, P.W., 2013, "Evaluating yield stress of soils from laboratory consolidation and in-situ cone penetration tests", Sound Geotechnical Research to Practice (Holtz Volume) GSP 230, ASCE, Reston/VA: 406-420.

Mayne, P.W., 2014, "Interpretation of geotechnical parameters from seismic piezocone tests", CPT'14 Keynote Address, Las Vegas, NV, May 2014.

Mayne, P.W. and Peuchen, J., 2012, "Unit weight trends with cone resistance in soft to firm clays", Geotechnical and Geophysical Site Characterization *4*, Vol. 1 (Proc. ISC-4, Pernambuco), CRC Press, London: 903-910.

Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27: 151-158.

Robertson, P.K., 2009, "Interpretation of cone penetration tests – a unified approach", Canadian Geotechnical Journal, Volume 46: 1337-1355.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K., Sully, J.P., Woeller, D.J., Lunne, T., Powell, J.J.M. and Gillespie, D.G., 1992, "Estimating coefficient of consolidation from piezocone tests", Canadian Geotechnical Journal, 29(4): 551-557.

Sully, J.P., Robertson, P.K., Campanella, R.G. and Woeller, D.J., 1999, "An approach to evaluation of field CPTU dissipation data in overconsolidated fine-grained soils", Canadian Geotechnical Journal, 36(2): 369-381.

Teh, C.I., and Houlsby, G.T., 1991, "An analytical study of the cone penetration test in clay", Geotechnique, 41(1): 17-34.

Flat plate dilatometer tests (DMT) are conducted using a flat steel blade with a thin, expandable, circular membrane mounted on one surface, a control unit and a compressed gas (typically nitrogen) supply. A photo of the system is presented in Figure DMT-1.

The dilatometer blade is connected to the up-hole control box by a pneumatic tube with an inner conductor wire. The tube is threaded through a set of steel push rods. The control unit has pressure gauges, an audio-visual signal, a gas flow control and vent valve. A syringe is used to quantify the stiffness of the blade membrane.



Figure DMT-1. Flat plate dilatometer system
(Marchetti, http://www.marchetti-dmt.it/pagespictures/blade&case.htm)

Prior to conducting a DMT profile, the blade membrane stiffness is recorded according to the current ASTM D6635 specifications and the system is assembled and tested for any leaks.

The dilatometer blade is pushed into the ground to the desired depth from surface or through a cased hole using a CPT rig or a drill rig. The blade is inflated using compressed gas and up to three pressure readings are recorded, the A reading at zero deflection (lift-off) and the B reading when a deflection of 1.1 mm has been achieved. An optional C reading representing the closing pressure can be recorded by slowly deflating the membrane soon after B is reached. The blade is advanced to subsequent depths

and the test procedures are repeated at each test depth, up to the sounding termination depth. After the blade is retracted membrane stiffness values are recorded.

The dilatometer operating procedures are performed in general accordance with the current ASTM D6635 standard.

The interpretation of the dilatometer data is based on the pressure related parameters p_o and p_1 that are derived from the recorded A and B pressure values corrected for membrane stiffness and the gauge zero offset. Figure DMT-2 shows p_o and p_1.

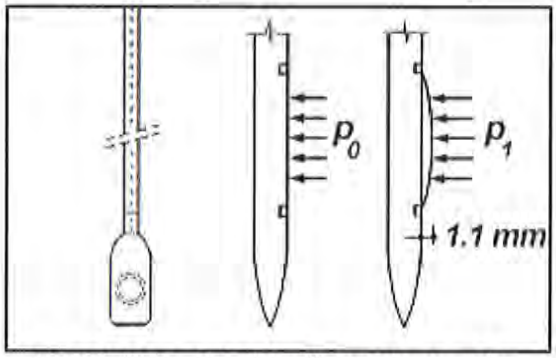


Figure DMT-2. Flat plate dilatometer p_0 and p_1
(Marchetti, http://www.marchetti-dmt.it/)

The A reading is the pressure required to lift-off the membrane while the B reading is the pressure required to move the center of the membrane by 1.1 mm. The C pressure measurement is the pressure at which the membrane returns to the A position and is used to estimate equilibrium pore pressures in sand. The A and B pressure readings are corrected by the membrane stiffness values at the respective membrane deflections that are recorded before and after each test location.

The empirical correlations use the parameters p_0, p_1 and p_2 derived from the A, B and C readings accounting for membrane stiffness and gauge offset. These parameters provide the basic values needed in the empirical correlations developed by Marchetti et al. (2001). The equations for these parameters are presented in the relevant appendix.

The p_o, p_1 and p_2 parameters are used to calculate the DMT indices, material index (I_D), horizontal stress index (K_D), and dilatometer modulus (E_D). Soil type is inferred from the material index. Clays generally have a material index of less than 0.6. The material index for silts is generally between 0.6 and 1.8, while sands generally exhibit a material index greater than 1.8. While K_D and E_D have limited direct use in geotechnical design, they are critical for determining parameters that are required for most design calculations such as earth pressure coefficient (K_o), undrained shear strength (S_u), and over consolidation ratio (OCR).

A summary of the tests including coordinates and estimated phreatic surface, along with plots and tabular results are provided in the relevant appendices. The calculated geotechnical parameters presented are based on published empirical correlations and are provided only as a first approximation. No warranty, expressed or implied, is made to the accuracy of these estimated geotechnical parameters.

References

ASTM D6635-01, Reapproved 2007, "Standard Test Method for Performing the Flat Plate Dilatometer ", ASTM, West Conshohocken, US.

Foti, D., Lancellotta, R., Marchetti, D., Monaco, P., and Totani, P., 2006, "Interpretation of SDMT tests in a transversely isotropic medium", Proceedings from the Second International Conference on the Flat Dilatometer, Washington, DC., April 2-5.

Marchetti, S., Monaco P., Totani G. and Calabrese M., 2001, "The Flat Dilatometer Test (DMT) in soil investigations", A Report by the ISSMEGE Committee TC16. Proc. IN SITU 2001, Intnl. Conf. On In Situ Measurement of Soil Properties, Bali, Indonesia, May 2001, 41 pp.

Marchetti, S., n.d, [Photographs of DMT and SDMT system], Retrieved from http://www.marchetti-dmt.it/pagespictures/blade&case.htm.

Marchetti, S., n.d, [Illustration of DMT blade, po and p1], http://www.marchetti-dmt.it/.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots
- Flat Plate Dilatometer Test Summary, Plots, and Tabular Results

Cone Penetration Test Summary and

Standard Cone Penetration Test Plots

CONETEC

CONETEC

Job No:	18-54025
Client:	Schnabel Engineering
Project:	Wallops Island Break Waters
Start Date:	15-Jun-2018
End Date:	24-Jun-2018

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Water Depth[2] (ft)	Final Depth (ft)	Latitude[1] (degrees)	Longitude[1] (degrees)
C-1	18-54025_CP C-1	18-Jun-2018	367:T1500F15U500	10.5	71.7	37.82922	-75.48952
C-2	18-54025_CP C-2	18-Jun-2018	367:T1500F15U500	14.0	71.5	37.83355	-75.48512
C-3	18-54025_CP C-3	18-Jun-2018	367:T1500F15U500	10.0	71.2	37.83675	-75.48190
C-4	18-54025_CP C-4	17-Jun-2018	367:T1500F15U500	11.0	61.0	37.84403	-75.47408
C-5	18-54025_CP C-5	17-Jun-2018	367:T1500F15U500	13.0	70.2	37.84706	-75.47054
C-6	18-54025_CP C-6	17-Jun-2018	367:T1500F15U500	4.5	71.5	37.85416	-75.46255
C-7	18-54025_CP C-7	16-Jun-2018	367:T1500F15U500	6.0	72.2	37.85698	-75.45753
Totals	7 Soundings				489.3		

1. WGS 84 Lat/Long. Coordinates were taken with a handheld GPS and should be considered approximate.

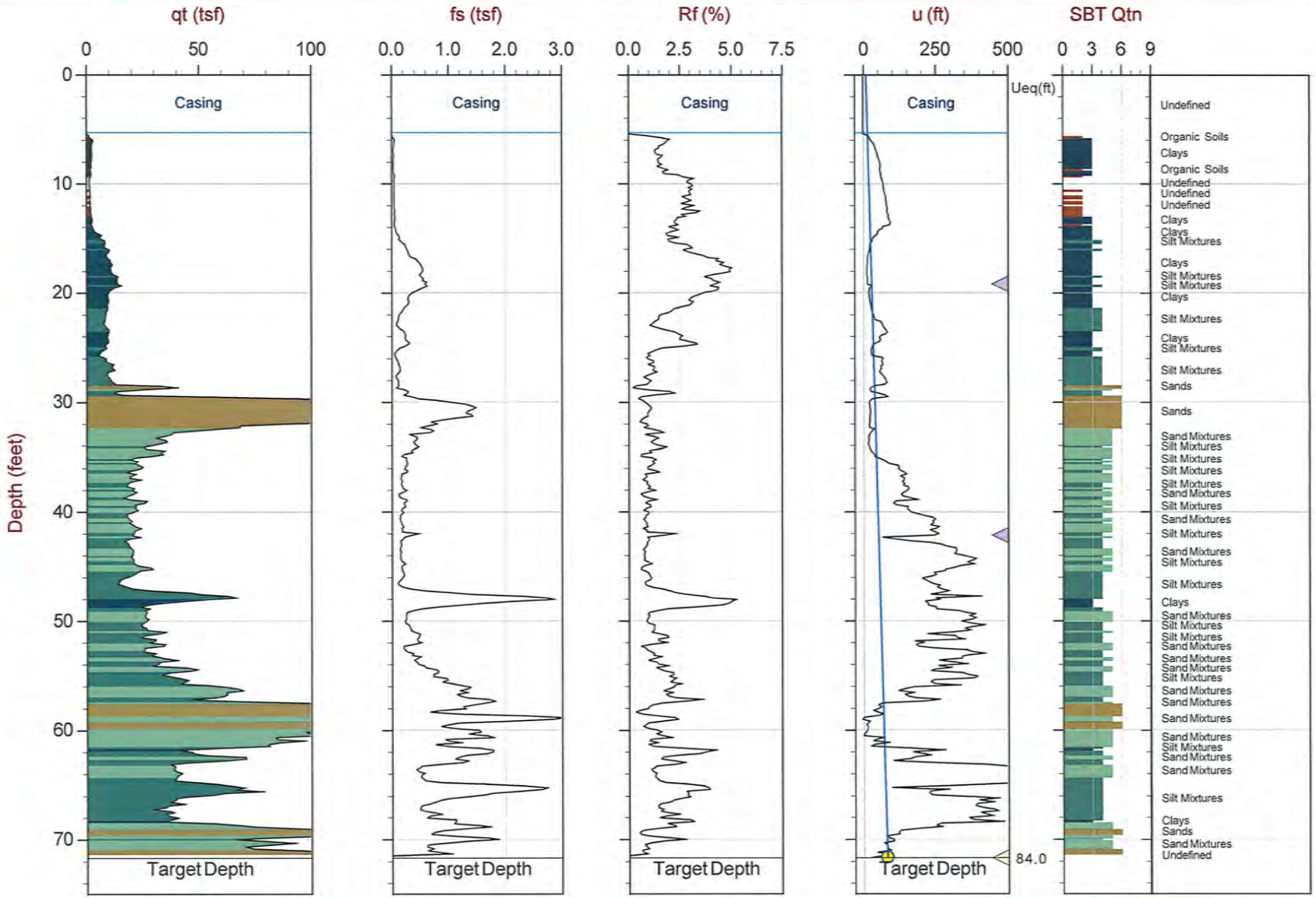
2. The assumed phreatic surface was based on the initial water depth reading taken during test setup. Hydrostatically increasing pore water pressures with depth were used for interpretation tables.

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 2018-06-18 15:11
Site: Wallops Island Break Waters

Sounding: C-1
Cone: 367:T1500F15U500



Max Depth: 21.850 m / 71.69 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 18-54025_CPC-1.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: Lat: 37.82922 Long: -75.48952

△ Dissipation with estimated Ueq value ▲ Dissipation, equilibrium not achieved ○ Equilibrium Pore Pressure (Ueq)

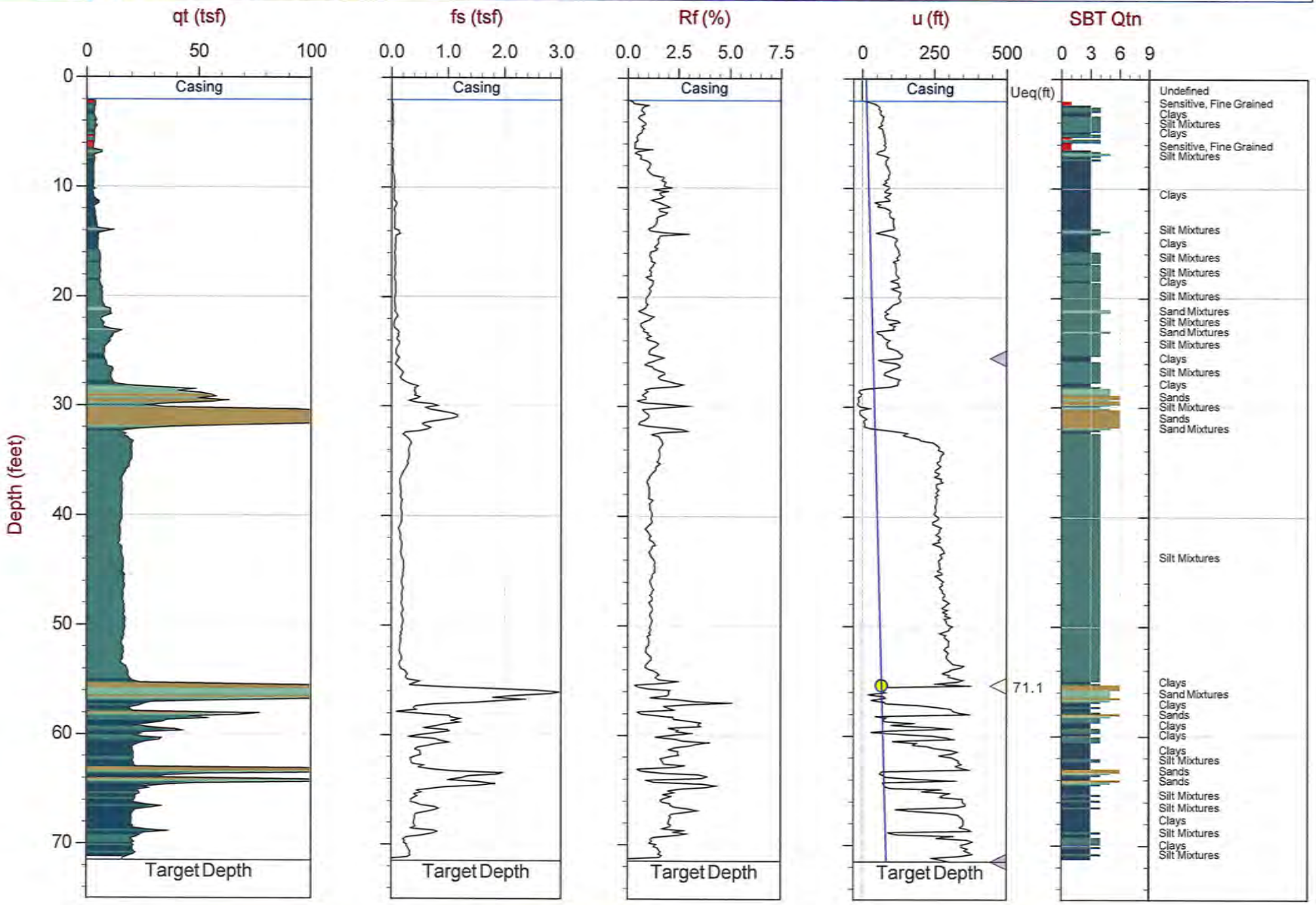
The reported coordinates were acquired from hand-held GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 2018-06-18 12:11
Site: Wallops Island Break Waters

Sounding: C-2
Cone: 367:T1500F15U500



Max Depth: 21.800 m / 71.52 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 18-54025_CPC-2.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: Lat: 37.83355 Long: -75.48512

△ Dissipation with estimated Ueq value △ Dissipation, equilibrium not achieved ○ Equilibrium Pore Pressure (Ueq)

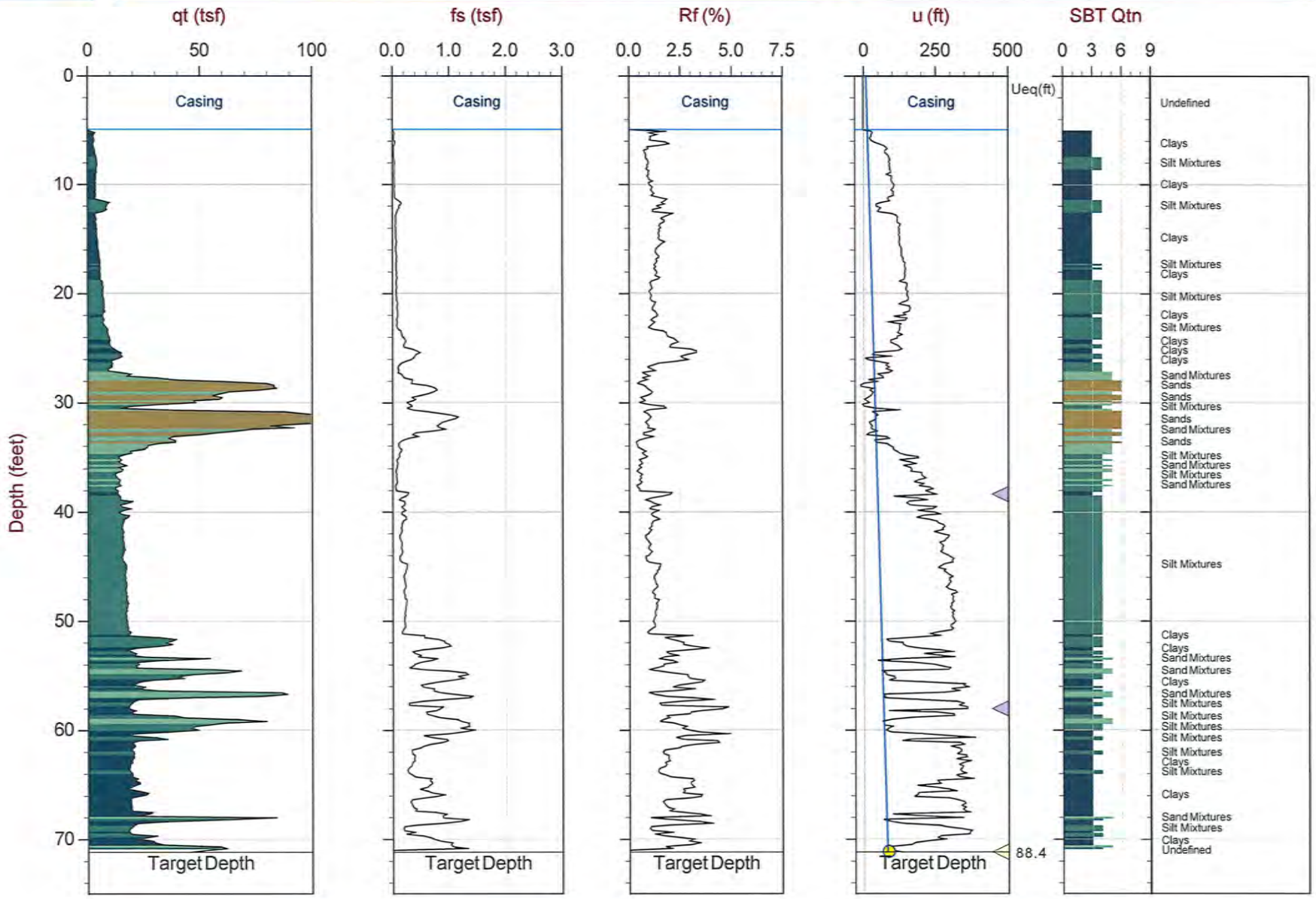
The reported coordinates were acquired from hand-held GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 2018-06-18 09:10
Site: Wallops Island Break Waters

Sounding: C-3
Cone: 367:T1500F15U500



Max Depth: 21.700 m / 71.19 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 18-54025_CPC-3.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: Lat: 37.83675 Long: -75.48190

△ Dissipation with estimated Ueq value ◬ Dissipation, equilibrium not achieved ○ Equilibrium Pore Pressure (Ueq)

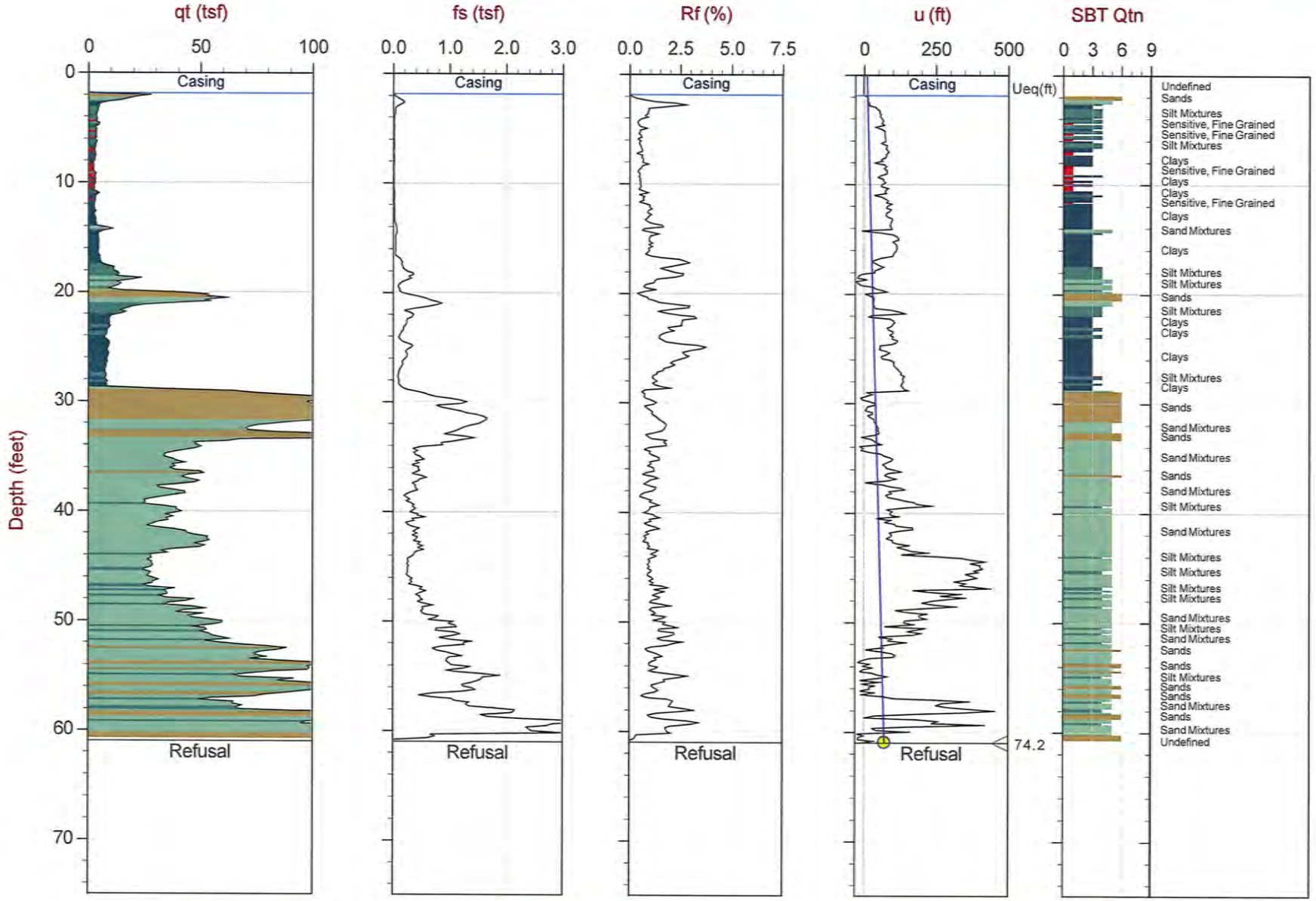
The reported coordinates were acquired from hand-held GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 2018-06-17 13:29
Site: Wallops Island Break Waters

Sounding: C-4
Cone: 367:T1500F15U500



Max Depth: 18.600 m / 61.02 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 18-54025_CPC-4.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: Lat: 37.84403 Long: -75.47408

△ Dissipation with estimated Ueq value △ Dissipation, equilibrium not achieved ○ Equilibrium Pore Pressure (Ueq)

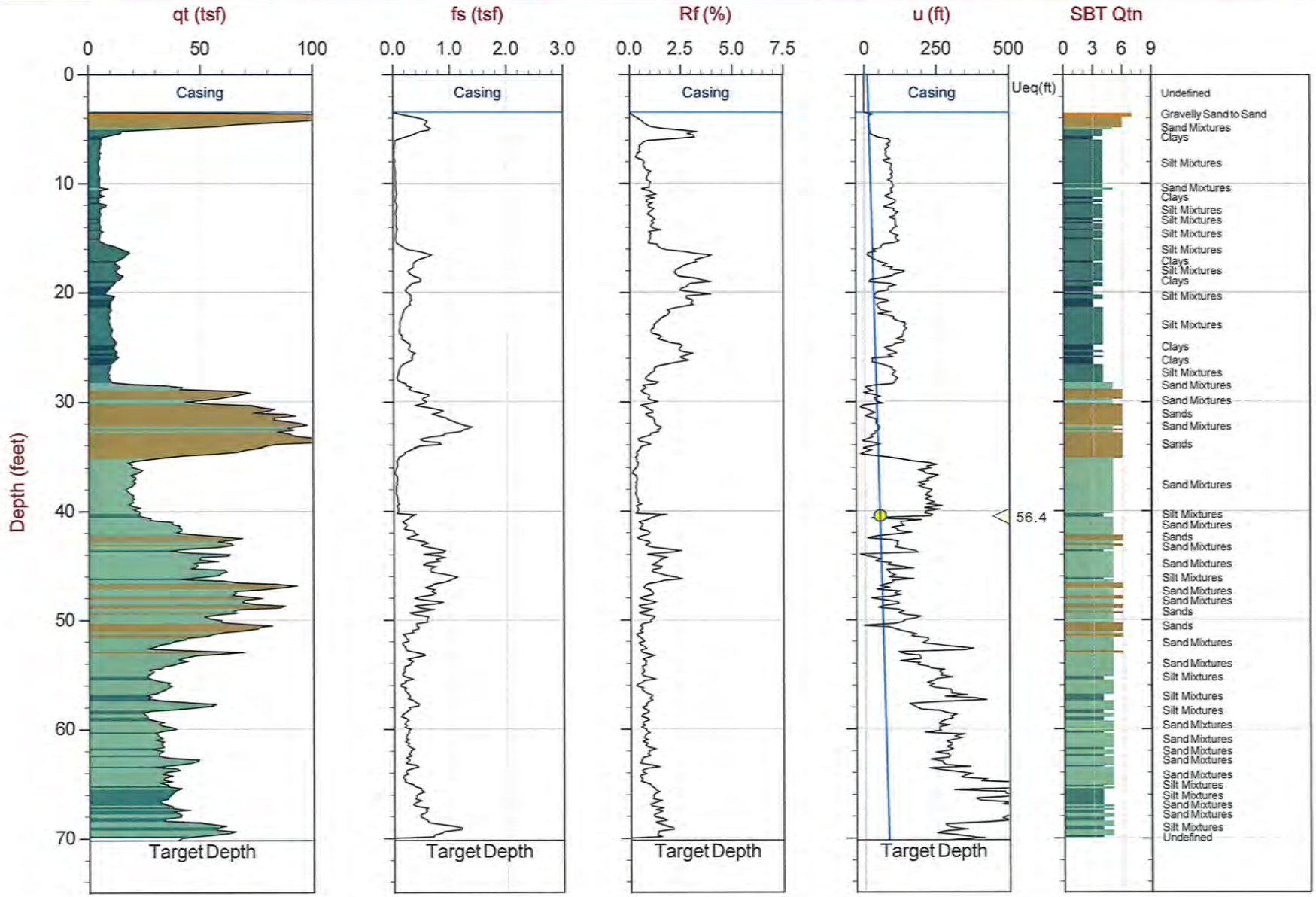
The reported coordinates were acquired from hand-held GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 2018-06-17 10:24
Site: Wallops Island Break Waters

Sounding: C-5
Cone: 367:T1500F15U500



Max Depth: 21.400 m / 70.21 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 18-54025_CPC-5.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: Lat: 37.84706 Long: -75.47054

△ Dissipation with estimated Ueq value ◬ Dissipation, equilibrium not achieved ○ Equilibrium Pore Pressure (Ueq)

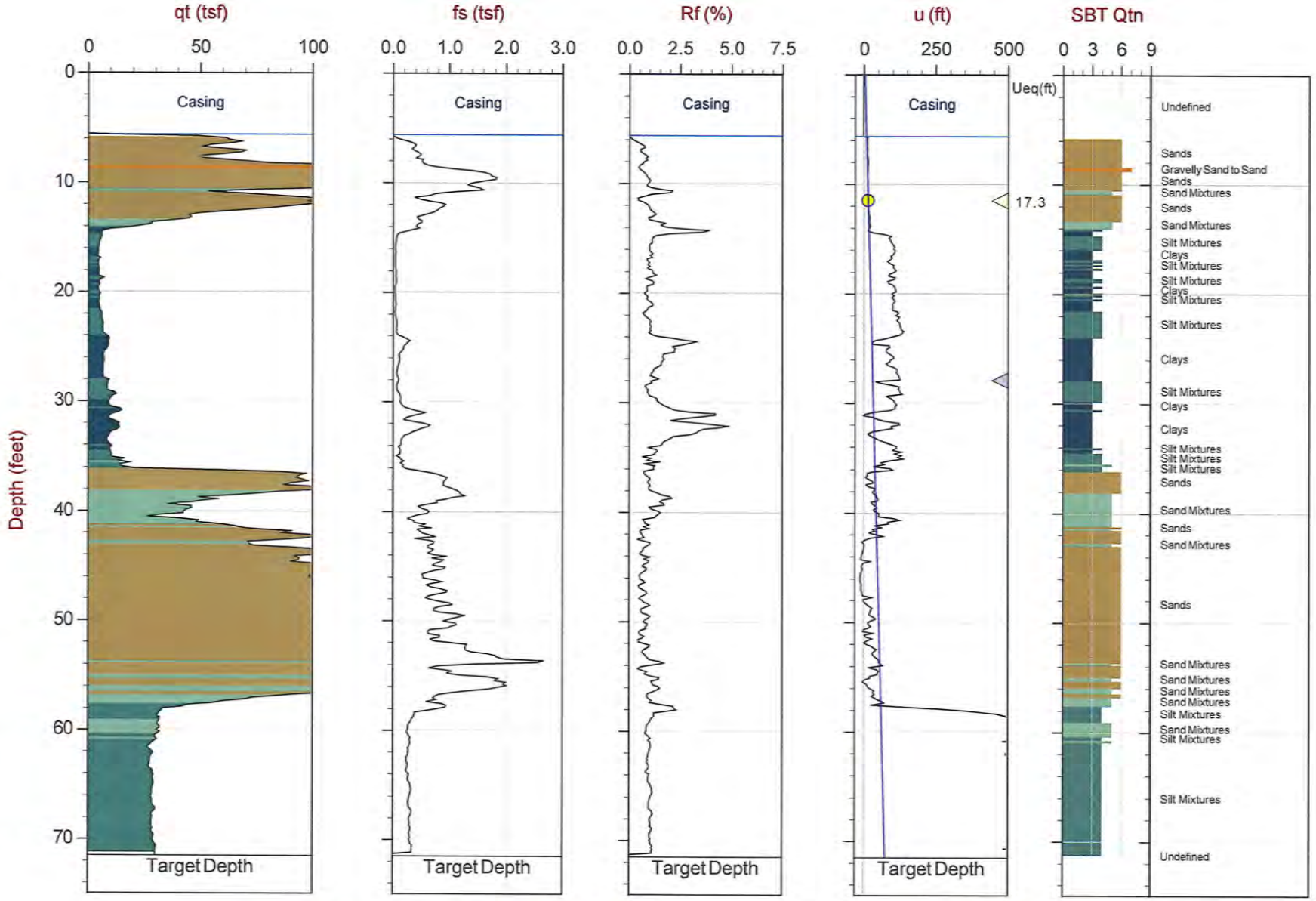
The reported coordinates were acquired from hand-held GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 2018-06-17 07:22
Site: Wallops Island Break Waters

Sounding: C-6
Cone: 367:T1500F15U500



Max Depth: 21.800 m / 71.52 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 18-54025_CPC-6.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: Lat: 37.85416 Long: -75.46255

△ Dissipation with estimated Ueq value △ Dissipation, equilibrium not achieved ○ Equilibrium Pore Pressure (Ueq)

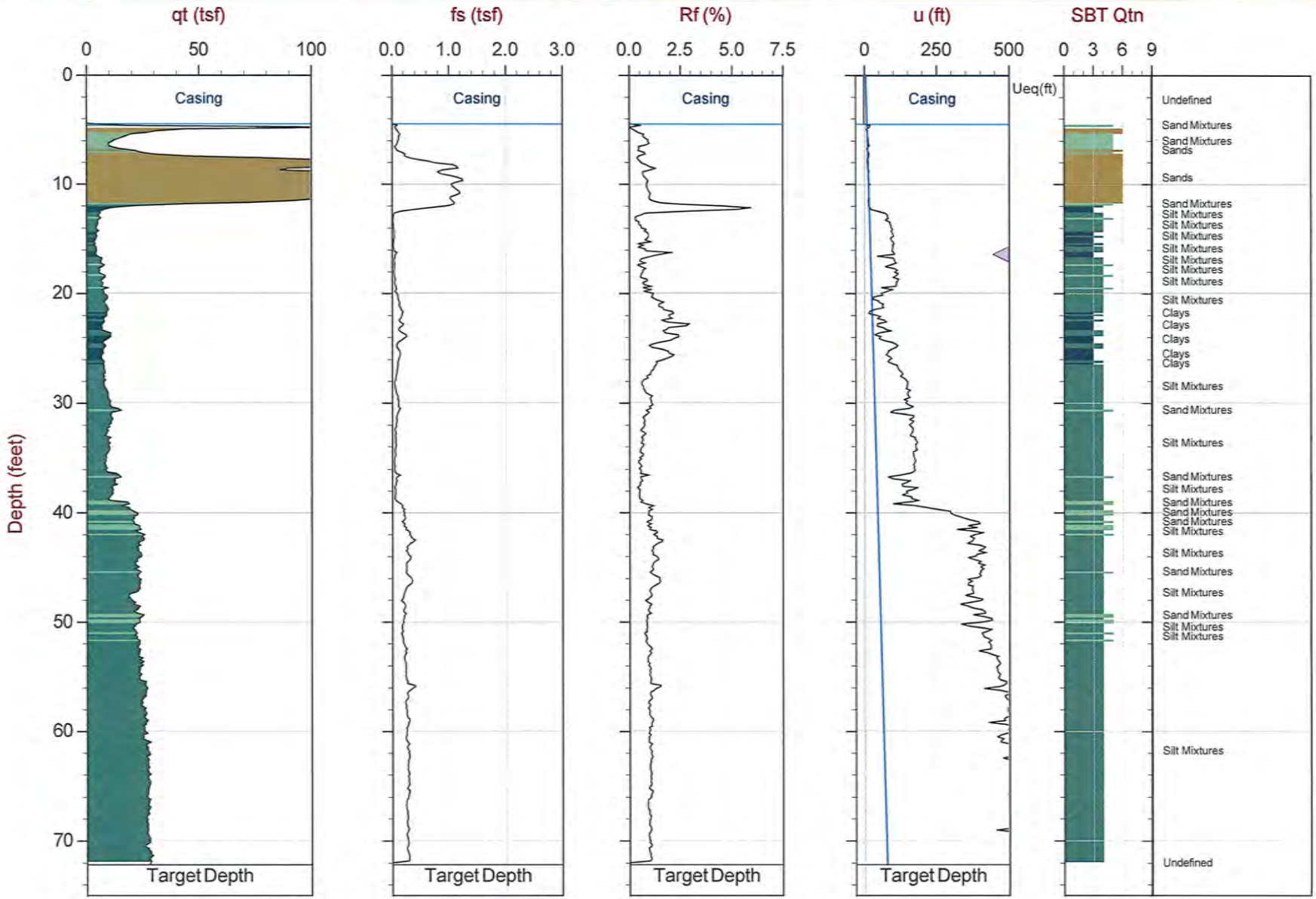
The reported coordinates were acquired from hand-held GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 2018-06-16 14:13
Site: Wallops Island Break Waters

Sounding: C-7
Cone: 367:T1500F15U500



Max Depth: 22.000 m / 72.18 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 18-54025_CP C-7.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: Lat: 37.85698 Long: -75.45753

△ Dissipation with estimated Ueq value △ Dissipation, equilibrium not achieved ○ Equilibrium Pore Pressure (Ueq)

The reported coordinates were acquired from hand-held GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Pore Pressure Dissipation Summary and

Pore Pressure Dissipation Plots

CONETEC

Job No:	18-54025
Client:	Schnabel Engineering
Project:	Wallops Island Break Waters
Start Date:	15-Jun-2018
End Date:	24-Jun-2018

CPTu PORE PRESSURE DISSIPATION SUMMARY

Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (ft)	Estimated Equilibrium Pore Pressure U_{eq}[1] (ft)	Calculated Phreatic Surface[1] (ft)
C-1	18-54025_CP C-1.PPF	15	1185	19.2		
C-1	18-54025_CP C-1.PPF	15	400	42.2		
C-1	18-54025_CP C-1.PPF	15	690	71.7	84.1	-12.4
C-2	18-54025_CP C-2.PPF	15	1265	25.6		
C-2	18-54025_CP C-2.PPF	15	435	55.4	71.2	-15.7
C-2	18-54025_CP C-2.PPF	15	185	71.5		
C-3	18-54025_CP C-3.PPF	15	1020	38.4		
C-3	18-54025_CP C-3.PPF	15	1590	58.1		
C-3	18-54025_CP C-3.PPF	15	340	71.2	88.4	-17.2
C-4	18-54025_CP C-4.PPF	15	335	61.0	74.2	-13.2
C-5	18-54025_CP C-5.PPF	15	2005	40.5	56.4	-15.9
C-6	18-54025_CP C-6.PPF	15	340	11.5	17.3	-5.8
C-6	18-54025_CP C-6.PPF	15	1205	27.9		
C-7	18-54025_CP C-7.PPF	15	1575	16.4		
Totals			3.5 hrs			

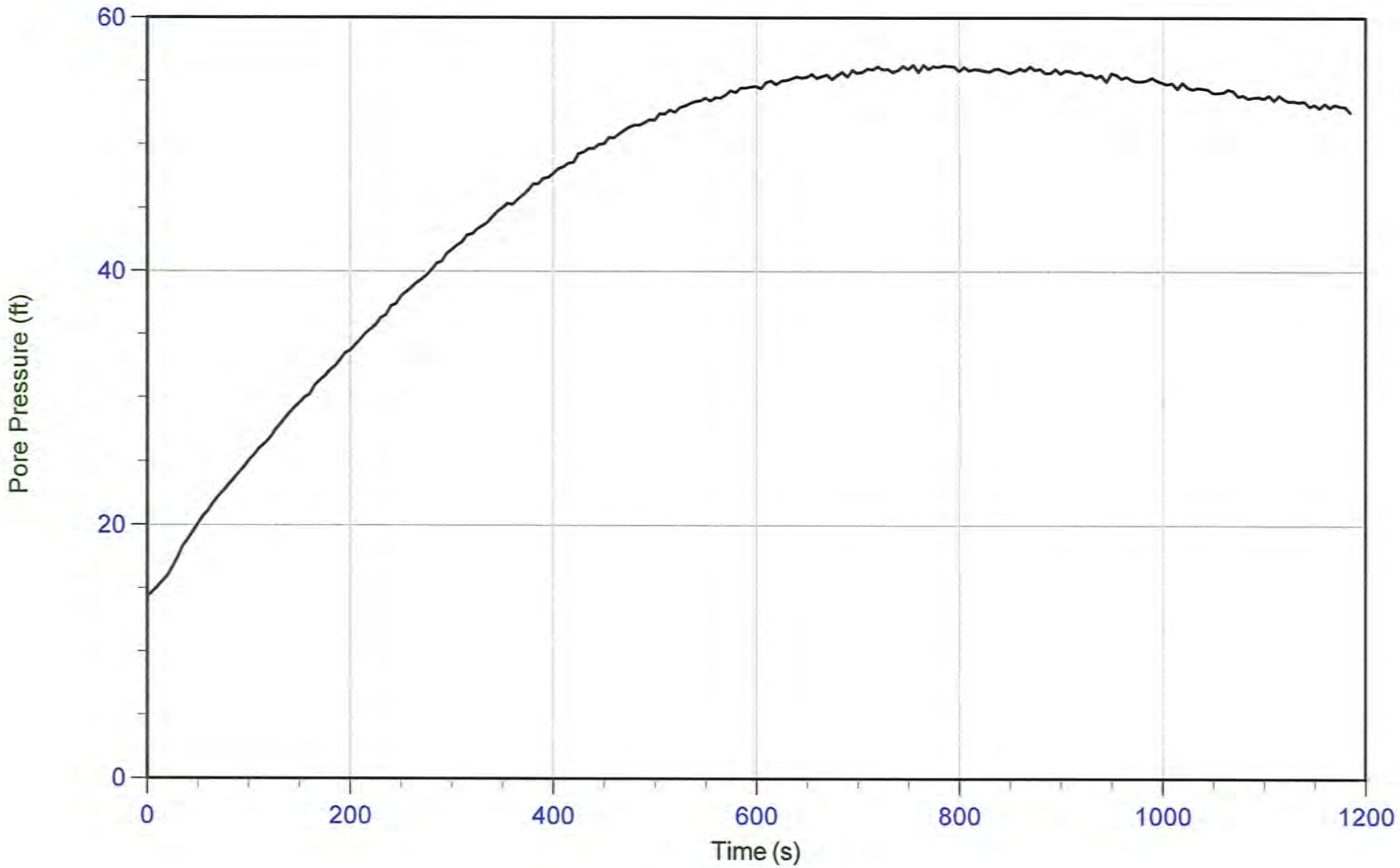
1. The unit is feet of freshwater (unit weight of 62.4 pcf).

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 15:11
Site: Wallops Island Break Waters

Sounding: C-1
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-1.PPF
Depth: 5.850 m / 19.193 ft
Duration: 1185.0 s

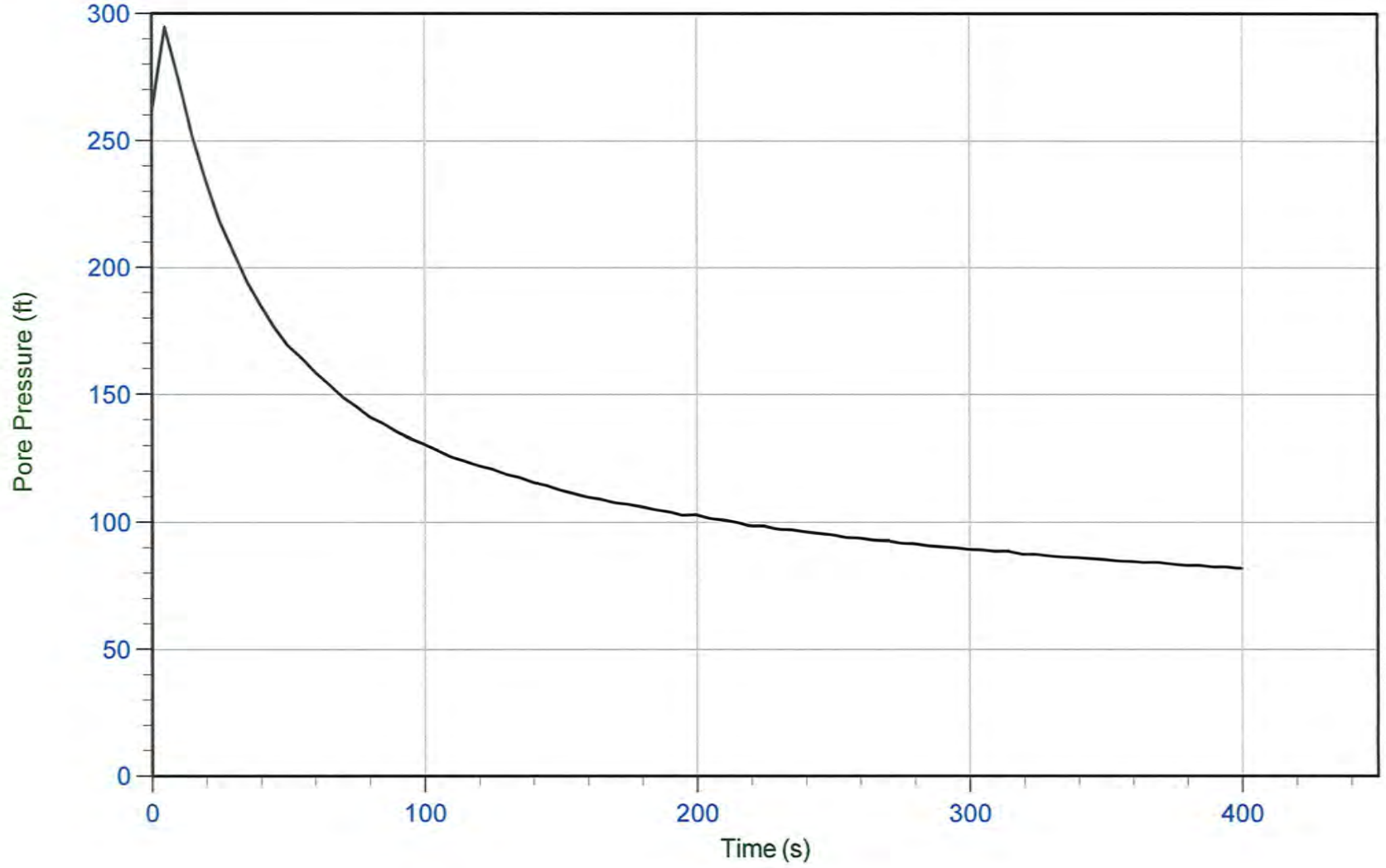
U Min: 14.4 ft
U Max: 56.3 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 15:11
Site: Wallops Island Break Waters

Sounding: C-1
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-1.PPF
Depth: 12.850 m / 42.158 ft
Duration: 400.0 s

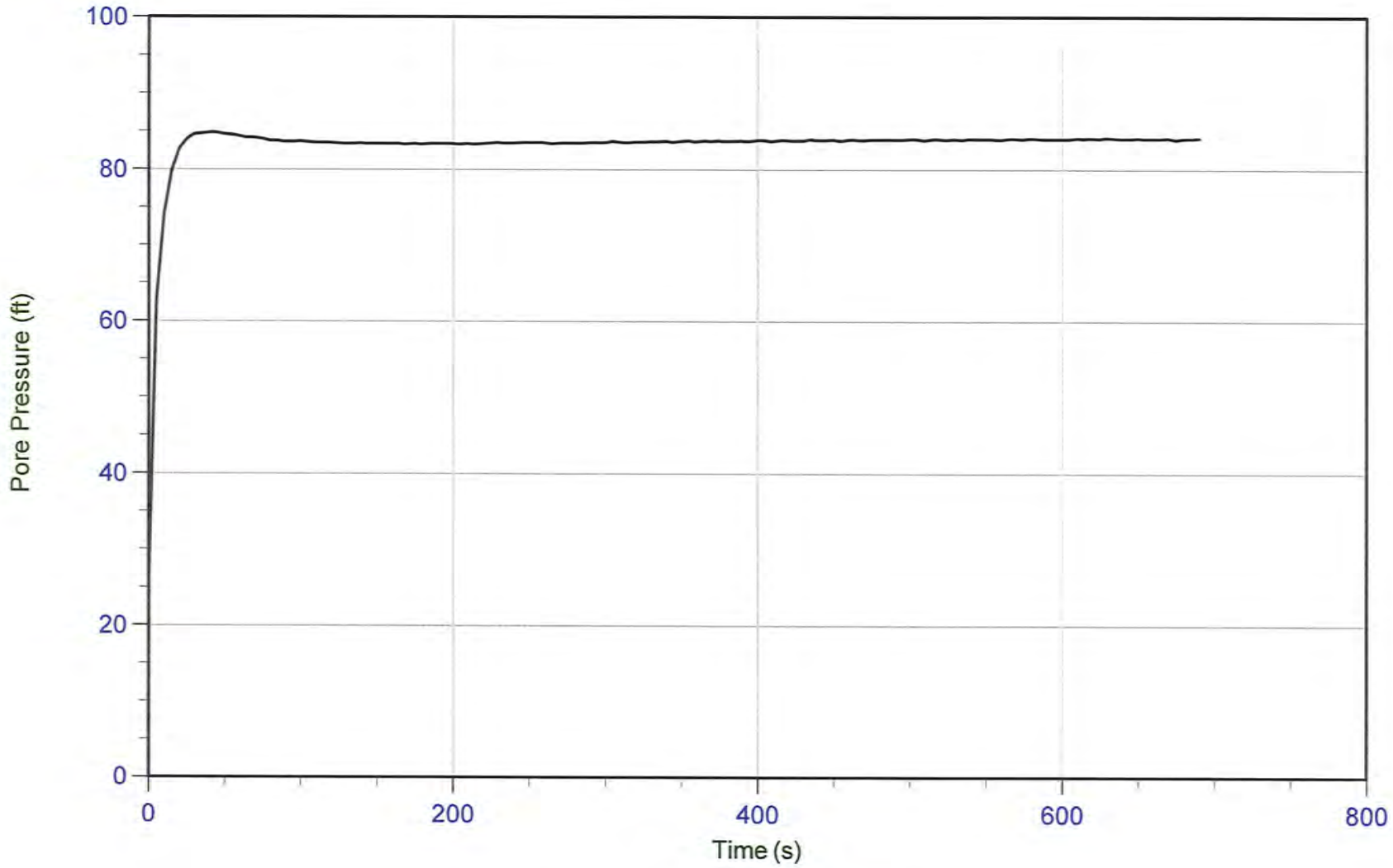
U Min: 82.0 ft
U Max: 294.6 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 15:11
Site: Wallops Island Break Waters

Sounding: C-1
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-1.PPF
Depth: 21.850 m / 71.685 ft
Duration: 690.0 s

U Min: 26.4 ft
U Max: 84.9 ft

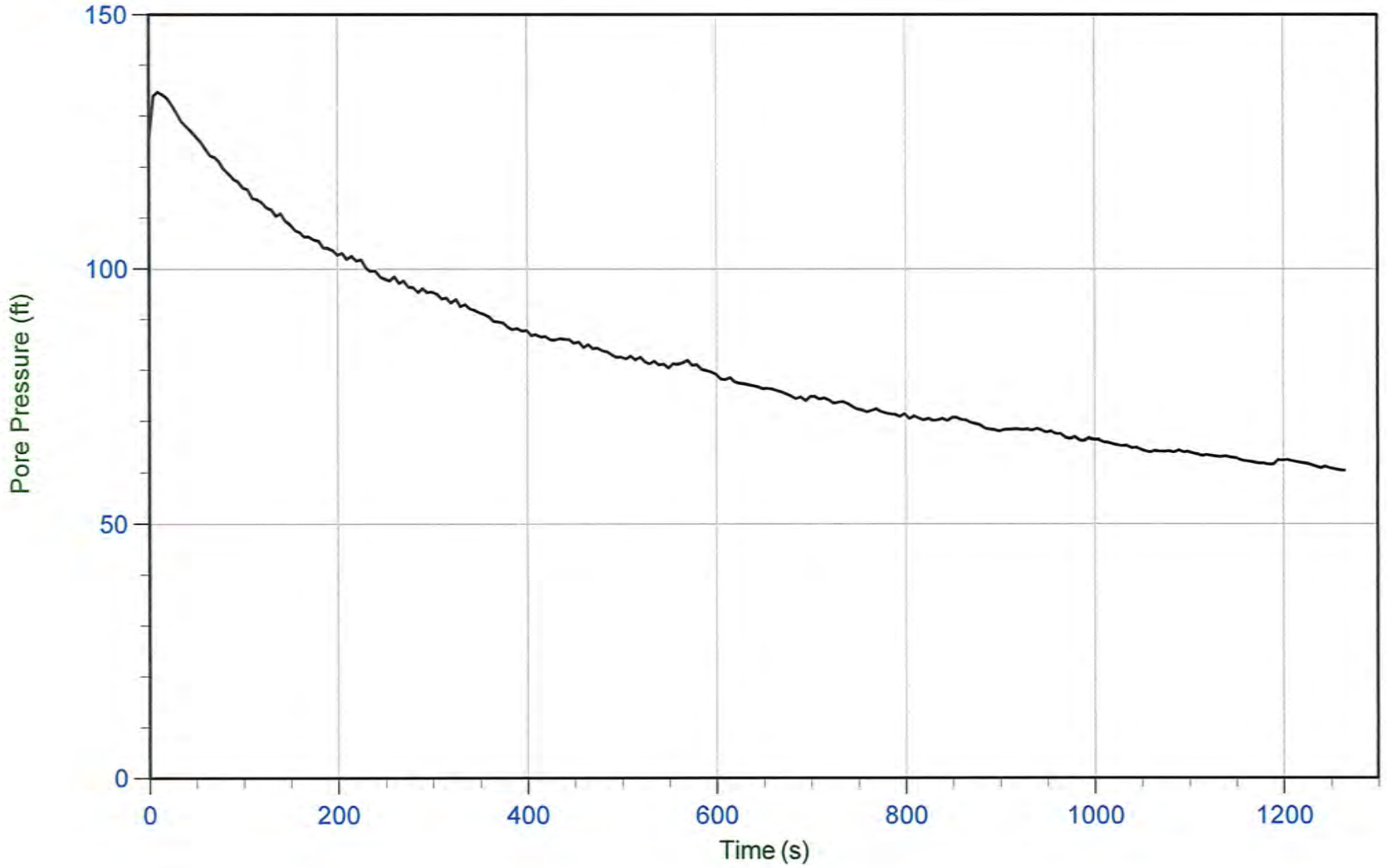
WT: -3.772 m / -12.375 ft
Ueq: 84.1 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 12:11
Site: Wallops Island Break Waters

Sounding: C-2
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-2.PPF
Depth: 7.800 m / 25.590 ft
Duration: 1265.0 s

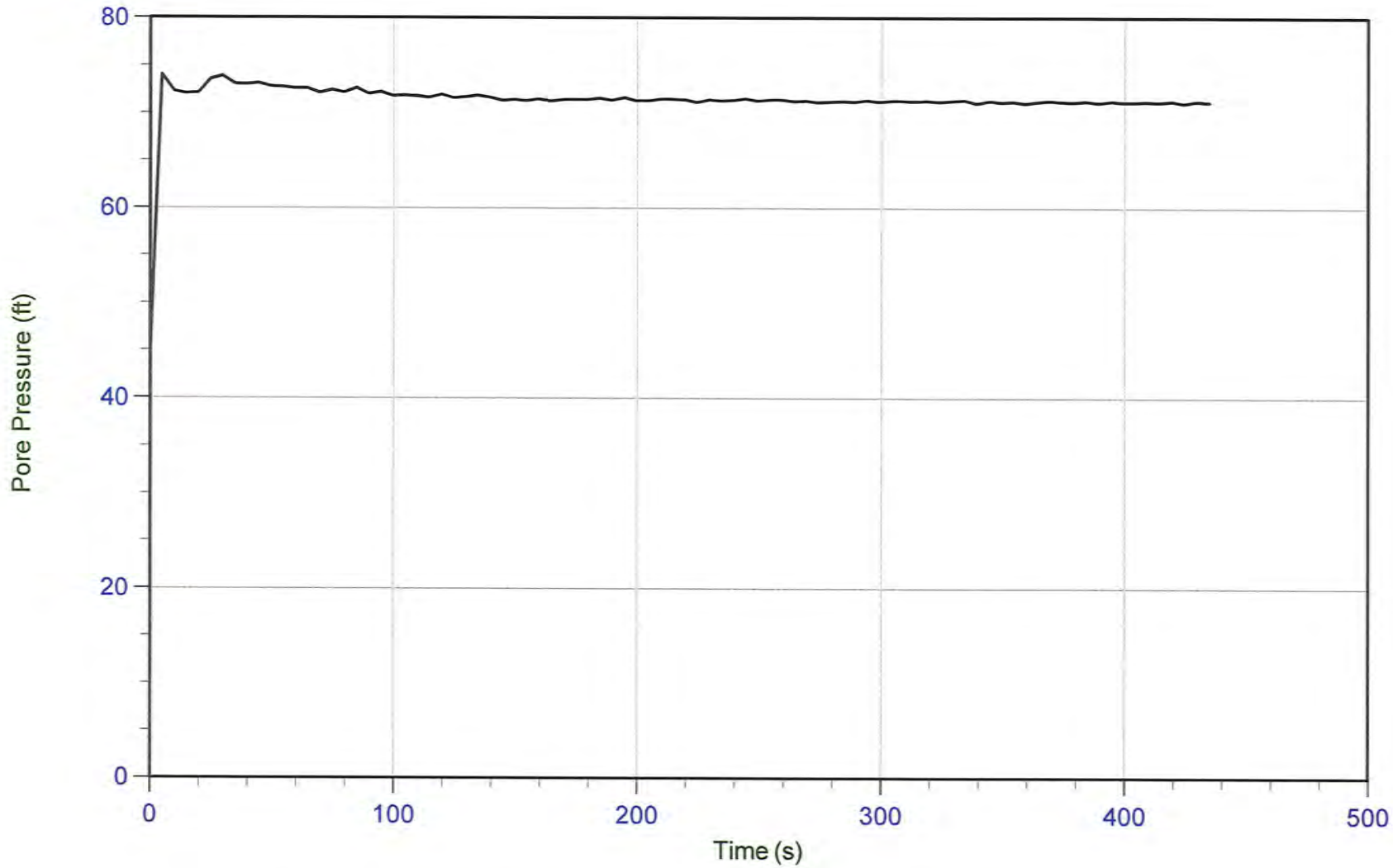
U Min: 60.5 ft
U Max: 134.7 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 12:11
Site: Wallops Island Break Waters

Sounding: C-2
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-2.PPF
Depth: 16.900 m / 55.446 ft
Duration: 435.0 s

U Min: 45.3 ft
U Max: 74.1 ft

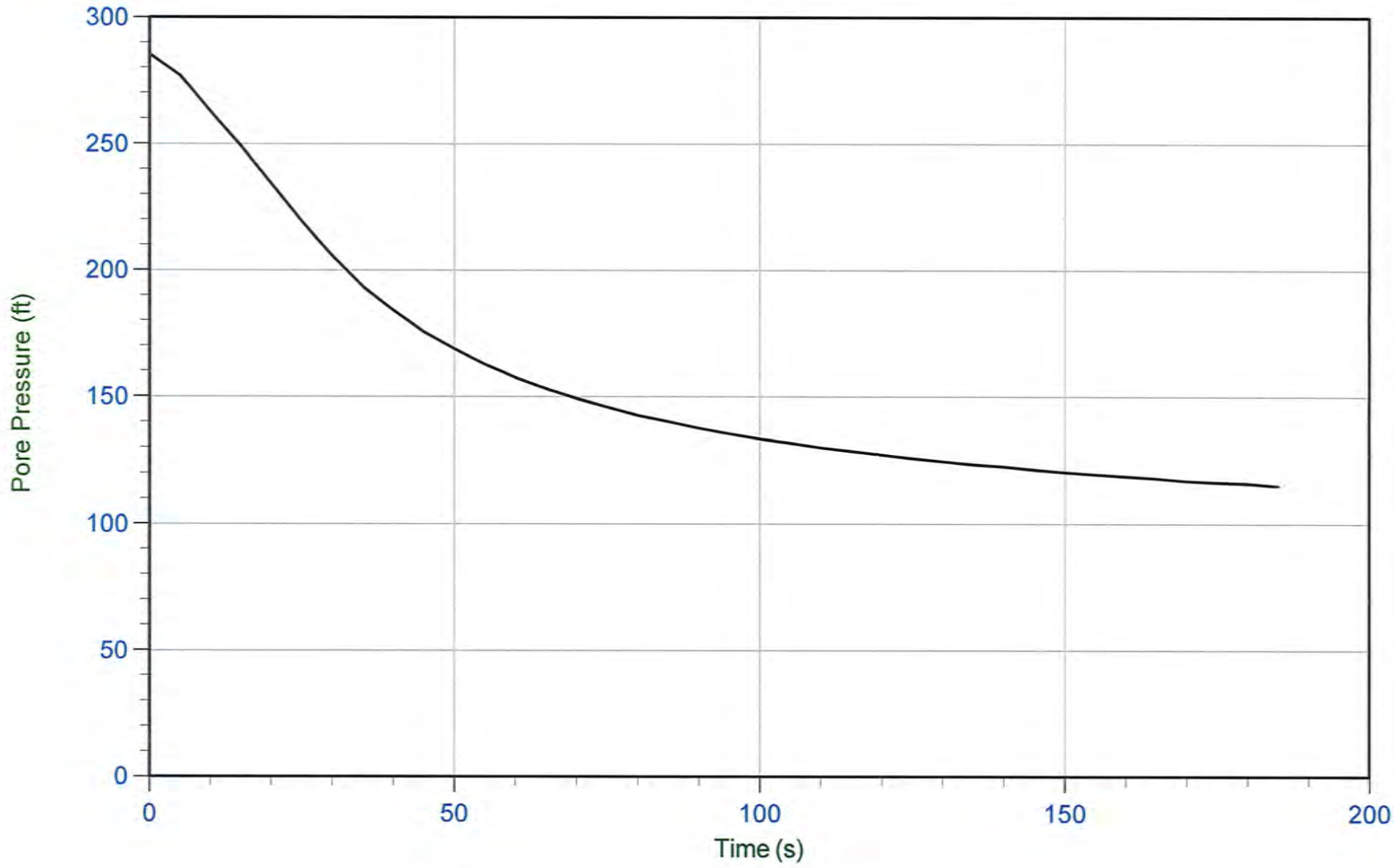
WT: -4.796 m / -15.735 ft
Ueq: 71.2 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 12:11
Site: Wallops Island Break Waters

Sounding: C-2
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-2.PPF
Depth: 21.800 m / 71.521 ft
Duration: 185.0 s

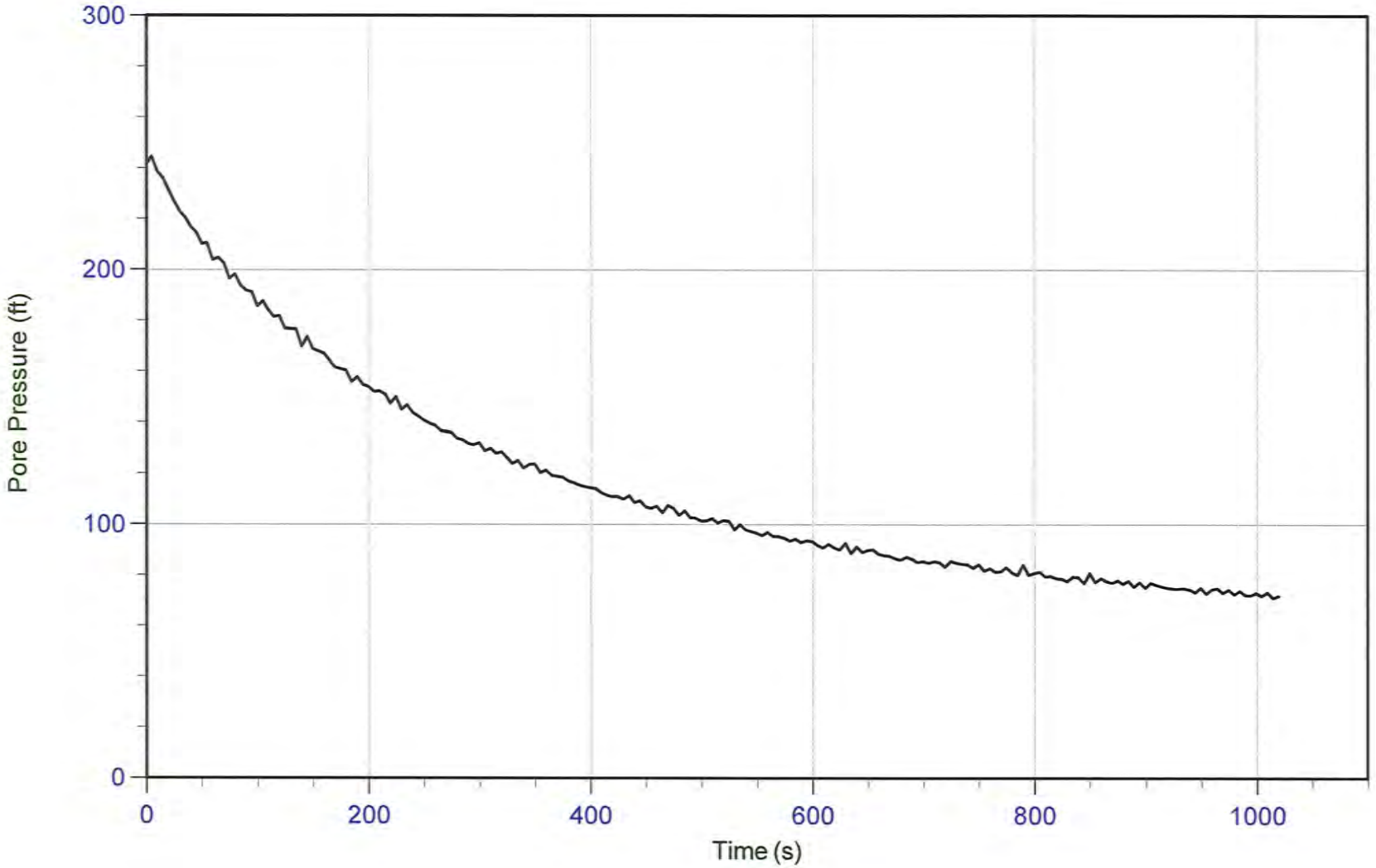
U Min: 115.1 ft
U Max: 285.5 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 09:10
Site: Wallops Island Break Waters

Sounding: C-3
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-3.PPF
Depth: 11.700 m / 38.385 ft
Duration: 1020.0 s

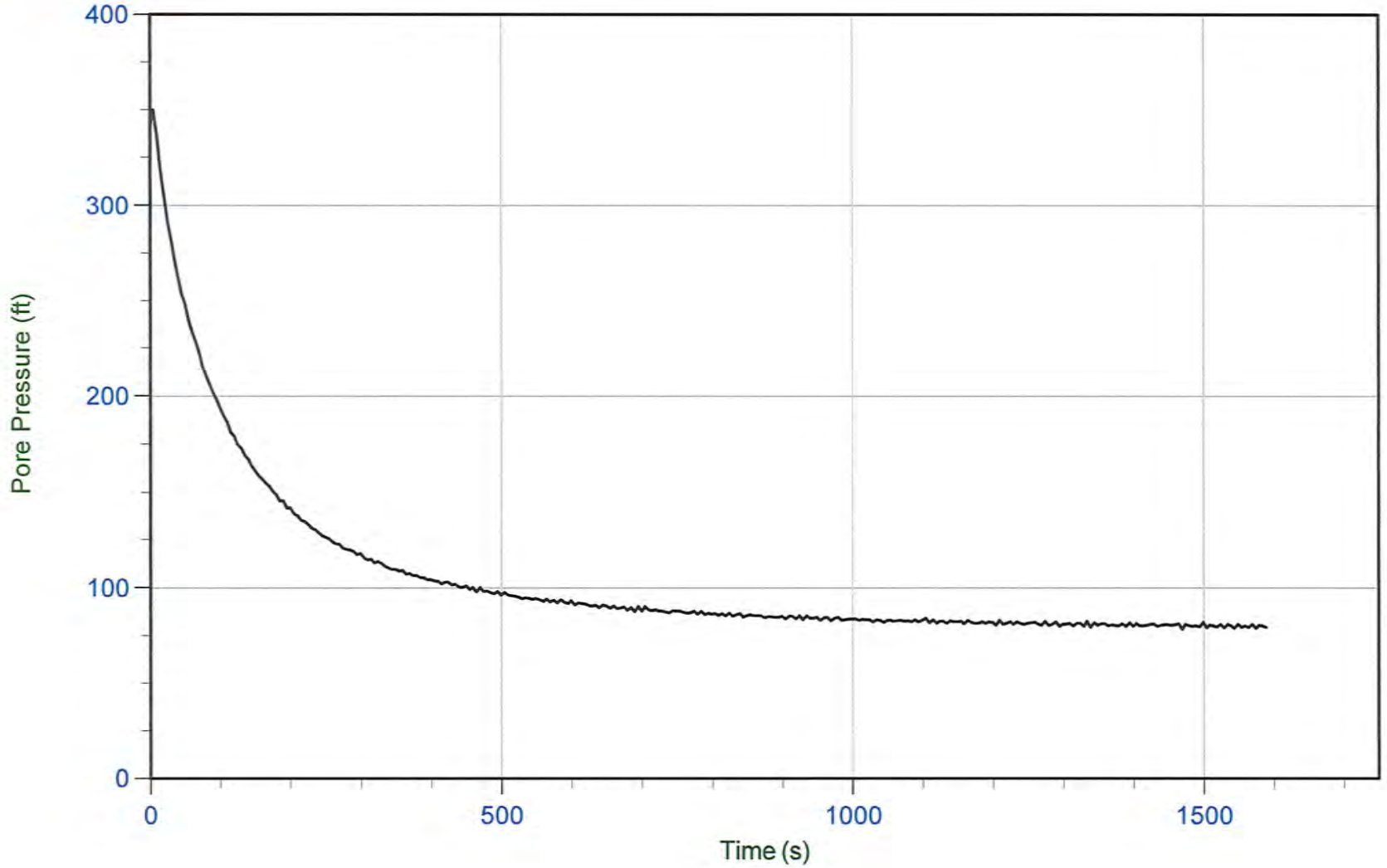
U Min: 71.1 ft
U Max: 244.7 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 09:10
Site: Wallops Island Break Waters

Sounding: C-3
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-3.PPF
Depth: 17.700 m / 58.070 ft
Duration: 1590.0 s

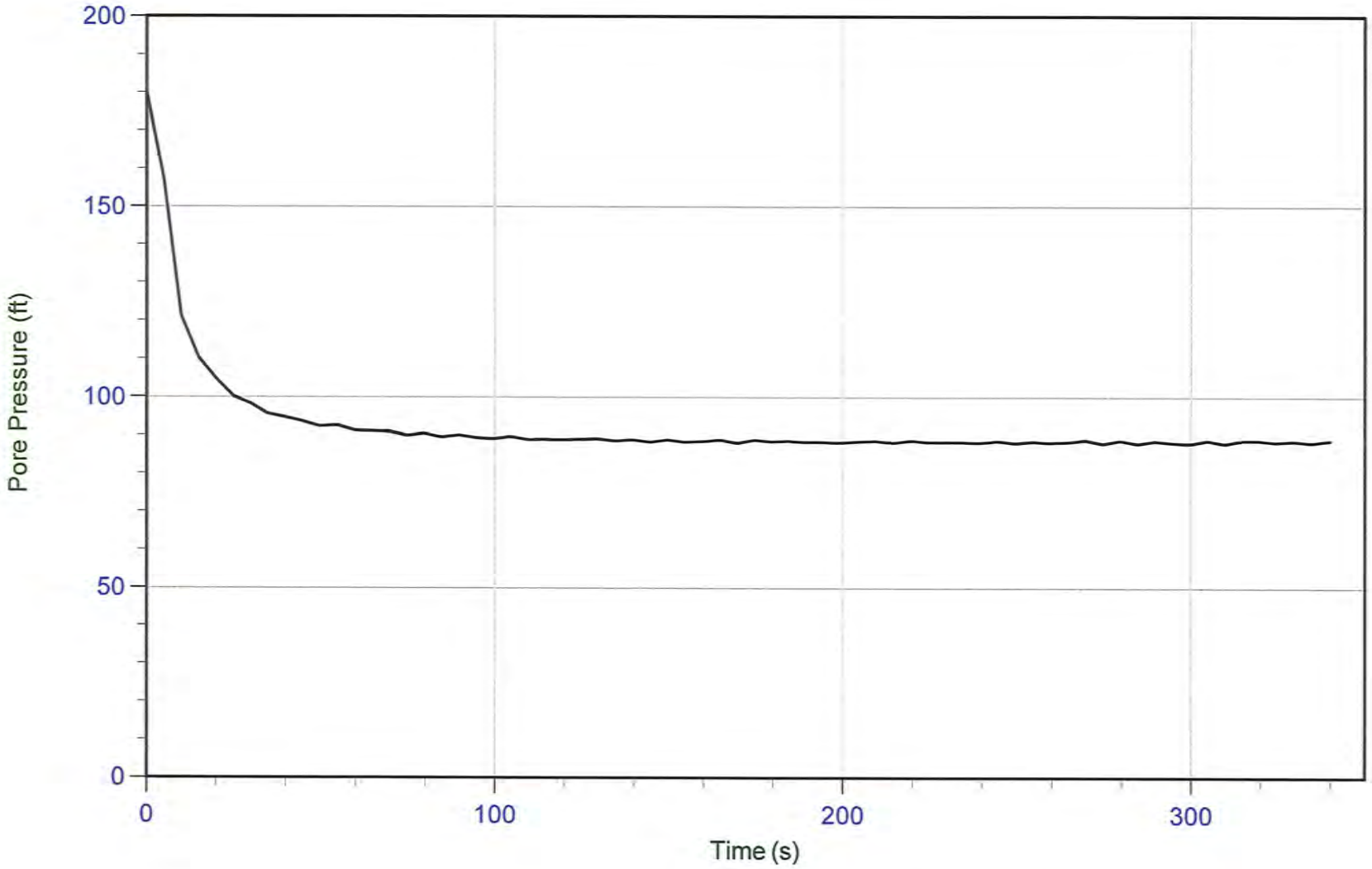
U Min: 78.3 ft
U Max: 350.1 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/18/2018 09:10
Site: Wallops Island Break Waters

Sounding: C-3
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-3.PPF
Depth: 21.700 m / 71.193 ft
Duration: 340.0 s

U Min: 87.9 ft
U Max: 180.2 ft

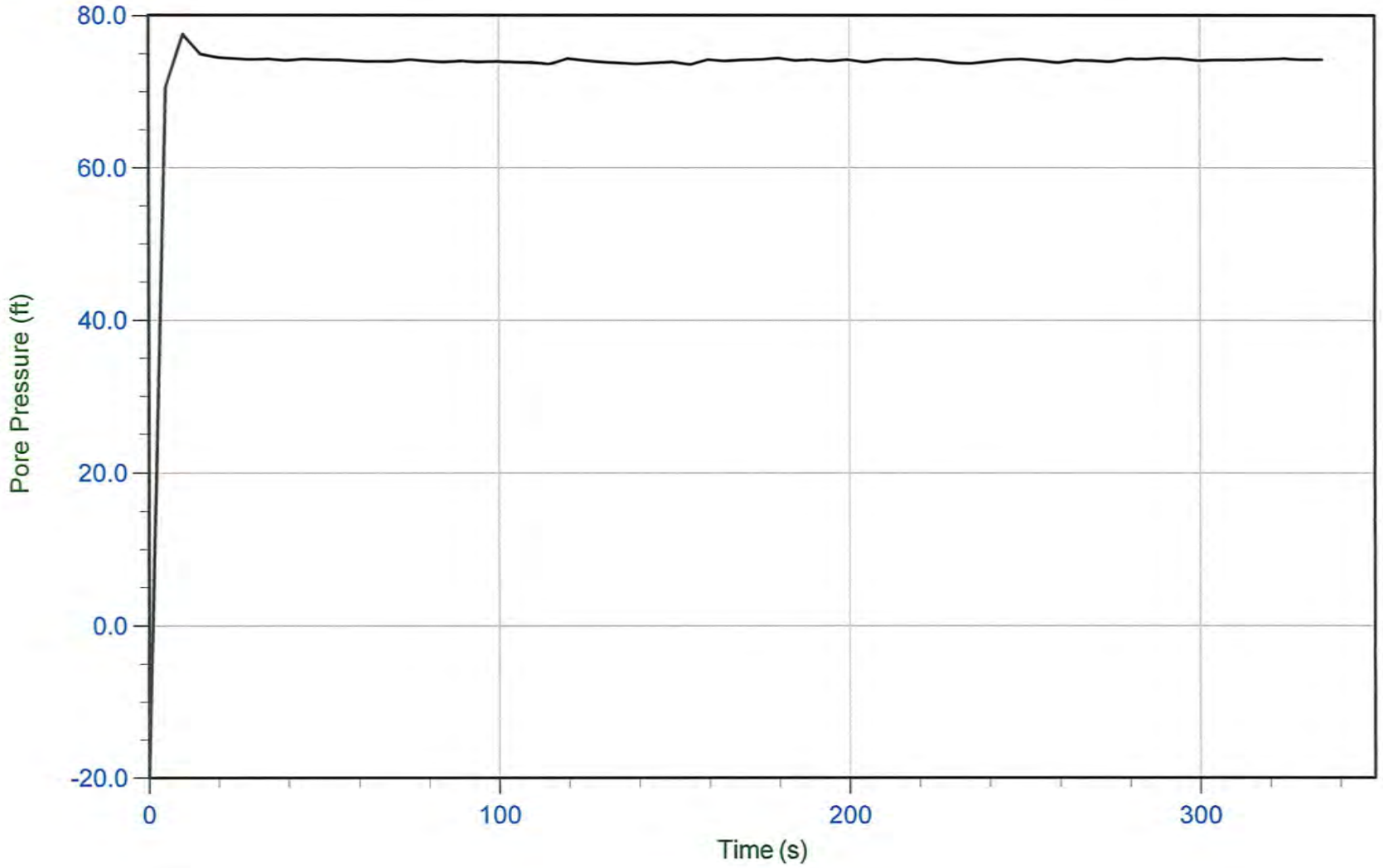
WT: -5.256 m / -17.244 ft
Ueq: 88.4 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/17/2018 13:29
Site: Wallops Island Break Waters

Sounding: C-4
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-4.PPF
Depth: 18.600 m / 61.023 ft
Duration: 335.0 s

U Min: -19.4 ft
U Max: 77.6 ft

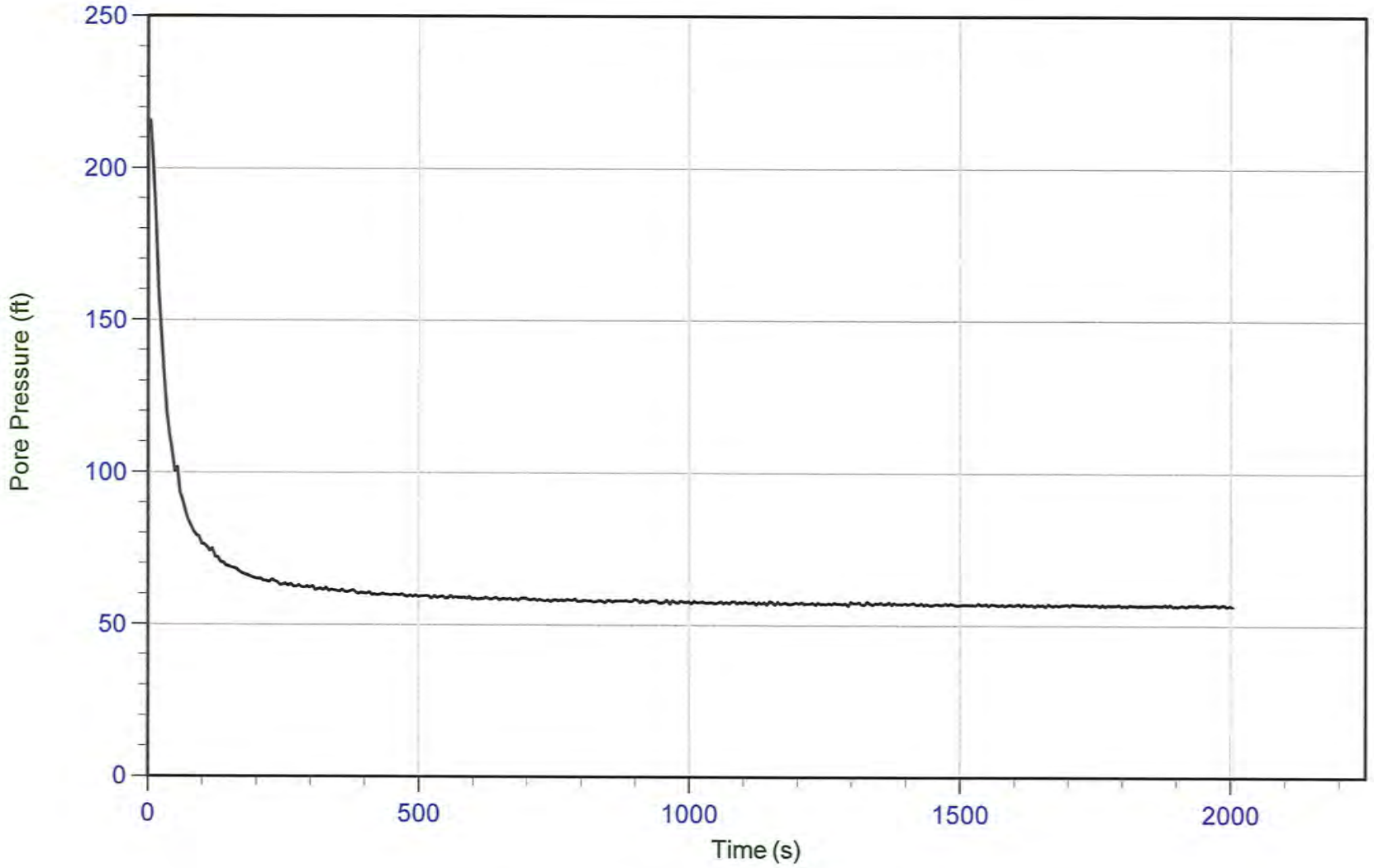
WT: -4.027 m / -13.212 ft
Ueq: 74.2 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/17/2018 10:24
Site: Wallops Island Break Waters

Sounding: C-5
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-5.PPF
Depth: 12.350 m / 40.518 ft
Duration: 2005.0 s

U Min: 56.2 ft
U Max: 215.8 ft

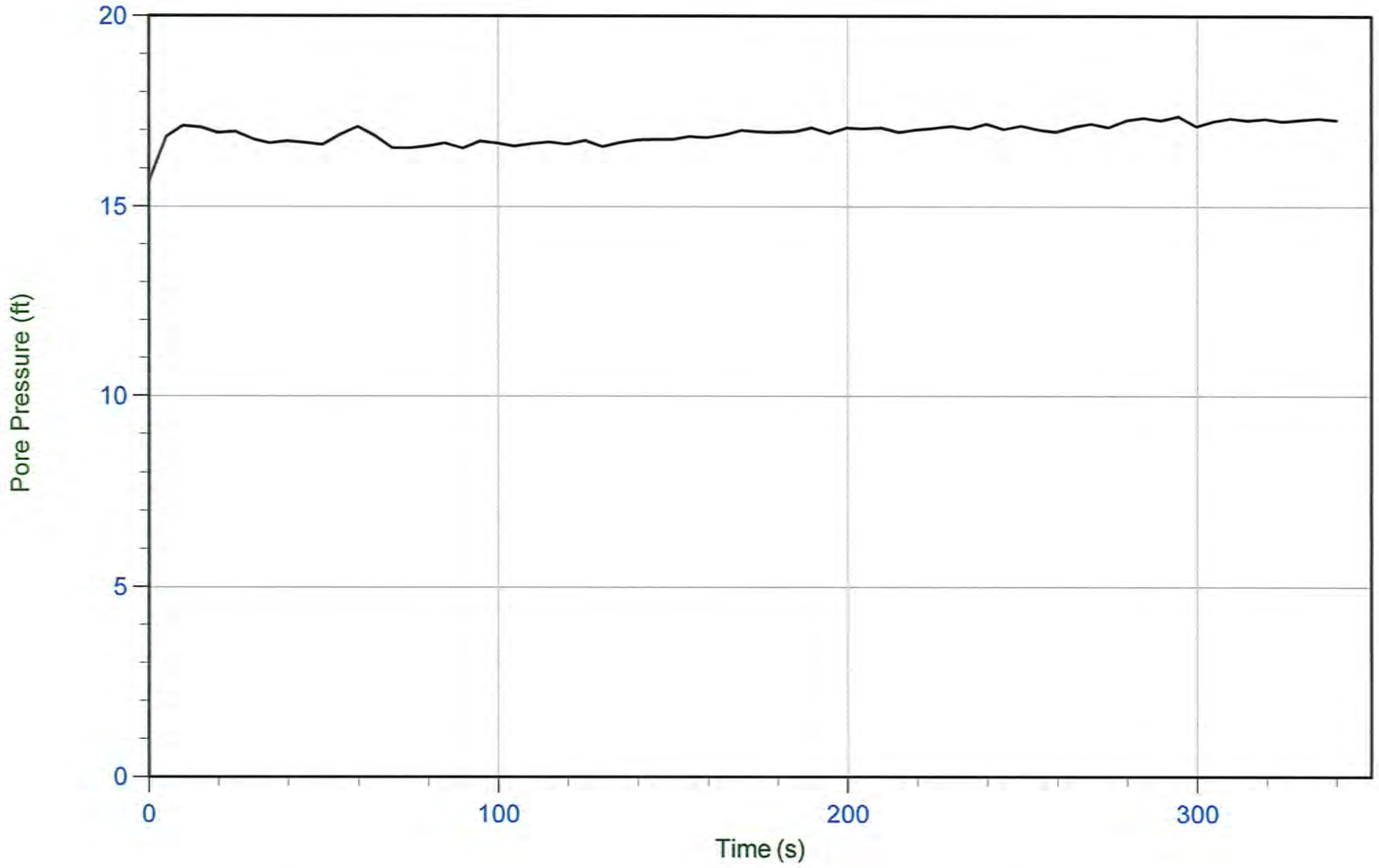
WT: -4.848 m / -15.905 ft
Ueq: 56.4 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/17/2018 07:22
Site: Wallops Island Break Waters

Sounding: C-6
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-6.PPF
Depth: 3.500 m / 11.483 ft
Duration: 340.0 s

U Min: 15.7 ft
U Max: 17.4 ft

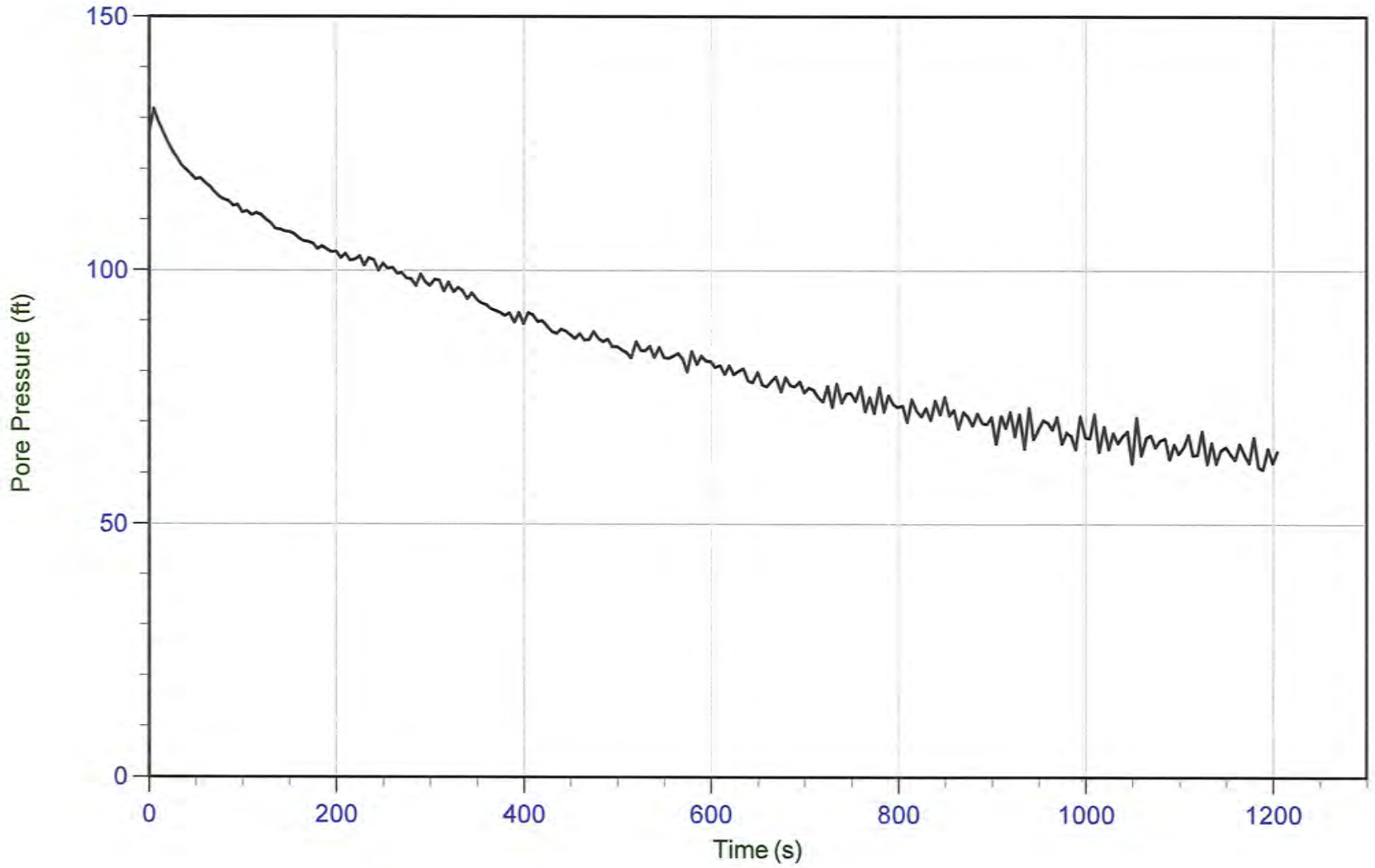
WT: -1.771 m / -5.810 ft
Ueq: 17.3 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/17/2018 07:22
Site: Wallops Island Break Waters

Sounding: C-6
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-6.PPF
Depth: 8.500 m / 27.887 ft
Duration: 1205.0 s

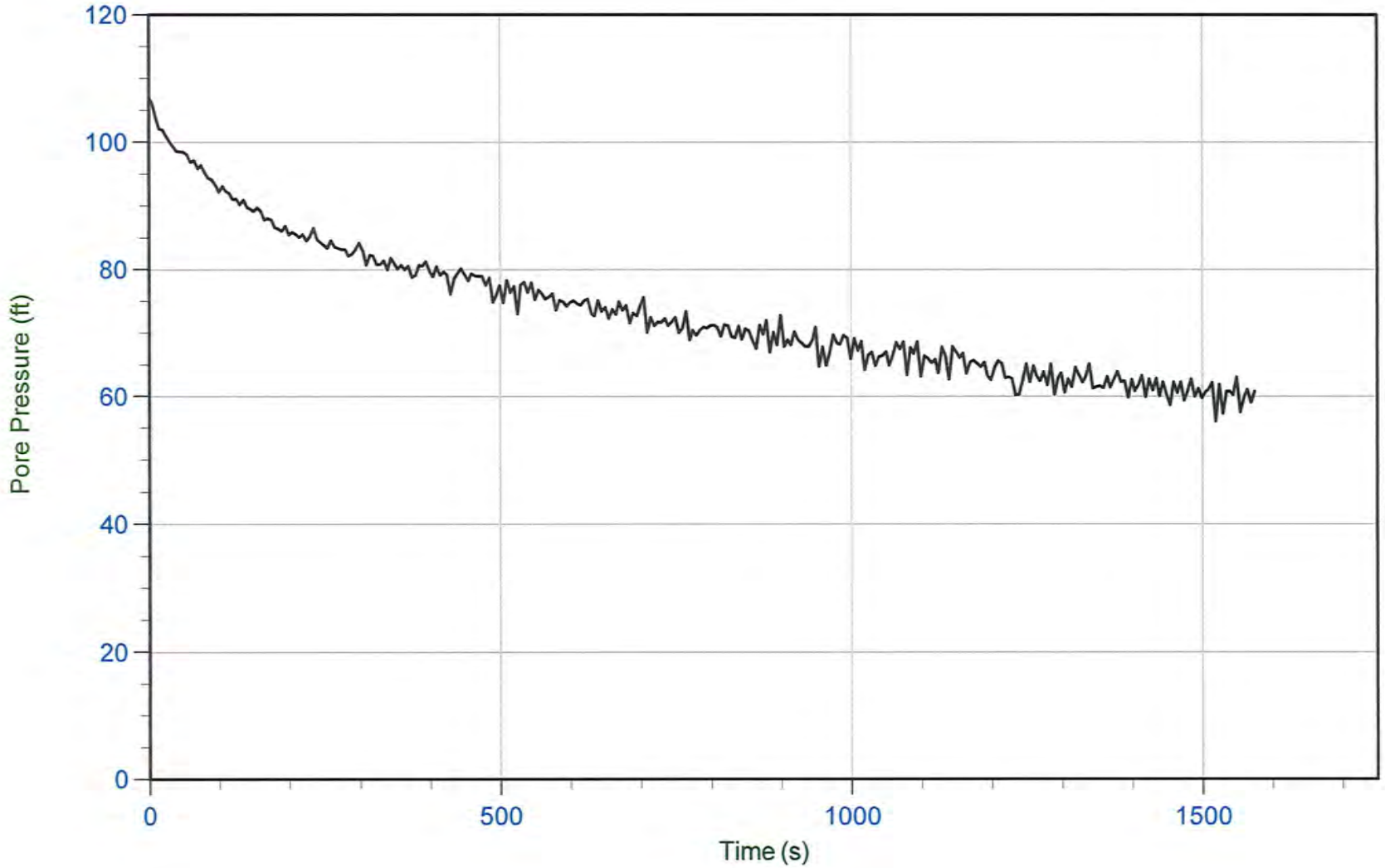
U Min: 60.7 ft
U Max: 131.9 ft

CONETEC

Schnabel Engineering

Job No: 18-54025
Date: 06/16/2018 14:13
Site: Wallops Island Break Waters

Sounding: C-7
Cone: 367:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 18-54025_CP C-7.PPF
Depth: 5.000 m / 16.404 ft
Duration: 1575.0 s

U Min: 56.0 ft
U Max: 107.0 ft

Flat Plate Dilatometer Test Summary, Plots, and Tabular Results

CONETEC

Job No:	18-54025
Client:	Schnabel Engineering
Project:	Wallops Island Break Waters
Start Date:	15-Jun-2018
End Date:	24-Jun-2018

FLAT PLATE DILATOMETER TEST SUMMARY

Sounding ID	File Name	Date	Depth From (ft)	Depth To (ft)	Assumed Phreatic Surface[2] (ft)	Latitude[1] (degrees)	Longitude[1] (degrees)	Refer to Notation Number
D-1	18-54025_DMT D-1	19-Jun-2018	5.0	29.0	-13.0	37.83020	-75.48845	3
D-1A	18-54025_DMT D-1A	20-Jun-2018	8.0	58.0	-10.5	37.83019	-75.48843	
D-2	18-54025_DMT D-2	19-Jun-2018	5.0	68.0	-11.0	37.83463	-75.48399	
D-3	18-54025_DMT D-3	20-Jun-2018	4.0	57.0	-13.0	37.83991	-75.47855	
D-4	18-54025_DMT D-4	21-Jun-2018	4.0	70.0	-11.0	37.84501	-75.47295	
D-5	18-54025_DMT D-5	21-Jun-2018	5.0	68.0	-7.0	37.84927	-75.46851	
D-6	18-54025_DMT D-6	24-Jun-2018	2.0	70.0	-7.5	37.85218	-75.46472	
D-7	18-54025_DMT D-7	24-Jun-2018	3.0	70.0	-5.0	37.85585	-75.45987	
D-8	18-54025_DMT D-8	15-Jun-2018	6.0	62.0	-9.0	37.85948	-75.45278	4, 5

1. WGS 84 Lat/Long. Coordinates were taken with a handheld GPS and should be considered approximate.

2. The assumed phreatic surface was based on the initial water depth reading taken during test setup.

3. The membrane was potentially overinflated at a depth of 30 ft. B readings were unobtainable beyond this depth.

4. The membrane (membrane 1) was potentially overinflated at a depth of 23 ft, which may have a slight effect on data between 23 and 30 ft due to the change in ΔA and ΔB values.

5. The membrane (membrane 2) was potentially overinflated at a depth of 30 ft, which may have a slight effect on data between 30 and 62 ft due to the change in ΔA and ΔB values.

CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83020
Client:	Schnabel Engineering	Longitude:	-75.48845
Sounding ID:	D-1	Elevation (ft):	
Date:	19-Jun-2018	Ground Water Depth (ft):	-13.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

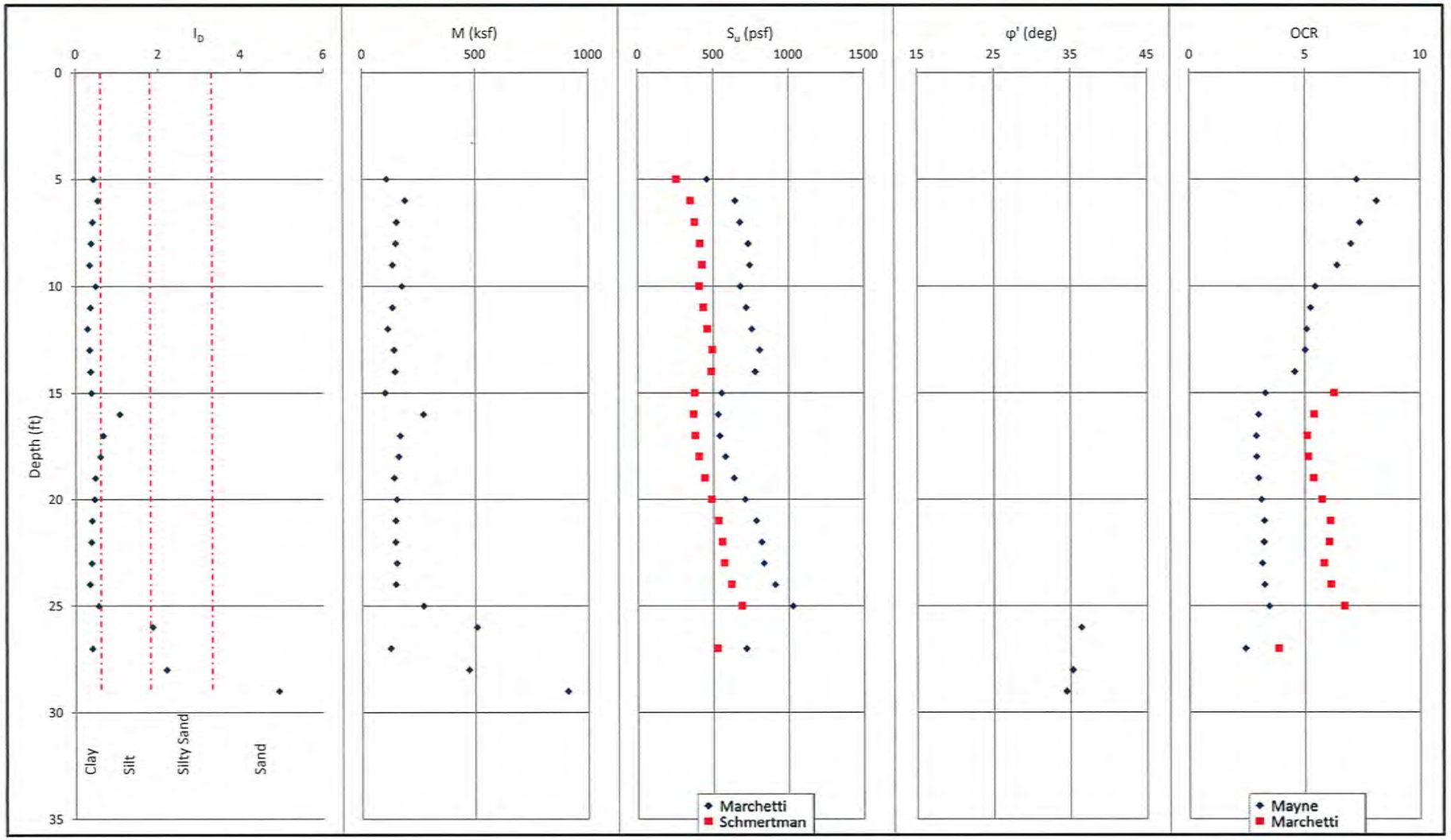
FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	OCR[4]	ϕ[5] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
5.00	1.70	2.85		0.15	0.50	1.78	2.30		1153.80	99.98	1333.20	179.41	0.43	14.25	38.05	2.28	7.24	21.36		2.83	458.74	255.34	107.83
6.00	2.20	3.70		0.15	0.50	2.26	3.15		1217.90	104.29	1437.50	219.60	0.53	15.92	64.68	2.44	8.11	25.44		2.94	646.16	349.70	190.19
7.00	2.35	3.70		0.15	0.50	2.42	3.15		1282.00	103.66	1541.18	259.17	0.41	14.51	53.27	2.31	7.39	22.02		2.85	679.18	376.18	151.96
8.00	2.55	3.90		0.15	0.50	2.62	3.35		1346.11	104.13	1645.31	299.21	0.37	13.75	53.27	2.23	7.00	20.25		2.80	733.10	411.54	149.24
9.00	2.65	3.95	1.90	0.15	0.50	2.72	3.40	2.00	1410.21	103.93	1749.25	339.04	0.33	12.58	49.46	2.12	6.40	17.62		2.72	743.06	426.54	134.41
10.00	2.60	4.15		0.15	0.50	2.66	3.60		1474.32	105.39	1854.65	380.33	0.48	10.70	68.49	1.92	5.45	13.69		2.56	681.07	407.08	175.62
11.00	2.75	4.10		0.15	0.50	2.82	3.55		1538.42	104.41	1959.07	420.64	0.35	10.32	53.27	1.88	5.25	12.93		2.53	719.65	434.08	134.75
12.00	2.90	4.15		0.15	0.50	2.97	3.60		1602.53	103.91	2062.98	460.46	0.29	9.99	45.66	1.84	5.09	12.30		2.50	756.55	460.04	114.10
13.00	3.10	4.50		0.15	0.50	3.16	3.85		1666.63	105.45	2168.44	501.81	0.33	9.84	57.07	1.82	5.01	12.01		2.48	809.06	493.84	141.74
14.00	3.10	4.55	3.50	0.15	0.50	3.16	4.00	3.60	1730.74	105.71	2274.16	543.42	0.36	8.96	60.88	1.72	4.56	10.38		2.39	779.21	486.91	145.34
15.00	2.60	3.90		0.15	0.50	2.67	3.35		1794.84	103.30	2377.47	582.63	0.38	6.48	49.46	1.39	3.30	6.26		2.06	557.35	377.64	101.67
16.00	2.65	5.10		0.15	0.50	2.66	4.55		1858.94	108.58	2486.06	627.11	1.07	5.89	136.97	1.30	3.00	5.40		1.97	532.78	369.66	270.44
17.00	2.70	4.50		0.15	0.50	2.74	3.95		1923.05	106.33	2592.39	669.35	0.66	5.68	87.51	1.27	2.89	5.10		1.92	543.42	380.48	168.31
18.00	2.85	4.60		0.15	0.50	2.90	4.05		1987.15	106.44	2698.84	711.69	0.59	5.70	83.71	1.27	2.90	5.13		1.92	580.24	405.92	161.09
19.00	3.05	4.65		0.15	0.50	3.10	4.10		2051.26	106.12	2804.97	753.71	0.47	5.88	72.29	1.30	2.99	5.37		1.95	637.75	442.84	141.33
20.00	3.30	4.95		0.15	0.50	3.35	4.40		2115.36	106.91	2911.89	796.53	0.45	6.13	76.10	1.34	3.12	5.74		2.00	710.40	488.13	152.05
21.00	3.55	5.15		0.15	0.50	3.60	4.60		2179.47	107.12	3019.02	839.55	0.39	6.37	72.29	1.37	3.24	6.09		2.04	785.25	534.45	147.27
22.00	3.70	5.30	2.75	0.15	0.50	3.75	4.75	2.85	2243.57	107.37	3126.39	882.82	0.37	6.34	72.29	1.37	3.23	6.04		2.03	820.90	559.37	146.92
23.00	3.80	5.45		0.15	0.50	3.85	4.90		2307.67	107.78	3234.18	926.50	0.38	6.19	76.10	1.35	3.15	5.82		2.01	836.41	573.32	152.81
24.00	4.05	5.65		0.15	0.50	4.10	5.10		2371.78	107.92	3342.11	970.33	0.34	6.39	72.29	1.38	3.25	6.12		2.04	911.14	619.65	147.50
25.00	4.45	6.80		0.15	0.50	4.47	6.25		2435.88	111.69	3453.81	1017.92	0.54	6.77	129.36	1.43	3.44	6.70		2.10	1027.87	688.95	271.65
26.00	3.50	8.05		0.15	0.50	3.41	7.50		2499.99	114.12	3567.93	1067.95	1.85	4.32	296.77				36.43	1.71			306.87
27.00	3.70	5.30		0.15	0.50	3.75	4.75		2564.09	107.05	3674.99	1110.90	0.40	4.75	72.29	1.12	2.42	3.85		1.74	719.95	527.32	125.52
28.00	3.30	8.00		0.15	0.50	3.20	7.45		2628.20	113.59	3788.59	1160.40	2.19	3.49	308.19				35.31	1.53			471.63
29.00	3.35	12.20		0.15	0.50	3.04	11.65		2692.30	117.07	3905.67	1213.37	4.92	3.01	623.99				34.51	1.46			909.92

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83020
Client:	Schnabel Engineering	Longitude:	-75.48845
Sounding ID:	D-1	Elevation (ft):	
Date:	19-Jun-2018	Ground Water Depth (ft):	-13.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

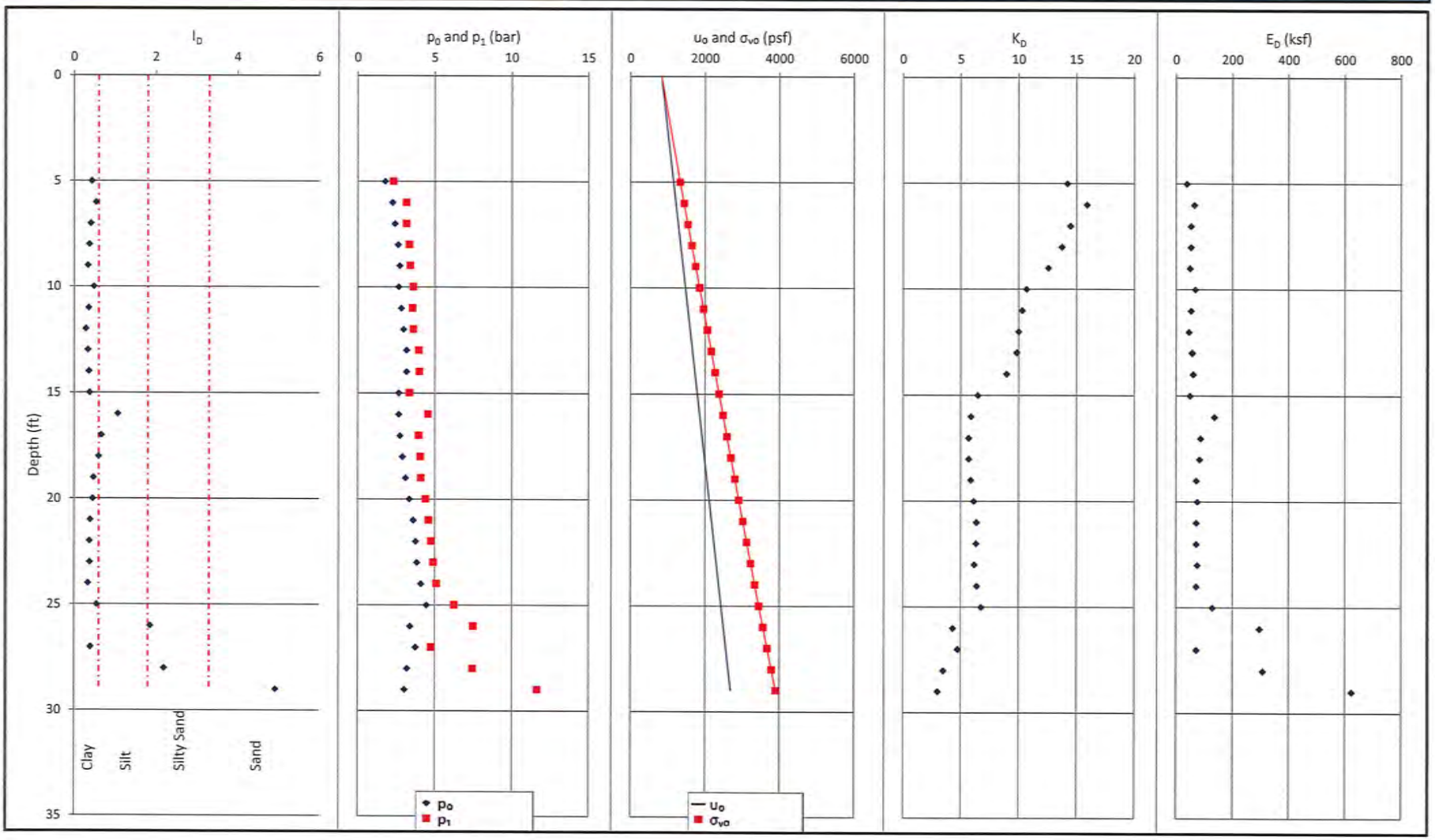


CONETEC

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-1
Date:	19-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.83020
Longitude:	-75.48845
Elevation (ft):	
Ground Water Depth (ft):	-13.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83019
Client:	Schnabel Engineering	Longitude:	-75.48843
Sounding ID:	D-1A	Elevation (ft):	
Date:	20-Jun-2018	Ground Water Depth (ft):	-10.5
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

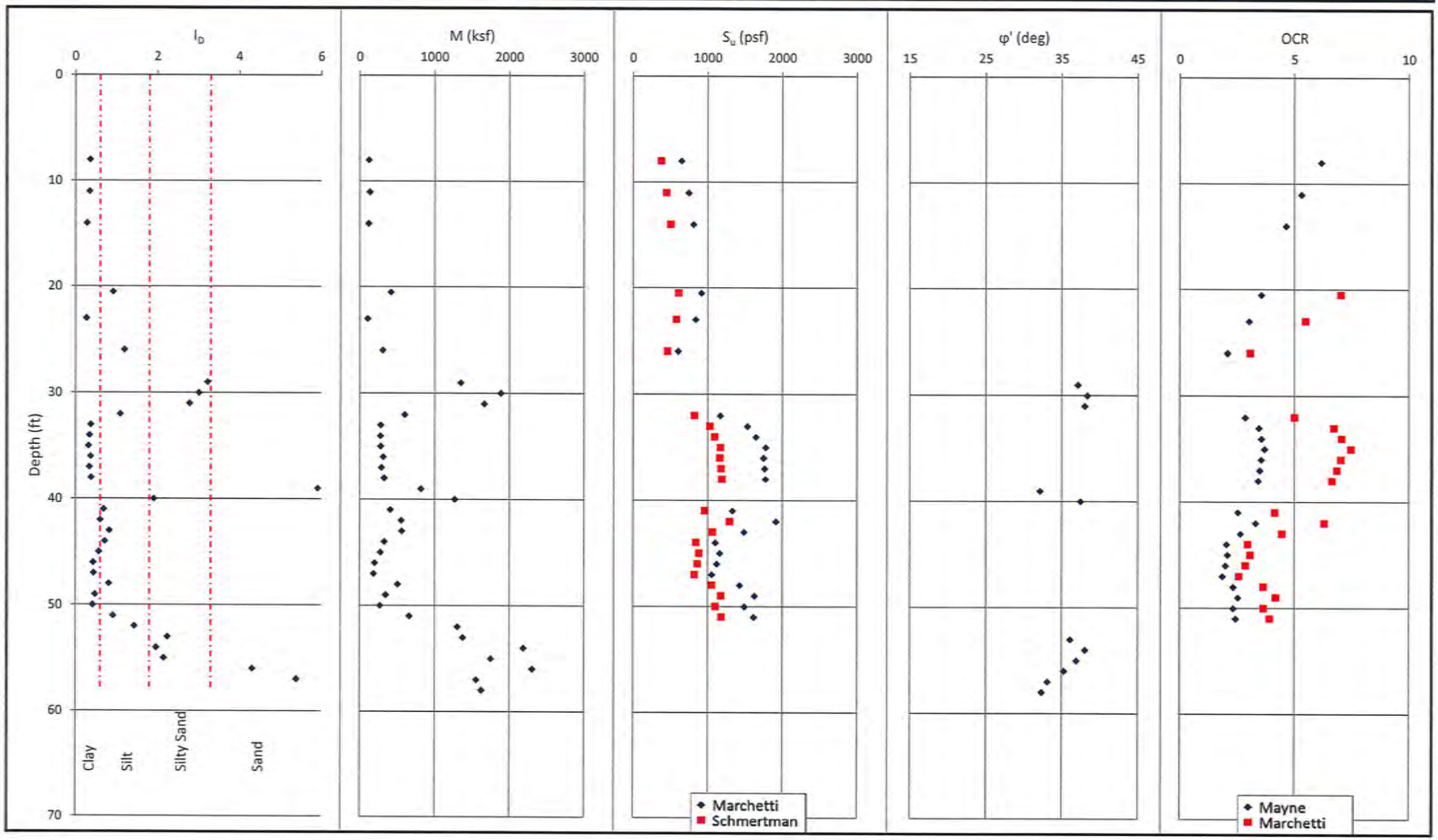
Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	OCR[4]	φ[3,4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
8.00	2.30	3.65	1.70	0.15	0.60	2.37	3.00	1.80	1185.85	102.87	1496.04	310.19	0.35	12.13	45.66	2.07	6.18	16.65		2.68	649.81	376.40	122.51
11.00	2.75	4.20		0.15	0.60	2.82	3.55		1378.16	104.60	1809.86	431.70	0.34	10.43	53.27	1.89	5.31	13.14		2.54	748.15	450.11	135.27
14.00	3.10	4.50	2.05	0.15	0.60	3.17	3.85	2.15	1570.47	104.81	2124.30	553.83	0.28	9.11	49.46	1.73	4.64	10.65		2.40	810.71	504.50	118.93
20.50	3.90	7.20		0.15	0.60	3.87	6.55		1987.15	113.29	2860.75	873.60	0.92	6.98	194.04	1.46	3.55	7.03		2.14	917.35	610.07	415.14
23.00	3.75	5.20	2.80	0.15	0.60	3.82	4.55	2.90	2147.41	105.95	3125.65	978.24	0.26	5.95	53.27	1.31	3.03	5.48		1.97	840.84	582.04	104.82
26.00	3.35	6.60		0.15	0.60	3.33	5.95		2339.73	111.60	3460.47	1120.74	1.19	4.11	190.24	1.01	2.09	3.07		1.62	606.40	460.47	308.67
29.00	4.65	14.80		0.15	0.60	4.28	14.15		2532.04	121.22	3824.17	1292.13	3.22	4.96	715.30				37.14	1.89			1352.41
30.00	5.85	18.40		0.15	0.60	5.36	17.75		2596.14	124.43	3948.61	1352.46	3.01	6.36	897.93				38.37	2.11			1891.58
31.00	5.75	17.20	0.95	0.15	0.60	5.32	16.55	1.05	2660.25	123.70	4072.32	1412.08	2.78	5.98	814.23				38.07	2.05			1665.61
32.00	5.35	10.20		0.15	0.60	5.25	9.55		2724.35	117.76	4190.10	1465.74	1.09	5.61	311.99	1.26	2.86	5.00		1.93	1171.86	823.01	601.20
33.00	6.25	8.75		0.15	0.60	6.26	8.10		2788.46	114.12	4304.23	1515.77	0.37	6.79	133.17	1.43	3.46	6.73		2.10	1536.57	1029.10	280.07
34.00	6.60	9.05		0.15	0.60	6.62	8.40		2852.56	114.32	4418.56	1566.00	0.34	7.00	129.36	1.46	3.56	7.06		2.13	1649.52	1096.32	276.13
35.00	7.00	9.45	4.90	0.15	0.60	7.02	8.80	5.00	2916.67	114.71	4533.28	1616.61	0.32	7.26	129.36	1.50	3.69	7.47		2.17	1781.61	1173.45	280.93
36.00	7.00	9.70		0.15	0.60	7.00	9.05		2980.77	115.45	4648.74	1667.97	0.37	6.98	148.39	1.46	3.55	7.03		2.13	1750.77	1164.43	316.31
37.00	7.10	9.65		0.15	0.60	7.11	9.00		3044.88	115.07	4763.82	1718.94	0.33	6.87	136.97	1.44	3.50	6.85		2.11	1767.61	1180.47	289.67
38.00	7.20	10.00		0.15	0.60	7.20	9.35		3108.98	115.88	4879.71	1770.73	0.38	6.73	156.00	1.43	3.43	6.64		2.09	1776.62	1192.33	326.76
39.00	3.65	14.20		0.15	0.60	3.26	13.55		3173.08	118.08	4997.80	1824.72	5.91	1.99	745.74				32.18	1.10			819.39
40.00	6.70	16.20		0.15	0.60	6.36	15.55		3237.19	123.54	5121.35	1884.16	1.91	5.33	665.84				37.51	1.91			1271.45
41.00	6.25	10.00		0.15	0.60	6.20	9.35		3301.29	116.86	5238.22	1936.93	0.68	4.98	228.29	1.16	2.54	4.15		1.79	1333.17	964.77	408.49
42.00	7.90	12.20	3.45	0.15	0.60	7.82	11.55	3.55	3365.40	119.61	5357.84	1992.44	0.60	6.51	270.14	1.39	3.31	6.30		2.06	1916.71	1297.22	556.54
43.00	6.85	11.60		0.15	0.60	6.75	10.95		3429.50	119.15	5477.00	2047.50	0.82	5.21	304.38	1.20	2.65	4.45		1.84	1490.88	1066.82	560.44
44.00	5.75	9.25		0.15	0.60	5.71	8.60		3493.61	115.58	5592.59	2098.99	0.71	4.02	209.26	0.99	2.05	2.97		1.57	1105.05	843.72	329.11
45.00	5.95	9.00		0.15	0.60	5.94	8.35		3557.71	114.82	5707.42	2149.71	0.57	4.11	175.02	1.01	2.09	3.08		1.59	1164.05	883.78	278.10
46.00	5.85	8.30		0.15	0.60	5.87	7.65		3621.82	112.96	5820.38	2198.57	0.43	3.92	129.36	0.97	2.00	2.86		1.54	1123.20	862.75	199.38
47.00	5.70	8.10		0.15	0.60	5.72	7.45		3685.92	112.54	5932.93	2247.01	0.44	3.67	125.56	0.92	1.87	2.58		1.47	1057.19	825.53	185.04
48.00	6.95	11.60		0.15	0.60	6.86	10.95		3750.02	118.95	6051.89	2301.87	0.81	4.59	296.77	1.09	2.34	3.66		1.71	1430.71	1056.69	508.27
49.00	7.50	10.80	3.20	0.15	0.60	7.47	10.15	3.30	3814.13	117.09	6168.99	2354.86	0.47	5.01	194.04	1.16	2.55	4.19		1.79	1631.74	1179.25	347.56
50.00	7.15	10.00		0.15	0.60	7.15	9.35		3878.23	115.58	6284.57	2406.34	0.42	4.59	159.80	1.09	2.34	3.65		1.70	1495.29	1104.44	271.95
51.00	7.70	13.40		0.15	0.60	7.55	12.75		3942.34	121.05	6405.64	2463.30	0.92	4.80	376.68	1.13	2.44	3.92		1.76	1620.13	1183.14	664.29
52.00	8.85	18.60		0.15	0.60	8.50	17.95		4006.44	125.67	6531.31	2524.87	1.44	5.44	684.86					1.91			1308.04
53.00	7.45	19.00		0.15	0.60	7.01	18.35		4070.55	125.16	6656.49	2585.94	2.24	4.09	821.84				36.14	1.68			1379.59
54.00	10.20	25.20		0.15	0.60	9.59	24.55		4134.65	129.52	6786.02	2651.37	1.97	5.99	1084.37				38.08	2.02			2191.30
55.00	8.75	22.20		0.15	0.60	8.22	21.55		4198.75	127.47	6913.50	2714.75	2.15	4.77	966.42				36.94	1.82			1755.67
56.00	7.55	27.40	1.80	0.15	0.60	6.70	26.75	1.90	4262.86	128.24	7041.76	2778.90	4.31	3.50	1453.44				35.32	1.59			2307.45
57.00	6.00	23.20		0.15	0.60	5.28	22.55		4326.96	124.94	7166.70	2839.74	5.39	2.36	1251.78				33.15	1.24			1558.45
58.00	5.80	25.60		0.15	0.60	4.95	24.95		4391.07	125.11	7291.82	2900.76	7.03	2.05	1449.63				32.34	1.12			1627.71

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-1A
Date:	20-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.83019
Longitude:	-75.48843
Elevation (ft):	
Ground Water Depth (ft):	-10.5
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

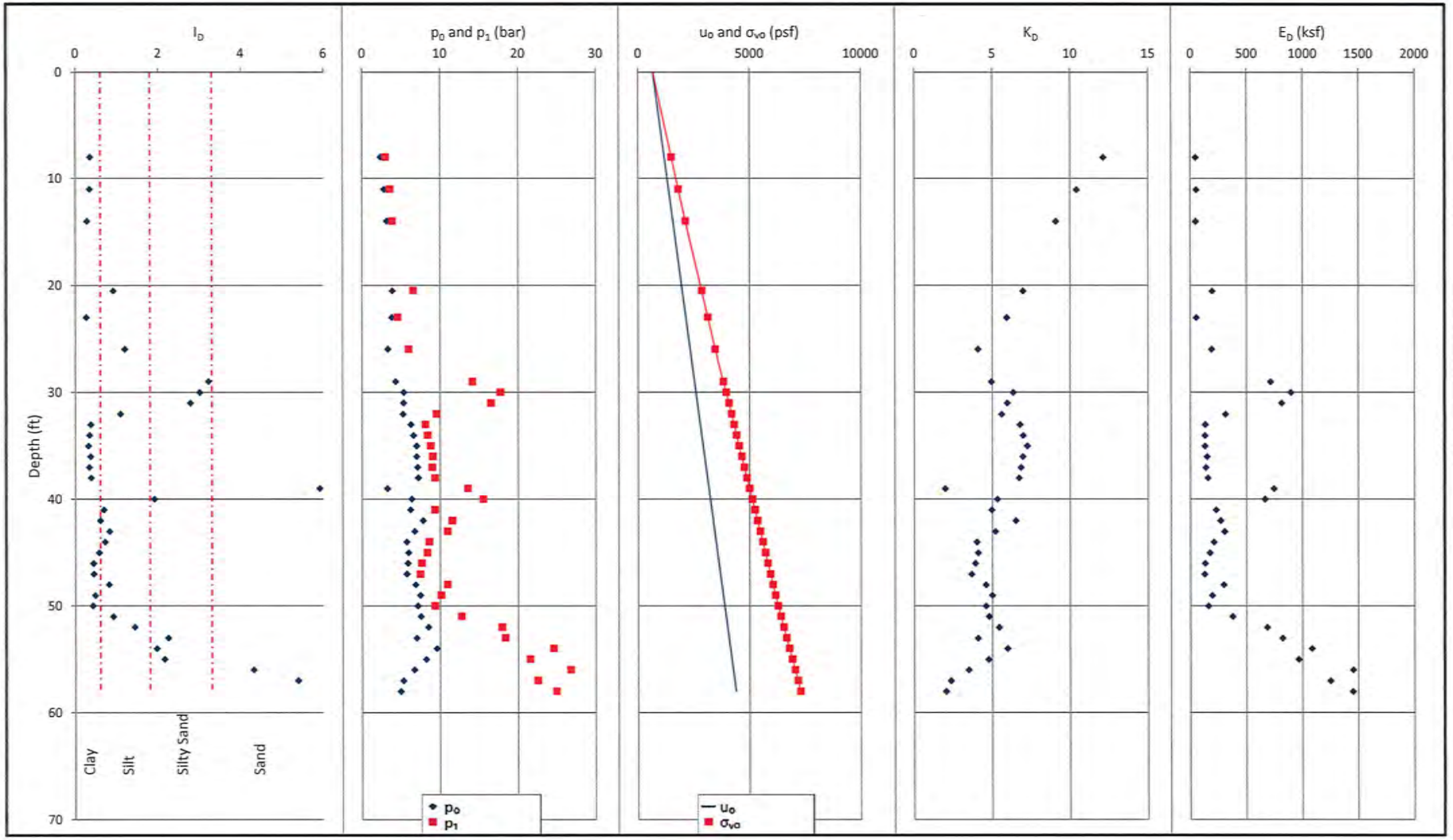


CONETEC

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-1A
Date:	20-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.83019
Longitude:	-75.48843
Elevation (ft):	
Ground Water Depth (ft):	-10.5
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83463
Client:	Schnabel Engineering	Longitude:	-75.48399
Sounding ID:	D-2	Elevation (ft):	
Date:	19-Jun-2018	Ground Water Depth (ft):	-11.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_t[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_o	OCR[3]	OCR[4]	φ[5] (deg)	R_M	s_u[6] (psf)	s_u[7] (psf)	M (ksf)
5.00	1.15	2.25		0.15	0.58	1.23	1.63		1025.71	96.11	1185.77	160.06	0.53	9.66	28.54	1.80	4.92	11.66		2.46	252.06	154.58	70.32
6.00	2.60	4.10		0.15	0.58	2.66	3.48		1089.82	105.09	1290.87	201.05	0.38	22.22	58.97	2.95	11.31	42.80		3.26	897.40	446.83	192.03
7.00	2.55	4.05	1.80	0.15	0.58	2.61	3.43	1.90	1153.92	104.89	1395.77	241.85	0.40	17.78	58.97	2.60	9.05	30.22		3.04	816.69	429.98	179.57
8.00	2.70	4.15		0.15	0.58	2.76	3.53		1218.03	104.84	1500.62	282.59	0.35	16.12	55.17	2.45	8.20	25.92		2.95	844.03	455.42	162.85
9.00	2.80	4.35		0.15	0.58	2.86	3.73		1282.13	105.68	1606.30	324.17	0.39	14.46	62.78	2.30	7.36	21.90		2.85	845.73	468.85	178.88
10.00	2.95	4.45		0.15	0.58	3.01	3.83		1346.23	105.62	1711.94	365.70	0.34	13.52	58.97	2.21	6.88	19.70		2.79	876.66	494.29	164.26
11.00	3.05	4.60		0.15	0.58	3.11	3.98		1410.34	106.10	1818.05	407.71	0.36	12.47	62.78	2.11	6.35	17.37		2.71	883.36	508.24	170.05
12.00	3.15	4.70		0.15	0.58	3.21	4.08		1474.44	106.25	1924.31	449.86	0.35	11.62	62.78	2.02	5.91	15.56		2.64	892.68	522.72	165.87
13.00	2.75	4.15		0.15	0.58	2.82	3.53		1538.55	104.22	2028.54	489.99	0.34	8.86	51.36	1.70	4.51	10.20		2.38	693.21	434.33	122.06
14.00	2.70	4.20	1.90	0.15	0.58	2.76	3.58	2.00	1602.65	104.72	2133.27	530.62	0.41	7.85	58.97	1.58	3.99	8.44		2.25	644.72	416.43	132.79
15.00	2.40	3.70		0.15	0.58	2.47	3.08		1666.76	102.27	2235.55	568.79	0.36	6.14	43.76	1.34	3.13	5.76		2.00	508.91	349.46	87.54
16.50	2.35	10.40		0.15	0.58	2.08	9.78		1762.91	114.42	2407.19	644.28	6.20	4.02	557.40				36.05	1.71			952.13
17.50	2.10	8.35		0.15	0.58	1.92	7.73		1827.02	111.88	2519.08	692.06	5.53	3.17	420.43				34.78	1.50			631.04
18.00	1.75	5.75		0.15	0.58	1.69	5.13		1859.07	107.50	2572.83	713.76	4.32	2.33	249.21				33.08	1.23			307.67
19.00	2.25	8.40		0.15	0.58	2.08	7.78		1923.17	112.33	2685.17	762.00	4.92	3.17	412.82				34.79	1.50			620.53
20.00	1.80	8.35		0.15	0.58	1.61	7.73		1987.28	109.58	2794.76	807.48	9.31	1.70	443.26				31.25	0.96			425.91
21.00	2.50	12.40		0.15	0.58	2.14	11.78		2051.38	115.33	2910.10	858.71	8.31	2.82	698.18				34.15	1.40			977.59
22.00	2.75	10.00	0.75	0.15	0.58	2.52	9.38	0.85	2115.49	114.89	3025.00	909.51	4.53	3.47	496.53				35.27	1.58			784.77
23.00	3.15	11.20		0.15	0.58	2.88	10.58		2179.59	116.70	3141.71	962.11	4.18	3.99	557.40				36.02	1.70			949.23
24.00	4.55	6.00		0.15	0.58	4.61	5.38		2243.70	107.41	3249.13	1005.43	0.22	7.35	55.17	1.51	3.74	7.62		2.18	1125.96	739.23	120.53
25.00	4.60	6.20		0.15	0.58	4.66	5.58		2307.80	108.45	3357.58	1049.78	0.26	7.07	66.58	1.47	3.60	7.16		2.14	1118.52	741.70	142.75
26.00	4.90	6.75		0.15	0.58	4.94	6.13		2371.91	110.20	3467.79	1095.89	0.31	7.26	85.61	1.50	3.69	7.47		2.17	1207.48	795.33	185.89
27.00	5.00	6.85		0.15	0.58	5.04	6.23		2436.01	110.30	3578.10	1142.09	0.30	7.09	85.61	1.48	3.61	7.20		2.15	1222.33	809.81	183.85
28.00	5.35	7.35	3.95	0.15	0.58	5.39	6.73	4.05	2500.11	111.42	3689.53	1189.42	0.32	7.36	97.02	1.51	3.74	7.63		2.19	1332.81	874.93	212.02
29.00	5.30	16.60		0.15	0.58	4.87	15.98		2564.22	122.99	3812.54	1248.32	3.05	6.10	804.72				38.17	2.07			1665.82
30.00	4.30	13.60		0.15	0.58	3.97	12.98		2628.32	119.93	3932.47	1304.15	3.32	4.34	652.52				36.46	1.78			1158.80
31.00	5.85	17.80		0.15	0.58	5.39	17.18		2692.43	124.09	4056.57	1364.15	2.87	6.28	854.18				38.31	2.09			1786.65
32.00	2.90	12.00		0.15	0.58	2.58	11.38		2756.53	115.29	4171.87	1415.34	6.97	1.86	637.30				31.79	1.04			662.59
33.00	5.90	14.80		0.15	0.58	5.59	14.18		2820.64	122.35	4294.23	1473.59	2.02	6.01	622.09				38.10	2.03			1260.00
34.00	4.25	8.20		0.15	0.58	4.19	7.58		2884.74	114.40	4408.64	1523.90	1.21	3.85	245.41					1.56			382.55
35.00	9.40	13.40		0.15	0.58	9.34	12.78		2948.85	120.59	4529.24	1580.39	0.43	10.47	249.21	1.89	5.33	13.23		2.54	2753.92	1655.03	633.93
36.00	9.35	12.60	6.10	0.15	0.58	9.32	11.98	6.20	3012.95	119.00	4648.24	1635.29	0.34	10.07	192.14	1.85	5.12	12.44		2.51	2711.92	1646.01	481.54
37.00	9.50	13.00		0.15	0.58	9.46	12.38		3077.05	119.64	4767.89	1690.84	0.36	9.87	211.17	1.82	5.02	12.06		2.49	2735.01	1668.32	525.01
38.00	10.20	13.60		0.15	0.58	10.17	12.98		3141.16	119.91	4887.81	1746.65	0.32	10.36	203.56	1.88	5.27	13.01		2.53	3002.11	1809.15	515.67
39.00	9.75	13.20		0.15	0.58	9.71	12.58		3205.26	119.67	5007.49	1802.23	0.35	9.48	207.36	1.78	4.82	11.33		2.45	2772.47	1708.23	507.02
40.00	9.00	12.00		0.15	0.58	8.99	11.38		3269.37	118.02	5125.52	1856.15	0.32	8.35	173.12	1.64	4.25	9.29		2.32	2436.99	1549.88	400.80
41.00	7.90	10.40		0.15	0.58	7.91	9.78		3333.47	115.63	5241.16	1907.69	0.30	6.91	135.07	1.45	3.52	6.92		2.12	1978.31	1318.95	286.58
42.00	8.45	11.40	6.00	0.15	0.58	8.44	10.78	6.10	3397.58	117.39	5358.56	1960.98	0.34	7.26	169.31	1.50	3.69	7.46		2.17	2159.80	1422.71	367.60
43.00	8.70	11.60		0.15	0.58	8.69	10.98		3461.68	117.44	5476.01	2014.33	0.32	7.29	165.51	1.50	3.71	7.53		2.18	2233.03	1469.04	360.22
44.00	9.10	12.20		0.15	0.58	9.08	11.58		3525.78	118.25	5594.27	2068.49	0.34	7.46	180.73	1.53	3.80	7.80		2.20	2360.80	1544.08	397.66
45.00	9.25	12.20		0.15	0.58	9.24	11.58		3589.89	117.97	5712.25	2122.36	0.31	7.40	169.31	1.52	3.77	7.70		2.19	2396.07	1570.56	371.03
46.00	8.95	12.00		0.15	0.58	8.93	11.38		3653.99	117.96	5830.22	2176.23	0.34	6.89	176.92	1.45	3.51	6.89		2.12	2248.99	1500.45	374.88
47.00	9.20	12.40		0.15	0.58	9.18	11.78		3718.10	118.50	5948.73	2230.63	0.35	6.92	188.34	1.45	3.52	6.94		2.12	2317.82	1544.69	399.91
48.00	9.45	12.60		0.15	0.58	9.43	11.98		3782.20	118.55	6067.29	2285.09	0.33	6.96	184.53	1.46	3.54	7.00		2.13	2390.57	1591.02	392.86
49.00	9.00	11.60	6.90	0.15	0.58	9.01	10.98	7.00	3846.31	116.68	6183.98	2337.68	0.27	6.40	142.68	1.38	3.26	6.14		2.04	2201.59	1496.36	291.46
50.00	8.40	11.20		0.15	0.58	8.40	10.58		3910.41	116.73	6300.72	2390.31	0.33	5.70	157.90	1.27	2.90	5.12		1.92	1947.44	1362.55	303.79
51.00	8.15	10.40		0.15	0.58	8.17	9.78		3974.52	114.72	6415.44	2440.93	0.26	5.37	116.05	1.22	2.73	4.66		1.86	1843.74	1309.67	216.06
52.00	9.15	12.20		0.15	0.58	9.13	11.58		4038.62	117.97	6533.43	2494.81	0.34	6.03	176.92	1.32	3.07	5.59		1.98	2179.46	1503.76	350.51
53.00	8.10	10.80		0.15	0.58	8.10	10.18		4102.72	116.08	6649.52	2546.79	0.34	5.03	150.29	1.17	2.56	4.22		1.80	1775.72	1281.71	269.96
54.00	7.85	10.60		0.15	0.58	7.85	9.98		4166.83	115.95	6765.48	2598.65	0.36	4.70	154.09	1.11	2.39	3.80		1.73	1665.47	1222.56	266.15
55.00	8.50	11.60		0.15	0.58	8.48	10.98		4230.93	117.46	6882.95	2652.01	0.39	5.08	180.73	1.17	2.59	4.29		1.81	1872.64	1348.25	326.51

CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83463
Client:	Schnabel Engineering	Longitude:	-75.48399
Sounding ID:	D-2	Elevation (ft):	
Date:	19-Jun-2018	Ground Water Depth (ft):	-11.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	OCR[4]	φ[5] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
56.00	8.90	12.60	4.80	0.15	0.58	8.85	11.98	4.90	4295.04	119.09	7002.05	2707.01	0.46	5.24	226.39	1.20	2.67	4.50		1.84	1986.26	1419.12	416.12
57.00	9.35	15.00		0.15	0.58	9.20	14.38		4359.14	122.41	7124.47	2765.33	0.73	5.37	374.77	1.22	2.74	4.67		1.87	2093.35	1486.33	700.37
58.00	7.30	20.00		0.15	0.58	6.80	19.38		4423.25	125.32	7249.80	2826.55	2.68	3.46	911.25				35.26	1.56			1418.36
59.00	9.15	14.00		0.15	0.58	9.04	13.38		4487.35	121.14	7370.95	2883.60	0.63	4.99	313.90	1.16	2.54	4.17		1.79	1991.31	1440.09	561.76
60.00	8.85	19.40		0.15	0.58	8.46	18.78		4551.46	125.92	7496.88	2945.43	1.64	4.45	747.64					1.73			1290.22
61.00	7.60	16.40		0.15	0.58	7.30	15.78		4615.56	123.39	7620.28	3004.72	1.67	3.54	614.48					1.51			925.77
62.00	7.65	12.20		0.15	0.58	7.56	11.58		4679.66	119.13	7739.42	3059.75	0.76	3.63	291.07	0.91	1.85	2.53		1.47	1418.13	1110.71	428.35
63.00	6.90	12.40		0.15	0.58	6.76	11.78		4743.77	119.44	7858.87	3115.10	1.12	3.01	363.36	0.79	1.53	1.89		1.31	1142.54	937.74	475.97
64.00	8.75	17.40	2.10	0.15	0.58	8.45	16.78	2.20	4807.87	124.45	7983.33	3175.45	1.35	4.05	603.06					1.62			975.13
65.00	9.05	13.60		0.15	0.58	8.96	12.98		4871.98	120.44	8103.78	3231.80	0.61	4.28	291.07	1.04	2.18	3.28		1.63	1841.39	1383.88	474.74
66.00	7.80	14.60		0.15	0.58	7.60	13.98		4936.08	121.82	8225.61	3289.53	1.22	3.32	462.28					1.42			654.15
67.00	6.40	12.00		0.15	0.58	6.26	11.38		5000.19	118.67	8344.29	3344.10	1.33	2.41	370.97					1.11			411.64
68.00	11.20	27.40	2.10	0.15	0.58	10.53	26.78	2.20	5064.29	130.47	8474.76	3410.47	2.01	4.96	1177.59				37.14	1.85			2173.57

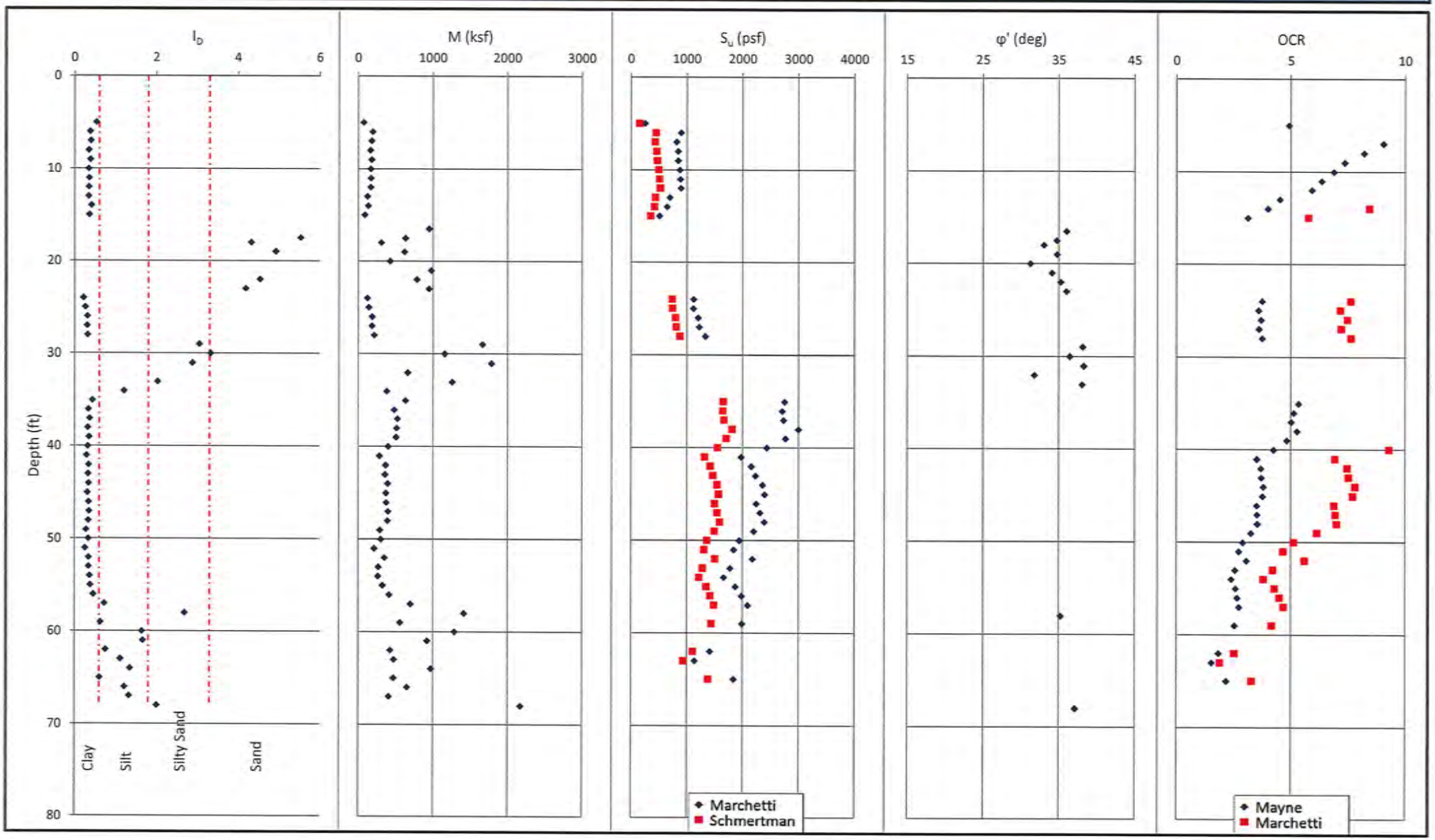
1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

CONETEC

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-2
Date:	19-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.83463
Longitude:	-75.48399
Elevation (ft):	
Ground Water Depth (ft):	-11.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

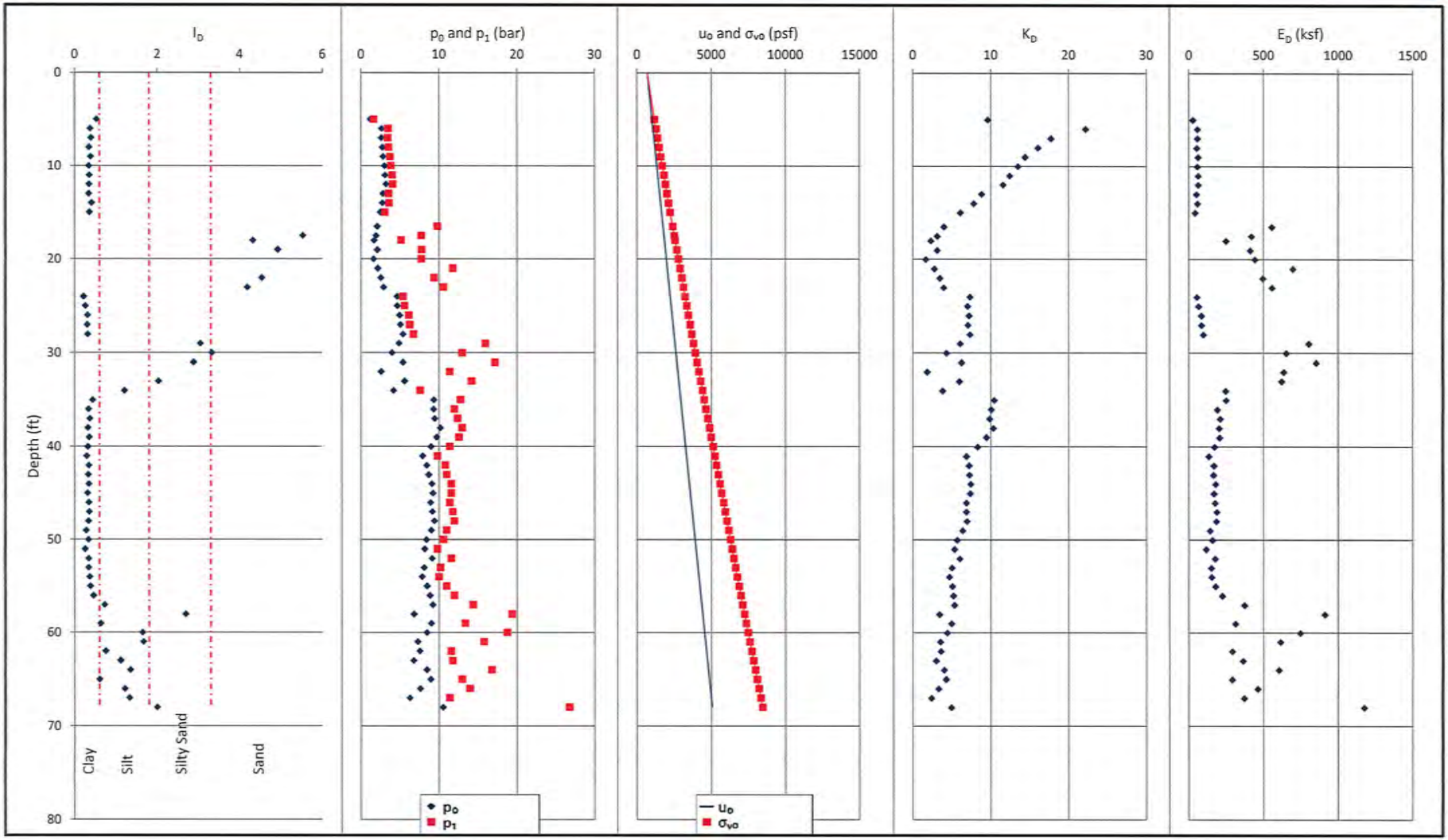


CONETEC

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-2
Date:	19-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.83463
Longitude:	-75.48399
Elevation (ft):	
Ground Water Depth (ft):	-11.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83991
Client:	Schnabel Engineering	Longitude:	-75.47855
Sounding ID:	D-3	Elevation (ft):	
Date:	20-Jun-2018	Ground Water Depth (ft):	-13.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	DCR[4]	ϕ[5] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
4.00	1.80	2.90		0.18	0.50	1.90	2.35		1089.69	99.78	1232.42	142.73	0.32	20.22	32.34	2.80	10.29	36.94		3.17	566.17	288.64	102.41
5.00	2.05	3.30		0.18	0.50	2.15	2.75		1153.80	102.02	1334.45	180.65	0.38	18.43	43.76	2.65	9.38	31.95		3.08	637.93	332.87	134.71
6.00	1.90	3.05		0.18	0.50	2.00	2.50		1217.90	100.46	1434.92	217.02	0.35	13.65	36.15	2.22	6.95	20.00		2.79	526.57	296.18	101.01
7.00	2.00	3.10	1.40	0.18	0.50	2.10	2.55	1.53	1282.00	100.15	1535.08	253.08	0.30	12.30	32.34	2.09	6.26	17.00		2.70	538.99	311.18	87.18
8.00	2.35	3.55		0.18	0.50	2.45	3.00		1346.11	102.19	1637.28	291.18	0.31	12.94	39.95	2.15	6.59	18.41		2.74	661.10	376.82	109.63
9.00	2.35	3.40		0.18	0.50	2.46	2.85		1410.21	100.42	1737.71	327.50	0.22	11.36	28.54	1.99	5.78	15.02		2.62	631.65	371.98	74.78
10.00	2.00	3.15		0.18	0.50	2.10	2.60		1474.32	100.38	1838.11	363.79	0.36	8.01	36.15	1.60	4.08	8.71		2.27	453.50	291.42	82.15
11.00	2.15	3.25		0.18	0.50	2.25	2.70		1538.42	100.25	1938.36	399.94	0.29	7.92	32.34	1.59	4.03	8.56		2.26	491.73	316.86	73.13
12.00	2.35	3.70		0.18	0.50	2.44	3.15		1602.53	103.10	2041.46	438.94	0.42	7.96	51.36	1.59	4.05	8.63		2.27	543.27	349.61	116.43
13.00	2.65	3.95		0.18	0.50	2.74	3.40		1666.63	103.48	2144.95	478.32	0.34	8.50	47.56	1.66	4.32	9.55		2.33	641.76	406.38	110.96
14.00	3.05	4.45	2.30	0.18	0.50	3.14	3.90	2.43	1730.74	105.15	2250.10	519.37	0.33	9.29	55.17	1.76	4.73	10.98		2.42	779.12	482.47	133.76
15.00	2.70	4.00		0.18	0.50	2.79	3.45		1794.84	103.45	2353.56	558.72	0.34	7.23	47.56	1.49	3.68	7.43		2.17	612.80	404.00	103.10
16.00	3.25	4.75		0.18	0.50	3.33	4.20		1858.94	106.12	2459.69	600.74	0.35	8.50	62.78	1.66	4.32	9.55		2.33	805.98	510.37	146.46
17.00	3.10	4.40		0.18	0.50	3.19	3.85		1923.05	104.28	2563.98	640.93	0.29	7.41	47.56	1.52	3.77	7.71		2.19	724.41	474.72	104.27
18.00	3.35	4.75		0.18	0.50	3.44	4.20		1987.15	105.53	2669.52	682.37	0.31	7.61	55.17	1.55	3.87	8.05		2.22	798.17	519.48	122.50
19.00	3.20	4.80		0.18	0.50	3.28	4.25		2051.26	106.40	2775.94	724.68	0.42	6.62	70.39	1.41	3.37	6.47		2.08	711.64	479.66	146.20
20.00	3.70	5.10		0.18	0.50	3.79	4.55		2115.36	106.12	2882.06	766.70	0.27	7.56	55.17	1.54	3.85	7.96		2.21	889.28	579.76	122.12
21.00	3.85	5.45		0.18	0.50	3.93	4.90		2179.47	107.62	2989.69	810.23	0.34	7.44	70.39	1.52	3.79	7.76		2.20	920.47	602.59	154.61
22.00	3.75	5.20	2.80	0.18	0.50	3.84	4.65	2.93	2243.57	106.44	3095.14	852.57	0.29	6.77	58.97	1.43	3.44	6.69		2.10	860.58	576.86	123.82
23.00	3.70	5.10		0.18	0.50	3.79	4.55		2307.67	105.94	3202.09	894.41	0.28	6.27	55.17	1.36	3.19	5.94		2.02	820.35	560.53	111.50
24.00	2.85	8.65		0.18	0.50	2.72	8.10		2371.78	113.78	3315.87	944.10	3.40	3.50	389.99				35.33	1.59			619.58
25.00	3.15	9.00		0.18	0.50	3.02	8.45		2435.88	114.72	3430.61	994.72	2.94	3.88	393.80				35.87	1.67			659.51
26.00	2.60	4.95		0.18	0.50	2.64	4.40		2499.99	107.10	3537.71	1037.72	1.22	2.91	127.46					1.28			163.58
27.00	2.70	9.05		0.18	0.50	2.54	8.50		2564.09	113.30	3651.01	1086.92	4.54	2.52	431.85				33.53	1.30			563.21
28.00	3.00	9.00		0.18	0.50	2.86	8.45		2628.20	114.06	3765.08	1136.88	3.49	2.94	405.21				34.38	1.44			582.16
29.00	2.75	6.05	1.10	0.18	0.50	2.74	5.50	1.23	2692.30	109.57	3874.66	1182.36	1.89	2.57	199.75				33.63	1.22			244.07
30.00	3.85	6.90		0.18	0.50	3.86	6.35		2756.41	112.10	3986.76	1230.36	0.98	4.31	180.73	1.04	2.19	3.31		1.66	705.86	529.75	299.53
31.00	2.75	4.60		0.18	0.50	2.82	4.05		2820.51	105.29	4092.06	1271.55	0.84	2.41	89.41	0.65	1.23	1.34		1.06	352.73	306.14	95.04
32.00	3.85	5.60		0.18	0.50	3.92	5.05		2884.61	107.75	4199.82	1315.20	0.44	4.03	81.80	0.99	2.05	2.99		1.57	695.43	530.51	128.39
33.25	3.00	5.90		0.18	0.50	3.01	5.35		2964.75	109.17	4335.29	1371.54	1.47	2.43	169.31					1.13			191.13
34.00	3.35	7.85		0.18	0.50	3.28	7.30		3012.82	112.97	4421.02	1408.20	2.18	2.73	291.07				33.97	1.30			379.36
35.00	5.05	12.20	0.60	0.18	0.50	4.85	11.65	0.73	3076.93	119.56	4540.59	1463.67	2.01	4.82	492.72				36.99	1.82			896.35
36.00	5.25	13.20		0.18	0.50	5.01	12.65		3141.03	120.48	4661.09	1520.06	2.18	4.82	553.60				36.99	1.83			1011.33
37.00	4.60	12.00		0.18	0.50	4.39	11.45		3205.14	118.78	4779.88	1574.74	2.47	3.79	511.75				35.74	1.62			830.53
38.00	4.70	10.60		0.18	0.50	4.56	10.05		3269.24	117.58	4897.47	1628.23	1.83	3.85	397.60				35.82	1.60			635.05
39.00	5.20	15.00		0.18	0.50	4.87	14.45		3333.35	121.44	5018.92	1685.57	2.93	4.06	694.38				36.10	1.71			1188.60
40.00	5.25	13.00		0.18	0.50	5.02	12.45		3397.45	120.12	5139.05	1741.60	2.19	4.07	538.38				36.12	1.67			900.08
41.00	5.65	14.20		0.18	0.50	5.38	13.65		3461.55	121.33	5260.38	1798.83	2.22	4.32	599.26				36.43	1.73			1036.18
42.00	4.80	12.40		0.18	0.50	4.58	11.85		3525.66	119.03	5379.42	1853.77	2.52	3.26	526.97				34.93	1.49			785.26
43.00	5.55	15.00		0.18	0.50	5.24	14.45		3589.76	121.64	5501.07	1911.31	2.62	3.84	667.74				35.82	1.65			1098.96
44.00	6.30	14.60	0.75	0.18	0.50	6.04	14.05	0.88	3653.87	122.00	5623.08	1969.21	1.86	4.55	580.23				36.70	1.76			1020.46
45.00	6.40	13.40		0.18	0.50	6.21	12.85		3717.97	121.05	5744.13	2026.16	1.50	4.56	481.31					1.74			838.54
46.00	6.55	15.60		0.18	0.50	6.26	15.05		3782.08	122.78	5866.93	2084.85	1.98	4.45	637.30				36.59	1.74			1111.14
47.00	5.90	15.40		0.18	0.50	5.58	14.85		3846.18	122.05	5988.99	2142.81	2.48	3.65	671.55				35.54	1.59			1067.46
48.00	5.85	15.80		0.18	0.50	5.51	15.25		3910.29	122.18	6111.18	2200.89	2.68	3.45	705.79				35.25	1.55			1096.82
49.00	5.85	13.80	0.80	0.18	0.50	5.61	13.25	0.93	3974.39	120.82	6232.01	2257.62	2.06	3.43	553.60				35.21	1.51			833.29
50.00	5.95	14.80		0.18	0.50	5.67	14.25		4038.49	121.57	6353.59	2315.09	2.30	3.37	622.09				35.11	1.50			936.19
51.00	5.95	12.00		0.18	0.50	5.81	11.45		4102.60	119.22	6472.81	2370.21	1.47	3.39	409.02					1.45			593.56
52.00	5.70	13.20		0.18	0.50	5.48	12.65		4166.70	120.07	6592.89	2426.19	2.05	3.00	519.36				34.49	1.38			717.26
53.00	7.25	17.20		0.18	0.50	6.91	16.65		4230.81	123.99	6716.89	2486.09	1.99	4.10	705.79				36.16	1.67			1177.32
54.00	9.35	19.40		0.18	0.50	9.01	18.85		4294.91	126.27	6843.17	2548.26	1.42	5.70	713.40					1.95			1393.33

Job No:	18-5402S	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.83991
Client:	Schnabel Engineering	Longitude:	-75.47855
Sounding ID:	D-3	Elevation (ft):	
Date:	20-Jun-2018	Ground Water Depth (ft):	-13.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

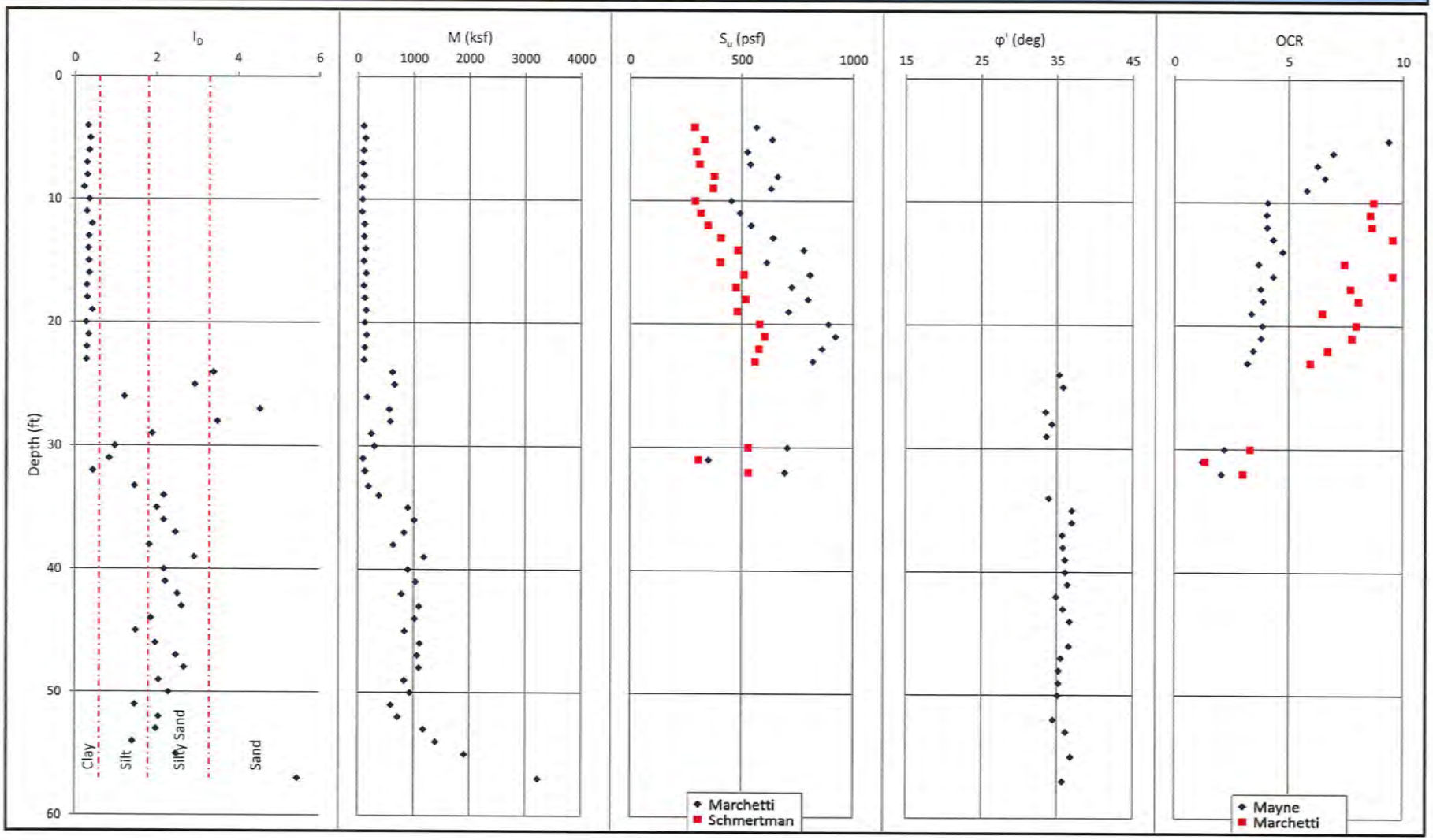
Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_t[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_d	OCR[3]	OCR[4]	φ[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
55.00	8.50	23.00		0.18	0.50	7.93	22.45		4359.02	127.64	6970.82	2611.80	2.48	4.68	1052.03				36.84	1.81			1908.38
57.00	8.25	34.60		0.18	0.50	7.09	34.05		4487.22	130.55	7231.93	2744.71	5.45	3.76	1953.77				35.70	1.65			3224.95

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-3
Date:	20-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.83991
Longitude:	-75.47855
Elevation (ft):	
Ground Water Depth (ft):	-13.0
Gauge Zero Offset (bar):	0.05

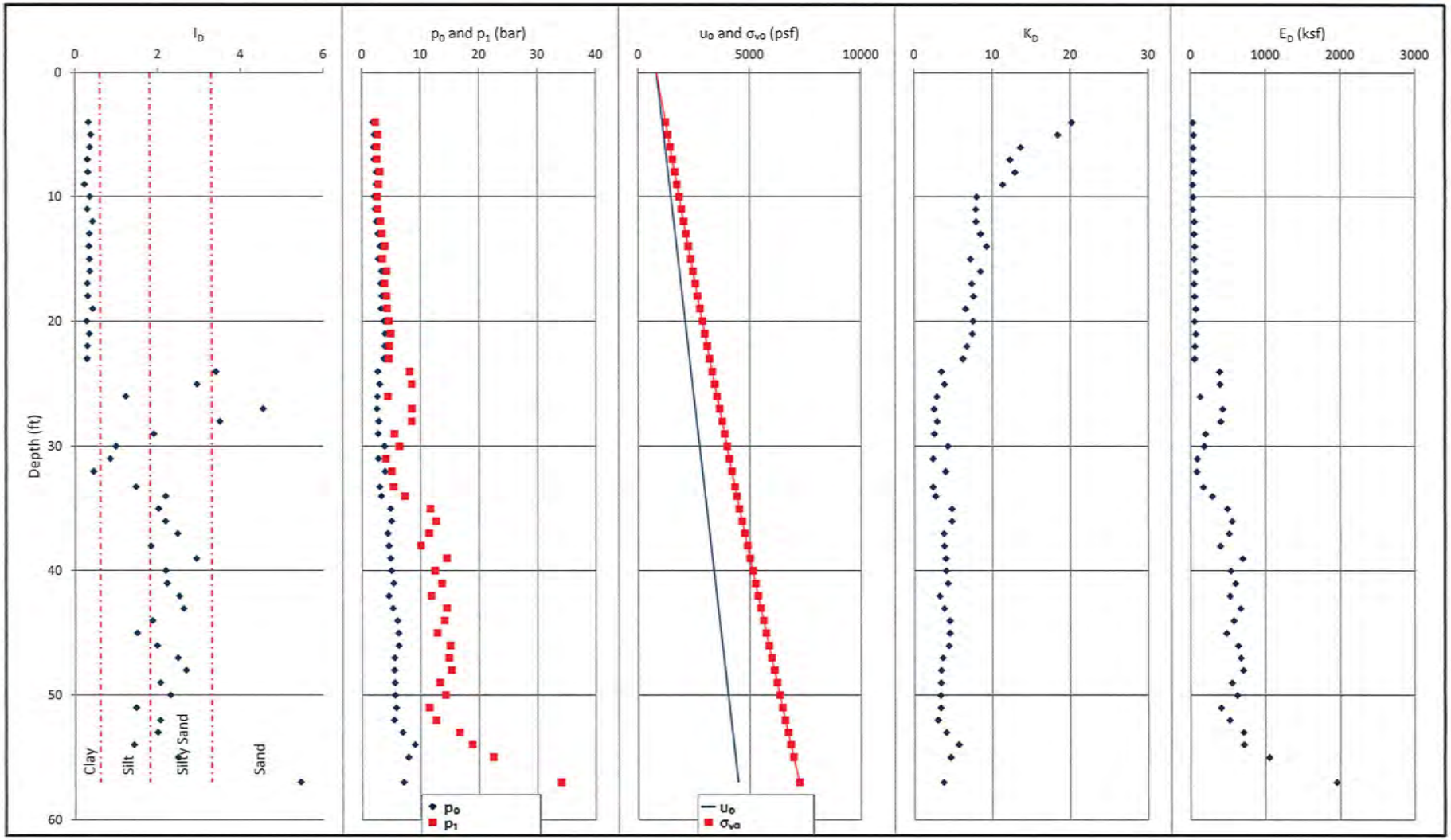
FLAT PLATE DILATOMETER TEST RESULTS



Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-3
Date:	20-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.83991
Longitude:	-75.47855
Elevation (ft):	
Ground Water Depth (ft):	-13.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.84501
Client:	Schnabel Engineering	Longitude:	-75.47295
Sounding ID:	D-4	Elevation (ft):	
Date:	21-Jun-2018	Ground Water Depth (ft):	-11.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	OCR[4]	φ[5] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
4.00	1.70	2.65		0.18	0.43	1.81	2.18		961.61	98.69	1099.97	138.37	0.27	20.33	25.63	2.80	10.35	37.26		3.17	552.62	281.34	84.48
5.00	2.00	3.05		0.18	0.43	2.10	2.58		1025.71	100.84	1200.82	175.11	0.29	19.22	34.24	2.72	9.78	34.12		3.12	651.80	336.54	106.79
6.00	1.55	2.65		0.18	0.43	1.65	2.18		1089.82	99.58	1300.40	210.59	0.47	11.19	38.05	1.97	5.70	14.67		2.61	398.62	235.63	99.17
7.00	1.85	2.90		0.18	0.43	1.95	2.43		1153.92	100.13	1400.54	246.62	0.34	11.86	34.24	2.04	6.03	16.06		2.66	501.87	292.40	91.13
8.00	2.25	3.40	1.55	0.18	0.43	2.35	2.93	1.68	1218.03	102.31	1502.86	284.84	0.33	12.94	41.85	2.15	6.58	18.40		2.74	646.41	368.48	114.83
9.00	2.30	3.40		0.18	0.43	2.40	2.93		1282.13	101.89	1604.76	322.63	0.29	11.56	38.05	2.01	5.89	15.44		2.64	636.28	373.04	100.35
10.00	2.30	3.50		0.18	0.43	2.40	3.03		1346.23	102.72	1707.49	361.26	0.35	10.12	45.66	1.85	5.15	12.54		2.51	609.13	365.58	114.66
11.00	2.50	3.60		0.18	0.43	2.60	3.13		1410.34	102.27	1809.77	399.43	0.27	10.06	38.05	1.85	5.12	12.44		2.51	662.28	401.99	95.35
12.00	2.25	3.30		0.18	0.43	2.35	2.83		1474.44	100.94	1910.72	436.28	0.29	7.88	34.24	1.58	4.01	8.50		2.26	532.98	343.89	77.26
13.00	2.50	3.60		0.18	0.43	2.60	3.13		1538.55	102.11	2012.84	474.29	0.28	8.21	38.05	1.62	4.18	9.04		2.30	609.25	389.17	87.41
14.00	2.40	3.50		0.18	0.43	2.50	3.03		1602.65	101.74	2114.58	511.93	0.30	7.07	38.05	1.47	3.60	7.17		2.14	545.79	361.87	81.59
15.00	2.75	3.75	1.90	0.18	0.43	2.86	3.28	2.03	1666.76	101.47	2216.07	549.31	0.20	7.82	30.44	1.57	3.98	8.39		2.25	664.53	429.60	68.43
16.00	3.10	4.35		0.18	0.43	3.19	3.88		1730.86	104.69	2320.77	589.91	0.29	8.37	49.46	1.64	4.26	9.33		2.32	776.69	493.68	114.63
17.00	3.20	4.50		0.18	0.43	3.29	4.03		1794.97	105.23	2426.00	631.04	0.30	8.04	53.27	1.60	4.09	8.77		2.28	790.79	507.63	121.29
18.00	3.35	4.80		0.18	0.43	3.43	4.33		1859.07	106.49	2532.51	673.44	0.35	7.88	64.68	1.58	4.01	8.50		2.26	823.03	530.99	145.95
19.00	3.70	5.05		0.18	0.43	3.79	4.58		1923.17	106.47	2638.98	715.81	0.27	8.36	57.07	1.64	4.26	9.32		2.32	941.81	598.72	132.23
20.00	3.55	4.95		0.18	0.43	3.64	4.48		1987.28	106.46	2745.45	758.17	0.31	7.39	60.88	1.52	3.76	7.69		2.19	854.81	560.46	133.34
21.00	3.85	5.25		0.18	0.43	3.94	4.78		2051.38	106.97	2852.43	801.04	0.28	7.70	60.88	1.56	3.92	8.19		2.23	950.20	616.70	135.87
22.00	3.95	5.40	3.00	0.18	0.43	4.03	4.93	3.13	2115.49	107.41	2959.85	844.36	0.30	7.47	64.68	1.53	3.80	7.81		2.20	964.37	630.66	142.36
23.00	3.95	5.35		0.18	0.43	4.04	4.88		2179.59	107.04	3066.90	887.30	0.28	7.04	60.88	1.47	3.58	7.12		2.14	941.38	624.77	130.30
24.00	4.10	5.50		0.18	0.43	4.19	5.03		2243.70	107.25	3174.15	930.46	0.27	6.98	60.88	1.46	3.55	7.03		2.13	976.88	649.69	129.78
25.00	4.05	5.35		0.18	0.43	4.14	4.88		2307.80	106.40	3280.56	972.76	0.24	6.52	53.27	1.39	3.32	6.31		2.06	936.78	633.88	109.79
26.00	4.10	5.50		0.18	0.43	4.19	5.03		2371.91	107.14	3387.71	1015.81	0.28	6.27	60.88	1.36	3.19	5.94		2.02	932.16	636.86	123.06
27.00	3.25	5.20		0.18	0.43	3.31	4.73		2436.01	108.05	3495.78	1059.77	0.66	4.22	102.73	1.03	2.15	3.20		1.62	592.85	447.18	166.33
28.00	4.30	7.00	2.35	0.18	0.43	4.32	6.53	2.48	2500.11	112.57	3608.36	1108.24	0.71	5.89	159.80	1.30	3.00	5.39		1.96	939.69	652.24	313.26
29.00	4.65	6.25		0.18	0.43	4.73	5.78		2564.22	109.09	3717.46	1153.24	0.30	6.33	76.10	1.37	3.22	6.04		2.03	1071.81	730.41	154.62
30.00	4.65	6.15		0.18	0.43	4.73	5.68		2628.32	108.48	3825.94	1197.62	0.27	6.05	68.49	1.33	3.08	5.63		1.99	1052.00	725.05	135.99
31.00	5.15	7.55		0.18	0.43	5.19	7.08		2692.43	112.95	3938.90	1246.47	0.49	6.53	136.97	1.40	3.32	6.33		2.06	1203.02	813.67	282.55
32.00	5.05	9.15		0.18	0.43	5.00	8.68		2756.53	116.44	4055.34	1298.81	1.00	5.92	266.34	1.31	3.01	5.43		1.98	1108.89	768.62	526.26
33.00	2.75	10.40		0.18	0.43	2.52	9.93		2820.64	113.88	4169.23	1348.60	6.32	1.82	536.48				31.64	1.02			546.00
34.00	4.75	11.80		0.18	0.43	4.55	11.33		2884.74	119.16	4288.40	1403.66	2.14	4.72	490.82				36.88	1.81			886.09
35.00	4.05	9.65		0.18	0.43	3.93	9.18		2948.85	116.29	4404.70	1455.86	2.09	3.61	380.48				35.48	1.55			591.01
36.00	4.25	11.60	0.75	0.18	0.43	4.04	11.13	0.88	3012.95	118.24	4522.95	1510.00	2.73	3.59	513.65				35.46	1.59			817.75
37.00	3.75	8.45		0.18	0.43	3.67	7.98		3077.05	114.37	4637.33	1560.28	1.96	2.94	311.99				34.38	1.35			422.40
38.00	4.05	11.20		0.18	0.43	3.85	10.73		3141.16	117.45	4754.81	1613.65	2.93	3.03	498.43				34.55	1.46			727.07
39.00	5.00	12.20		0.18	0.43	4.80	11.73		3205.26	119.46	4874.28	1669.02	2.13	4.08	502.23				36.13	1.67			838.84
40.00	6.15	11.80		0.18	0.43	6.02	11.33		3269.37	119.73	4994.02	1724.65	1.19	5.40	384.29	1.23	2.75	4.71		1.89	1312.45	930.89	726.94
41.00	7.05	12.00		0.18	0.43	6.96	11.53		3333.47	119.94	5113.97	1780.50	0.85	6.29	331.02	1.36	3.20	5.97		2.03	1640.23	1119.76	672.72
42.00	7.75	12.00	3.25	0.18	0.43	7.69	11.53	3.38	3397.58	119.63	5233.62	1836.04	0.63	6.90	277.75	1.45	3.51	6.90		2.12	1899.21	1266.85	588.95
43.00	7.55	12.40		0.18	0.43	7.46	11.93		3461.68	120.28	5353.91	1892.23	0.77	6.41	323.41	1.38	3.26	6.15		2.05	1784.24	1212.41	662.55
44.00	6.85	15.00		0.18	0.43	6.60	14.53		3525.78	122.75	5476.67	1950.89	1.61	5.26	574.53					1.88			1081.96
45.00	6.45	13.00		0.18	0.43	6.28	12.53		3589.89	120.85	5597.54	2007.65	1.37	4.74	452.77					1.77			802.67
46.00	6.45	14.60		0.18	0.43	6.20	14.13		3653.99	122.15	5719.70	2065.70	1.78	4.50	574.53					1.74			1001.10
47.00	6.55	14.00		0.18	0.43	6.33	13.53		3718.10	121.70	5841.41	2123.31	1.58	4.48	521.26					1.73			900.62
48.00	5.70	18.80	1.90	0.18	0.43	5.20	18.33	1.43	3782.20	123.58	5964.99	2182.79	3.87	3.24	951.20				34.91	1.52			1447.56
49.00	6.30	19.00	1.15	0.18	0.43	5.82	18.53	1.28	3846.31	124.37	6089.37	2243.07	3.19	3.70	920.76				35.62	1.64			1507.67
50.00	5.15	20.40		0.18	0.43	5.59	19.93		3910.41	124.70	6214.09	2303.68	3.85	3.37	1038.71				35.12	1.56			1616.21
51.00	8.95	24.60		0.18	0.43	8.32	24.13		3974.52	128.78	6342.88	2368.36	2.46	5.66	1145.25				37.80	1.99			2274.27
52.00	6.45	20.80		0.18	0.43	5.89	20.33		4038.62	125.13	6468.02	2429.39	3.65	3.40	1046.32				35.16	1.56			1635.11
53.00	6.95	21.60		0.18	0.43	6.37	21.13		4102.72	125.95	6593.97	2491.25	3.35	3.70	1069.15				35.61	1.64			1748.44
54.00	7.10	22.20		0.18	0.43	6.50	21.73		4166.83	126.28	6720.27	2553.44	3.38	3.68	1103.39				35.60	1.63			1801.63

CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.84501
Client:	Schnabel Engineering	Longitude:	-75.47295
Sounding ID:	D-4	Elevation (ft):	
Date:	21-Jun-2018	Ground Water Depth (ft):	-11.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

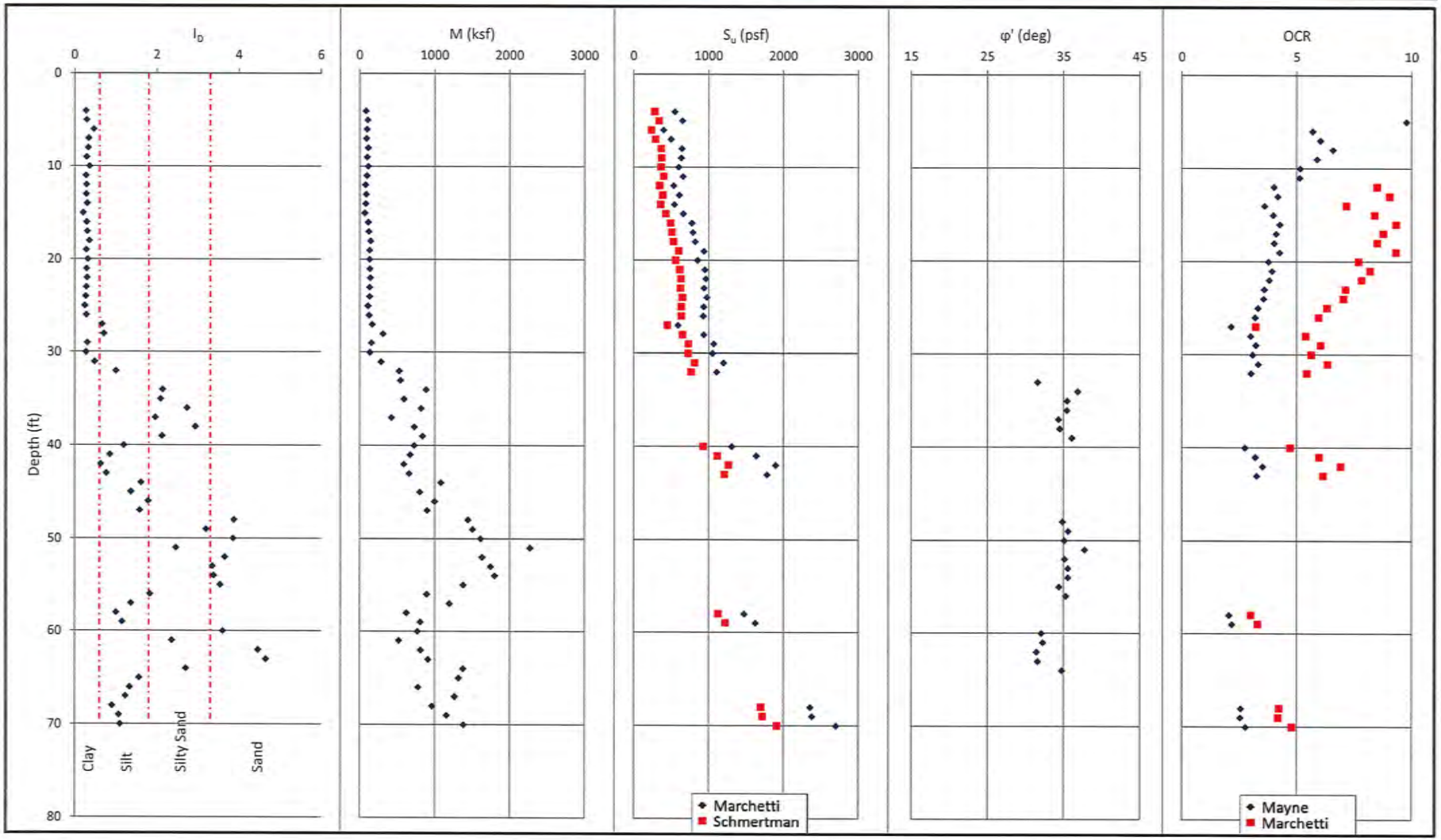
Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_o	OCR[3]	OCR[4]	φ[5] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
55.00	6.25	19.40		0.18	0.43	5.75	18.93		4230.93	124.18	6844.46	2613.52	3.54	2.97	955.01				34.44	1.45			1381.63
56.00	6.80	15.20	1.05	0.18	0.43	6.54	14.73	1.18	4295.04	122.39	6966.86	2671.82	1.83	3.50	593.55				35.32	1.51			895.22
57.00	9.00	18.20		0.18	0.43	8.70	17.73		4359.14	125.41	7092.28	2733.13	1.37	5.05	654.43					1.83			1200.07
58.00	7.65	13.40		0.18	0.43	7.52	12.93		4423.25	121.00	7213.29	2790.04	1.00	4.04	391.89	0.99	2.06	3.00		1.60	1479.08	1127.74	625.17
59.00	8.20	15.20		0.18	0.43	8.01	14.73		4487.35	122.82	7336.12	2848.77	1.15	4.29	487.01	1.04	2.19	3.29		1.66	1628.61	1223.14	810.20
60.00	5.25	15.20		0.18	0.43	4.91	14.73		4551.46	120.48	7456.62	2905.16	3.60	1.96	711.50				32.09	1.09			772.06
61.00	5.30	12.40		0.18	0.43	5.10	11.93		4615.56	118.65	7575.28	2959.72	2.36	2.04	494.62				32.32	1.05			520.78
62.00	5.20	16.60		0.18	0.43	4.79	16.13		4679.66	120.93	7696.22	3016.56	4.46	1.76	821.84				31.46	0.99			815.12
63.00	5.40	17.80	1.15	0.18	0.43	4.94	17.33	1.28	4743.77	121.75	7817.98	3074.21	4.65	1.81	897.93				31.62	1.02			911.57
64.00	7.55	20.40		0.18	0.43	7.06	19.93		4807.87	125.57	7943.56	3135.69	2.70	3.17	932.18				34.79	1.48			1379.64
65.00	9.50	20.20		0.18	0.43	9.12	19.73		4871.98	126.59	8070.16	3198.18	1.56	4.43	768.57					1.72			1319.70
66.00	8.05	15.60		0.18	0.43	7.83	15.13		4936.08	122.90	8193.07	3256.99	1.34	3.50	528.87					1.48			780.28
67.00	10.60	20.40		0.18	0.43	10.27	19.93		5000.19	126.94	8320.02	3319.83	1.23	4.95	700.08					1.81			1265.99
68.00	10.80	18.40		0.18	0.43	10.58	17.93		5064.29	125.43	8445.46	3381.17	0.90	5.03	532.67	1.17	2.56	4.22		1.81	2358.49	1702.21	964.18
69.00	11.00	20.00		0.18	0.43	10.71	19.53		5128.40	126.66	8572.12	3443.73	1.07	5.00	639.21	1.16	2.55	4.18		1.81	2383.51	1722.95	1157.85
70.00	12.00	22.20	1.90	0.18	0.43	11.65	21.73	2.03	5192.50	128.17	8700.31	3507.81	1.10	5.45	730.52	1.23	2.78	4.78		1.90	2703.83	1912.86	1386.72

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-4
Date:	21-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.84501
Longitude:	-75.47295
Elevation (ft):	
Ground Water Depth (ft):	-11.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

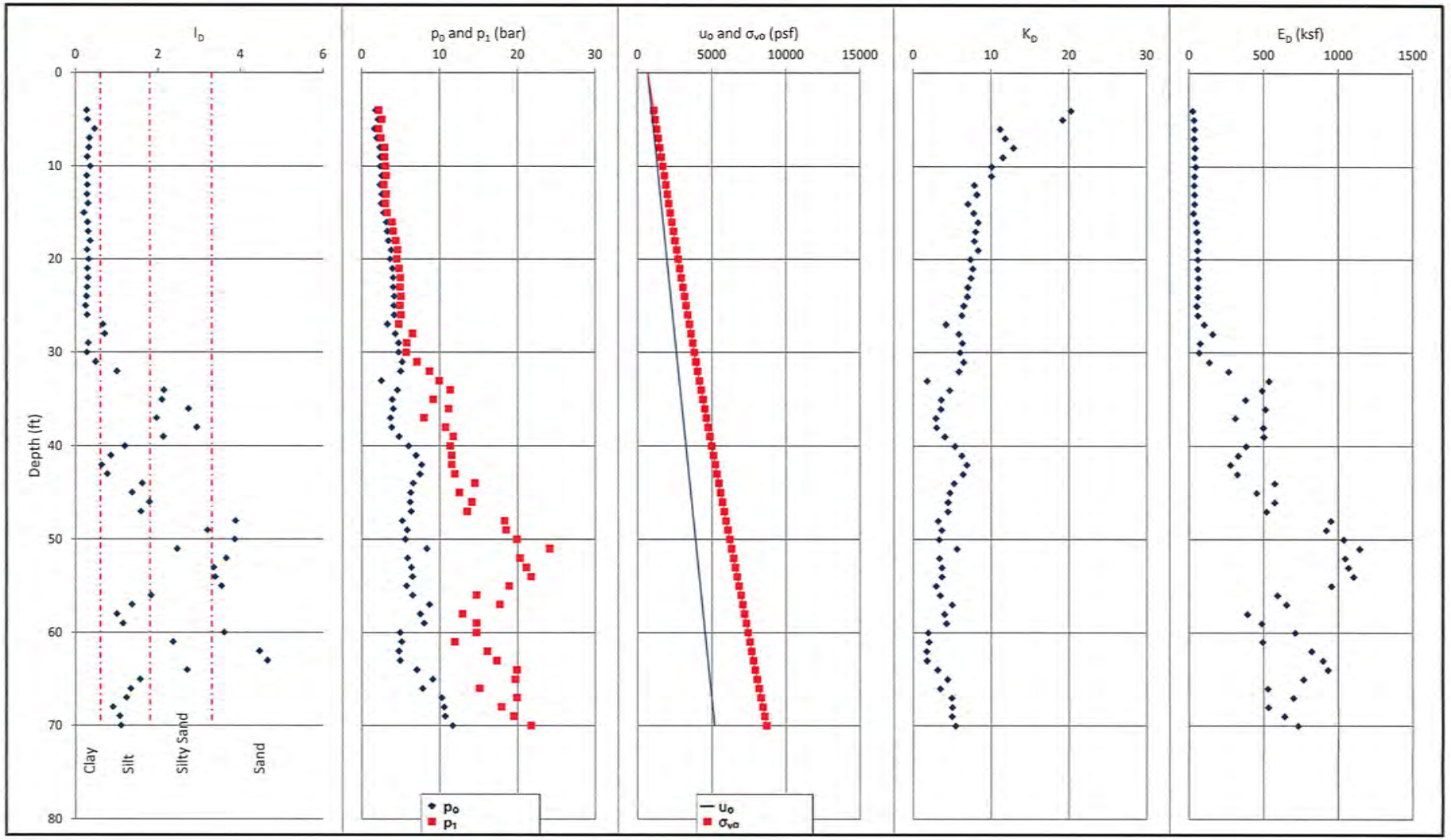


CONETEC

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-4
Date:	21-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.84501
Longitude:	-75.47295
Elevation (ft):	
Ground Water Depth (ft):	-11.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Lon
Project:	Wallops Island Break Waters	Latitude:	37.84927
Client:	Schnabel Engineering	Longitude:	-75.46851
Sounding ID:	D-5	Elevation (ft):	
Date:	21-Jun-2018	Ground Water Depth (ft):	-7.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_t[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	OCR[4]	φ[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
5.00	1.20	6.25		0.15	0.38	1.07	5.83		769.34	108.59	991.81	222.48	6.74	6.62	344.33				38.57	2.14			737.56
6.00	1.95	7.00		0.15	0.38	1.82	6.58		833.44	112.48	1104.30	270.86	3.33	10.99	344.33				40.92	2.59			891.48
7.00	1.10	5.00	0.10	0.15	0.38	1.03	4.58	0.20	897.55	106.16	1210.47	312.92	5.89	4.01	256.82				36.05	1.71			438.47
8.00	1.40	5.90		0.15	0.38	1.30	5.48		961.65	108.84	1319.32	357.67	4.96	4.91	302.48				37.09	1.88			569.31
9.00	1.85	6.85		0.15	0.38	1.73	6.43		1025.75	111.61	1430.94	405.19	3.80	6.37	340.53				38.38	2.11			717.77
10.00	2.60	3.70		0.15	0.38	2.67	3.28		1089.86	103.56	1534.51	444.65	0.28	10.10	43.76	1.85	5.14	12.50		2.51	740.18	448.92	109.78
11.00	2.45	3.55		0.15	0.38	2.52	3.13		1153.96	103.11	1637.62	483.66	0.31	8.50	43.76	1.66	4.33	9.56		2.33	649.44	411.18	102.11
12.00	2.50	3.75		0.15	0.38	2.56	3.33		1218.07	104.34	1741.97	523.90	0.38	7.90	55.17	1.58	4.02	8.52		2.26	641.36	413.64	124.56
13.00	2.60	3.85		0.15	0.38	2.66	3.43		1282.17	104.52	1846.50	564.33	0.37	7.59	55.17	1.54	3.86	8.00		2.22	657.22	428.12	122.30
14.00	2.70	3.85		0.15	0.38	2.77	3.43		1346.28	103.93	1950.44	604.16	0.31	7.34	47.56	1.51	3.74	7.61		2.18	675.51	443.64	103.85
15.00	3.00	4.35	2.05	0.15	0.38	3.05	3.93	2.15	1410.38	105.99	2056.44	646.06	0.36	7.71	62.78	1.56	3.92	8.20		2.23	767.15	497.80	140.17
16.00	2.80	4.10		0.15	0.38	2.85	3.68		1474.49	105.13	2161.58	687.09	0.38	6.55	58.97	1.40	3.33	6.37		2.07	666.13	450.14	121.87
17.00	3.05	4.30		0.15	0.38	3.11	3.88		1538.59	105.30	2266.88	728.29	0.32	6.82	55.17	1.44	3.47	6.77		2.11	742.02	496.46	116.26
18.00	2.60	3.95		0.15	0.38	2.66	3.53		1602.69	104.77	2371.67	768.97	0.46	5.14	62.78	1.18	2.61	4.36		1.82	550.09	395.02	114.09
19.00	3.15	4.40		0.15	0.38	3.21	3.98		1666.80	105.38	2477.05	810.26	0.32	6.23	55.17	1.35	3.17	5.88		2.01	737.20	504.53	111.14
20.00	3.10	4.50		0.15	0.38	3.16	4.08		1730.90	106.18	2583.24	852.34	0.39	5.70	66.58	1.27	2.90	5.13		1.92	694.86	486.11	128.14
21.00	4.40	8.85		0.15	0.38	4.30	8.43		1795.01	116.72	2699.97	904.96	1.20	7.95	298.68	1.59	4.05	8.61		2.27	1117.27	719.36	579.09
22.00	3.15	6.15	0.15	0.15	0.38	3.13	5.73	0.25	1859.11	111.62	2811.60	952.49	1.16	4.90	188.34	1.14	2.50	4.05		1.80	642.82	467.02	338.18
23.00	2.90	9.30		0.15	0.38	2.71	8.88		1923.22	115.25	2926.86	1003.64	3.46	3.72	447.06				35.64	1.64			733.19
24.00	3.60	9.55		0.15	0.38	3.43	9.13		1987.32	116.68	3043.55	1056.23	2.30	4.90	412.82				37.07	1.85			762.70
25.00	2.90	8.55		0.15	0.38	2.74	8.13		2051.43	114.39	3157.94	1106.52	3.05	3.32	389.99				35.05	1.54			601.97
26.00	2.85	7.65		0.15	0.38	2.74	7.23		2115.53	113.23	3271.18	1155.65	2.60	3.11	325.31				34.69	1.46			473.89
27.00	2.60	4.50		0.15	0.38	2.63	4.08		2179.63	106.55	3377.74	1198.10	0.91	2.77	104.63	0.73	1.41	1.66		1.21	395.60	331.58	126.53
28.00	2.45	5.45	0.35	0.15	0.38	2.43	5.03	0.45	2243.74	108.85	3486.59	1242.85	1.92	2.27	188.34				32.94	1.11			208.81
29.00	3.50	5.90		0.15	0.38	3.51	5.48		2307.84	110.47	3597.08	1289.23	0.82	3.89	142.68	0.96	1.98	2.82		1.55	651.48	501.51	220.56
30.00	4.05	7.65		0.15	0.38	4.00	7.23		2371.95	114.24	3711.32	1339.38	1.13	4.46	234.00	1.07	2.27	3.49		1.70	803.11	597.44	397.88
31.00	4.20	5.65		0.15	0.38	4.25	5.23		2436.05	107.99	3819.32	1383.27	0.31	4.66	70.39	1.10	2.37	3.74		1.72	876.39	644.81	120.91
32.00	3.75	4.85		0.15	0.38	3.82	4.43		2500.16	104.60	3923.93	1423.77	0.23	3.85	43.76	0.96	1.96	2.78		1.52	710.10	548.07	66.58
34.00	3.85	4.80		0.15	0.38	3.93	4.38		2628.37	103.12	4130.18	1501.82	0.17	3.71	32.34	0.93	1.89	2.63		1.48	716.11	557.70	48.02
35.00	4.35	5.70	3.05	0.15	0.38	4.41	5.28	3.15	2692.47	107.43	4237.62	1545.15	0.28	4.22	62.78	1.03	2.15	3.20		1.61	863.61	651.54	101.38
36.00	4.10	5.55		0.15	0.38	4.15	5.13		2756.57	107.53	4345.16	1588.58	0.34	3.73	70.39	0.93	1.90	2.64		1.49	760.62	591.87	104.74
37.00	3.75	6.50		0.15	0.38	3.74	6.08		2820.68	111.39	4456.56	1635.88	0.98	3.05	169.31	0.80	1.55	1.93		1.31	609.66	498.79	222.12
38.00	4.20	6.80		0.15	0.38	4.20	6.38		2884.78	111.92	4568.49	1683.71	0.77	3.49	157.90	0.89	1.78	2.39		1.43	743.40	587.93	226.35
39.00	2.30	6.65		0.15	0.38	2.21	6.23		2948.89	108.34	4676.84	1727.95	5.04	0.96	291.07				27.76	0.85			247.41
40.00	5.60	19.80		0.15	0.38	5.02	19.38		3012.99	124.46	4801.31	1788.32	4.02	4.17	1040.61				36.25	1.74			1811.72
41.00	4.70	17.60		0.15	0.38	4.18	17.18		3077.10	122.14	4923.46	1846.36	4.80	3.06	941.69				34.60	1.47			1386.47
42.00	4.20	18.40	1.20	0.15	0.38	3.62	17.98	1.30	3141.20	121.23	5044.70	1903.50	6.80	2.32	1040.61				33.05	1.23			1280.02
43.00	6.15	22.60		0.15	0.38	5.45	22.18		3205.30	126.00	5170.71	1965.41	4.27	4.16	1211.83				36.24	1.74			2107.55
44.00	5.55	18.20		0.15	0.38	5.04	17.78		3269.41	123.55	5294.27	2024.86	3.66	3.59	922.66				35.45	1.61			1485.16
45.00	6.20	17.40		0.15	0.38	5.77	16.98		3333.51	123.88	5418.17	2084.65	2.69	4.18	812.33				36.26	1.72			1400.59
46.00	5.80	23.40		0.15	0.38	5.05	22.98		3397.62	125.58	5543.75	2146.13	5.24	3.33	1299.34				35.05	1.54			2006.56
47.00	6.15	24.20		0.15	0.38	5.37	23.78		3461.72	126.26	5670.03	2208.30	4.95	3.51	1333.58				35.34	1.59			2122.78
48.00	4.75	16.00		0.15	0.38	4.31	15.58		3525.83	121.08	5791.12	2265.29	4.29	2.42	816.13				33.30	1.27			1034.76
48.50	4.00	17.40	0.85	0.15	0.38	3.46	16.98	0.95	3557.88	119.75	5850.99	2293.12	7.71	1.60	979.74				30.88	0.91			887.90
50.00	5.15	17.40		0.15	0.38	4.66	16.98		3654.04	122.26	6034.39	2380.36	4.22	2.56	892.23				33.60	1.32			1173.67
51.00	8.55	25.00		0.15	0.38	7.85	24.58		3718.14	128.79	6163.19	2445.05	2.75	5.19	1211.83				37.37	1.92			2326.03
52.00	4.25	16.20		0.15	0.38	3.78	15.78		3782.24	119.72	6282.92	2500.68	6.10	1.64	869.40				31.05	0.93			809.87
53.00	6.85	21.60		0.15	0.38	6.24	21.18		3846.35	126.01	6408.94	2562.60	3.40	3.58	1082.47				35.45	1.61			1741.32
54.00	5.95	24.20		0.15	0.38	5.16	23.78		3910.45	125.57	6534.53	2624.07	5.65	2.62	1348.80				33.74	1.34			1802.68
55.00	8.30	22.20		0.15	0.38	7.73	21.78		3974.56	127.40	6661.94	2687.38	2.41	4.53	1017.79				36.67	1.78			1813.33
56.00	6.55	25.60		0.15	0.38	5.72	25.18		4038.66	126.74	6788.69	2750.03	5.13	2.88	1409.68				34.26	1.42			1999.35

CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.84927
Client:	Schnabel Engineering	Longitude:	-75.46851
Sounding ID:	D-5	Elevation (ft):	
Date:	21-Jun-2018	Ground Water Depth (ft):	-7.0
Job Location:	Walloos Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

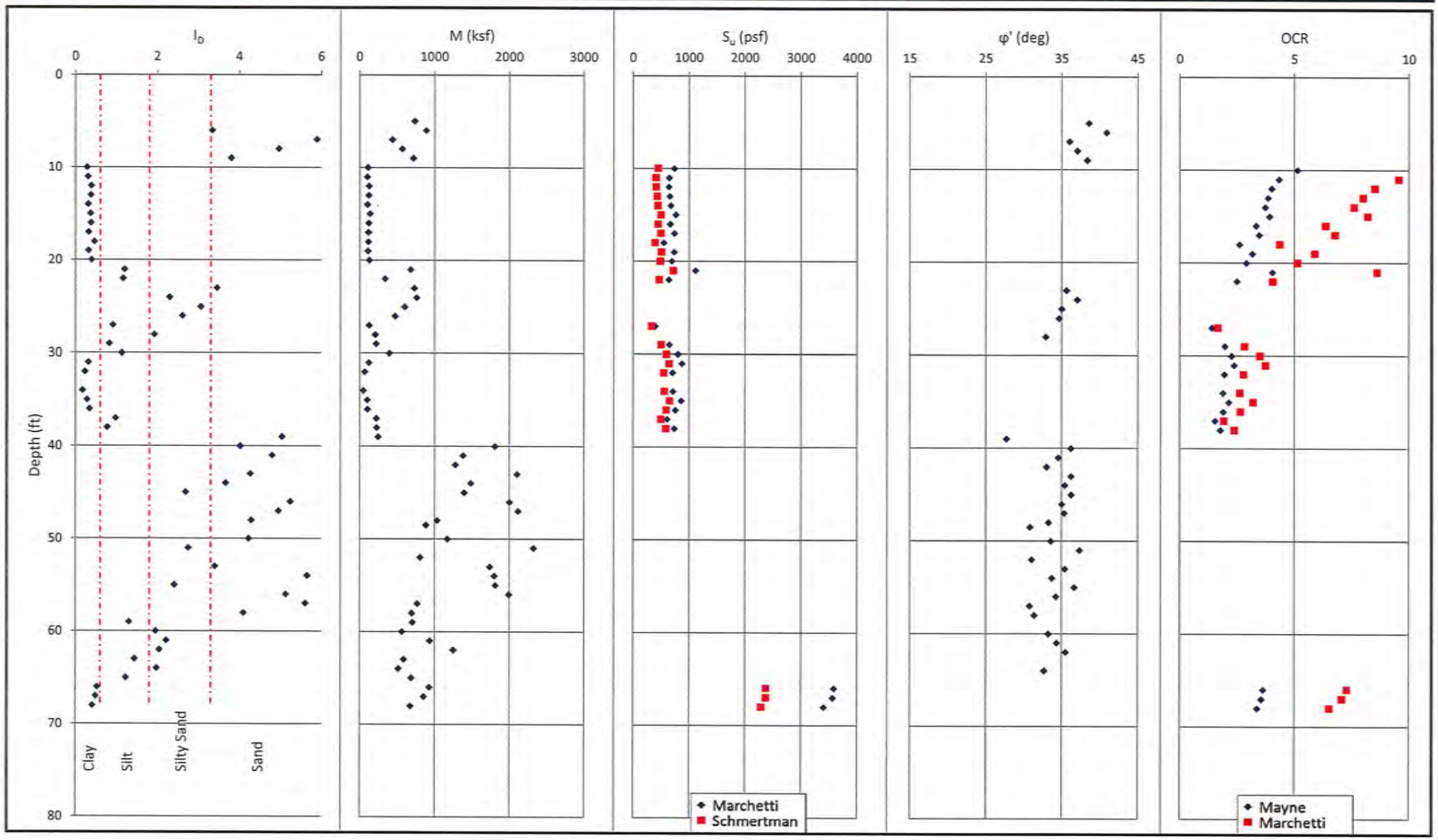
Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_t[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	OCR[4]	φ[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
57.00	4.55	16.40	1.65	0.15	0.38	4.08	15.98	1.75	4102.77	120.12	6908.82	2806.05	5.61	1.58	861.79				30.81	0.90			
58.00	4.75	14.60		0.15	0.38	4.38	14.18		4166.87	119.67	7028.49	2861.62	4.10	1.74	709.60				31.40	0.98			
59.00	7.25	14.00		0.15	0.38	7.04	13.58		4230.98	121.70	7150.21	2919.23	1.30	3.59	473.70					1.50			708.67
60.00	5.70	12.60		0.15	0.38	5.48	12.18		4295.08	119.55	7269.77	2974.69	1.95	2.40	485.11				33.26	1.16			565.15
61.00	6.70	16.20		0.15	0.38	6.35	15.78		4359.18	122.95	7392.73	3033.54	2.21	2.94	682.96				34.37	1.37			937.27
62.00	7.95	19.00		0.15	0.38	7.52	18.58		4423.29	125.41	7518.15	3094.86	2.04	3.65	800.91				35.54	1.56			1250.51
63.00	6.70	13.20		0.15	0.38	6.50	12.78		4487.39	120.60	7638.76	3151.37	1.44	2.88	454.67					1.29			588.34
64.00	5.75	12.60	1.50	0.15	0.38	5.53	12.18	1.60	4551.50	119.38	7758.15	3206.65	1.98	2.18	481.31				32.71	1.08			518.73
65.00	7.80	14.60		0.15	0.38	7.59	14.18		4615.60	122.18	7880.34	3264.74	1.23	3.44	477.50					1.45			692.18
66.00	13.80	20.00		0.15	0.38	13.62	19.58		4679.71	126.21	8006.56	3326.85	0.52	7.14	431.85	1.48	3.63	7.28		2.15	3592.52	2375.84	930.60
67.00	13.80	19.60		0.15	0.38	13.64	19.18		4743.81	125.74	8132.31	3388.50	0.49	7.00	401.41	1.46	3.57	7.07		2.14	3571.86	2373.61	857.06
68.00	13.40	18.20		0.15	0.38	13.29	17.78		4807.92	124.22	8256.54	3448.62	0.41	6.65	325.31	1.41	3.39	6.52		2.08	3407.92	2294.10	677.36

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-5
Date:	21-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.84927
Longitude:	-75.46851
Elevation (ft):	
Ground Water Depth (ft):	-7.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

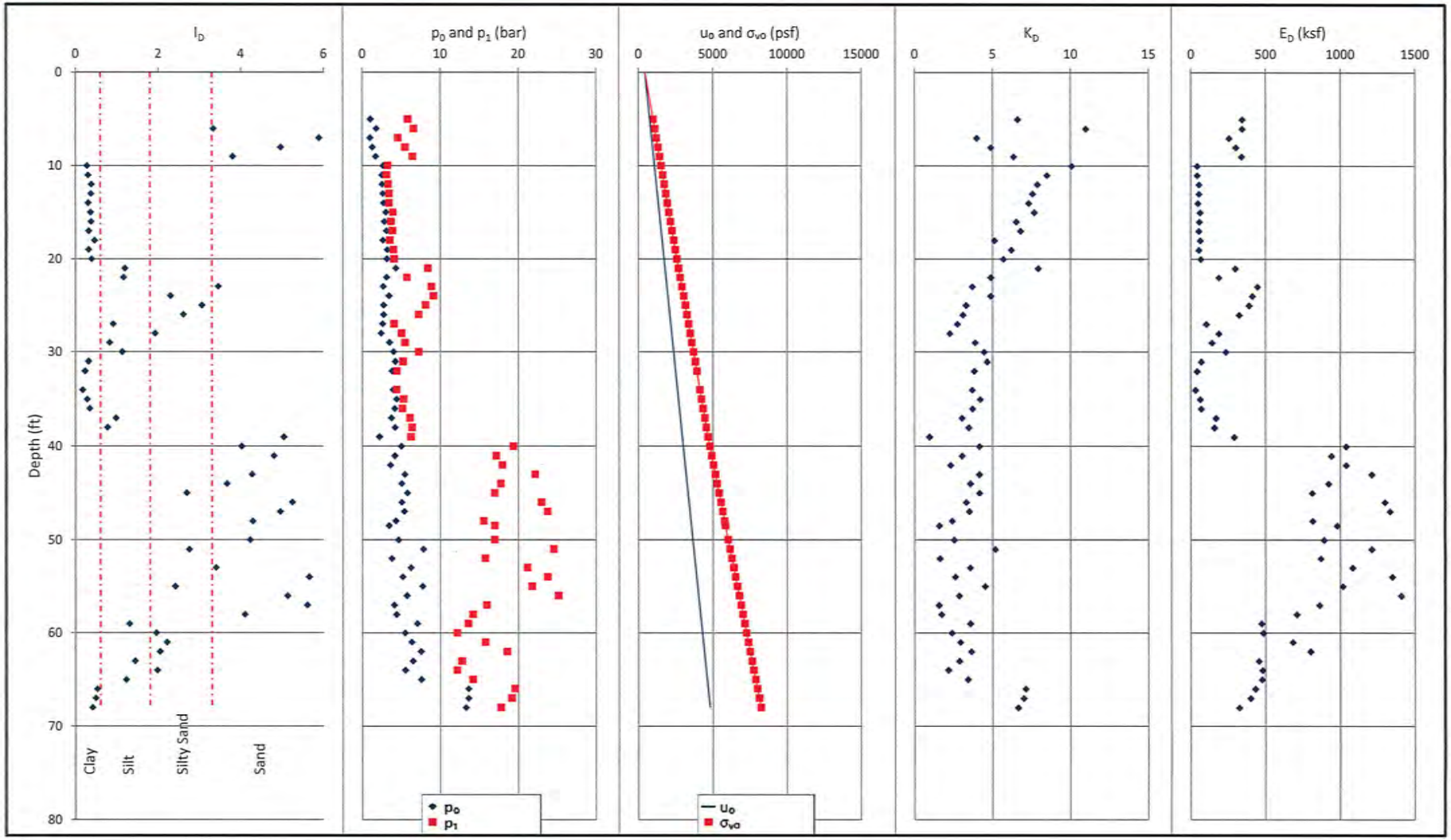


CONETEC

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-5
Date:	21-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.84927
Longitude:	-75.46851
Elevation (ft):	
Ground Water Depth (ft):	-7.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.85218
Client:	Schnabel Engineering	Longitude:	-75.46472
Sounding ID:	D-6	Elevation (ft):	
Date:	24-Jun-2018	Ground Water Depth (ft):	-7.5
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ'_{vo}[2] (psf)	I_D	K_D	E_D (ksf)	K_D	OCR[3]	OCR[4]	φ[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
2.00	0.40	1.85		0.18	0.33	0.48	1.48		608.99	93.96	668.72	59.73	5.37	6.50	72.29				38.48	2.13			153.69
3.00	2.90	11.60		0.18	0.33	2.62	11.23		673.10	118.66	787.39	114.29	3.76	41.90	623.99				46.16	3.86			2406.32
4.00	3.50	11.40		0.18	0.33	3.26	11.03		737.20	119.45	906.85	169.65	2.68	35.73	563.11				45.61	3.71			2086.63
5.00	1.75	6.15		0.18	0.33	1.68	5.78		801.31	111.12	1017.97	216.67	3.16	12.50	296.77				41.49	2.71			804.54
6.00	1.30	3.70		0.18	0.33	1.33	3.33		865.41	105.35	1123.33	257.92	2.18	7.41	144.58				39.11	2.22			321.58
7.00	1.30	5.75	0.15	0.18	0.33	1.23	5.38	0.28	929.51	108.42	1231.75	302.24	5.30	5.41	300.58				37.57	1.97			590.91
8.00	1.85	7.30		0.18	0.33	1.73	6.93		993.62	112.25	1344.01	350.40	4.15	7.46	376.68				39.14	2.25			845.87
9.00	1.75	6.05		0.18	0.33	1.69	5.68		1057.72	110.45	1454.47	396.75	3.39	6.20	289.17				38.25	2.09			603.02
10.25	2.25	6.80		0.18	0.33	2.17	6.43		1137.85	112.60	1595.23	457.38	2.61	7.43	308.19				39.12	2.23			688.74
11.00	2.60	3.70		0.18	0.33	2.70	3.33		1185.93	103.73	1673.03	487.10	0.30	9.12	45.66	1.74	4.64	10.67		2.41	714.15	444.27	109.84
12.00	2.80	3.90		0.18	0.33	2.90	3.53		1250.04	104.12	1777.17	527.13	0.27	9.10	45.66	1.73	4.63	10.63		2.40	770.53	479.63	109.73
13.00	2.95	4.30		0.18	0.33	3.03	3.93		1314.14	106.19	1883.37	569.23	0.37	8.82	64.68	1.70	4.49	10.12		2.37	800.06	501.94	153.36
14.00	2.60	3.65	1.70	0.18	0.33	2.70	3.28	1.83	1378.24	103.05	1986.43	608.19	0.28	7.00	41.85	1.46	3.56	7.05		2.13	640.22	425.56	89.31
15.00	2.40	3.35		0.18	0.33	2.50	2.98		1442.35	101.43	2087.87	645.52	0.26	5.86	34.24	1.30	2.98	5.35		1.95	544.67	378.42	66.86
16.00	2.90	4.05		0.18	0.33	2.99	3.68		1506.45	104.48	2192.36	685.91	0.30	6.92	49.46	1.45	3.52	6.93		2.12	711.53	474.35	104.96
17.00	2.90	3.95		0.18	0.33	3.00	3.58		1570.56	103.56	2295.92	725.37	0.26	6.47	41.85	1.39	3.29	6.24		2.05	691.74	468.99	85.92
18.00	3.25	4.40		0.18	0.33	3.34	4.03		1634.66	105.11	2401.04	766.38	0.27	6.98	49.46	1.46	3.55	7.02		2.13	803.69	534.63	105.40
19.00	3.15	4.30		0.18	0.33	3.24	3.93		1698.77	104.84	2505.89	807.12	0.28	6.29	49.46	1.36	3.20	5.97		2.02	743.05	507.33	100.12
20.00	3.05	3.95		0.18	0.33	3.16	3.58		1762.87	102.07	2607.96	845.09	0.18	5.71	30.44	1.27	2.91	5.14		1.93	690.16	482.65	58.62
21.00	3.25	4.90	1.35	0.18	0.33	3.32	4.53	1.48	1826.98	107.90	2715.87	888.90	0.49	5.74	87.51	1.28	2.92	5.18		1.93	730.42	510.18	168.98
22.00	5.75	9.50		0.18	0.33	5.71	9.13		1891.08	117.57	2833.45	942.37	0.71	10.65	247.31	1.91	5.42	13.59		2.56	1677.77	1003.97	633.11
23.00	5.35	9.05		0.18	0.33	5.32	8.68		1955.18	116.93	2950.38	995.20	0.77	9.19	243.51	1.74	4.68	10.79		2.41	1472.86	914.54	587.90
24.00	4.50	7.55		0.18	0.33	4.50	7.18		2019.29	114.37	3064.76	1045.47	0.76	7.05	194.04	1.47	3.59	7.14		2.15	1111.56	737.39	416.38
25.00	3.65	5.35		0.18	0.33	3.72	4.98		2083.39	108.71	3173.48	1090.09	0.46	5.21	91.32	1.19	2.65	4.45		1.83	793.01	567.55	167.20
26.00	3.70	5.15		0.18	0.33	3.78	4.78		2147.50	107.51	3280.99	1133.50	0.36	5.07	72.29	1.17	2.58	4.26		1.80	796.81	574.20	130.34
27.00	4.15	5.85		0.18	0.33	4.22	5.48		2211.60	109.52	3390.53	1178.93	0.40	5.59	91.32	1.26	2.85	4.97		1.90	937.57	659.16	173.87
28.00	3.75	5.40	2.60	0.18	0.33	3.82	5.03	2.73	2275.71	108.50	3499.03	1223.33	0.44	4.66	87.51	1.10	2.37	3.74		1.72	774.17	569.73	150.24
29.00	3.60	4.95		0.18	0.33	3.68	4.58		2339.81	106.54	3605.58	1265.77	0.35	4.23	64.68	1.03	2.15	3.21		1.62	709.77	535.12	104.63
30.00	4.15	6.15		0.18	0.33	4.20	5.78		2403.92	110.56	3716.15	1312.23	0.52	4.85	114.14	1.14	2.47	3.99		1.76	874.25	636.80	200.77
31.00	4.00	5.55		0.18	0.33	4.07	5.18		2468.02	108.32	3824.47	1356.45	0.38	4.45	79.90	1.07	2.27	3.48		1.67	811.17	603.76	133.46
32.00	3.55	5.00		0.18	0.33	3.63	4.63		2532.12	106.81	3931.30	1399.17	0.41	3.61	72.29	0.91	1.83	2.51		1.45	642.90	504.41	105.13
33.00	3.50	7.10		0.18	0.33	3.47	6.73		2596.23	112.86	4044.17	1447.94	1.46	3.21	235.90					1.40			330.21
34.00	3.45	8.00		0.18	0.33	3.37	7.63		2660.33	114.04	4158.22	1497.88	2.03	2.93	308.19				34.35	1.35			417.50
35.00	4.65	14.40	0.95	0.18	0.33	4.31	14.03	1.08	2724.44	121.01	4279.23	1554.80	3.23	4.04	703.89				36.08	1.71			1205.69
36.00	5.15	14.80		0.18	0.33	4.82	14.43		2788.54	121.83	4401.07	1612.53	2.76	4.51	696.28				36.65	1.80			1250.45
37.00	3.60	10.40		0.18	0.33	3.41	10.03		2852.65	116.44	4517.52	1664.87	3.24	2.56	479.41				33.62	1.32			631.83
38.00	7.10	21.20		0.18	0.33	6.55	20.83		2916.75	126.72	4644.25	1727.50	2.77	6.22	1034.91				38.27	2.08			2153.86
39.00	6.75	19.40		0.18	0.33	6.27	19.03		2980.86	125.62	4769.88	1789.03	2.64	5.65	924.57				37.79	1.99			1840.48
40.00	6.20	21.00		0.18	0.33	5.61	20.63		3044.96	125.68	4895.58	1850.62	3.62	4.69	1088.17				36.85	1.84			2003.96
41.00	5.25	19.40		0.18	0.33	4.69	19.03		3109.06	123.77	5019.36	1910.30	4.47	3.50	1038.71				35.33	1.59			1650.34
42.00	5.75	21.40	1.05	0.18	0.33	5.12	21.03	1.18	3173.17	125.15	5144.52	1971.35	4.42	3.81	1152.86				35.78	1.66			1916.42
43.00	4.40	16.00		0.18	0.33	3.97	15.63		3237.27	120.79	5265.32	2028.05	4.82	2.49	844.67				33.46	1.29			1092.29
44.00	7.75	19.20		0.18	0.33	7.33	18.83		3301.38	126.05	5391.38	2090.00	2.00	5.74	833.25				37.87	1.98			1651.62
45.00	5.60	18.40		0.18	0.33	5.11	18.03		3365.48	123.68	5515.06	2149.58	3.69	3.40	935.98				35.17	1.56			1462.72
46.00	4.90	16.40		0.18	0.33	4.48	16.03		3429.59	121.70	5636.77	2207.18	4.08	2.68	837.06				33.87	1.36			1135.45
47.00	3.80	16.00		0.18	0.33	3.34	15.63		3493.69	118.88	5755.66	2261.96	7.37	1.54	890.32				30.66	0.87			778.76
48.00	5.05	18.60		0.18	0.33	4.52	18.23		3557.79	122.71	5878.37	2320.58	4.86	2.54	993.05				33.56	1.31			1299.60
49.00	4.35	14.80	1.25	0.18	0.33	3.98	14.43	1.38	3621.90	119.68	5998.07	2376.17	4.66	1.97	757.16				32.12	1.09			825.09
50.00	5.60	19.60		0.18	0.33	5.05	19.23		3686.00	123.86	6121.94	2435.93	4.31	2.82	1027.30				34.14	1.40			1437.66
51.00	4.90	18.20		0.18	0.33	4.39	17.83		3750.11	122.07	6244.02	2493.91	5.19	2.17	974.03				32.67	1.17			1141.89
52.00	4.60	15.40		0.18	0.33	4.21	15.03		3814.21	120.25	6364.28	2550.07	4.54	1.95	783.79				32.06	1.08			847.36

CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.85218
Client:	Schnabel Engineering	Longitude:	-75.46472
Sounding ID:	D-6	Elevation (ft):	
Date:	24-Jun-2018	Ground Water Depth (ft):	-7.5
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

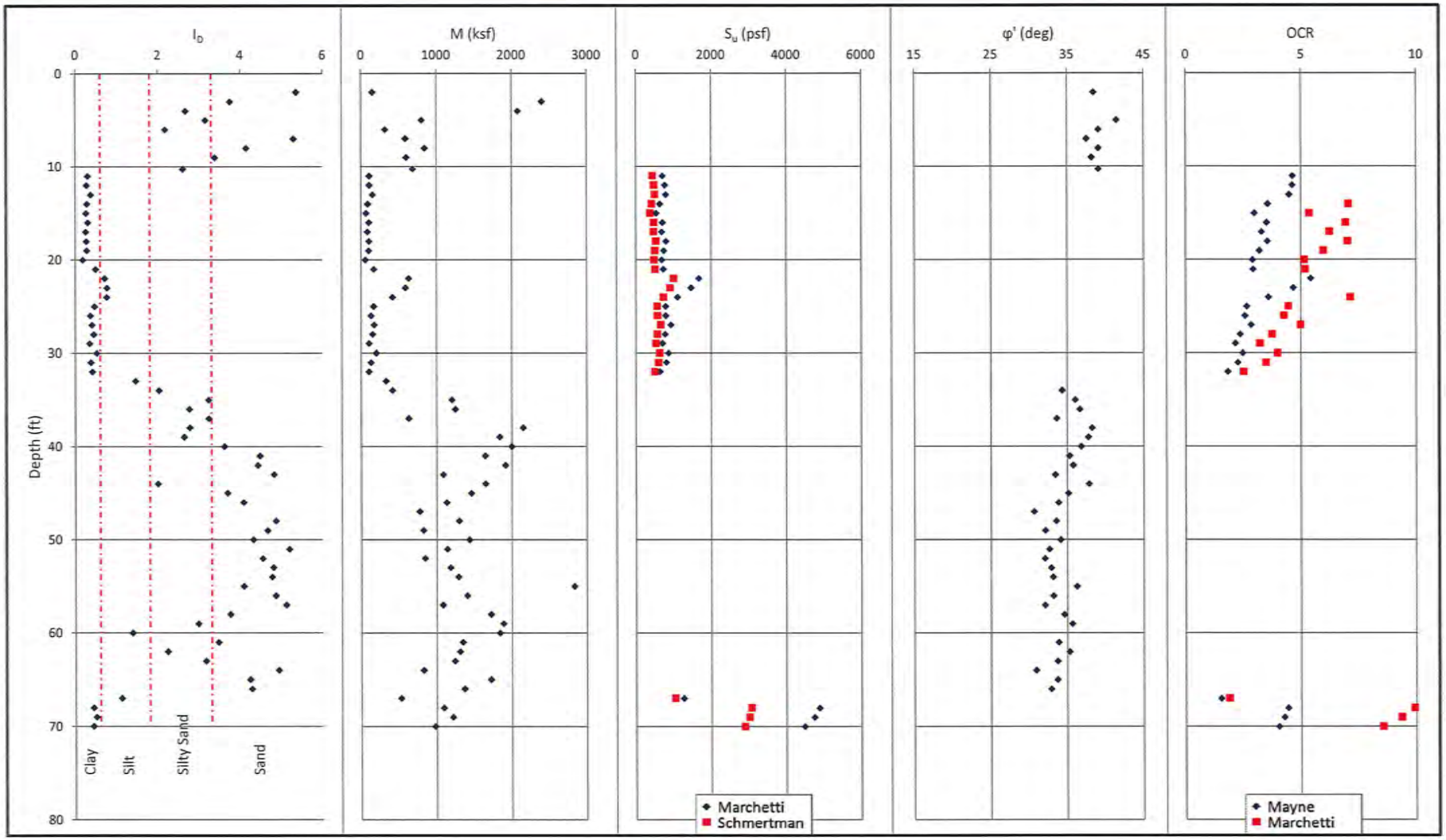
Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[5] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_0	OCR[3]	OCR[4]	φ[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
53.00	5.20	18.60		0.18	0.33	4.68	18.23		3878.32	122.65	6486.94	2608.62	4.80	2.26	981.64				32.91	1.21			1186.12
54.00	5.45	19.60		0.18	0.33	4.89	19.23		3942.42	123.38	6610.33	2667.90	4.77	2.35	1038.71				33.13	1.24			1291.11
55.00	8.35	30.20		0.18	0.33	7.41	29.83		4006.53	130.03	6740.36	2733.84	4.08	4.19	1624.65				36.28	1.75			2835.27
56.00	5.75	21.00	1.50	0.18	0.33	5.14	20.63	1.63	4070.63	124.23	6864.60	2793.97	4.86	2.38	1122.42				33.21	1.25			1407.97
57.00	5.20	18.80		0.18	0.33	4.67	18.43		4134.73	122.45	6987.06	2852.32	5.11	1.97	996.86				32.12	1.09			1085.46
58.00	6.95	22.80		0.18	0.33	6.31	22.43		4198.84	126.34	7113.41	2914.57	3.75	3.08	1168.07				34.63	1.48			1725.11
59.00	8.00	23.60		0.18	0.33	7.37	23.23		4262.94	127.61	7241.03	2978.08	2.98	3.74	1149.05				35.67	1.64			1888.47
60.00	11.60	24.00		0.18	0.33	11.13	23.63		4327.05	129.49	7370.52	3043.48	1.38	5.22	905.54					2.04			1844.44
61.00	6.60	20.20		0.18	0.33	6.07	19.83		4391.15	124.85	7495.38	3104.23	3.47	2.67	996.86				33.84	1.35			1348.56
62.00	7.85	19.60		0.18	0.33	7.41	19.23		4455.26	125.68	7621.07	3165.82	2.24	3.48	856.08				35.30	1.53			1311.07
63.00	6.70	19.40	1.40	0.18	0.33	6.22	19.03	1.53	4519.36	124.53	7745.62	3225.26	3.16	2.62	928.37				33.75	1.34			1241.64
64.00	5.20	17.60		0.18	0.33	4.73	17.23		4583.47	121.50	7867.13	3283.66	4.93	1.61	905.54				30.94	0.92			828.64
65.00	7.15	24.60		0.18	0.33	6.43	24.23		4647.57	126.83	7993.97	3346.40	4.24	2.62	1289.83				33.75	1.34			1725.13
66.00	6.55	22.00		0.18	0.33	5.93	21.63		4711.67	125.19	8119.17	3407.49	4.28	2.25	1137.64				32.88	1.20			1370.30
67.00	7.40	13.20		0.18	0.33	7.26	12.83		4775.78	120.68	8239.86	3464.08	1.12	3.00	403.31	0.78	1.53	1.88		1.31	1264.31	1038.70	526.81
68.00	17.20	23.80		0.18	0.33	17.02	23.43		4839.88	128.30	8368.17	3528.29	0.44	8.70	464.19	1.68	4.43	9.91		2.36	4878.58	3070.71	1094.38
69.00	17.00	24.40		0.18	0.33	16.78	24.03		4903.99	128.97	8497.15	3593.16	0.50	8.39	525.06	1.65	4.27	9.36		2.32	4744.90	3014.18	1218.10
70.00	16.40	22.60	9.60	0.18	0.33	16.24	22.23	9.73	4968.09	127.49	8624.65	3656.56	0.43	7.92	433.75	1.59	4.03	8.55		2.26	4491.85	2894.99	980.54

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-6
Date:	24-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.85218
Longitude:	-75.46472
Elevation (ft):	
Ground Water Depth (ft):	-7.5
Gauge Zero Offset (bar):	0.05

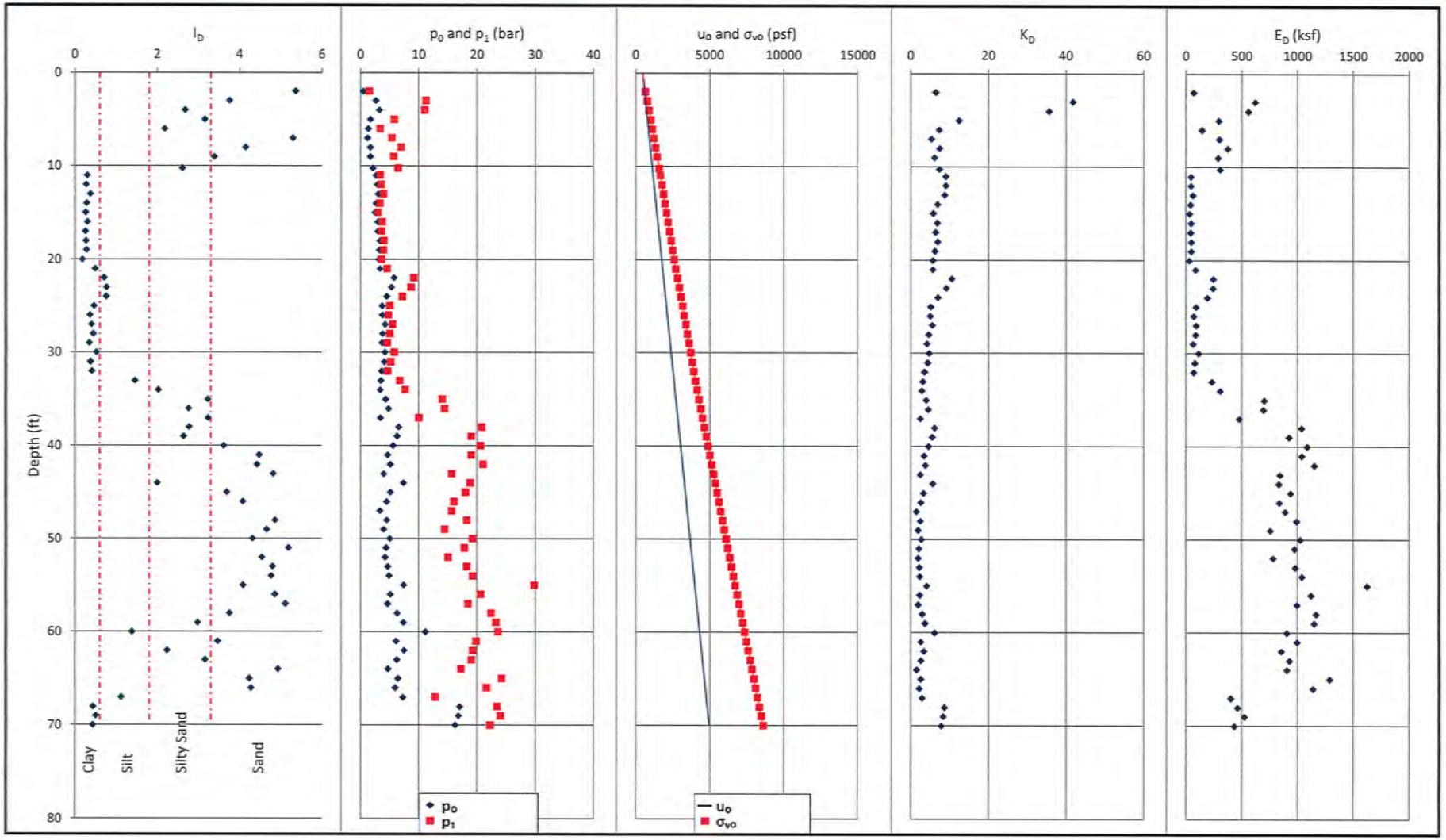
FLAT PLATE DILATOMETER TEST RESULTS



Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-6
Date:	24-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.85218
Longitude:	-75.46472
Elevation (ft):	
Ground Water Depth (ft):	-7.5
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.85585
Client:	Schnabel Engineering	Longitude:	-75.45987
Sounding ID:	D-7	Elevation (ft):	
Date:	24-Jun-2018	Ground Water Depth (ft):	-5.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_o	OCR[3]	OCR[4]	φ[4] (deg)	R_M	s_u[4] (psf)	s_u[3] (psf)	M (ksf)
3.00	0.65	2.10		0.15	0.35	0.70	1.70		512.84	98.28	615.39	102.55	2.18	9.31	72.29				40.17	2.43			175.93
4.00	2.75	11.00		0.15	0.35	2.46	10.60		576.94	118.04	733.44	156.50	3.72	29.18	589.74				44.88	3.51			2072.21
5.00	4.80	15.20		0.15	0.35	4.41	14.80		641.04	123.31	856.76	215.72	2.54	39.68	753.35				45.97	3.80			2866.35
6.00	1.90	5.70		0.15	0.35	1.84	5.30		705.15	110.99	967.76	262.61	2.31	11.91	251.12				41.28	2.67			669.32
7.00	1.50	5.40	0.05	0.15	0.35	1.43	5.00	0.15	769.25	109.26	1077.03	307.78	3.36	7.20	258.73				38.98	2.22			573.13
8.00	1.35	4.10		0.15	0.35	1.34	3.70		833.36	106.37	1183.41	350.05	2.52	5.60	171.22				37.75	1.98			338.67
9.00	1.50	7.10		0.15	0.35	1.35	6.70		897.46	110.67	1294.10	396.63	5.85	4.82	388.09				36.99	1.87			724.19
10.00	2.70	11.20		0.15	0.35	2.40	10.80		961.57	117.53	1411.63	450.06	4.33	9.00	608.77				40.02	2.41			1466.25
11.00	2.10	8.60		0.15	0.35	1.90	8.20		1025.67	114.01	1525.65	499.98	4.47	5.89	456.58				37.99	2.04			931.21
12.00	2.15	8.35		0.15	0.35	1.97	7.95		1089.78	113.86	1639.51	549.74	4.15	5.48	433.75				37.64	1.98			857.97
13.00	2.15	7.20		0.15	0.35	2.02	6.80		1153.88	112.68	1752.21	598.33	3.25	5.13	346.24				37.31	1.92			664.93
14.00	2.60	3.45	1.90	0.15	0.35	2.68	3.05	2.00	1217.98	100.90	1853.12	635.13	0.18	6.90	26.63	1.45	3.51	6.91		2.12	657.39	438.45	56.47
15.00	2.75	3.70		0.15	0.35	2.83	3.30		1282.09	102.45	1955.57	673.49	0.21	6.86	34.24	1.44	3.49	6.85		2.11	692.21	462.33	72.40
16.00	2.55	3.65		0.15	0.35	2.62	3.25		1346.19	103.34	2058.93	712.73	0.32	5.79	45.66	1.29	2.95	5.25		1.94	591.95	412.58	88.56
17.00	2.80	3.80		0.15	0.35	2.88	3.40		1410.30	102.96	2161.89	751.59	0.24	6.11	38.05	1.34	3.11	5.71		2.00	668.20	459.43	75.93
18.00	2.80	3.90		0.15	0.35	2.87	3.50		1474.40	103.82	2265.72	791.31	0.29	5.71	45.66	1.27	2.91	5.14		1.93	646.30	451.97	87.93
19.00	2.70	3.65		0.15	0.35	2.78	3.25		1538.51	102.03	2367.76	829.25	0.23	5.14	34.24	1.18	2.62	4.36		1.82	593.66	426.24	62.25
20.00	4.15	7.20		0.15	0.35	4.12	6.80		1602.61	114.08	2481.84	879.23	0.80	7.97	194.04	1.59	4.06	8.64		2.27	1089.07	700.74	440.55
21.00	3.00	5.85		0.15	0.35	2.98	5.45		1666.71	111.20	2593.06	926.34	1.13	4.93	178.83	1.15	2.51	4.08		1.80	628.68	456.24	321.63
22.00	3.05	6.90	0.00	0.15	0.35	2.98	6.50		1730.82	113.11	2706.18	975.36	1.63	4.61	254.92					1.76			448.37
23.00	2.95	8.60		0.15	0.35	2.79	8.20		1794.92	114.95	2821.13	1026.21	2.80	3.93	391.89				35.94	1.68			657.37
24.00	3.10	10.00		0.15	0.35	2.88	9.60		1859.03	116.37	2937.51	1078.48	3.38	3.85	487.01				35.83	1.67			814.15
25.00	3.35	7.10		0.15	0.35	3.29	6.70		1923.13	113.47	3050.99	1127.86	1.44	4.38	247.31					1.70			420.36
26.00	3.85	8.45		0.15	0.35	3.75	8.05		1987.24	115.75	3166.76	1179.52	1.54	4.95	311.99					1.82			568.35
27.00	3.20	5.00		0.15	0.35	3.24	4.60		2051.34	108.12	3274.89	1223.55	0.61	3.85	98.92	0.96	1.96	2.77		1.52	609.45	470.51	150.45
28.00	2.80	4.85	0.80	0.15	0.35	2.82	4.45	0.90	2115.45	107.89	3382.79	1267.35	0.90	2.98	117.95	0.78	1.52	1.86		1.28	459.41	377.95	151.39
29.00	3.30	5.15		0.15	0.35	3.33	4.75		2179.55	108.42	3491.21	1311.66	0.62	3.64	102.73	0.92	1.86	2.55		1.47	610.96	478.05	150.68
30.00	2.75	3.60		0.15	0.35	2.83	3.20		2243.65	100.01	3591.23	1347.58	0.21	2.72	26.63	0.72	1.39	1.62		1.17	436.41	367.21	31.09
31.00	3.55	6.75		0.15	0.35	3.52	6.35		2307.76	112.53	3703.77	1396.01	1.18	3.61	205.46	0.91	1.84	2.51		1.49	641.57	503.35	306.70
32.00	4.20	5.25		0.15	0.35	4.27	4.85		2371.86	105.30	3809.08	1437.22	0.18	4.56	41.85	1.09	2.32	3.62		1.69	885.47	655.14	70.93
33.00	4.20	5.50		0.15	0.35	4.26	5.10		2435.97	107.22	3916.31	1480.34	0.27	4.36	60.88	1.05	2.22	3.38		1.65	863.85	646.12	100.46
34.00	4.15	5.40		0.15	0.35	4.21	5.00		2500.07	106.74	4023.05	1522.98	0.26	4.14	57.07	1.01	2.10	3.11		1.59	830.73	629.79	91.03
35.00	3.90	5.25		0.15	0.35	3.96	4.85		2564.18	106.87	4129.94	1565.76	0.33	3.64	64.68	0.92	1.85	2.55		1.46	728.48	570.12	94.73
36.00	3.50	5.40	1.85	0.15	0.35	3.53	5.00	1.95	2628.28	108.57	4238.52	1610.23	0.65	2.95	106.53	0.77	1.50	1.83		1.25	574.94	474.43	133.30
37.00	3.75	5.85		0.15	0.35	3.77	5.45		2692.39	109.78	4348.31	1655.92	0.68	3.13	121.75	0.81	1.59	2.01		1.32	637.44	518.14	160.11
38.00	3.40	5.05		0.15	0.35	3.44	4.65		2756.49	107.14	4455.46	1698.97	0.57	2.61	87.51	0.70	1.33	1.51		1.12	521.20	443.33	98.28
39.00	4.00	6.95		0.15	0.35	3.98	6.55		2820.59	112.47	4567.93	1747.34	0.98	3.14	186.44	0.82	1.60	2.02		1.34	675.57	548.66	250.08
40.00	4.45	15.20		0.15	0.35	4.04	14.80		2884.70	120.88	4688.82	1804.12	4.05	3.08	779.98				34.62	1.48			1151.03
41.00	6.20	9.00		0.15	0.35	6.19	8.60		2948.80	115.51	4804.34	1855.54	0.51	5.37	175.02	1.22	2.73	4.67		1.86	1403.86	996.88	326.10
42.00	7.85	11.80	3.75	0.15	0.35	7.78	11.40	3.85	3012.91	119.56	4923.90	1911.00	0.57	6.92	262.53	1.45	3.52	6.94		2.12	1985.18	1323.07	557.40
43.00	9.45	13.40		0.15	0.35	9.38	13.00		3077.01	120.89	5044.80	1967.79	0.46	8.39	262.53	1.65	4.27	9.36		2.32	2598.77	1650.83	609.07
44.00	10.20	14.00		0.15	0.35	10.14	13.60		3141.12	121.15	5165.96	2024.84	0.40	8.90	251.12	1.71	4.53	10.27		2.38	2880.18	1802.63	597.87
45.00	9.35	12.80		0.15	0.35	9.30	12.40		3205.22	119.84	5285.81	2080.59	0.40	7.80	224.48	1.57	3.97	8.35		2.25	2507.66	1622.35	503.97
46.00	10.60	13.80		0.15	0.35	10.57	13.40		3269.33	120.19	5406.01	2136.68	0.32	8.80	205.46	1.70	4.48	10.08		2.37	2994.24	1879.61	486.65
47.00	10.40	14.60		0.15	0.35	10.32	14.20		3333.43	121.91	5527.92	2194.49	0.45	8.30	281.56	1.63	4.22	9.20		2.31	2858.81	1820.99	650.05
48.00	10.40	14.60		0.15	0.35	10.32	14.20		3397.53	121.88	5649.82	2252.28	0.45	8.06	281.56	1.60	4.10	8.79		2.28	2827.80	1814.58	641.53
49.00	9.80	13.00	6.90	0.15	0.35	9.77	12.60	7.00	3461.64	119.57	5769.39	2307.75	0.35	7.34	205.46	1.51	3.73	7.60		2.18	2577.83	1693.30	448.45
50.00	11.40	15.00	7.10	0.15	0.35	11.35	14.60	7.20	3525.74	121.45	5890.85	2365.11	0.34	8.53	235.90	1.66	4.34	9.60		2.34	3188.03	2016.88	551.24
51.00	11.60	15.60		0.15	0.35	11.53	15.20		3589.85	122.28	6013.15	2423.30	0.37	8.45	266.34	1.65	4.30	9.47		2.33	3230.07	2048.06	619.92
52.00	10.00	14.20		0.15	0.35	9.92	13.80		3653.95	121.51	6134.66	2480.71	0.48	6.87	281.56	1.45	3.50	6.86		2.12	2554.30	1705.40	595.75
53.00	9.65	14.60		0.15	0.35	9.53	14.20		3718.06	122.31	6256.99	2538.93	0.60	6.37	338.63	1.37	3.24	6.10		2.04	2378.01	1618.05	690.24

CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.85585
Client:	Schnabel Engineering	Longitude:	-75.45987
Sounding ID:	D-7	Elevation (ft):	
Date:	24-Jun-2018	Ground Water Depth (ft):	-5.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

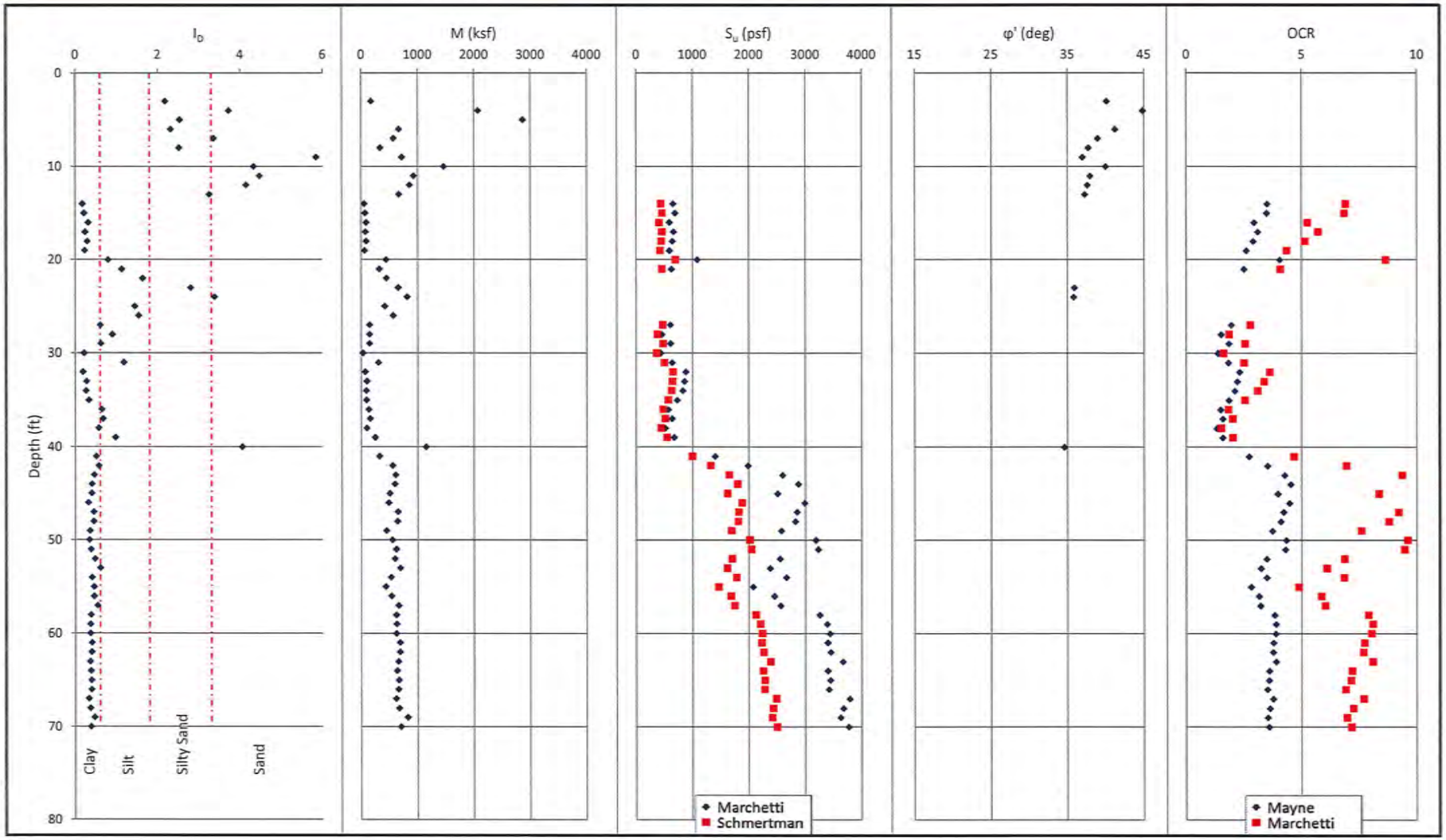
FLAT PLATE DILATOMETER TEST RESULTS

Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_c	OCR[3]	OCR[4]	φ[1,4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
54.00	10.40	14.20		0.15	0.35	10.34	13.80		3782.16	121.07	6378.07	2595.91	0.41	6.86	251.12	1.44	3.49	6.84		2.11	2664.88	1780.29	530.72
55.00	8.90	12.40		0.15	0.35	8.85	12.00		3846.26	119.32	6497.40	2651.14	0.45	5.52	228.29	1.24	2.81	4.87		1.89	2075.41	1463.73	431.74
56.00	10.00	14.00		0.15	0.35	9.93	13.60		3910.37	121.09	6618.50	2708.13	0.46	6.21	266.34	1.35	3.16	5.86		2.01	2455.84	1681.84	535.80
57.00	10.40	15.20	6.10	0.15	0.35	10.29	14.80	6.20	3974.47	122.58	6741.09	2766.62	0.54	6.33	327.21	1.37	3.22	6.03		2.03	2568.25	1750.62	664.55
58.00	12.20	16.40		0.15	0.35	12.12	16.00		4038.58	122.85	6863.96	2825.38	0.38	7.53	281.56	1.53	3.83	7.90		2.21	3257.81	2126.41	621.87
59.00	12.60	16.80		0.15	0.35	12.52	16.40		4102.68	123.07	6987.04	2884.36	0.37	7.64	281.56	1.55	3.89	8.09		2.22	3388.64	2203.54	626.19
60.00	12.80	17.00		0.15	0.35	12.72	16.60		4166.79	123.17	7110.22	2943.44	0.36	7.61	281.56	1.54	3.87	8.04		2.22	3439.27	2238.90	624.94
61.00	12.80	17.40		0.15	0.35	12.70	17.00		4230.89	123.78	7234.01	3003.12	0.40	7.42	311.99	1.52	3.78	7.73		2.19	3401.84	2228.32	684.56
62.00	13.00	17.60		0.15	0.35	12.90	17.20		4295.00	123.87	7357.89	3062.90	0.40	7.39	311.99	1.52	3.76	7.68		2.19	3452.39	2263.68	683.29
63.00	13.60	18.00		0.15	0.35	13.51	17.60		4359.10	123.89	7481.79	3122.69	0.36	7.64	296.77	1.55	3.89	8.09		2.22	3666.81	2384.67	659.92
64.00	13.00	17.40	9.50	0.15	0.35	12.91	17.00	9.60	4423.20	123.54	7605.33	3182.13	0.38	7.08	296.77	1.47	3.60	7.19		2.15	3399.33	2252.94	636.90
65.00	13.20	17.80	8.60	0.15	0.35	13.10	17.40	8.70	4487.31	123.94	7729.28	3241.97	0.39	7.05	311.99	1.47	3.59	7.14		2.14	3446.11	2286.22	668.29
66.00	13.20	17.80		0.15	0.35	13.10	17.40		4551.41	123.92	7853.21	3301.79	0.39	6.90	311.99	1.45	3.51	6.91		2.12	3418.38	2279.81	661.55
67.00	14.20	18.40		0.15	0.35	14.12	18.00		4615.52	123.82	7977.04	3361.52	0.33	7.40	281.56	1.52	3.76	7.69		2.19	3792.90	2486.43	616.87
68.00	14.00	18.60		0.15	0.35	13.90	18.20		4679.62	124.32	8101.37	3421.75	0.37	7.11	311.99	1.48	3.62	7.24		2.15	3676.96	2434.07	671.07
69.00	14.00	19.60		0.15	0.35	13.85	19.20		4743.73	125.64	8227.02	3483.30	0.46	6.94	388.09	1.45	3.53	6.96		2.13	3628.96	2417.22	824.90
70.00	14.40	19.20	9.00	0.15	0.35	14.29	18.80	9.10	4807.83	124.79	8351.83	3544.00	0.38	7.06	327.21	1.47	3.59	7.16		2.14	3773.75	2502.70	701.36

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.85585
Client:	Schnabel Engineering	Longitude:	-75.45987
Sounding ID:	D-7	Elevation (ft):	
Date:	24-Jun-2018	Ground Water Depth (ft):	-5.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

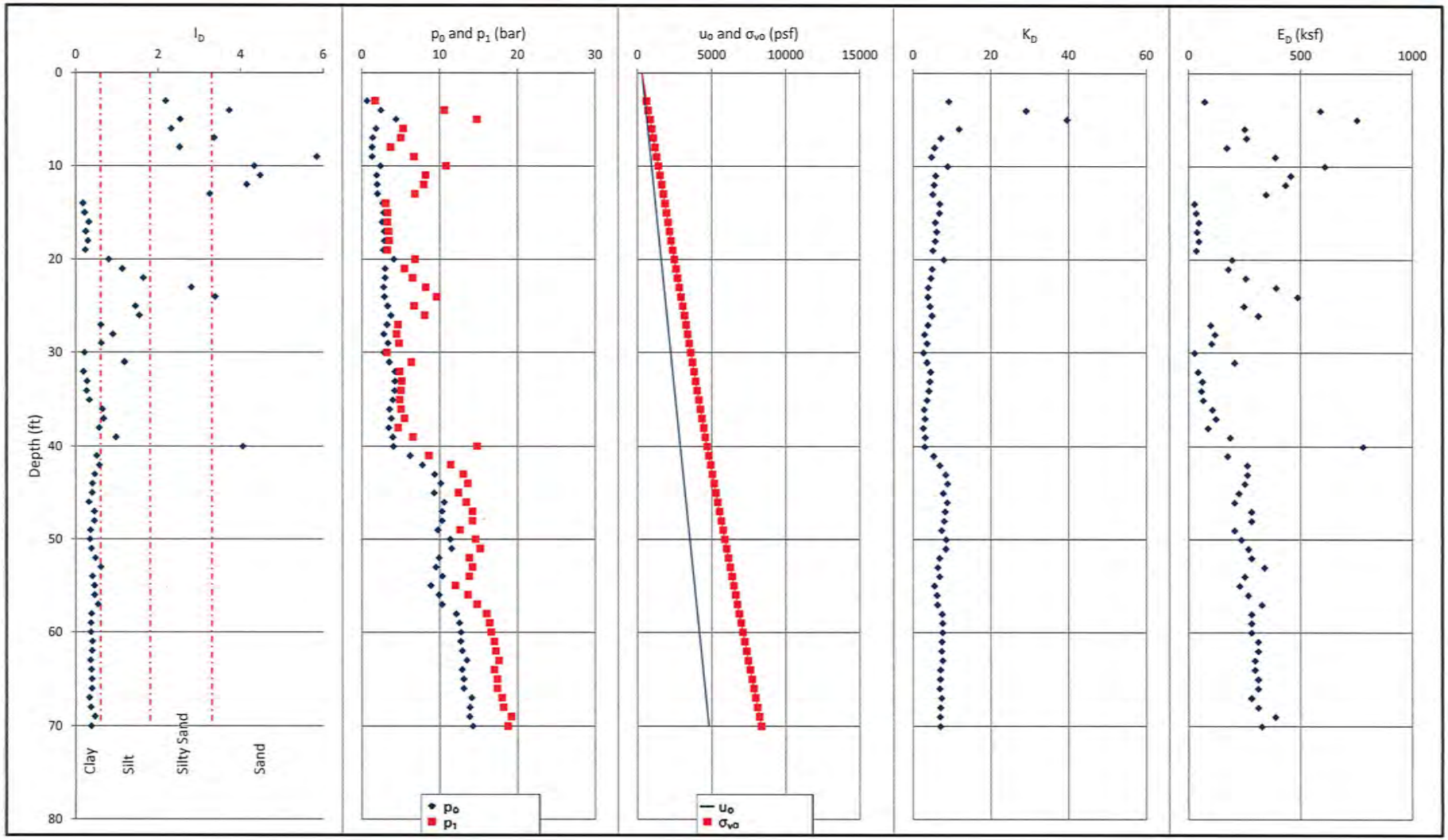


CONETEC

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-7
Date:	24-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.85585
Longitude:	-75.45987
Elevation (ft):	
Ground Water Depth (ft):	-5.0
Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS



CONETEC

Job No:	18-54025	Coordinate System:	WGS 84 Lat/Long
Project:	Wallops Island Break Waters	Latitude:	37.85948
Client:	Schnabel Engineering	Longitude:	-75.45278
Sounding ID:	D-8	Elevation (ft):	
Date:	15-Jun-2018	Ground Water Depth (ft):	-9.0
Job Location:	Wallops Island, VA	Gauge Zero Offset (bar):	0.05

FLAT PLATE DILATOMETER TEST RESULTS

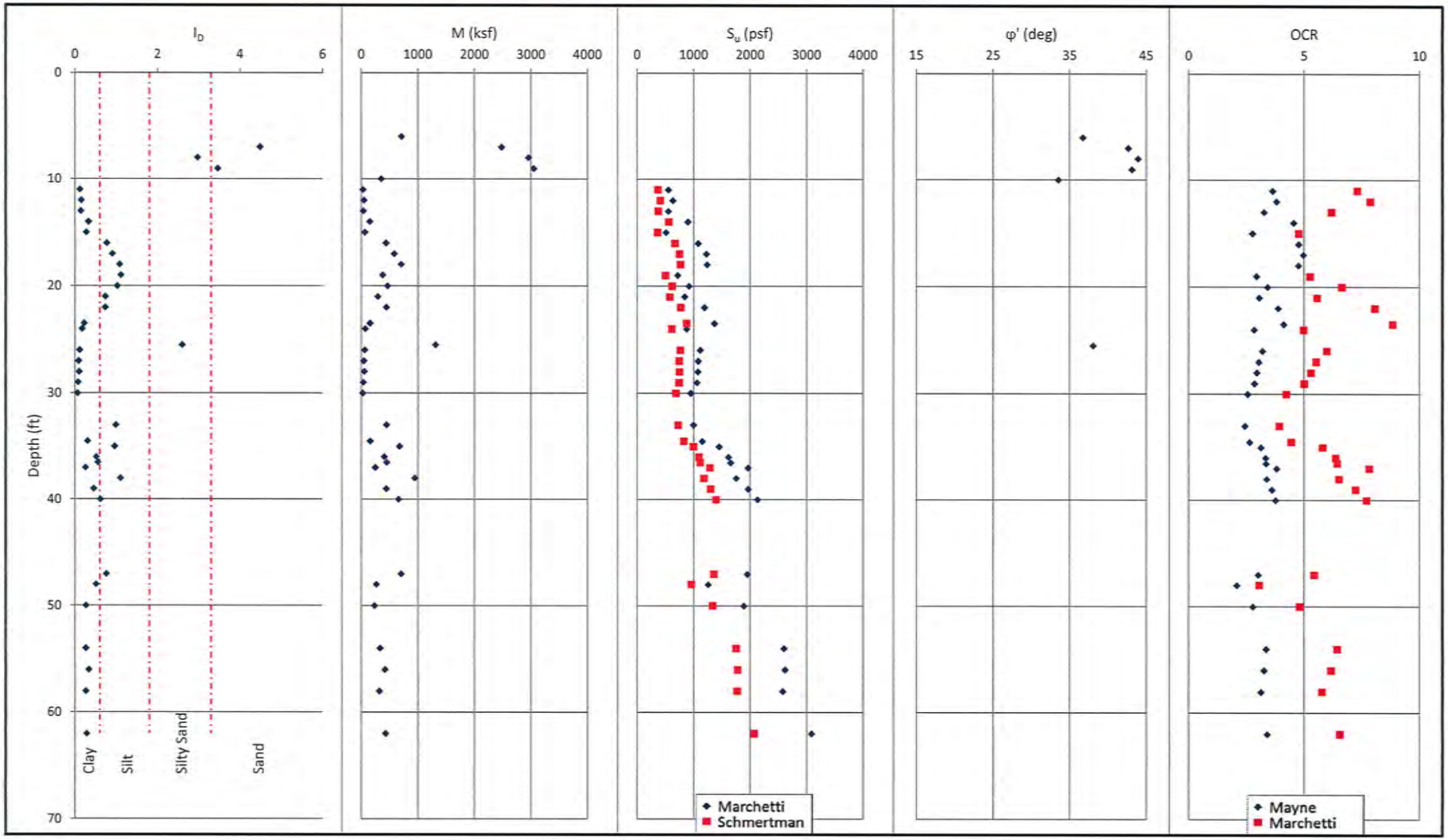
Depth[1] (ft)	A (bar)	B (bar)	C (bar)	ΔA (bar)	ΔB (bar)	p_0 (bar)	p_1 (bar)	p_2 (bar)	u_0 (psf)	γ_T[2] (pcf)	σ_{vo} (psf)	σ_{vo}' (psf)	I_D	K_D	E_D (ksf)	K_G	OCR[3]	OCR[4]	φ[4] (deg)	R_M	s_u[4] (psf)	s_u[5] (psf)	M (ksf)
6.00	1.20	6.65		0.15	0.20	1.05	6.40		961.52	108.22	1226.28	264.76	9.16	4.61	388.09				36.77	1.83			709.33
7.00	3.50	14.80	0.05	0.15	0.20	3.05	14.55	0.15	1025.63	121.06	1347.35	321.72	4.49	16.63	833.25				42.69	2.98			2484.30
8.00	5.20	17.40		0.15	0.20	4.71	17.15		1089.73	124.56	1471.91	382.18	2.97	22.87	901.74				43.97	3.28			2960.75
9.00	5.05	18.40		0.15	0.20	4.50	18.15		1153.84	124.77	1596.69	442.85	3.46	18.62	989.25				43.15	3.09			3055.20
10.00	1.25	5.15		0.15	0.20	1.17	4.90		1217.94	106.32	1703.02	485.08	6.32	2.54	270.14				33.56	1.31			353.56
11.00	2.30	2.85		0.15	0.20	2.39	2.60		1282.05	97.30	1800.33	518.28	0.12	7.16	15.22	1.48	3.64	7.31		2.16	561.24	370.96	32.83
12.00	2.55	3.20		0.15	0.20	2.64	2.95		1346.15	99.86	1900.20	554.05	0.16	7.50	22.83	1.53	3.82	7.87		2.21	636.42	415.72	50.35
13.00	2.40	3.00		0.15	0.20	2.49	2.75		1410.26	98.49	1998.70	588.44	0.14	6.43	19.02	1.38	3.27	6.19		2.05	557.56	378.50	38.96
14.00	3.35	4.55		0.15	0.20	3.41	4.30		1474.36	106.82	2105.52	631.16	0.33	8.94	64.68	1.71	4.55	10.34		2.39	902.45	564.24	154.27
15.00	2.40	3.20	1.20	0.15	0.20	2.48	2.95	1.30	1538.46	101.23	2206.76	668.29	0.27	5.44	34.24	1.23	2.77	4.76		1.88	513.64	363.59	64.24
16.00	4.00	6.70		0.15	0.20	3.98	6.45		1602.57	113.37	2320.14	717.57	0.77	9.36	178.83	1.76	4.76	11.10		2.43	1086.38	671.51	435.03
17.00	4.45	7.90		0.15	0.20	4.40	7.65		1666.67	115.60	2435.75	769.08	0.90	9.77	235.90	1.81	4.97	11.87		2.48	1228.49	751.25	584.18
18.00	4.60	8.75		0.15	0.20	4.51	8.50		1730.78	116.92	2552.68	821.90	1.08	9.35	289.17	1.76	4.76	11.10		2.43	1243.76	768.86	703.75
19.00	3.30	6.20		0.15	0.20	3.27	5.95		1794.88	112.21	2664.90	870.02	1.11	5.79	194.04	1.29	2.95	5.25		1.96	723.23	503.99	380.05
20.00	3.90	7.15		0.15	0.20	3.86	6.90		1858.99	114.11	2779.02	920.03	1.03	6.73	220.68	1.42	3.43	6.64		2.11	922.58	619.23	464.58
21.00	3.70	6.00	1.35	0.15	0.20	3.70	5.75	1.45	1923.09	111.51	2890.53	967.44	0.74	6.01	148.39	1.32	3.06	5.56		1.98	841.25	580.97	294.08
22.00	4.70	7.65		0.15	0.20	4.67	7.40		1987.19	114.78	3005.32	1018.13	0.73	7.63	197.85	1.55	3.88	8.07		2.22	1193.86	776.63	440.19
23.50	5.15	6.40		0.15	0.20	5.21	6.15		2083.35	109.52	3169.62	1086.27	0.22	8.09	68.49	1.61	4.12	8.85		2.28	1370.83	878.75	156.34
24.00	3.90	4.75		0.15	0.20	3.98	4.50		2115.40	104.50	3221.87	1106.47	0.18	5.59	38.05	1.26	2.85	4.97		1.90	879.96	618.66	72.45
25.50	4.80	13.60		0.15	0.20	4.48	13.35		2211.56	121.23	3403.74	1192.18	2.60	5.99	643.01				38.08	2.04			1312.51
26.00	4.65	5.40		0.15	0.20	4.73	5.15		2243.61	104.43	3455.96	1212.35	0.11	6.30	30.44	1.36	3.21	5.99		2.03	1118.80	763.52	61.67
27.00	4.60	5.25		0.15	0.20	4.69	5.00		2307.72	102.84	3558.80	1251.09	0.09	5.98	22.83	1.31	3.04	5.52		1.97	1081.39	747.71	45.03
28.00	4.65	5.35		0.15	0.20	4.73	5.10		2371.82	103.66	3662.47	1290.65	0.10	5.82	26.63	1.29	2.96	5.29		1.95	1079.30	751.22	51.81
29.00	4.65	5.25	3.40	0.15	0.20	4.74	5.00	3.50	2435.93	101.89	3764.37	1328.44	0.07	5.61	19.02	1.26	2.86	5.00		1.91	1061.98	745.85	36.31
30.00	4.40	4.95		0.15	0.20	4.49	4.70		2500.03	100.35	3864.72	1364.69	0.06	5.04	15.22	1.17	2.57	4.23		1.80	953.16	687.75	27.36
33.00	4.90	8.90		0.10	0.60	4.79	8.25		2692.34	115.80	4212.14	1519.80	0.99	4.80	251.12	1.13	2.45	3.92		1.77	999.87	730.13	443.80
34.50	5.30	7.15		0.10	0.60	5.29	6.50		2788.50	110.53	4377.96	1589.46	0.31	5.20	87.51	1.19	2.65	4.44		1.83	1154.47	826.51	160.12
35.00	6.30	11.40	3.15	0.10	0.60	6.13	10.75	3.20	2820.55	119.33	4437.62	1617.07	0.97	6.17	334.82	1.34	3.14	5.80		2.02	1455.41	998.22	675.37
36.00	6.70	10.00		0.10	0.60	6.62	9.35		2884.66	116.76	4554.40	1669.74	0.52	6.55	197.85	1.40	3.34	6.37		2.07	1619.27	1094.15	408.91
36.50	6.85	10.40		0.10	0.60	6.76	9.75		2916.71	117.43	4613.12	1696.41	0.56	6.60	216.87	1.41	3.36	6.44		2.07	1660.01	1119.66	449.83
37.00	7.60	9.80		0.10	0.60	7.58	9.15		2948.76	114.52	4670.38	1721.62	0.26	7.48	114.14	1.53	3.81	7.82		2.20	1968.82	1287.20	251.34
38.00	7.35	14.00		0.10	0.60	7.10	13.35		3012.87	122.17	4792.56	1779.70	1.10	6.64	452.77	1.41	3.38	6.50		2.09	1755.36	1182.10	948.14
39.00	7.80	11.20		0.10	0.60	7.72	10.55		3076.97	118.01	4910.58	1833.61	0.45	7.11	205.46	1.48	3.62	7.23		2.15	1969.00	1303.61	441.81
40.00	8.35	13.00		0.10	0.60	8.20	12.35		3141.07	120.70	5031.30	1890.22	0.62	7.40	300.58	1.52	3.77	7.70		2.19	2134.46	1399.02	658.86
47.00	8.40	13.80		0.10	0.60	8.22	13.15		3589.81	121.57	5882.36	2292.56	0.76	5.92	357.65	1.31	3.01	5.43		1.97	1957.42	1356.76	703.79
48.00	6.40	9.30		0.10	0.60	6.34	8.65		3653.91	115.03	5997.40	2343.49	0.50	4.09	167.41	1.00	2.08	3.05		1.58	1261.24	958.75	265.17
50.00	8.25	10.60	4.50	0.10	0.60	8.22	9.95	4.55	3782.12	115.29	6228.00	2445.88	0.27	5.47	125.56	1.24	2.78	4.81		1.88	1892.85	1338.05	236.27
54.00	10.40	13.20		0.10	0.60	10.35	12.55		4038.54	118.29	6701.20	2662.66	0.26	6.60	159.80	1.41	3.36	6.44		2.07	2604.31	1756.74	331.39
56.00	10.60	14.00	7.00	0.10	0.60	10.52	13.35	7.05	4166.74	119.86	6940.94	2774.19	0.33	6.41	205.46	1.38	3.26	6.16		2.04	2619.40	1779.43	420.14
58.00	10.60	13.40	7.20	0.10	0.60	10.55	12.75	7.25	4294.95	118.34	7177.65	2882.69	0.26	6.15	159.80	1.34	3.13	5.77		2.00	2582.46	1772.87	319.88
62.00	12.20	15.60		0.10	0.60	12.12	14.95		4551.37	120.79	7660.83	3109.46	0.29	6.67	205.46	1.42	3.40	6.55		2.09	3085.12	2075.13	428.48

1. Depth is referenced below the existing ground surface at the time of testing.
2. Mayne et al., 2002
3. Mayne, 1995
4. Marchetti et al., 2001
5. Schmertman, 1991

Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-8
Date:	15-Jun-2018
Job Location:	Wallops Island, VA

Coordinate System:	WGS 84 Lat/Long
Latitude:	37.85948
Longitude:	-75.45278
Elevation (ft):	
Ground Water Depth (ft):	-9.0
Gauge Zero Offset (bar):	0.05

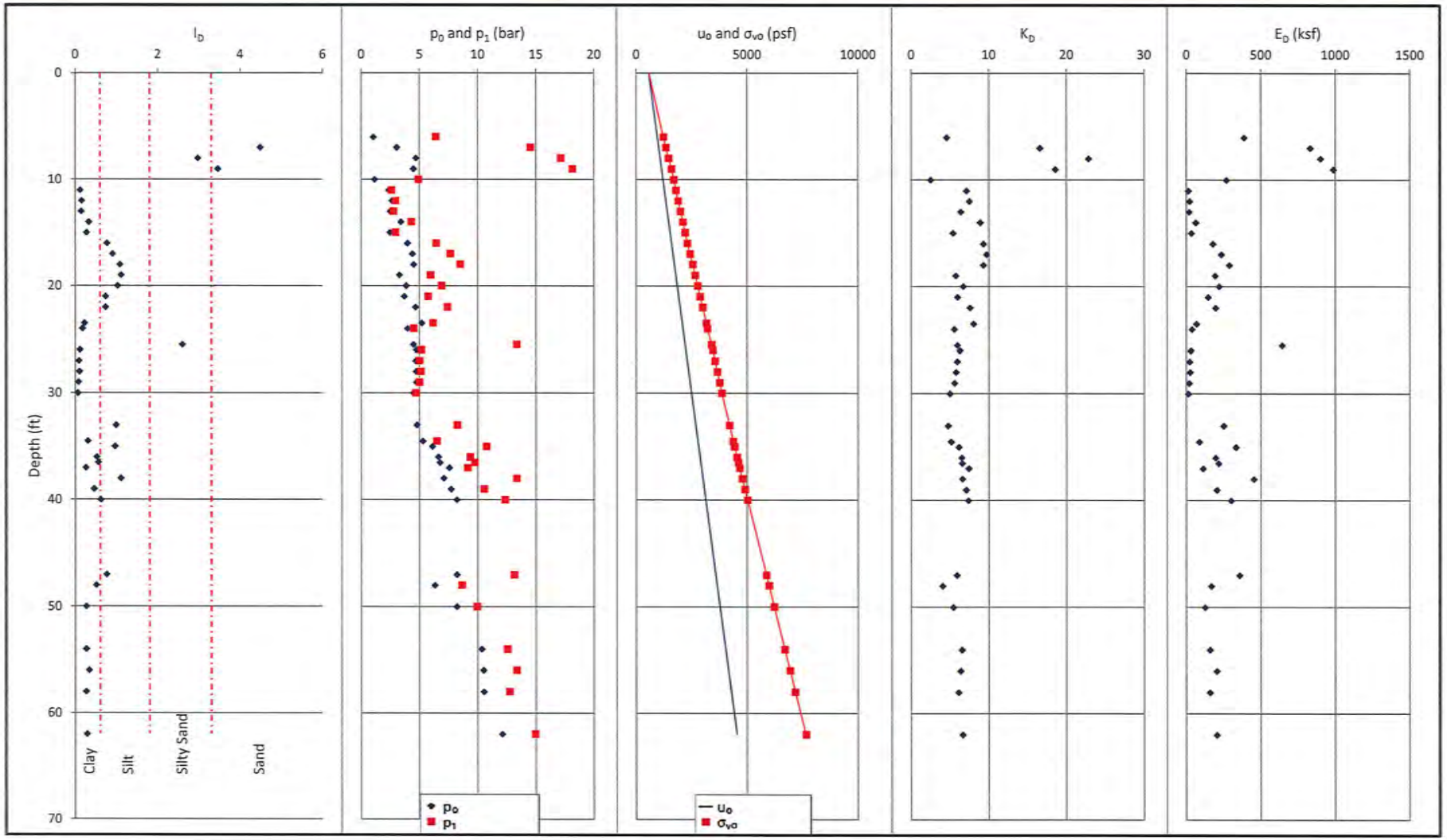
FLAT PLATE DILATOMETER TEST RESULTS



Job No:	18-54025
Project:	Wallops Island Break Waters
Client:	Schnabel Engineering
Sounding ID:	D-8
Date:	15-Jun-2018
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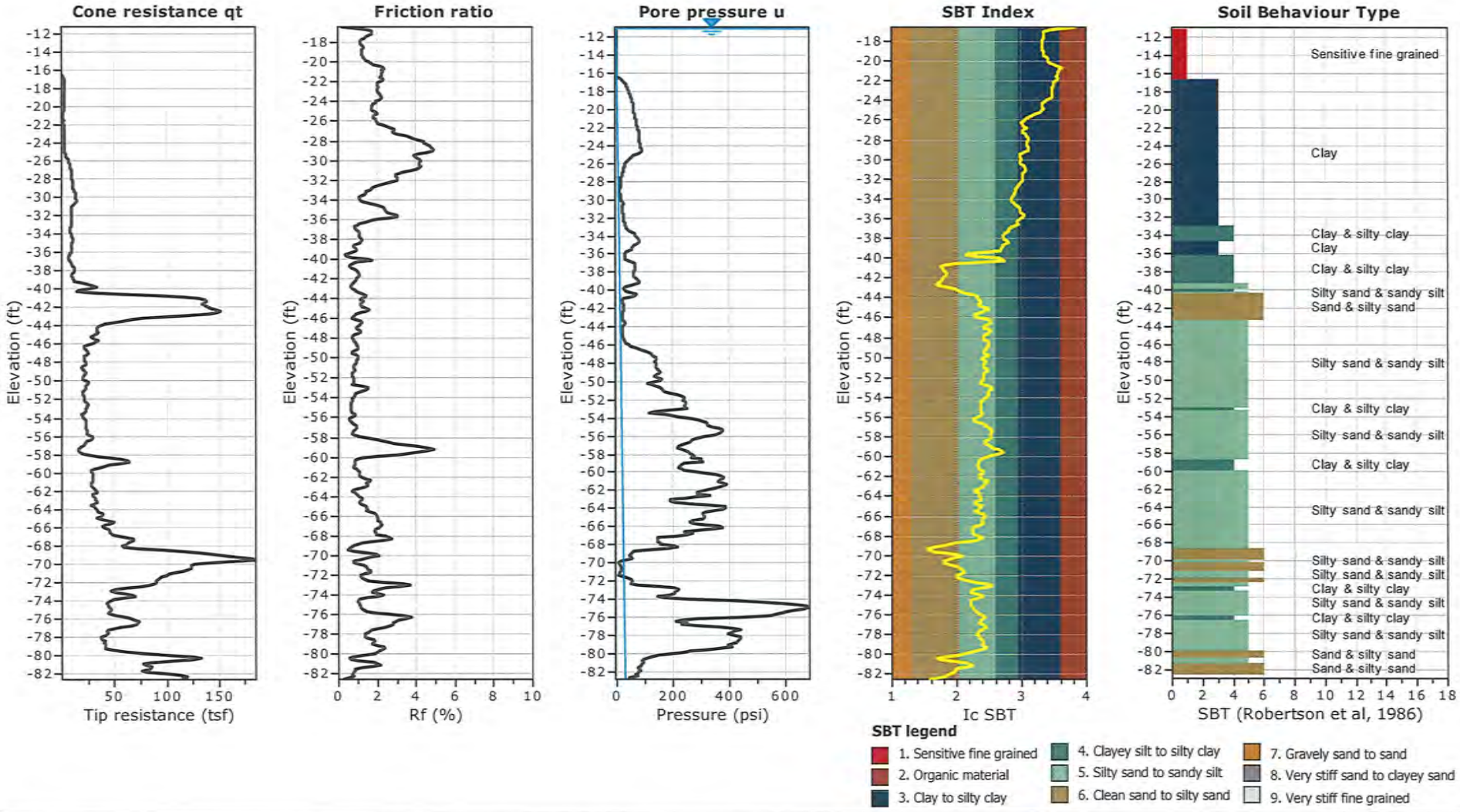
FLAT PLATE DILATOMETER TEST RESULTS



Schnabel Engineering
9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

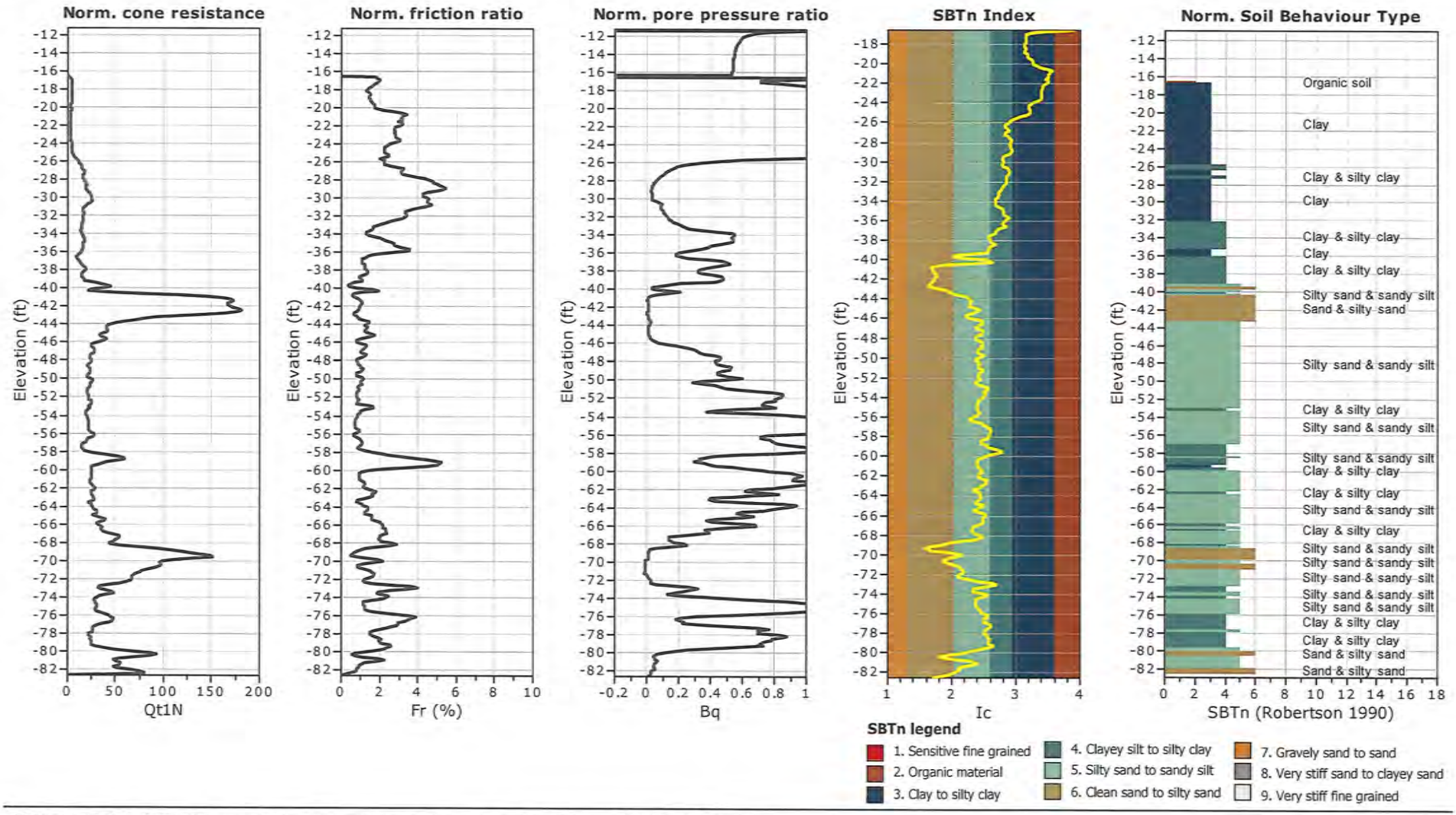
CPT: C-1
Total depth: 71.69 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.82922° lon -75.48952°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



Schnabel Engineering
9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

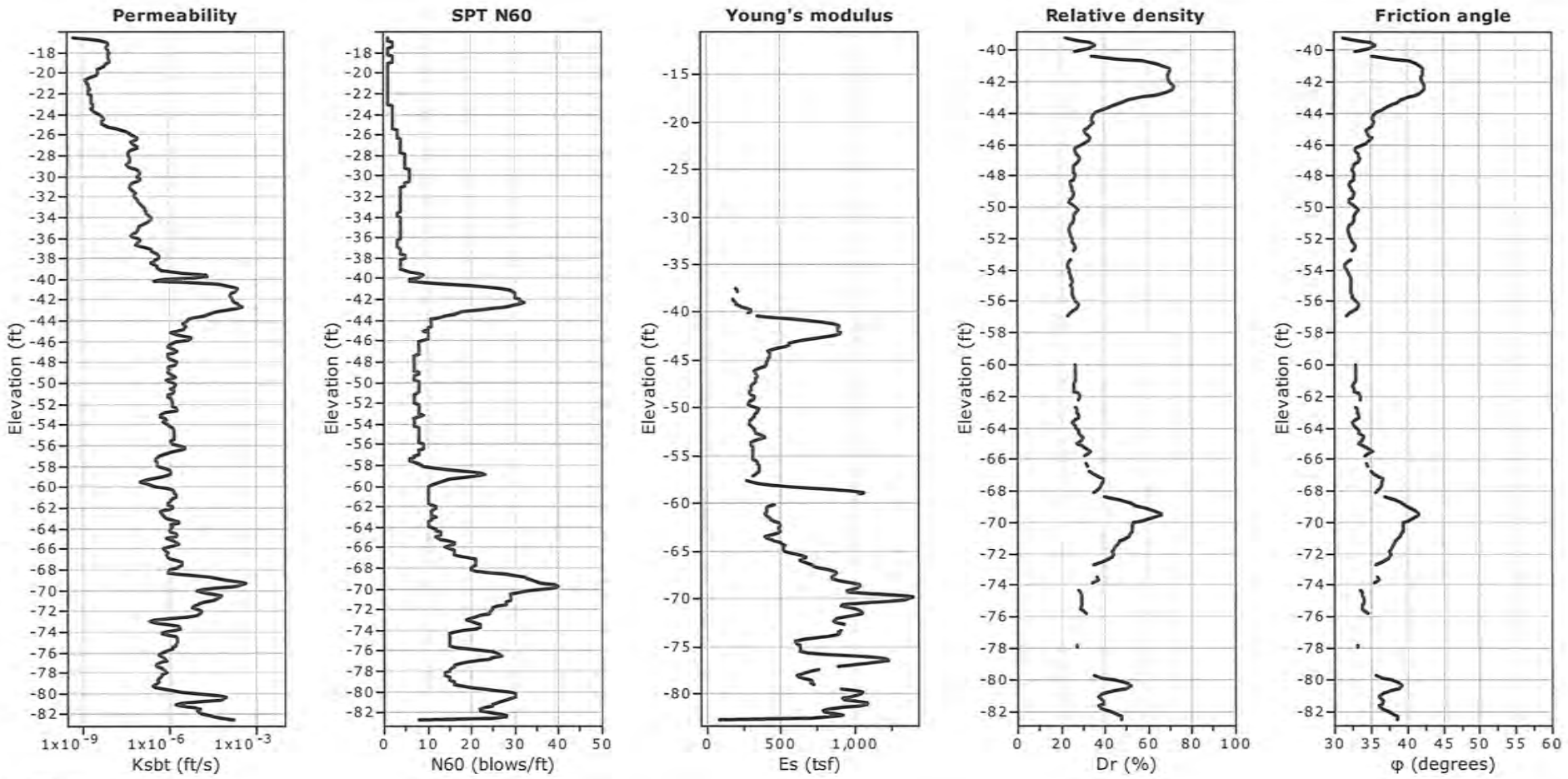
CPT: C-1
Total depth: 71.69 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.82922° lon -75.48952°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Glen Allen, VA 23059
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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-1
Total depth: 71.69 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.82922° lon -75.48952°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC

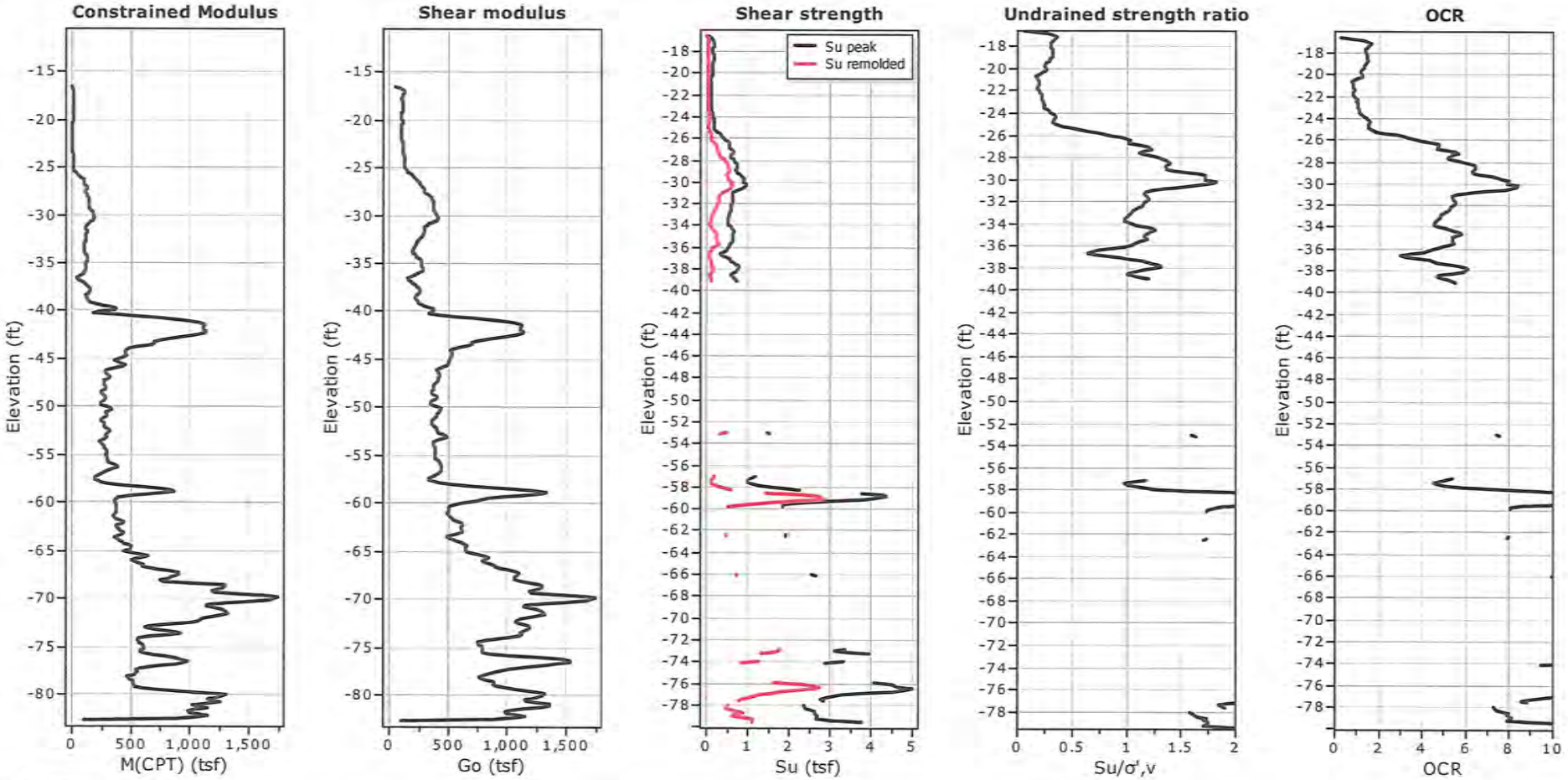


Calculation parameters
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative desnisty constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

Schnabel Engineering
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Glen Allen, VA 23059
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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-1
Total depth: 71.69 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.82922° lon -75.48952°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



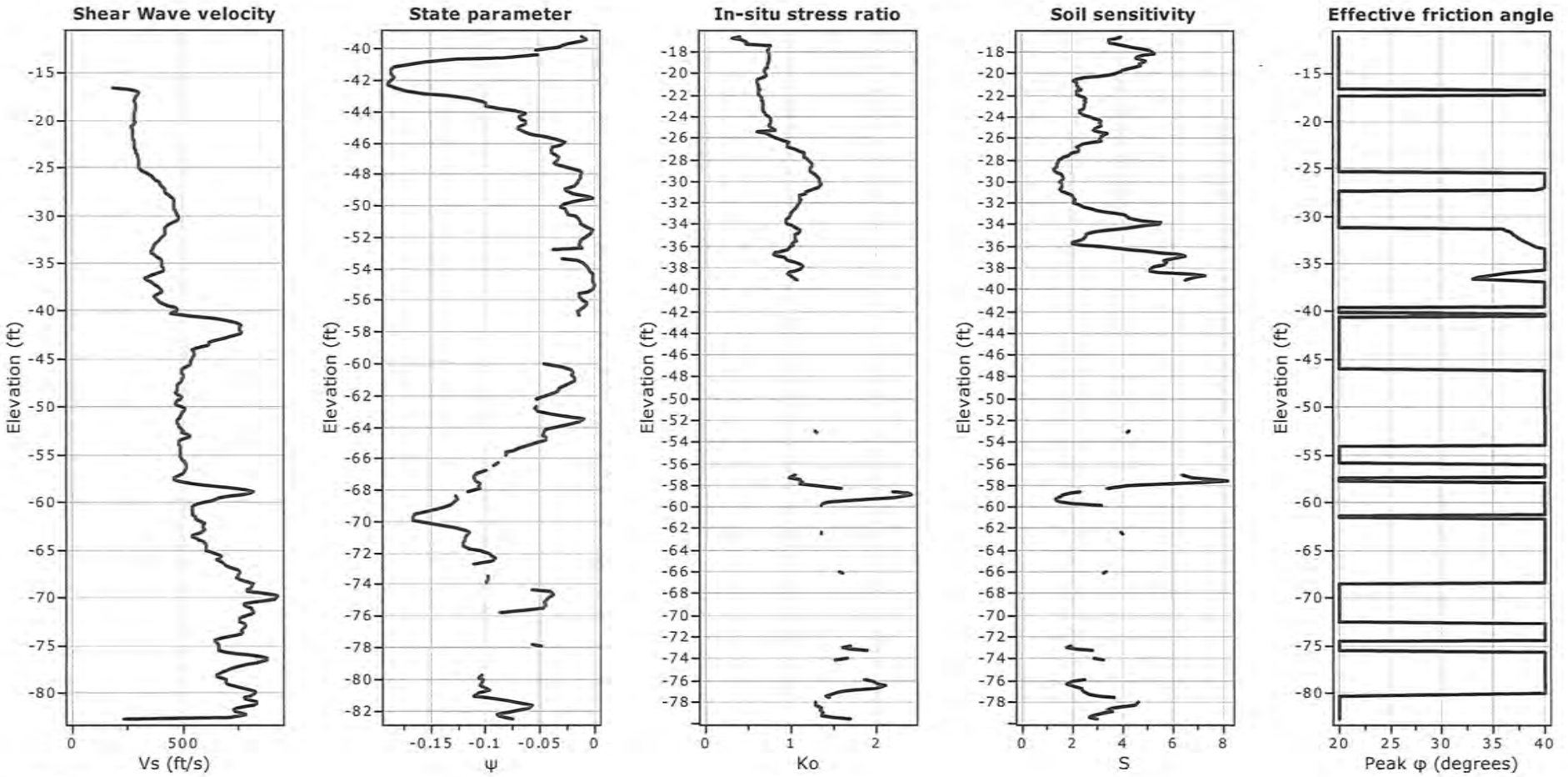
Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data

Schnabel Engineering
9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-1
Total depth: 71.69 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.82922° lon -75.48952°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



Calculation parameters

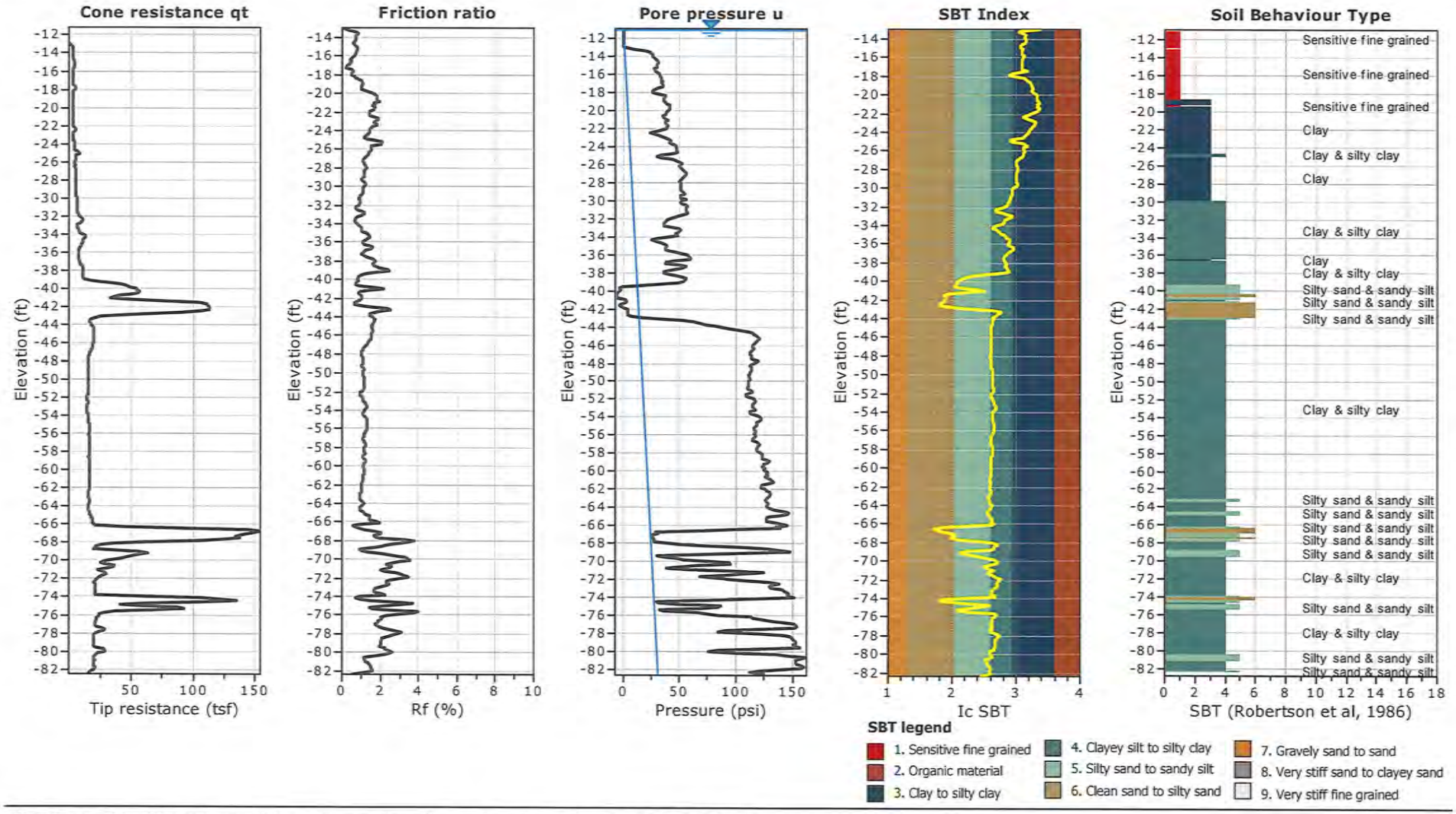
Soil Sensitivity factor, N_S: 7.00

User defined estimation data

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Glen Allen, VA 23059
https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

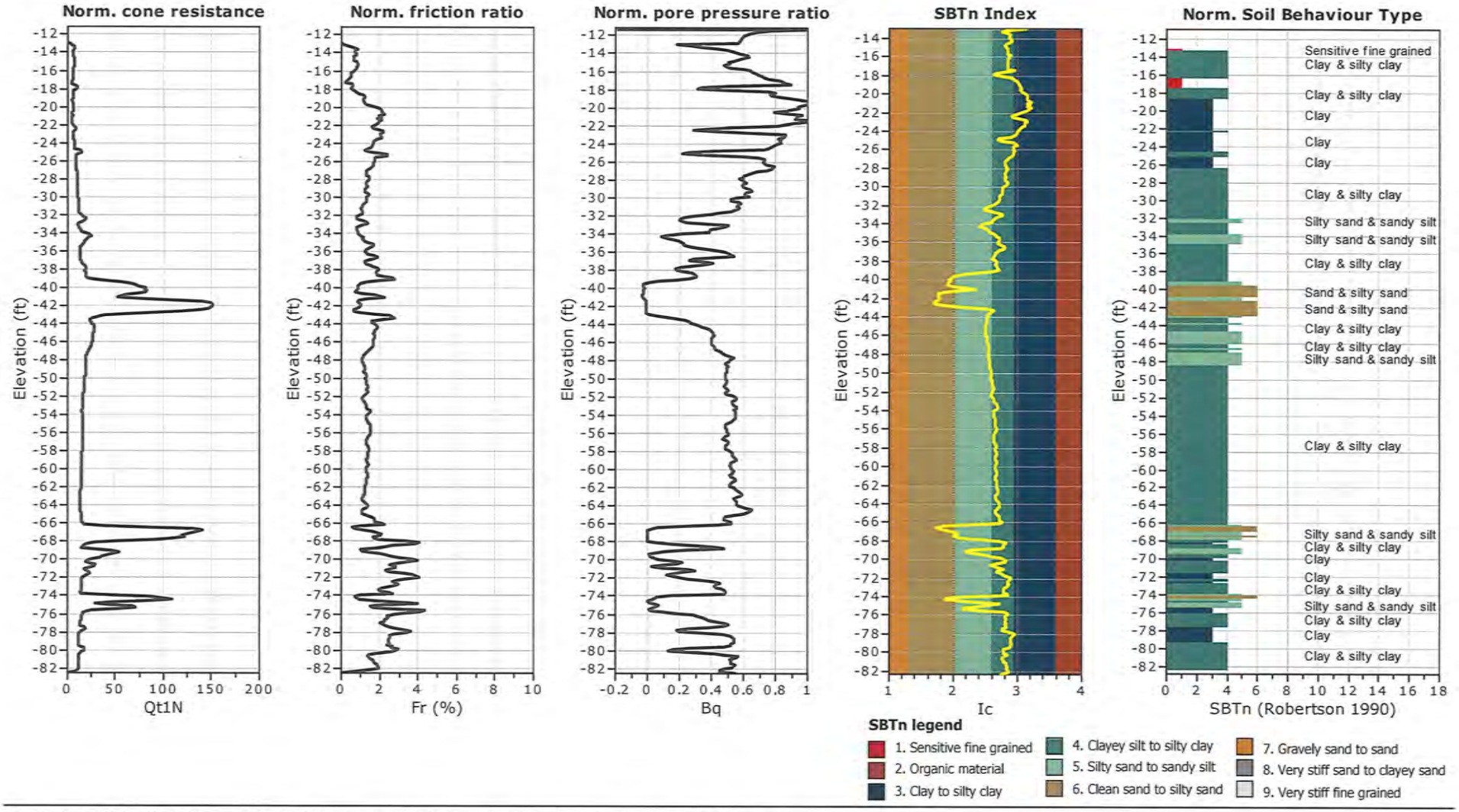
CPT: C-2
Total depth: 71.52 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.83355° lon -75.48512°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: Wallops Island Breakwaters
Location: Wallops Island, Virginia

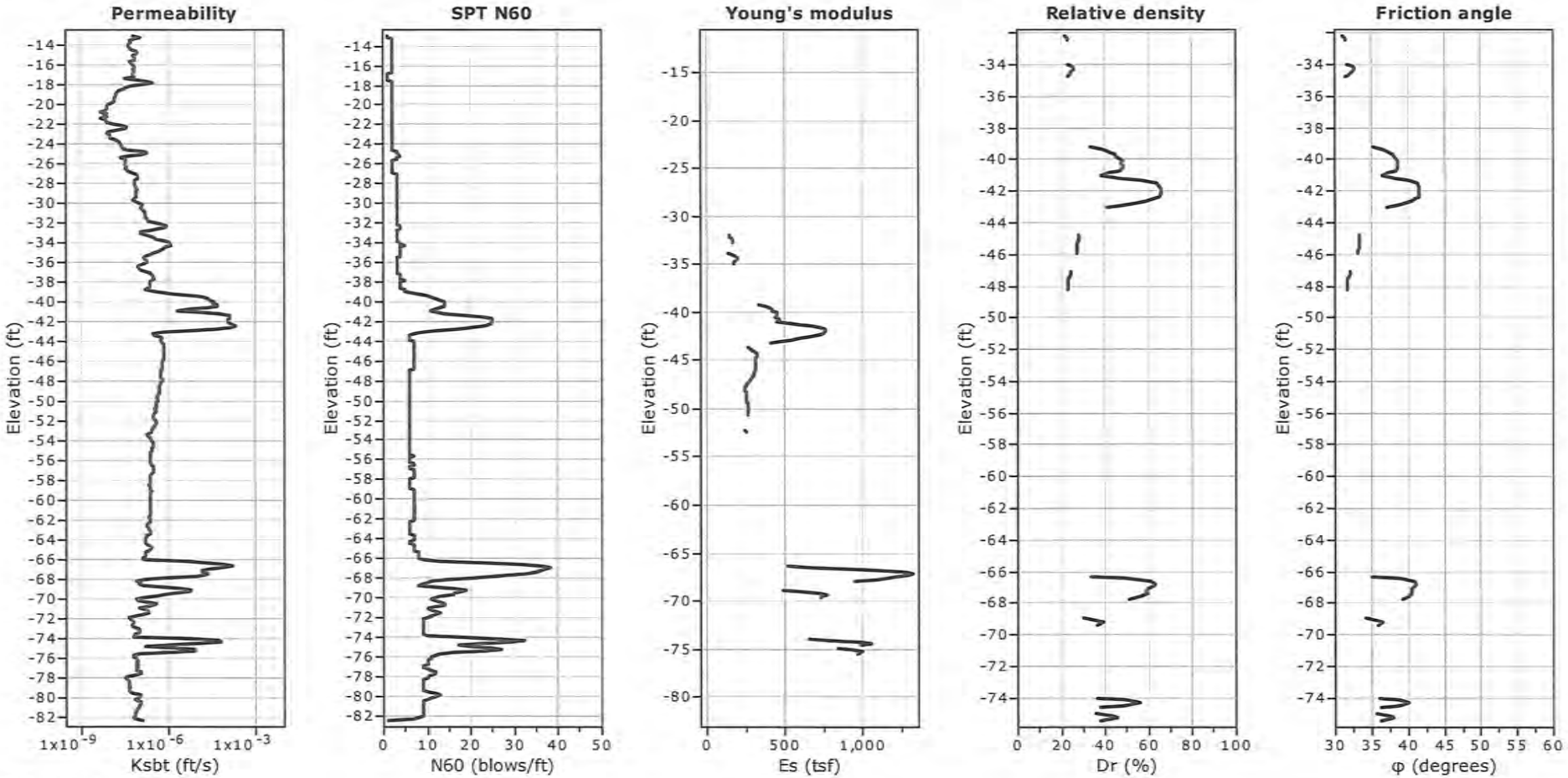
CPT: C-2
Total depth: 71.52 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.83355° lon -75.48512°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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CPT: C-2
Total depth: 71.52 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.83355° lon -75.48512°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**



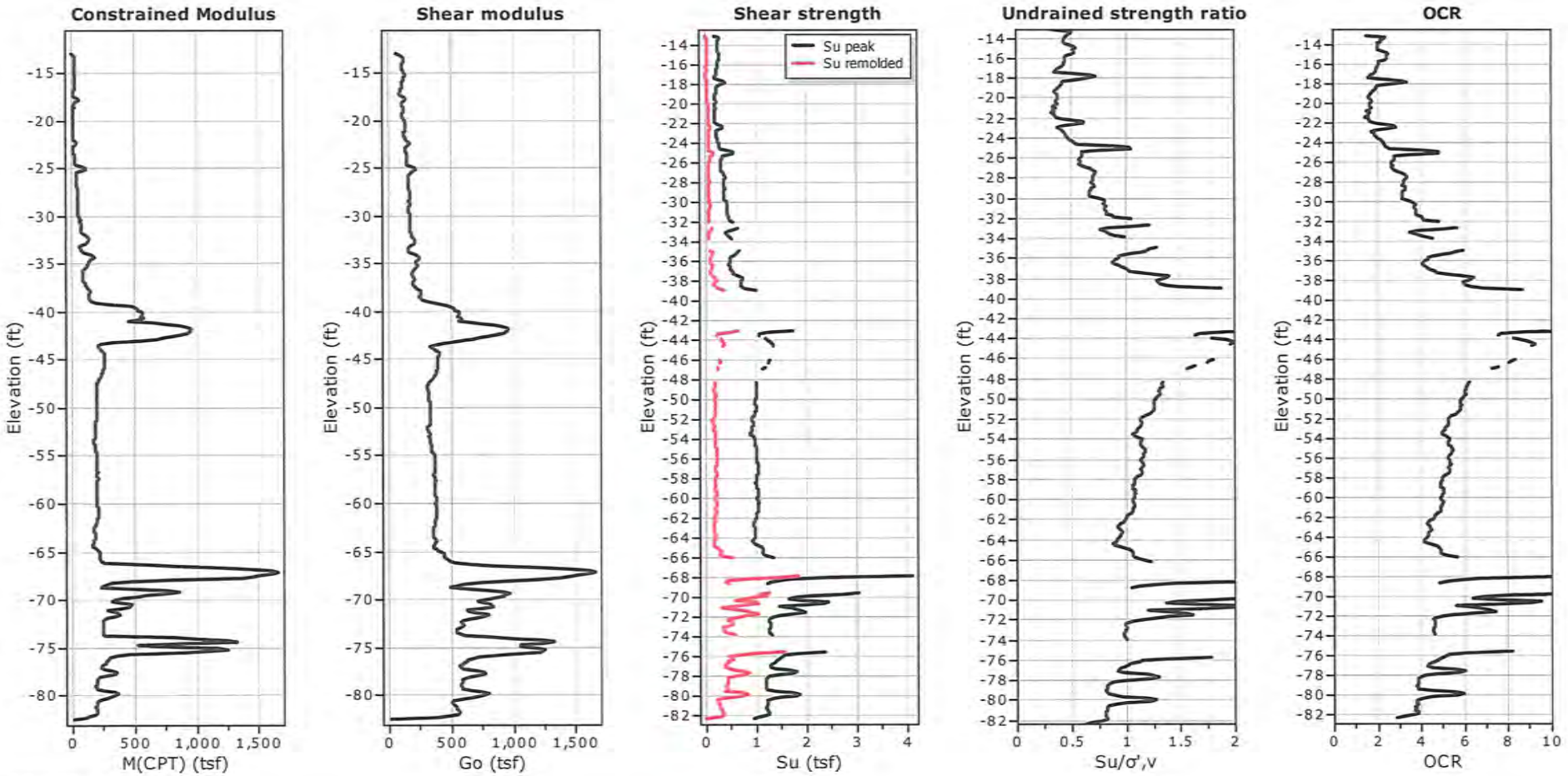
Calculation parameters

Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative desnisty constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-2
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Surface Elevation: -11.00 ft
Coords: lat 37.83355° lon -75.48512°
Cone Type: Piezocone
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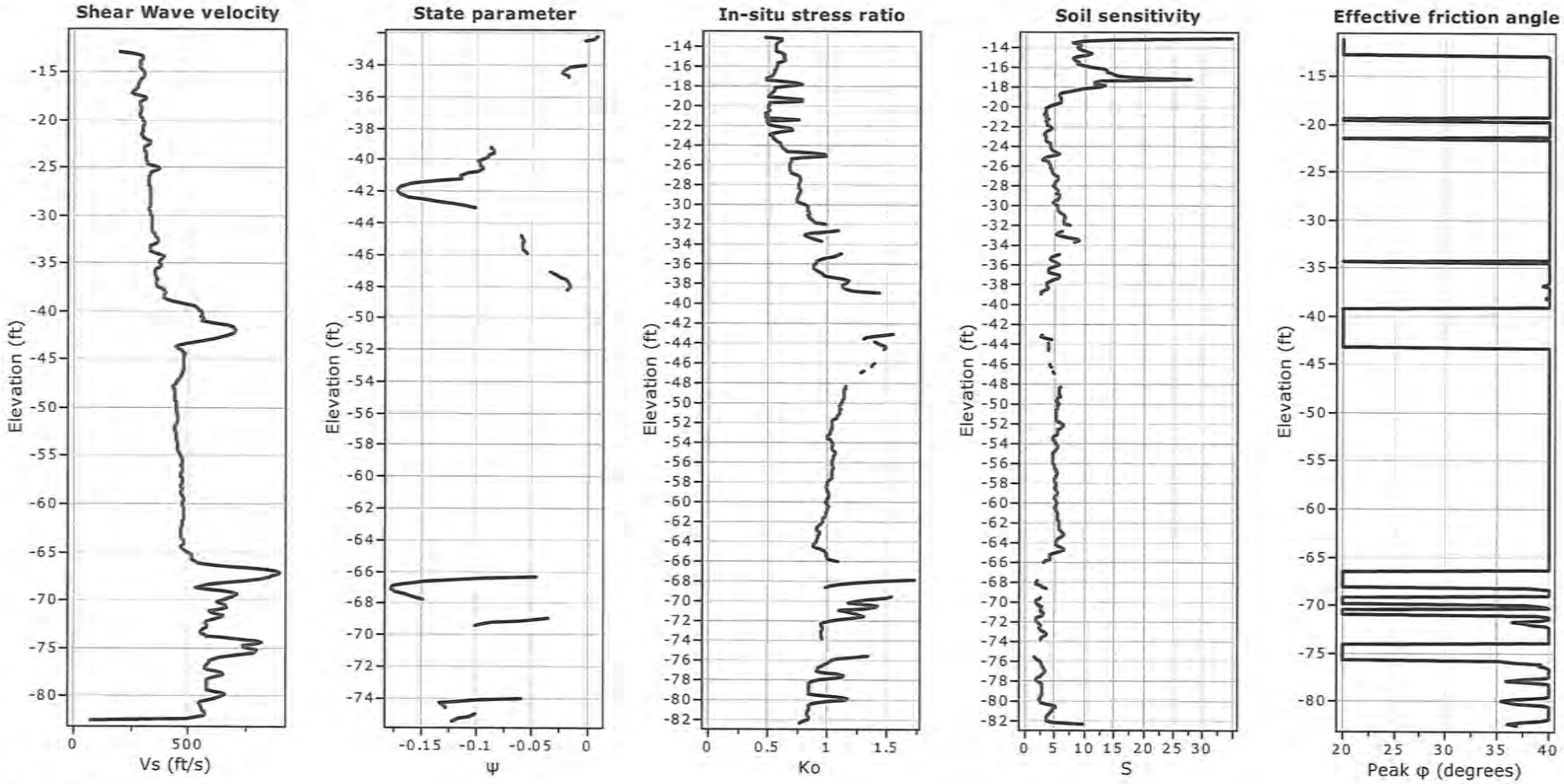
Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data

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Location: **Wallops Island, Virginia**

CPT: C-2
Total depth: 71.52 ft, Date: 6/18/2018
Surface Elevation: -11.00 ft
Coords: lat 37.83355° lon -75.48512°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



Calculation parameters

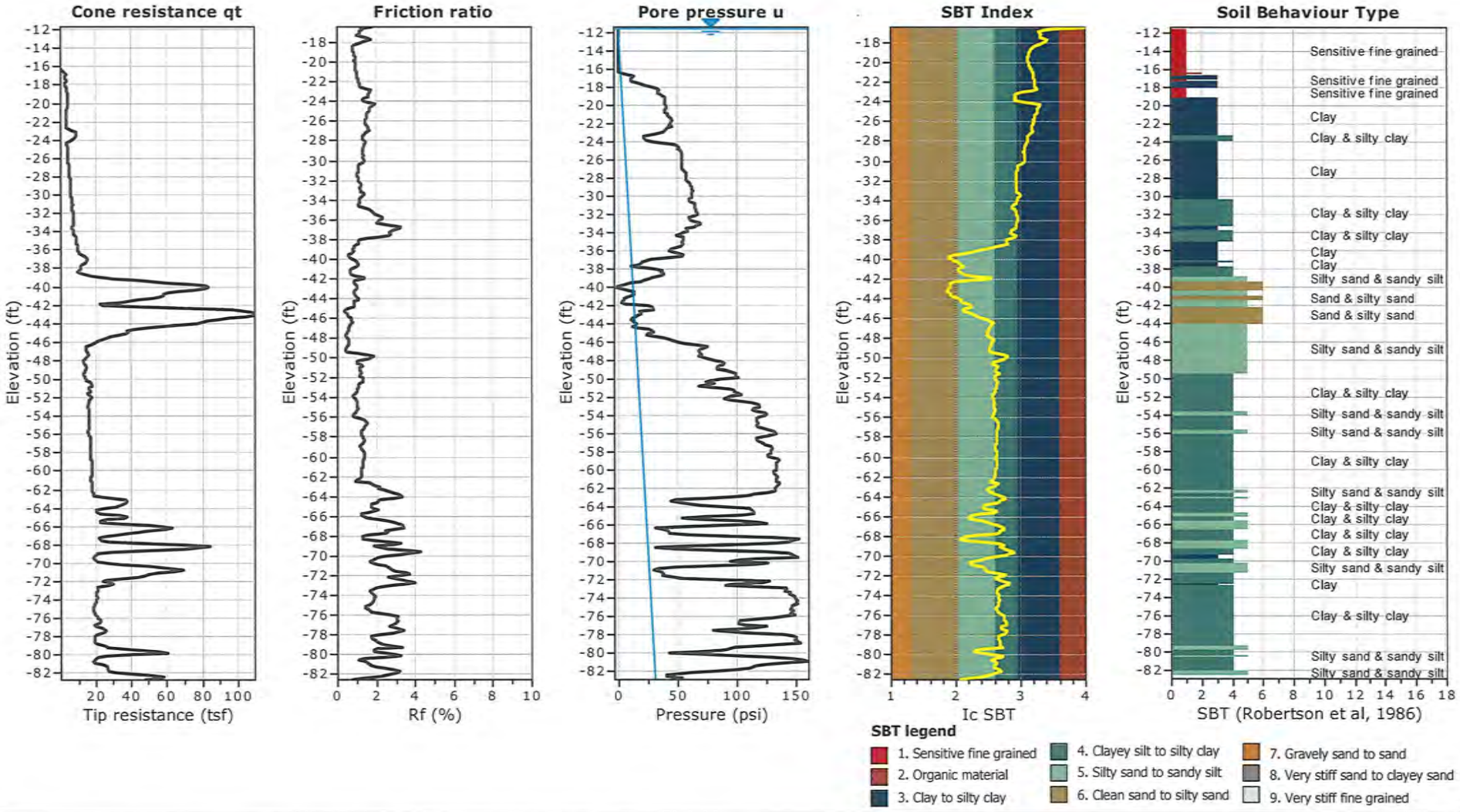
Soil Sensitivity factor, N_S: 7.00

User defined estimation data

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https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

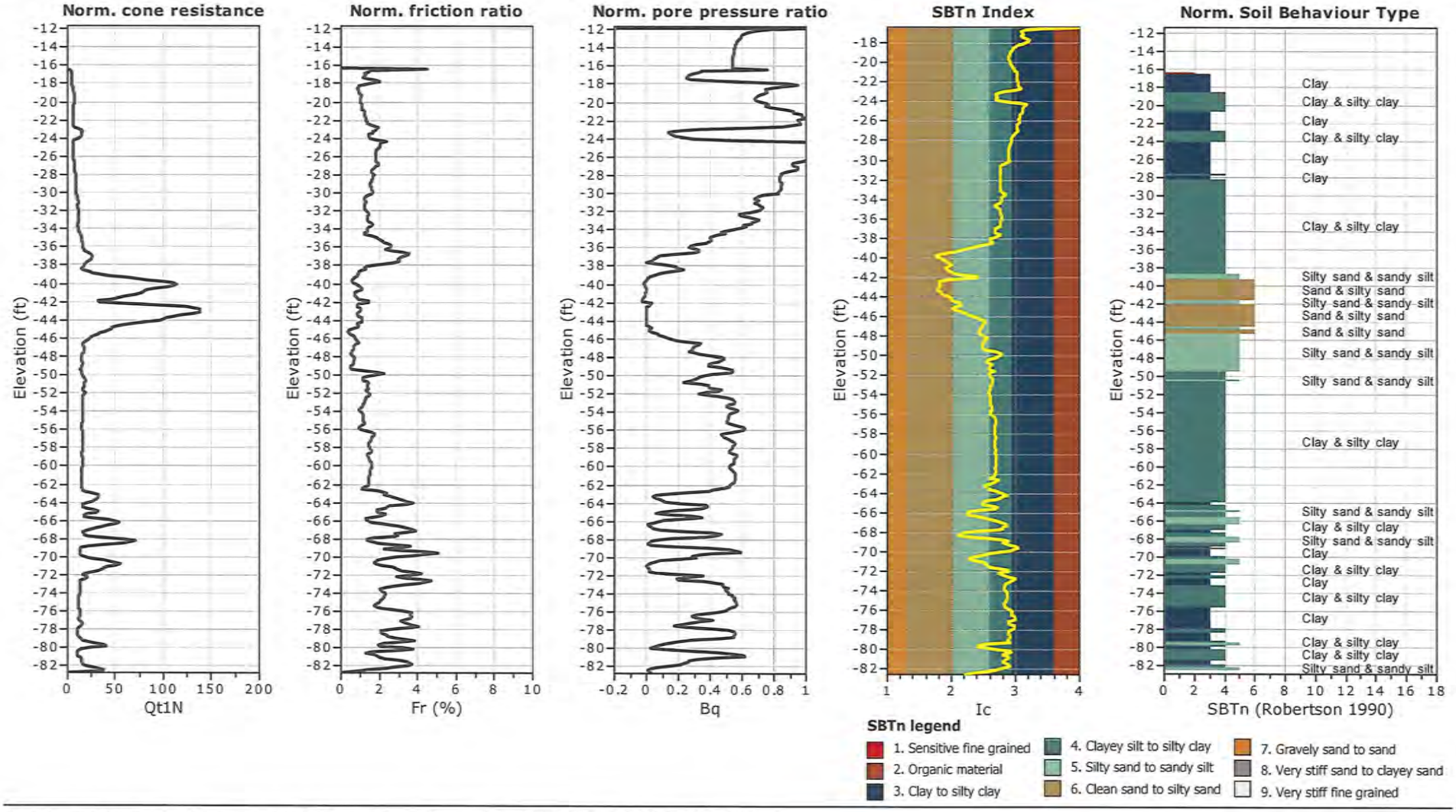
CPT: C-3
Total depth: 71.19 ft, Date: 6/18/2018
Surface Elevation: -11.50 ft
Coords: lat 37.83675° lon -75.4819°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

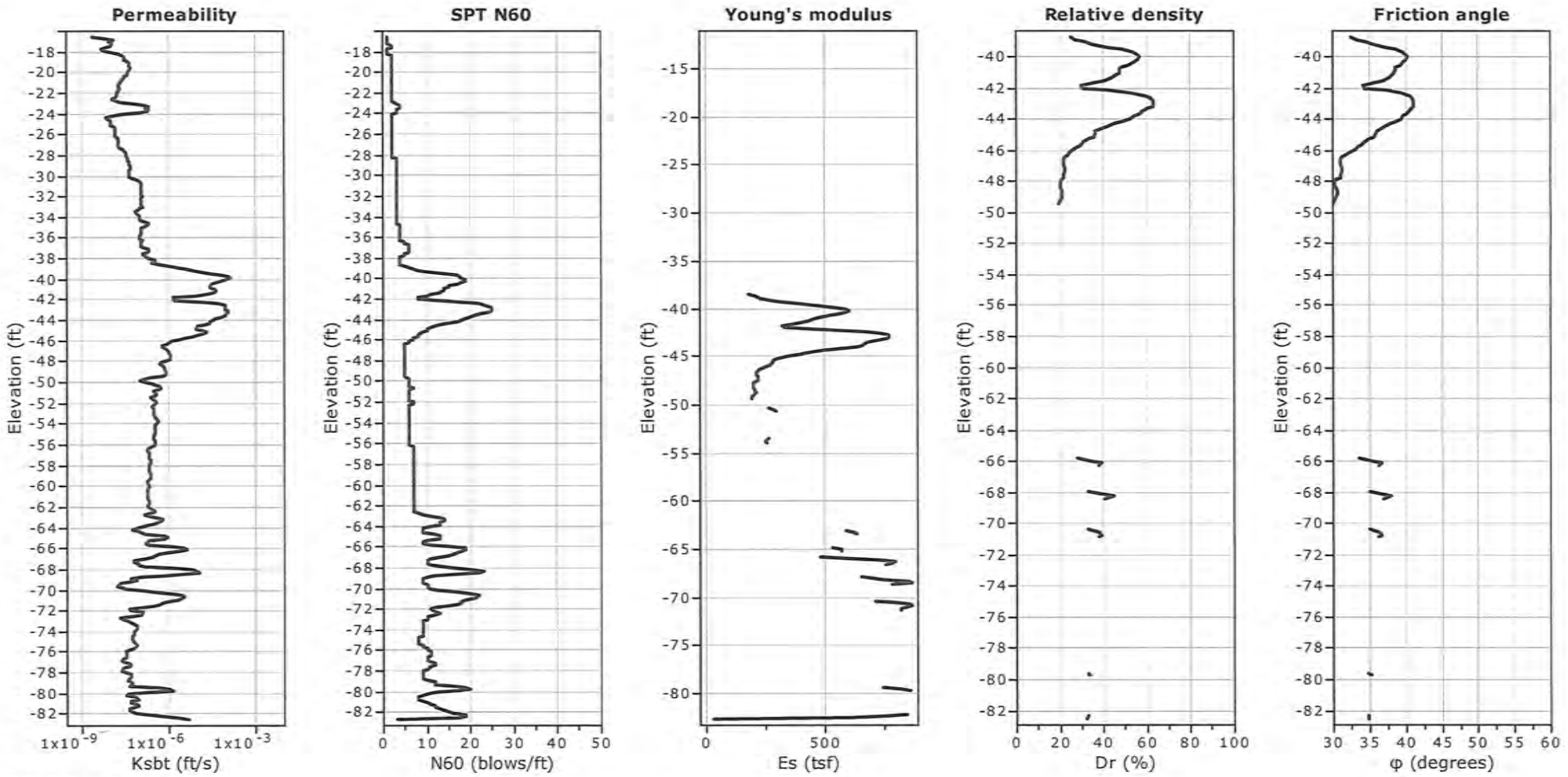
CPT: C-3
Total depth: 71.19 ft, Date: 6/18/2018
Surface Elevation: -11.50 ft
Coords: lat 37.83675° lon -75.4819°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

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Total depth: 71.19 ft, Date: 6/18/2018
Surface Elevation: -11.50 ft
Coords: lat 37.83675° lon -75.4819°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC

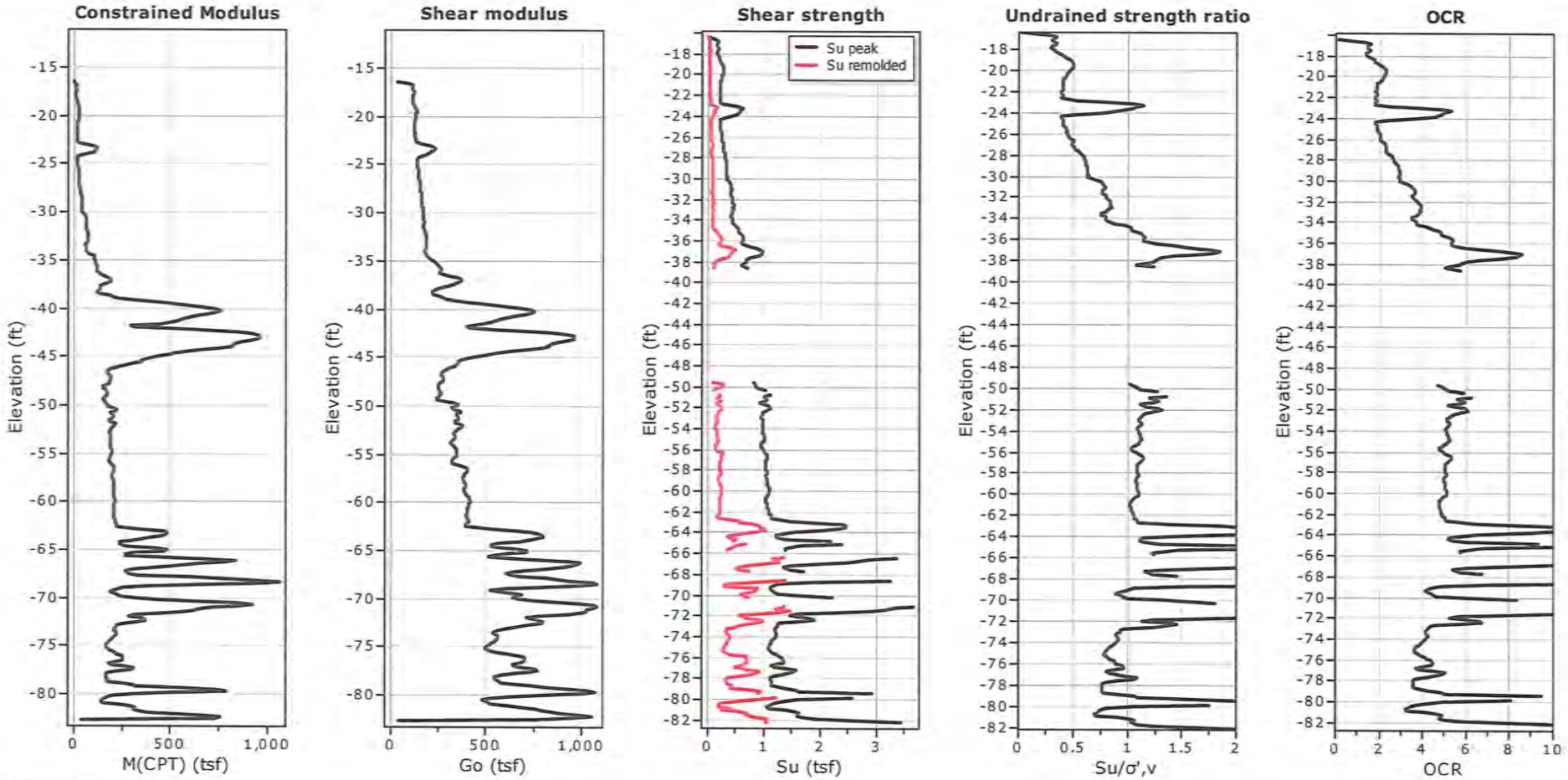


Calculation parameters
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative desnisty constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

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Surface Elevation: -11.50 ft
Coords: lat 37.83675° lon -75.4819°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



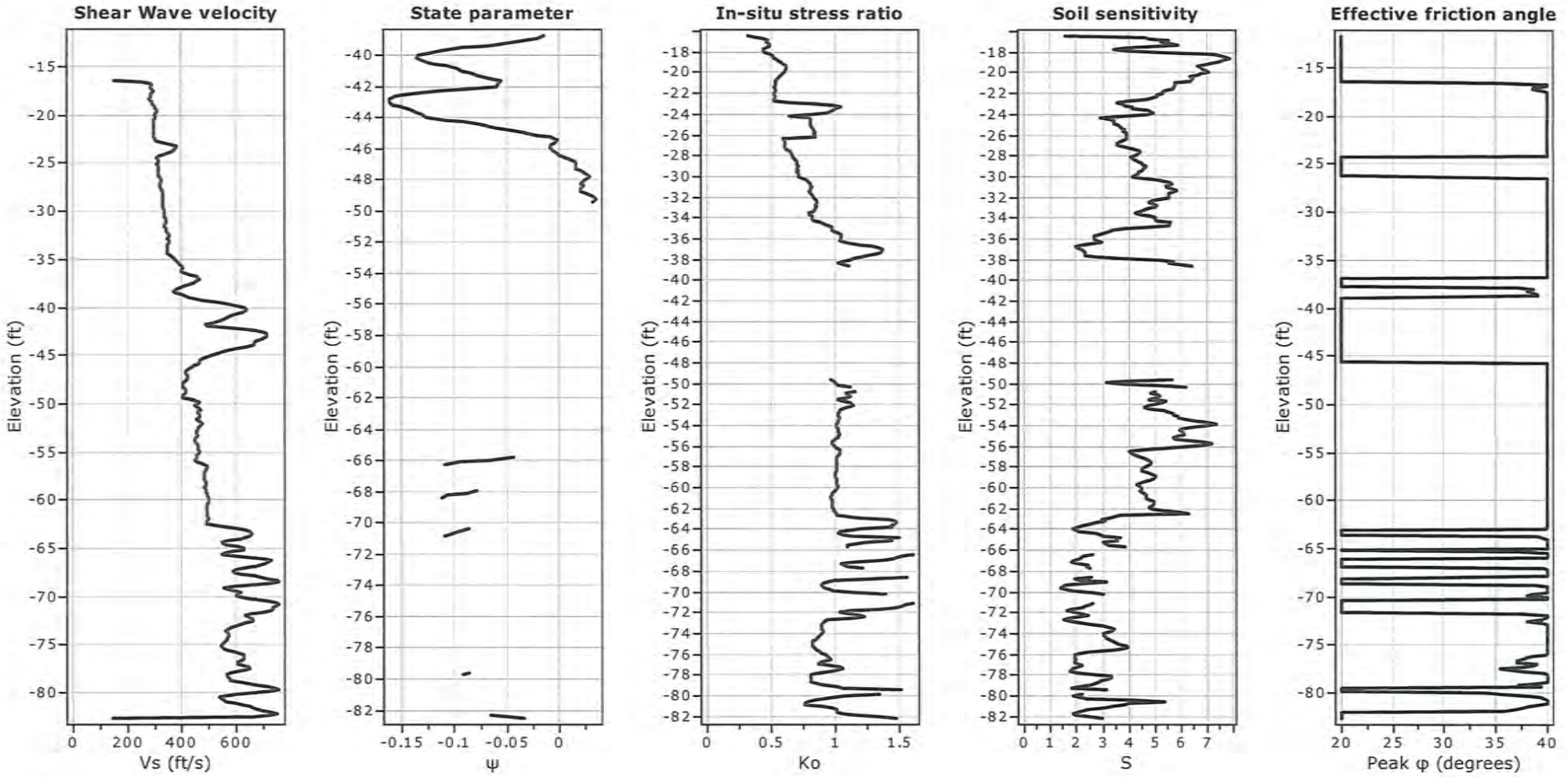
Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data

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Surface Elevation: -11.50 ft
Coords: lat 37.83675° lon -75.4819°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



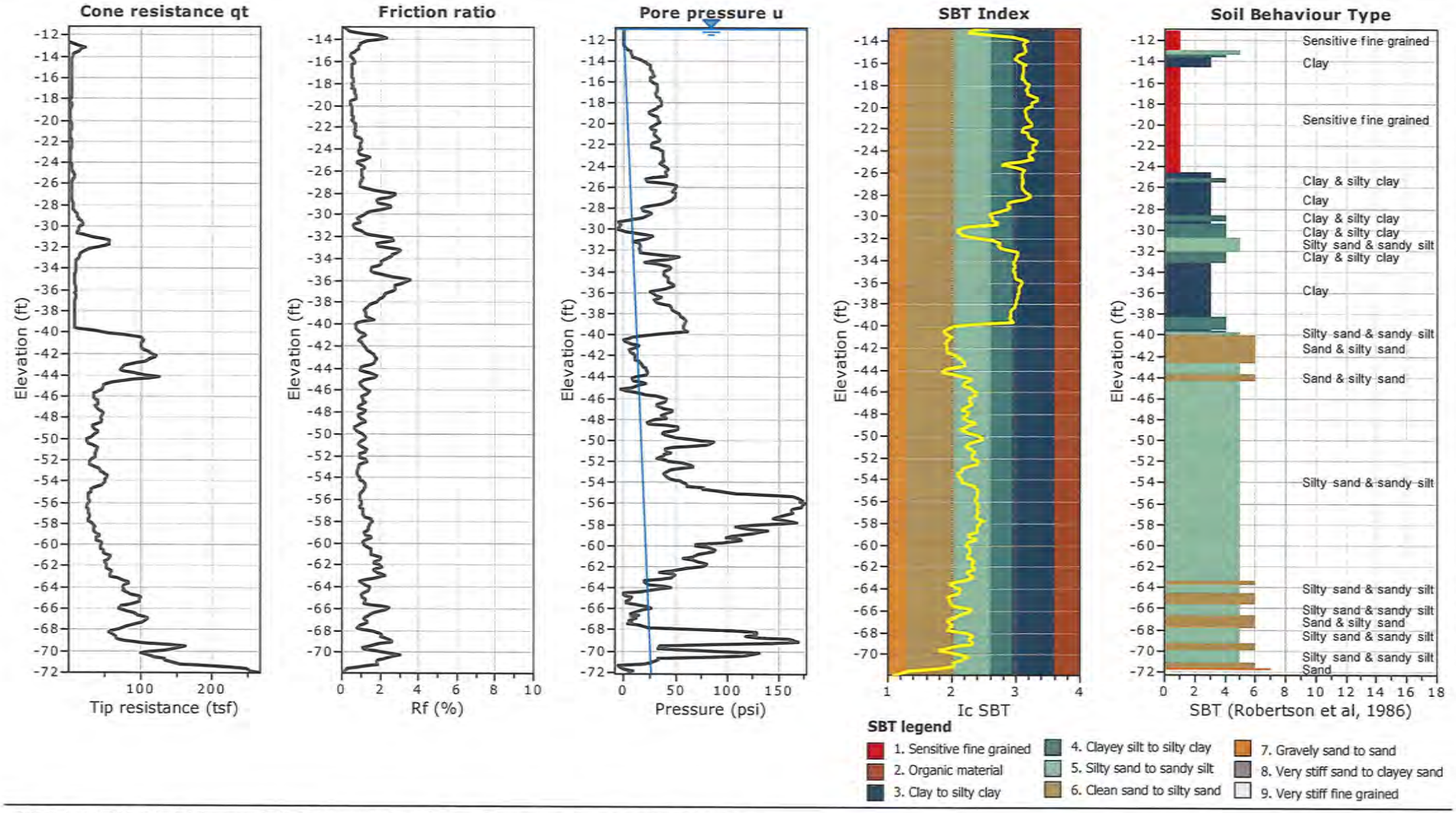
Calculation parameters

Soil Sensitivity factor, N_S: 7.00
User defined estimation data

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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

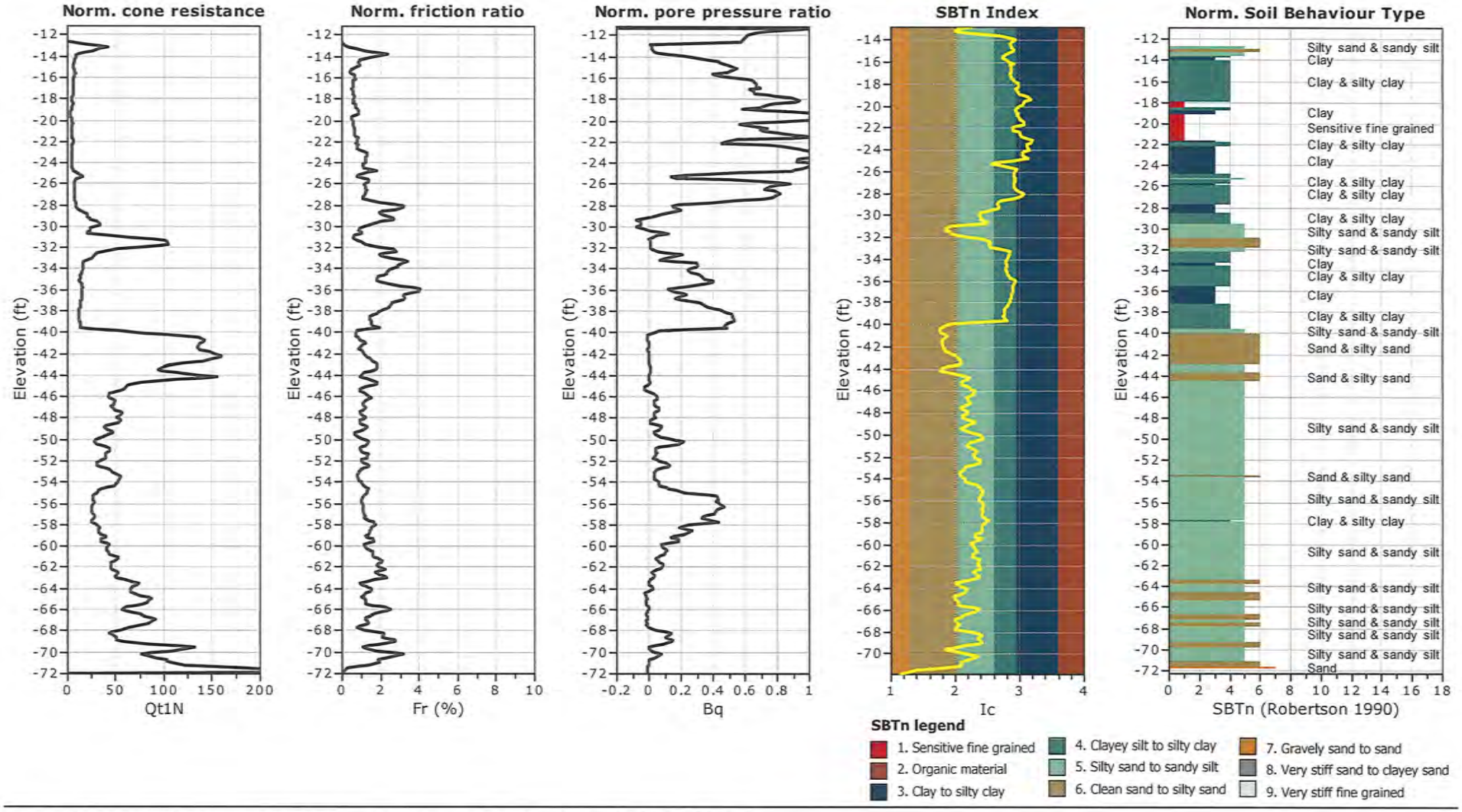
CPT: C-4
Total depth: 61.02 ft, Date: 6/17/2018
Surface Elevation: -11.00 ft
Coords: lat 37.84403° lon -75.47408°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

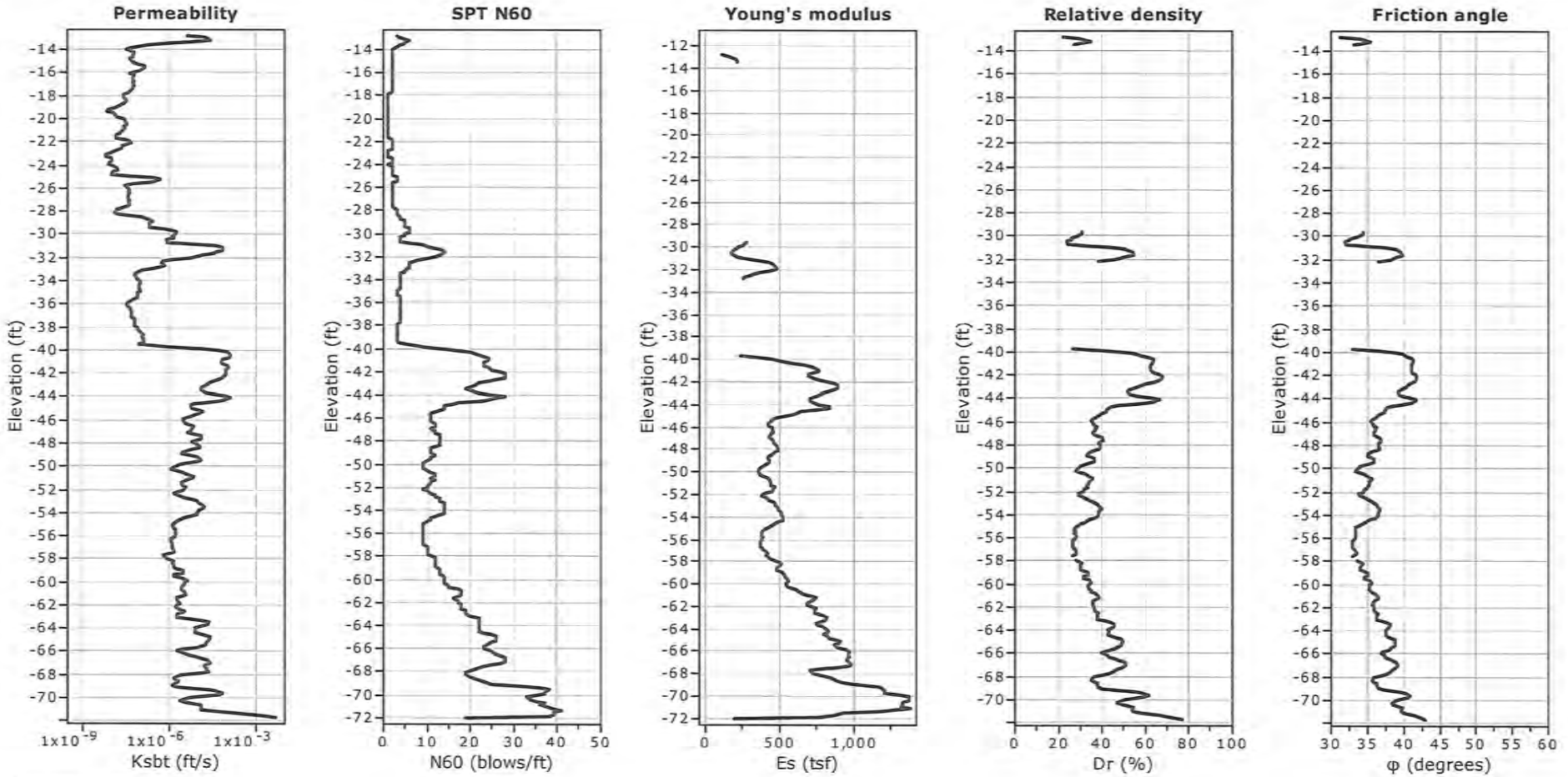
CPT: C-4
Total depth: 61.02 ft, Date: 6/17/2018
Surface Elevation: -11.00 ft
Coords: lat 37.84403° lon -75.47408°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

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Total depth: 61.02 ft, Date: 6/17/2018
Surface Elevation: -11.00 ft
Coords: lat 37.84403° lon -75.47408°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



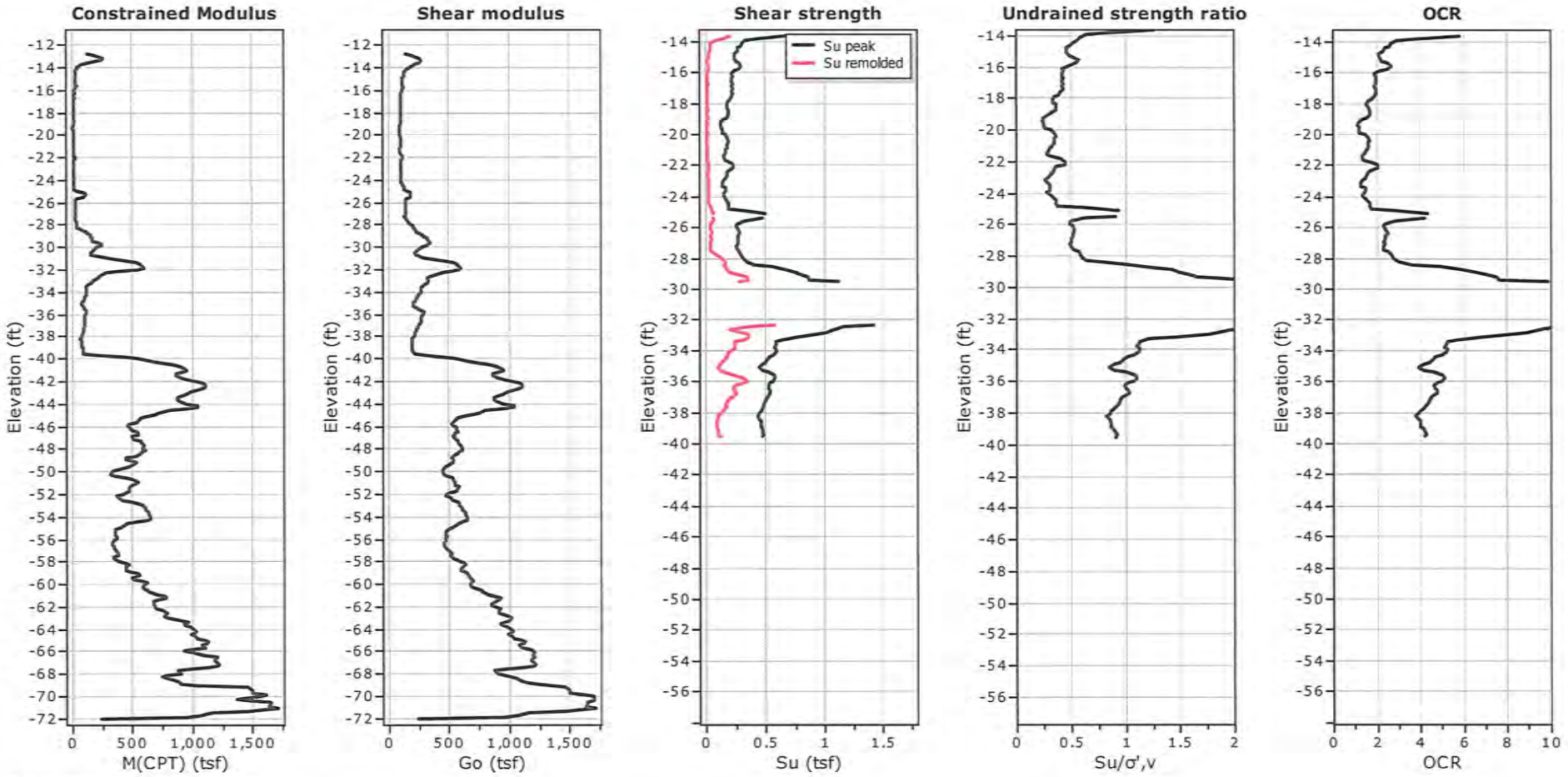
Calculation parameters

Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative desnisty constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-4
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Surface Elevation: -11.00 ft
Coords: lat 37.84403° lon -75.47408°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



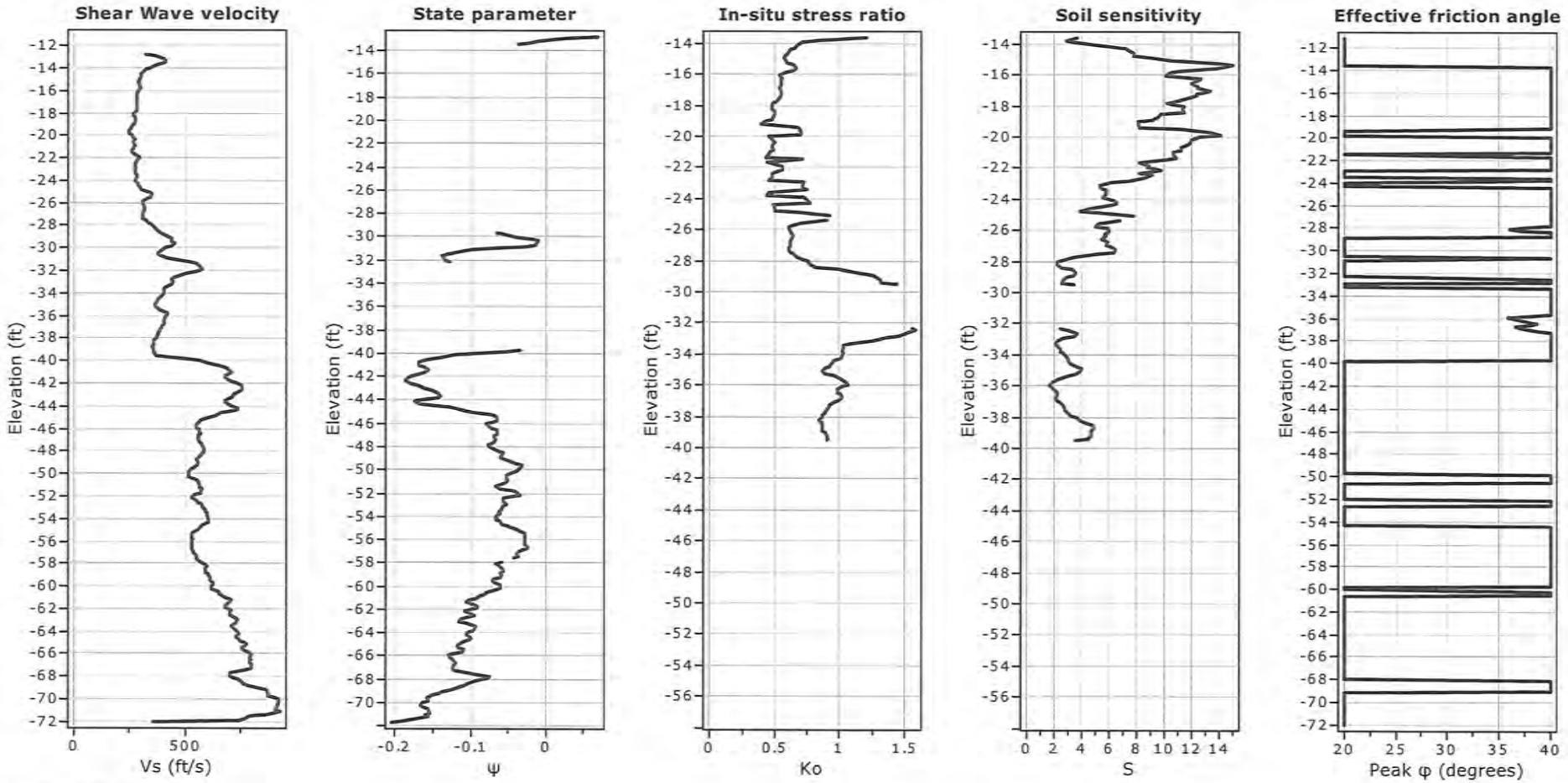
Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data

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CPT: C-4
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Coords: lat 37.84403° lon -75.47408°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**



Calculation parameters

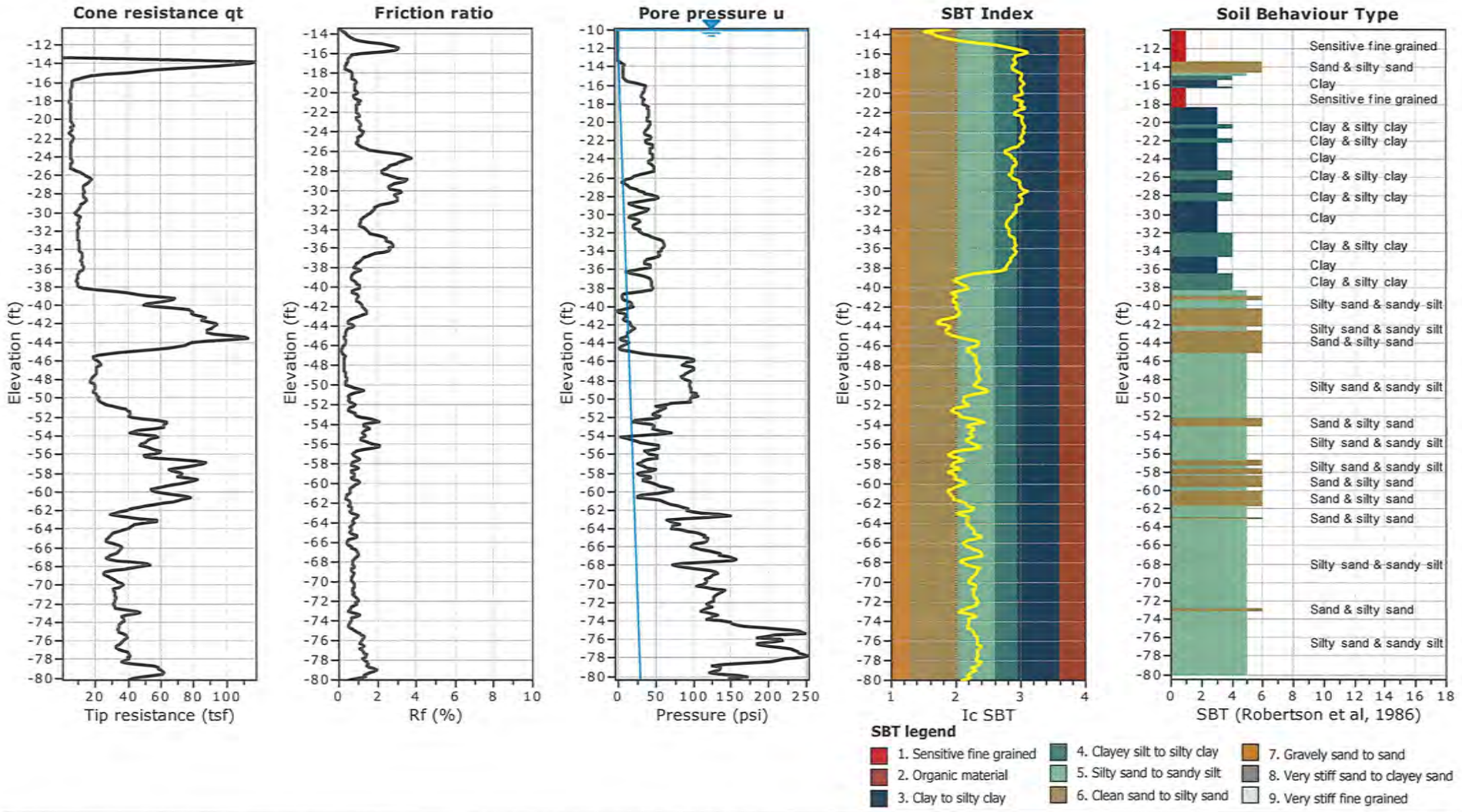
Soil Sensitivity factor, N_S: 7.00

User defined estimation data

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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

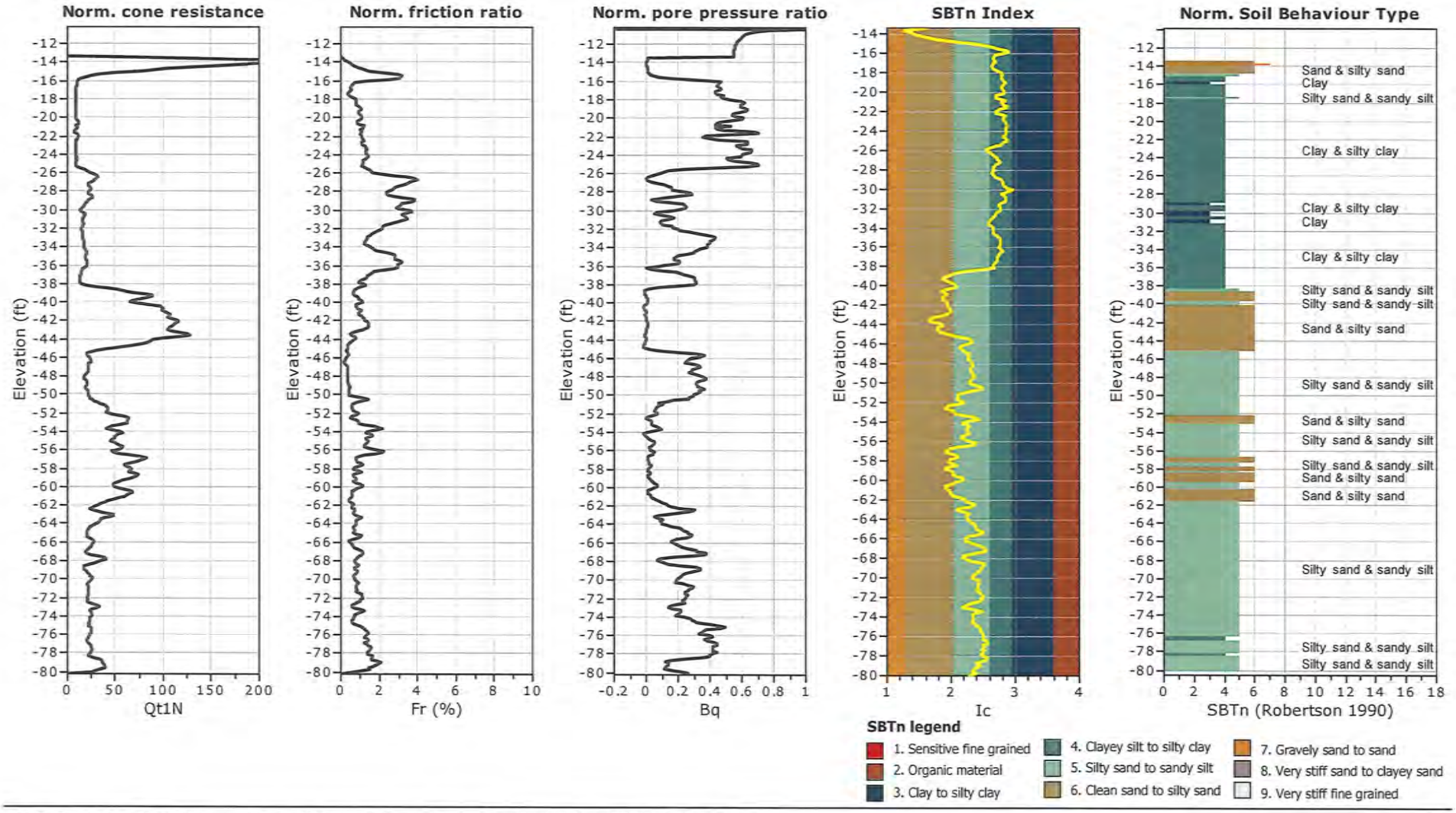
CPT: C-5
Total depth: 70.21 ft, Date: 6/17/2018
Surface Elevation: -10.00 ft
Coords: lat 37.84706° lon -75.47054°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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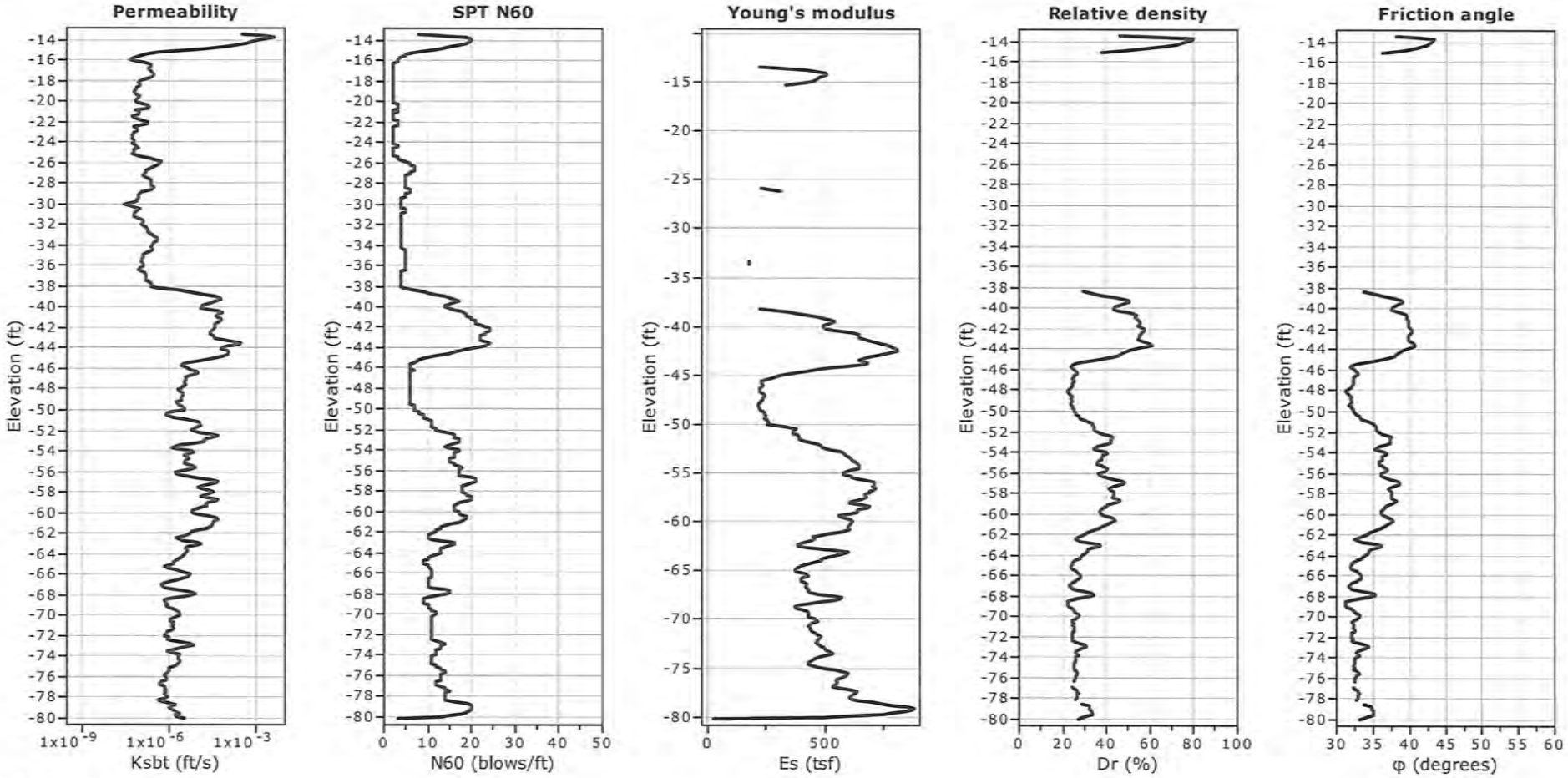
CPT: C-5
Total depth: 70.21 ft, Date: 6/17/2018
Surface Elevation: -10.00 ft
Coords: lat 37.84706° lon -75.47054°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

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Total depth: 70.21 ft, Date: 6/17/2018
Surface Elevation: -10.00 ft
Coords: lat 37.84706° lon -75.47054°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



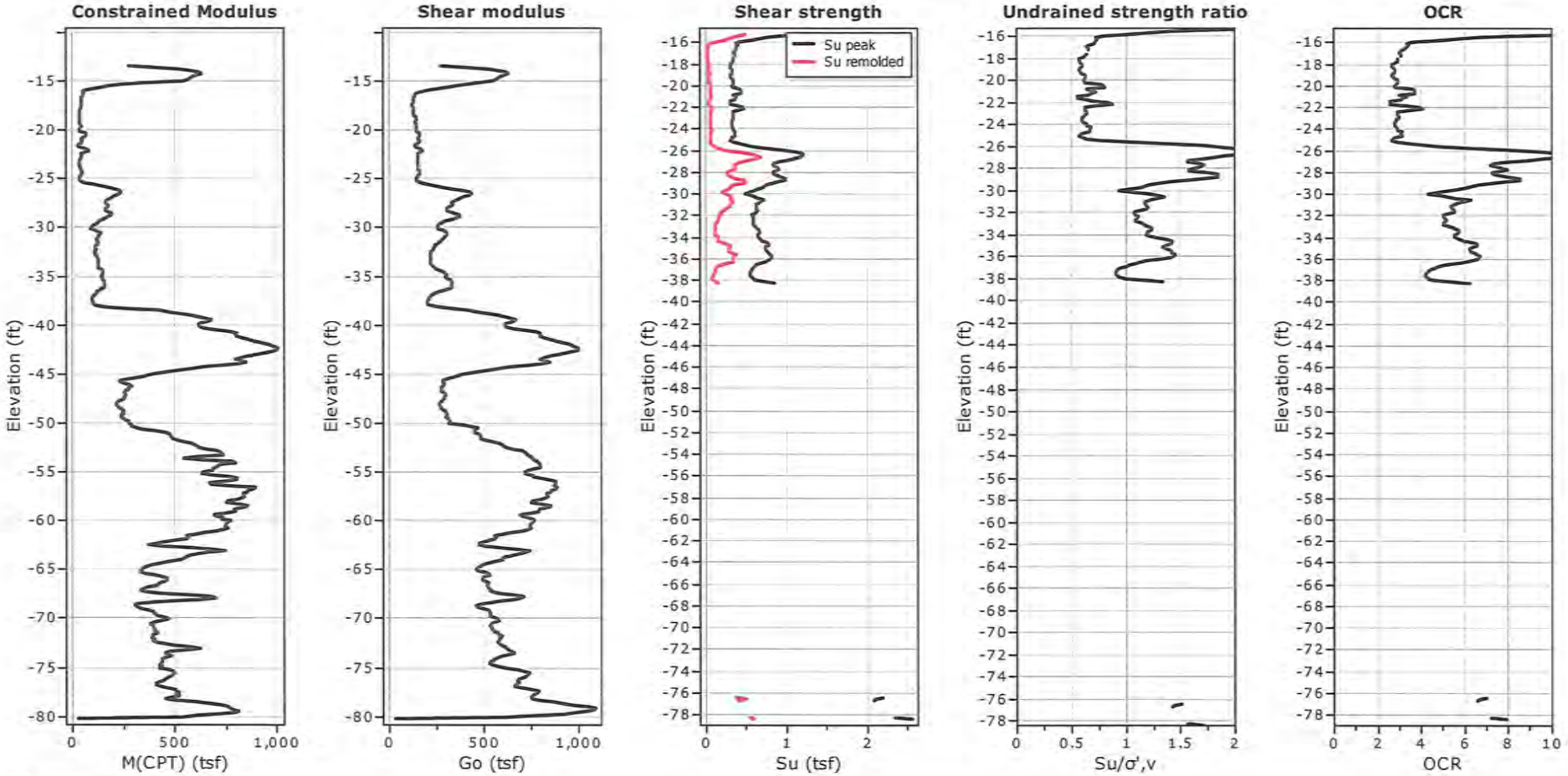
Calculation parameters

Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative desnisty constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

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Project: **Wallops Island Breakwaters**
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Surface Elevation: -10.00 ft
Coords: lat 37.84706° lon -75.47054°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



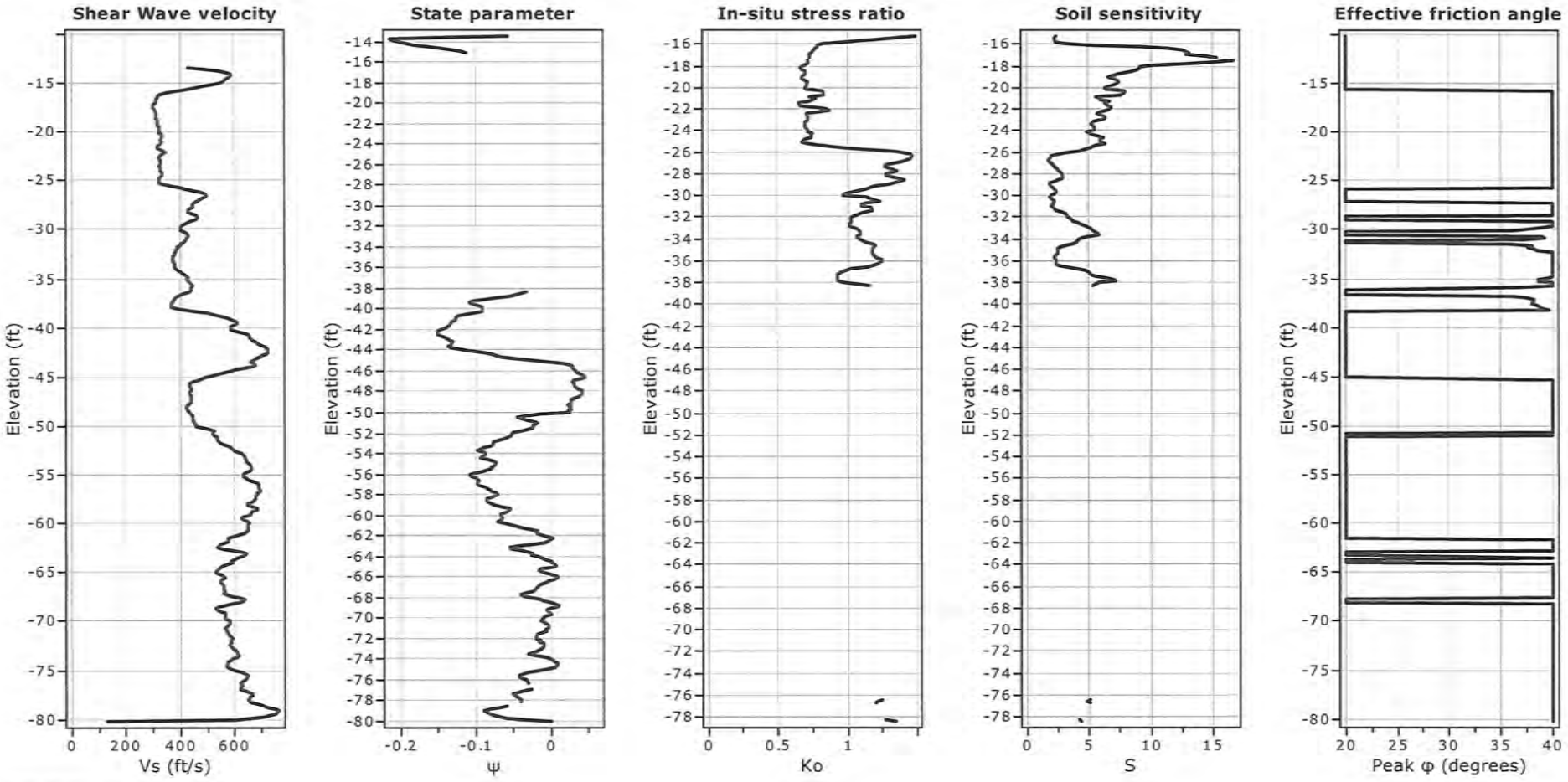
Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data

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Cone Type: Piezocone
Cone Operator: CM-ECh-NC



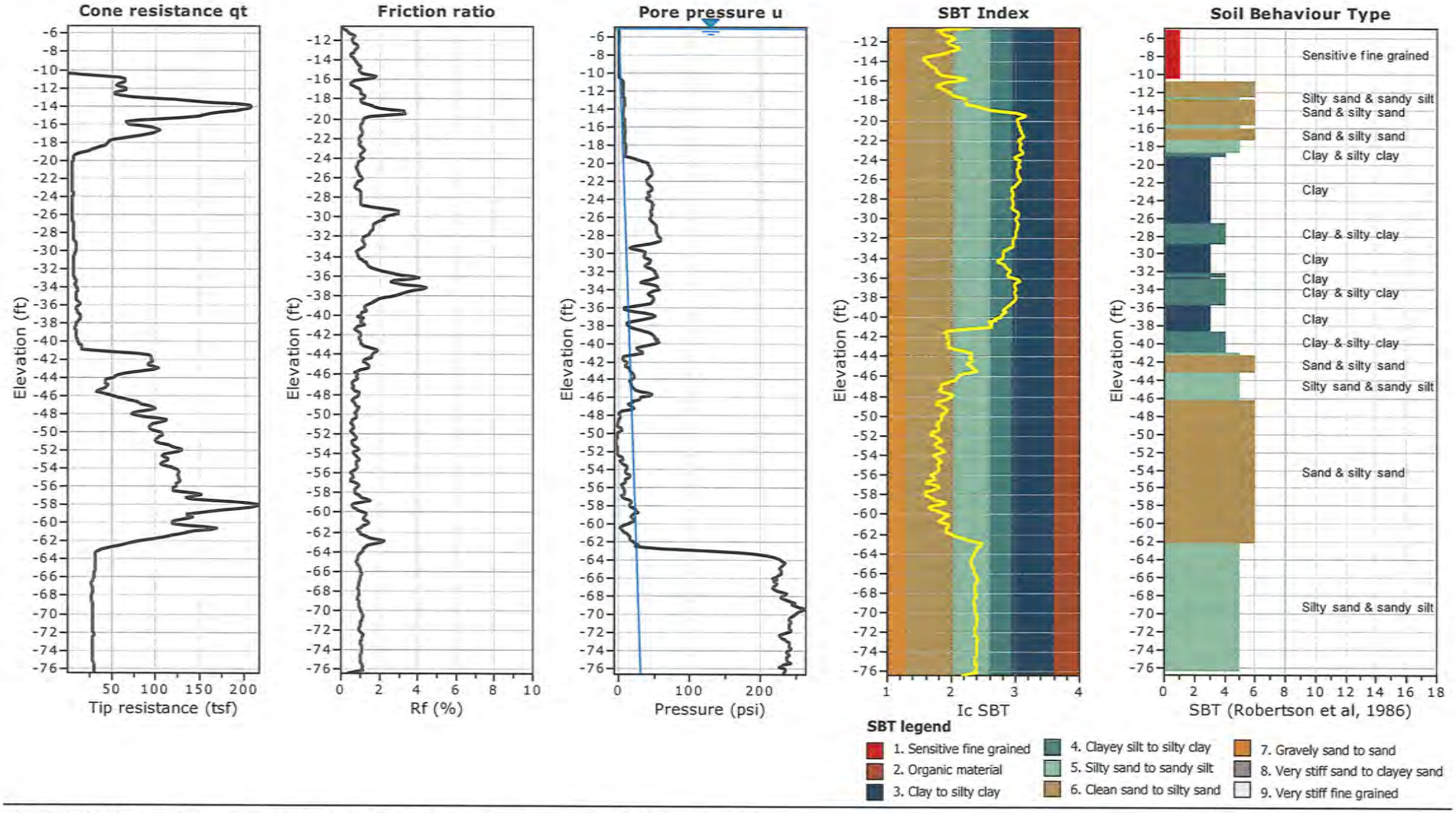
Calculation parameters

Soil Sensitivity factor, N_S: 7.00
User defined estimation data

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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

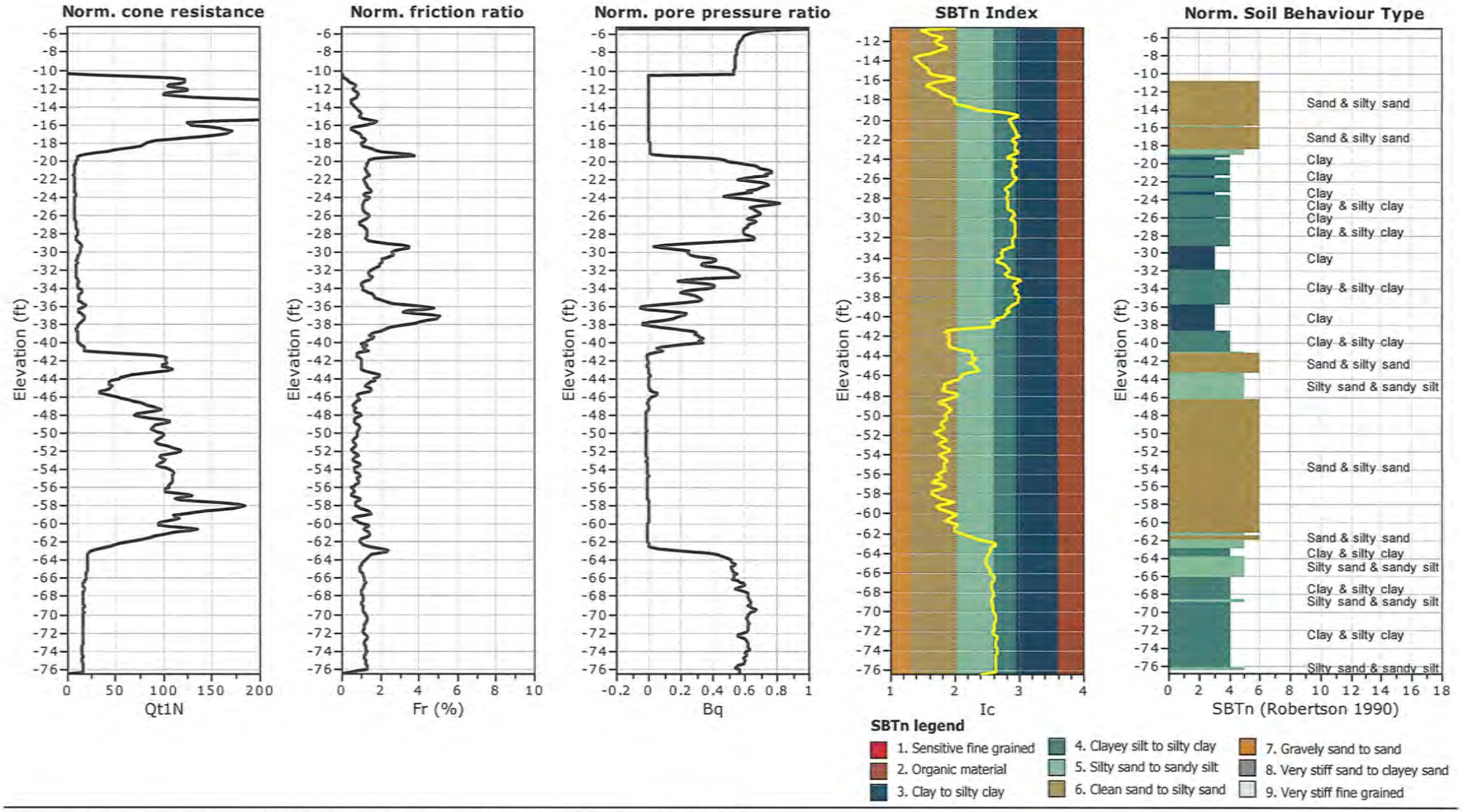
CPT: C-6
Total depth: 71.52 ft, Date: 6/17/2018
Surface Elevation: -5.00 ft
Coords: lat 37.85416° lon -75.46255°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

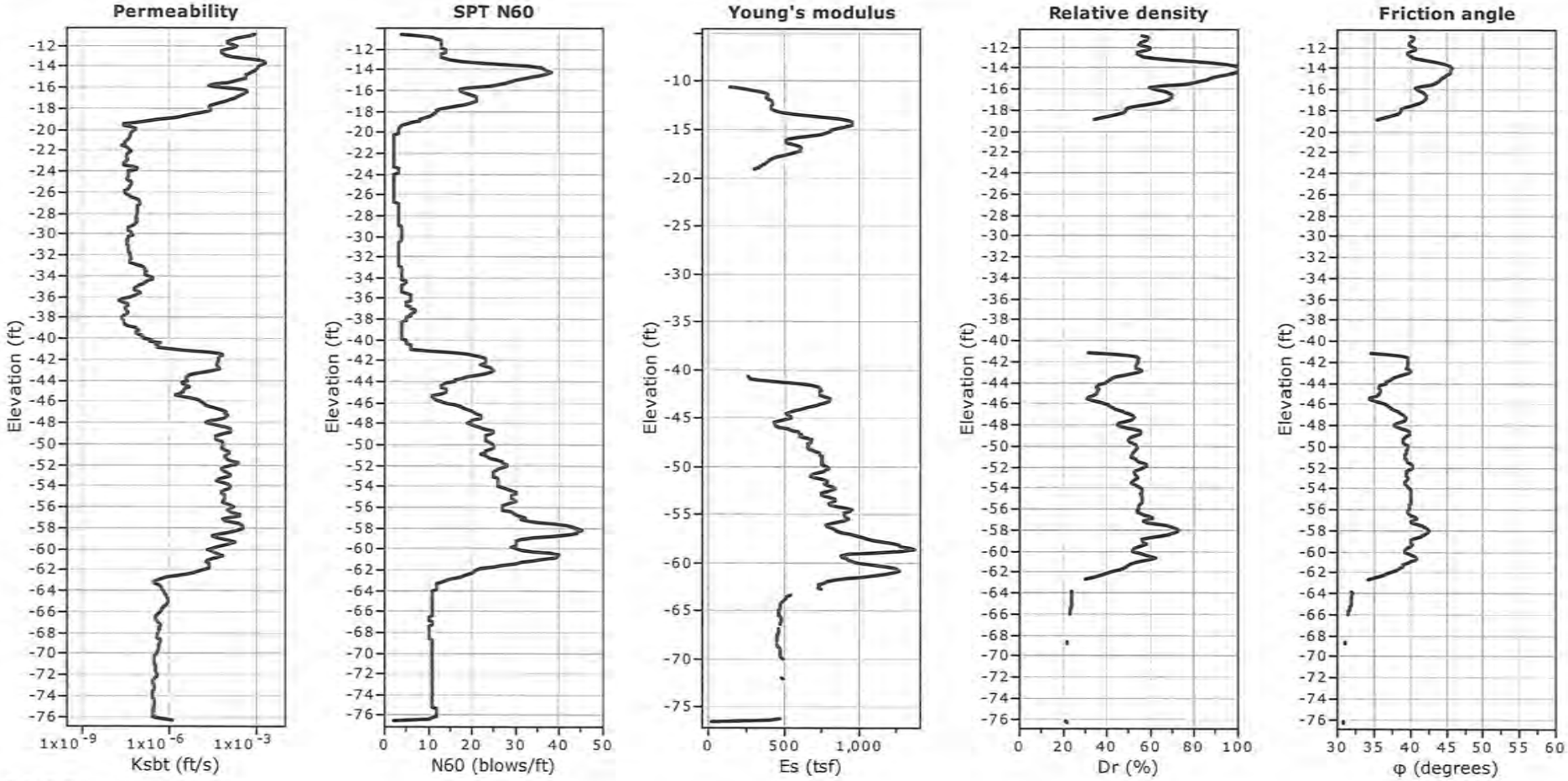
CPT: C-6
Total depth: 71.52 ft, Date: 6/17/2018
Surface Elevation: -5.00 ft
Coords: lat 37.85416° lon -75.46255°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-6
Total depth: 71.52 ft, Date: 6/17/2018
Surface Elevation: -5.00 ft
Coords: lat 37.85416° lon -75.46255°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



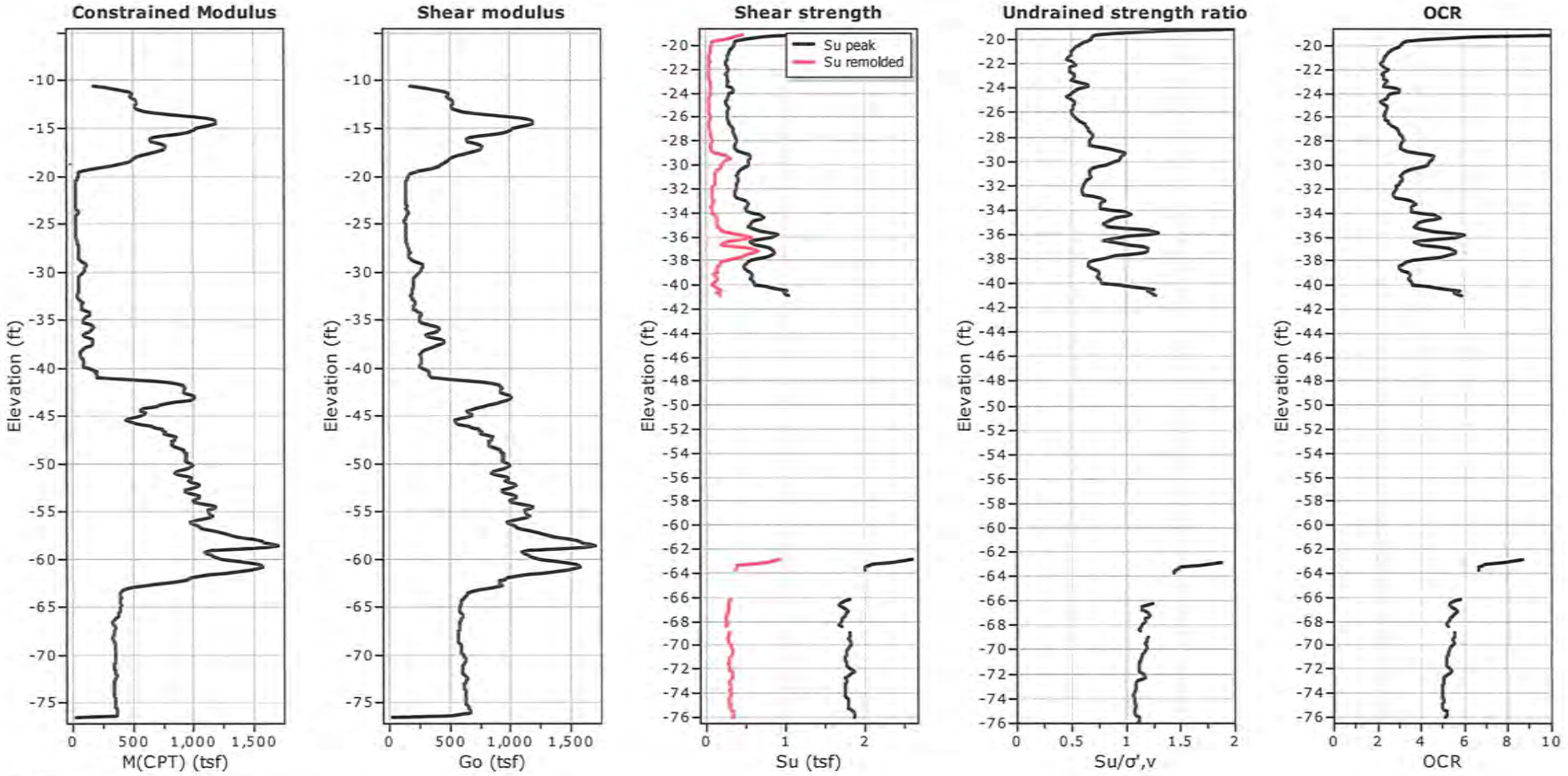
Calculation parameters

Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative desnisty constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

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Cone Type: Piezocone
Cone Operator: CM-ECh-NC



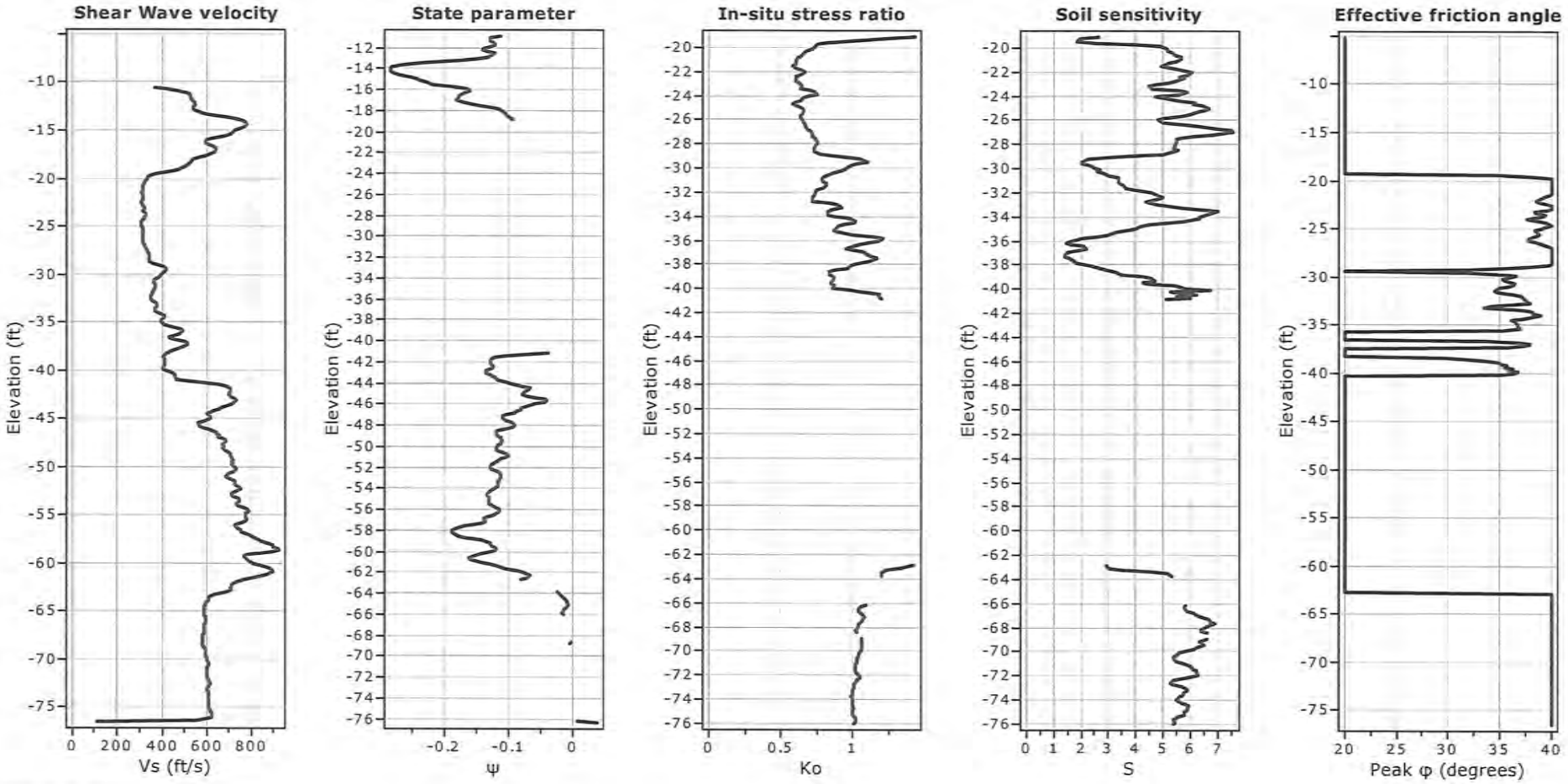
Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data

Schnabel Engineering
9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-6
Total depth: 71.52 ft, Date: 6/17/2018
Surface Elevation: -5.00 ft
Coords: lat 37.85416° lon -75.46255°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



Calculation parameters

Soil Sensitivity factor, N_S: 7.00

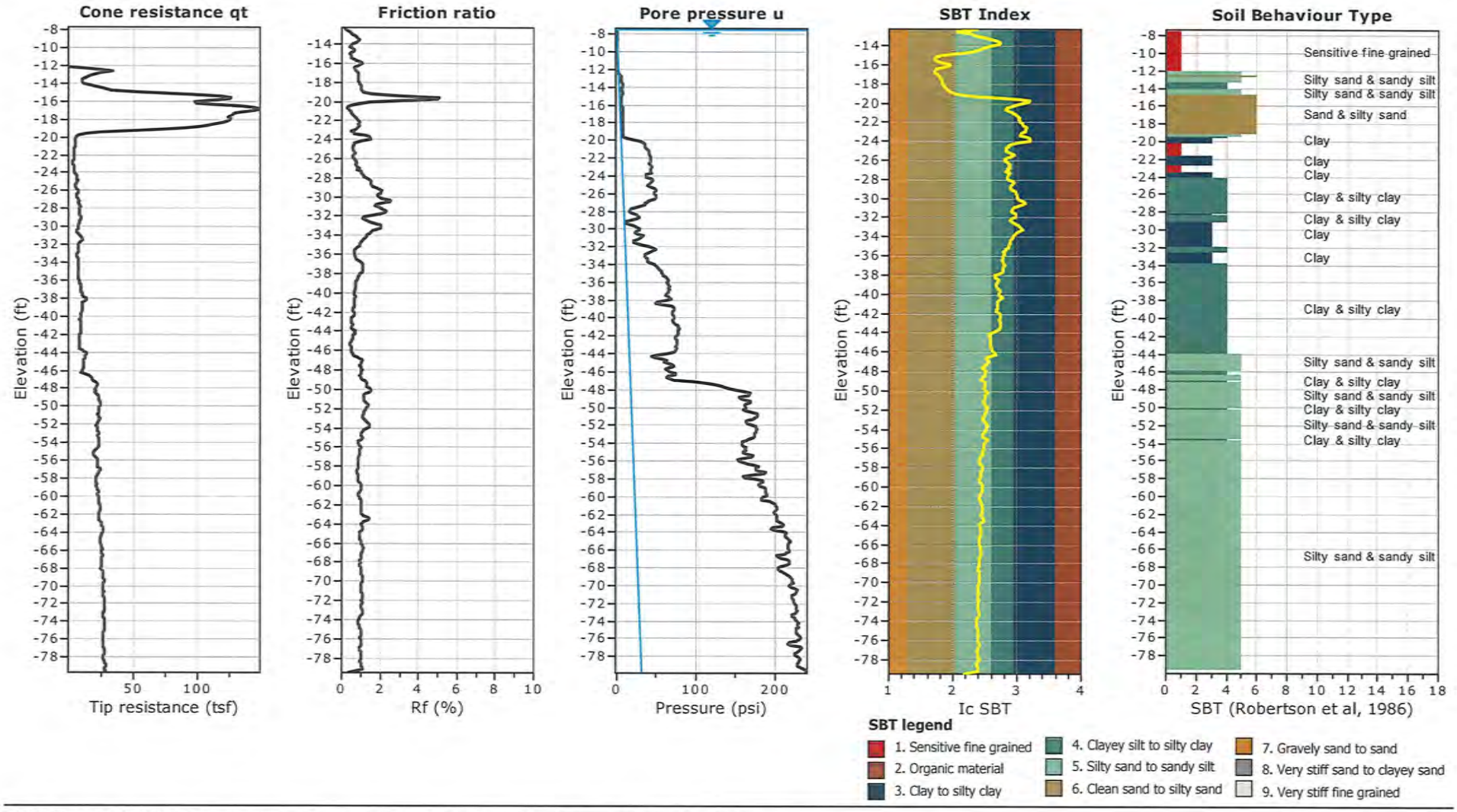
User defined estimation data

Schnabel Engineering
9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

-9

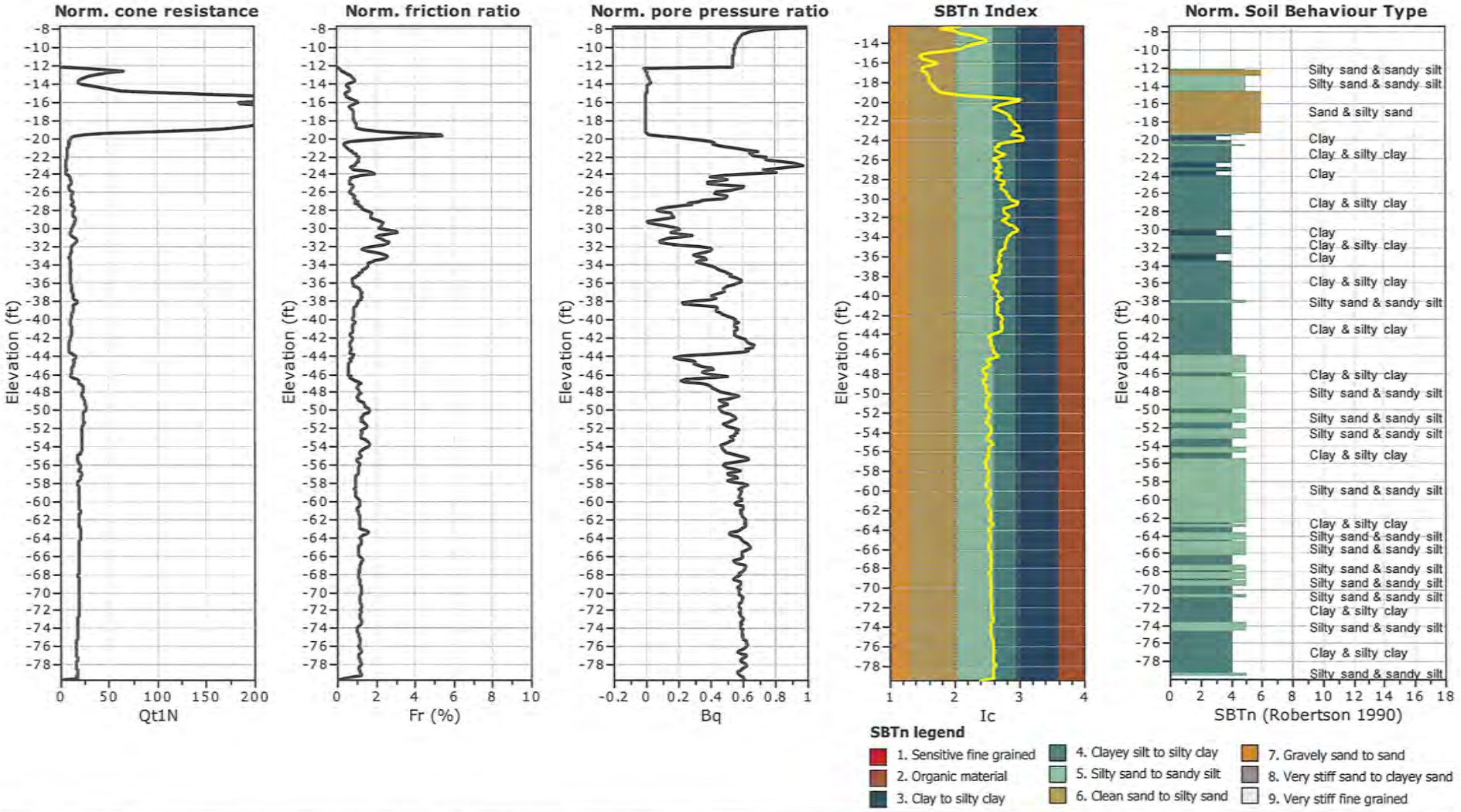
CPT: C-7
Total depth: 72.18 ft, Date: 6/16/2018
Surface Elevation: -7.50 ft
Coords: lat 37.85698° lon -75.45753°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



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9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
https://www.schnabel-eng.com/

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

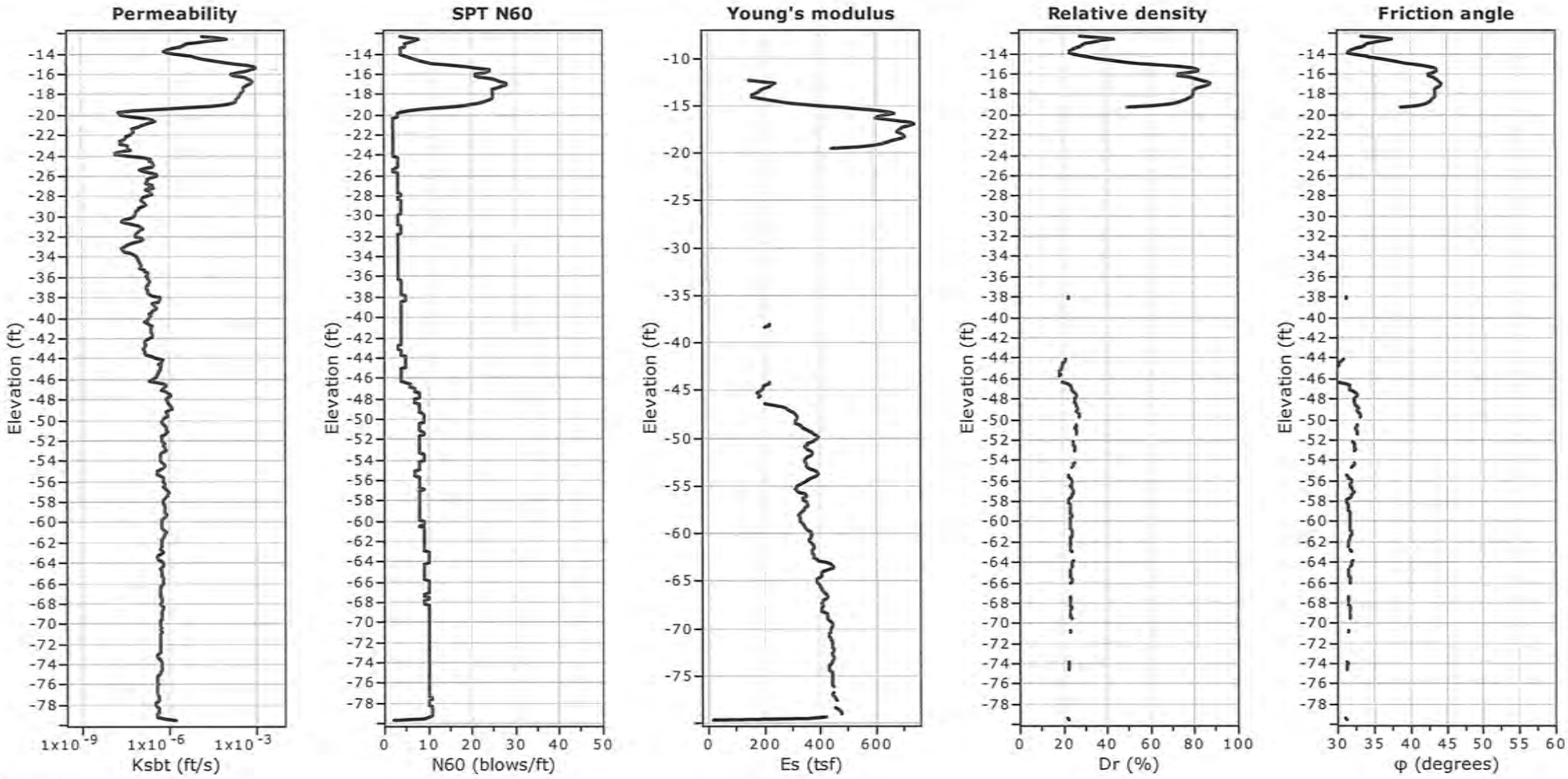
CPT: C-7
Total depth: 72.18 ft, Date: 6/16/2018
Surface Elevation: -7.50 ft
Coords: lat 37.85698° lon -75.45753°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



Schnabel Engineering
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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-7
Total depth: 72.18 ft, Date: 6/16/2018
Surface Elevation: -7.50 ft
Coords: lat 37.85698° lon -75.45753°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



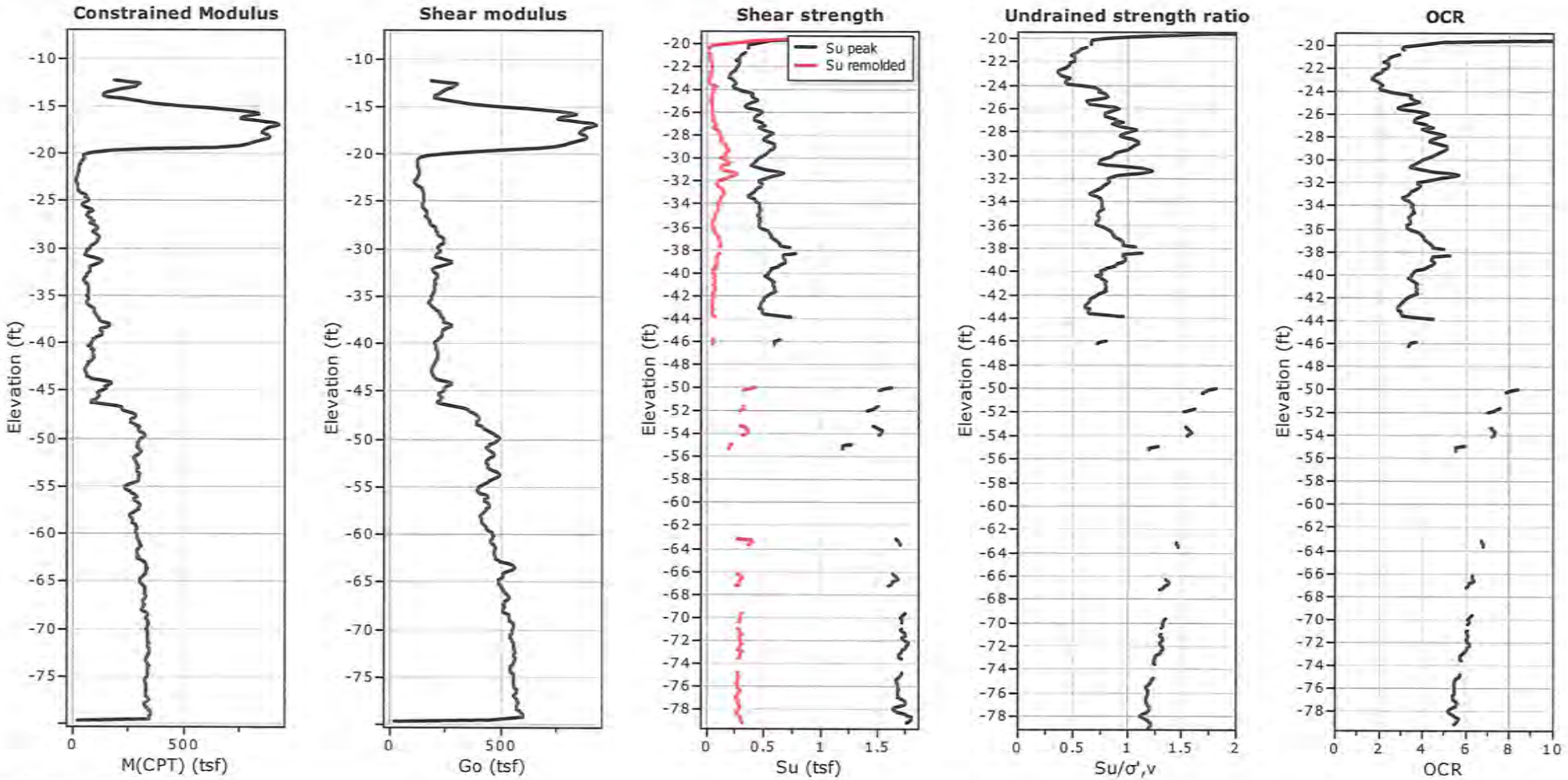
Calculation parameters

Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative desnisty constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

Schnabel Engineering
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Glen Allen, VA 23059
https://www.schnabel-eng.com/

CPT: C-7
Total depth: 72.18 ft, Date: 6/16/2018
Surface Elevation: -7.50 ft
Coords: lat 37.85698° lon -75.45753°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC

Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**



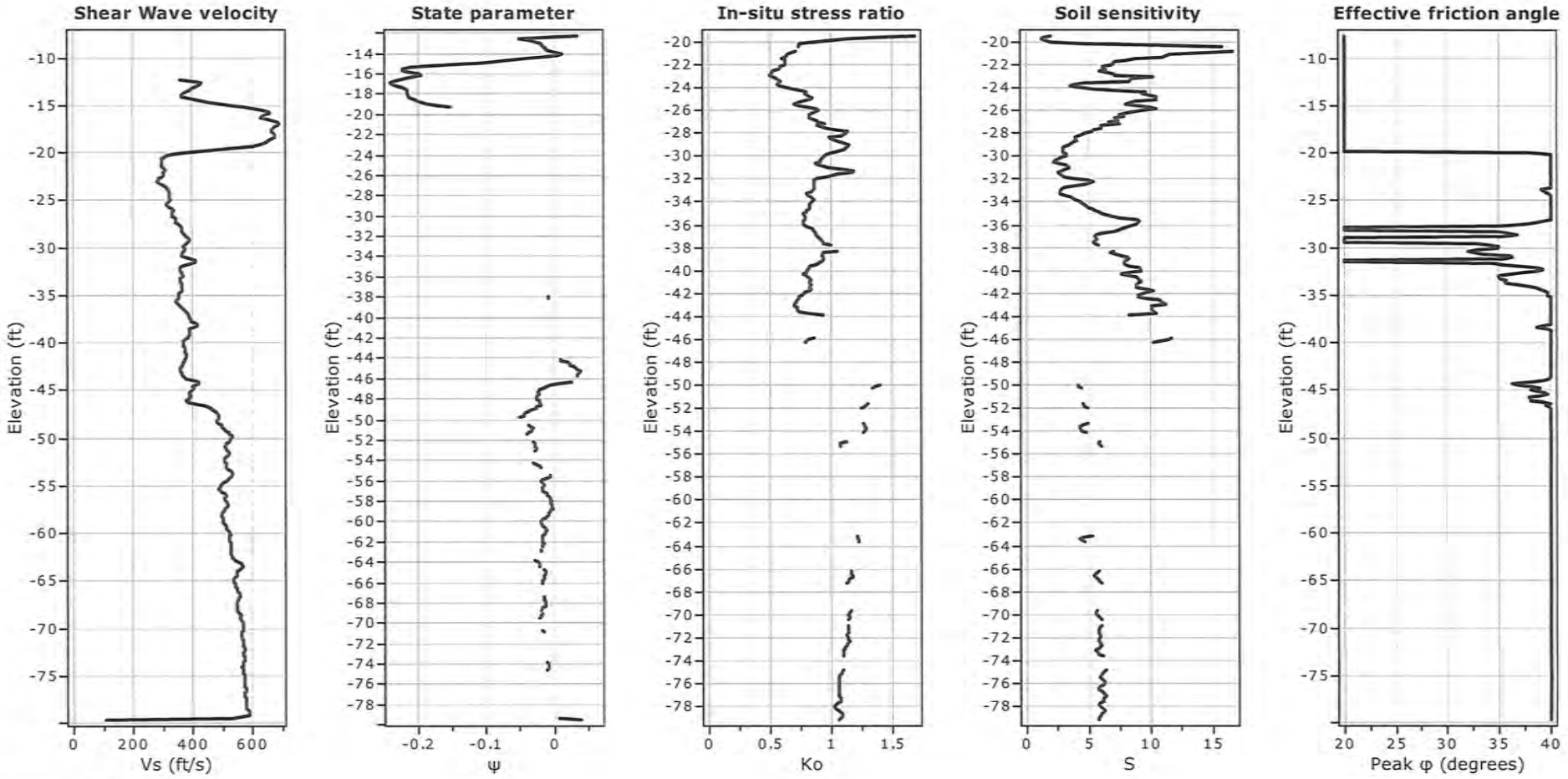
Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data

Schnabel Engineering
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Project: **Wallops Island Breakwaters**
Location: **Wallops Island, Virginia**

CPT: C-7
Total depth: 72.18 ft, Date: 6/16/2018
Surface Elevation: -7.50 ft
Coords: lat 37.85698° lon -75.45753°
Cone Type: Piezocone
Cone Operator: CM-ECh-NC



Calculation parameters

Soil Sensitivity factor, N_S: 7.00

User defined estimation data

Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log(\frac{q_t}{p_a}) + 1.236\right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 \cdot I_c + 1.68}$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$ (applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$

:: Peak drained friction angle, φ (°) ::

$\varphi = 17.60 + 11 \cdot \log(Q_{tn})$

(applicable only to SBT_n: 5, 6, 7 and 8)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$

$\alpha = 14$ for $Q_{tn} > 14$

$\alpha = Q_{tn}$ for $Q_{tn} \leq 14$

$M_{CPT} = \alpha \cdot (q_t - \sigma_v)$

If $I_c \leq 2.20$

$M_{CPT} = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$

:: Small strain shear Modulus, Go (MPa) ::

$$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 \cdot +7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$OCR = k_{OCR} \cdot Q_{tn}$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$$K_O = 0.1 \cdot \left(\frac{q_t - \sigma_v}{\sigma'_{vo}}\right)$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Effective Stress Friction Angle, φ' (°) ::

$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$

(applicable for $0.10 < B_q < 1.00$)

References

- Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 4th Edition, July 2010
- Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)

APPENDIX D

CALCULATIONS

Settlement Analyses
Slope Stability Calculations
Bearing Capacity Calculations

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Schnabel ENGINEERING

CALCULATION COVER SHEET

Project	Project Number
Wallops Island Breakwaters	18C13074

Title
Breakwater Settlement

Computer Programs Used	Version/Release No.
FoSSA	2.0

Purpose and Objective
Breakwaters will be constructed to El 5 off the coast of Wallops Island. The purpose is to calculate breakwater settlement.

Summary of Conclusions
The 50 year settlement of the breakwaters is expected to be between 5 and 16½ inches for the proposed breakwaters. Details are provided on the attached pages.

Originator	Print	Sign	Date
	K. Pocta		Aug 17, 2018

Checked	Print	Sign	Date
	J. Seli		Aug 21, 2018

Results of Consolidation Settlement -- 1D
Project Number: 18C13074
Wallops Island Breakwaters
Breakwater 1 (C-1, B-1, D-1)

Node #	X [ft]	Y [ft]	Original Z [ft]	Settlement Sc [ft]	Elastic Settlement [ft]	**Consolidation Settlement Due to New Embankment [in]**	**Elastic Settlement Due to New Embankment [in]**	**Total Settlement Due to New Embankment [in]**
1	-33.0	0.0	-11	0.07	0.04	**0.79**	**0.48**	**4.01**
2	-31.0	0.0	-11	0.08	0.04	**0.94**	**0.48**	**4.15**
3	-29.0	0.0	-11	0.09	0.05	**1.08**	**0.60**	**4.42**
4	-27.0	0.0	-11	0.11	0.05	**1.30**	**0.60**	**4.63**
5	-25.0	0.0	-11	0.14	0.06	**1.71**	**0.72**	**5.17**
6	-23.0	0.0	-11	0.17	0.06	**2.02**	**0.72**	**5.47**
7	-21.0	0.0	-11	0.20	0.06	**2.36**	**0.72**	**5.81**
8	-19.0	0.0	-11	0.23	0.07	**2.78**	**0.84**	**6.35**
9	-17.0	0.0	-11	0.27	0.07	**3.24**	**0.84**	**6.81**
10	-15.0	0.0	-11	0.32	0.07	**3.86**	**0.84**	**7.44**
11	-13.0	0.0	-11	0.38	0.08	**4.51**	**0.96**	**8.20**
12	-11.0	0.0	-11	0.43	0.08	**5.10**	**0.96**	**8.80**
13	-9.0	0.0	-11	0.48	0.09	**5.70**	**1.08**	**9.52**
14	-7.0	0.0	-11	0.52	0.09	**6.22**	**1.08**	**10.04**
15	-5.0	0.0	-11	0.55	0.09	**6.61**	**1.08**	**10.43**
16	-3.0	0.0	-11	0.57	0.09	**6.85**	**1.08**	**10.67**
17	-1.0	0.0	-11	0.58	0.09	**6.97**	**1.08**	**10.78**
18	1.0	0.0	-11	0.58	0.09	**6.96**	**1.08**	**10.77**
19	3.0	0.0	-11	0.57	0.09	**6.82**	**1.08**	**10.64**
20	5.0	0.0	-11	0.55	0.09	**6.55**	**1.08**	**10.37**
21	7.0	0.0	-11	0.51	0.09	**6.13**	**1.08**	**9.94**
22	9.0	0.0	-11	0.46	0.08	**5.56**	**0.96**	**9.26**
23	11.0	0.0	-11	0.41	0.08	**4.96**	**0.96**	**8.65**
24	13.0	0.0	-11	0.36	0.08	**4.28**	**0.96**	**7.97**
25	15.0	0.0	-11	0.29	0.07	**3.50**	**0.84**	**7.08**
26	17.0	0.0	-11	0.24	0.07	**2.83**	**0.84**	**6.40**
27	19.0	0.0	-11	0.17	0.06	**2.09**	**0.72**	**5.55**
28	21.0	0.0	-11	0.13	0.06	**1.56**	**0.72**	**5.02**
29	23.0	0.0	-11	0.10	0.05	**1.18**	**0.60**	**4.51**
30	25.0	0.0	-11	0.09	0.04	**1.02**	**0.48**	**4.24**
31	27.0	0.0	-11	0.07	0.04	**0.86**	**0.48**	**4.08**

Secondary Settlement = 2.74 [in]

Time to End of Primary (95% Consolidation) = 282 [days]

Time to End of Design Life = 50 [years]

t2/t1 = 64.7

Schnabel ENGINEERING

Wallops Island Breakwaters

Report created by FoSSA(2.0): Copyright (c) 2003-2012, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title: Wallops Island Breakwaters
Project Number: 18C13074 -
Client: USACE
Designer: K. Pocta
Station Number:

Description:
Breakwater 1

Company's information:

Name: Schnabel Engineering
Street: 9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
Telephone #: (804) 649-7035
Fax #: (804) 264-3244
E-Mail:

Original file path and name: G:\2011 - ..... ts\02-Calcs\01-Geotech\Settlement\Breakwater 1.2ST
Original date and time of creating this file:

GEOMETRY: Analysis of a 2D geometry

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INPUT DATA – FOUNDATION LAYERS – 6 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	115.00	0.30	Quaternary Sand (A1)
2	100.00	0.30	Quaternary Clay & Organic soil (A2/3)
3	115.00	0.30	Quaternary Sand (A1)
4	110.00	0.30	Quaternary Clay & Organic soil (A2/3)
5	115.00	0.30	Quaternary Sand (A1)
6	115.00	0.30	CG Yorktown (B1)

INPUT DATA – EMBANKMENT LAYERS – 2 layers

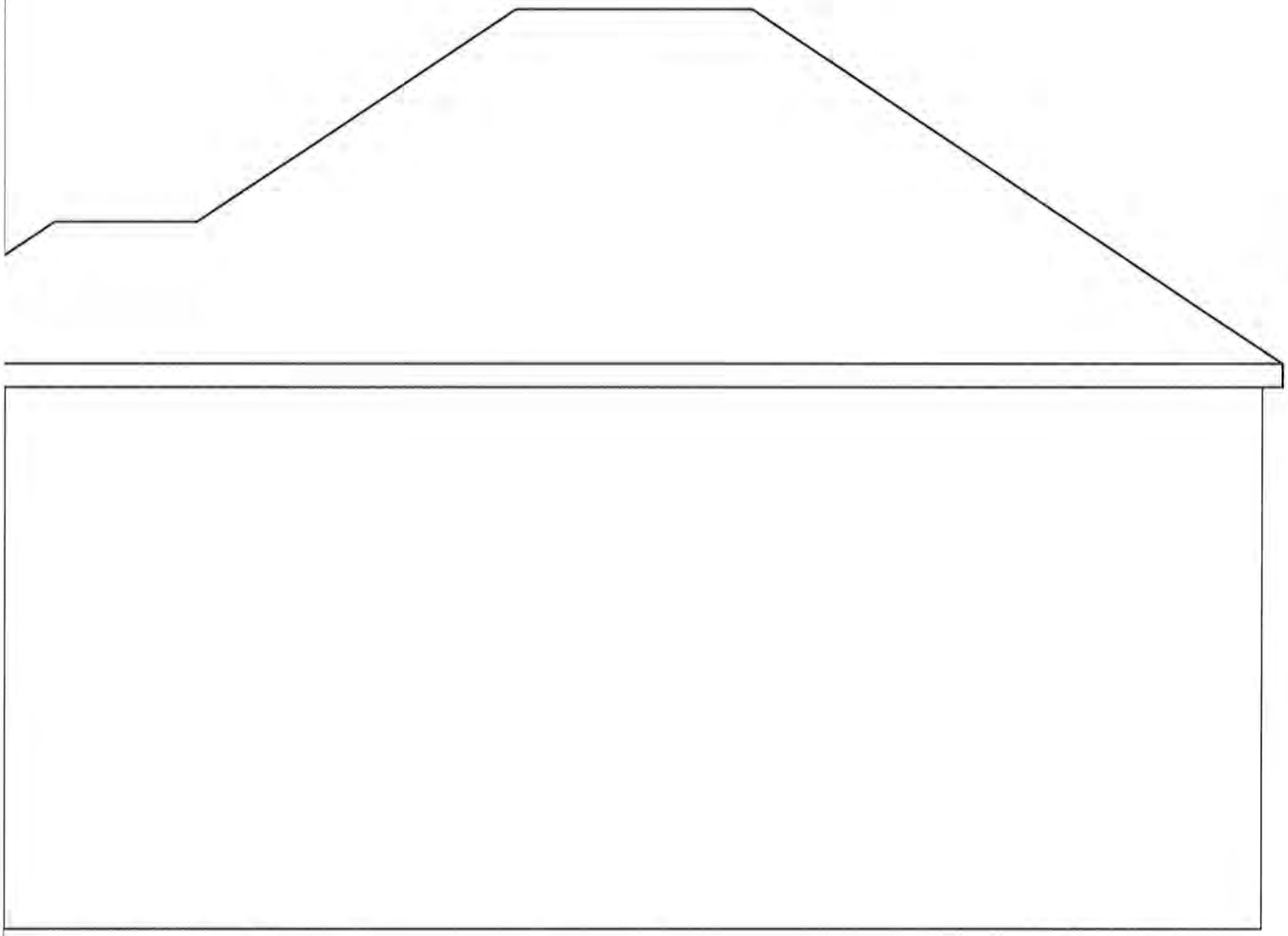
	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	115.00	12" Maritime Matress
2	150.00	Rip Rap

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	0.00

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DRAWING OF SPECIFIED GEOMETRY



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INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer #	Underging Consolidation [Yes/No]	OCR = Pc / Po	Cc / (1+e0)	Cr / (1+e0)	e0	Cv [ft ²/day]	Drains at :	CREEP Ca/Cc
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	3.50	0.150	0.011	N/A	0.5750	Top & Bot.	0.0300
3	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	Yes	3.50	0.150	0.011	N/A	0.5750	Top & Bot.	0.0300
5	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Secondary Comprassion (Creep) : Settlement is calculated at t2/t1 = 64.7

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	-33.00	0.00	1	300000	0.3000	0.0007	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0079			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0106			
			6	1200000	0.3000	0.0164			
2	-31.00	0.00	1	300000	0.3000	0.0026	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0091			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0117			
			6	1200000	0.3000	0.0173			
3	-29.00	0.00	1	300000	0.3000	0.0045	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0103			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0128			
			6	1200000	0.3000	0.0182			
4	-27.00	0.00	1	300000	0.3000	0.0063	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0116			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0139			
			6	1200000	0.3000	0.0190			
5	-25.00	0.00	1	300000	0.3000	0.0079	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0130			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0150			
			6	1200000	0.3000	0.0199			
6	-23.00	0.00	1	300000	0.3000	0.0083	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0143			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0161			
			6	1200000	0.3000	0.0207			
7	-21.00	0.00	1	300000	0.3000	0.0082	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0157			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0172			
			6	1200000	0.3000	0.0215			
8	-19.00	0.00	1	300000	0.3000	0.0082	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0170			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0183			
			6	1200000	0.3000	0.0222			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
9	-17.00	0.00	1	300000	0.3000	0.0094	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0183			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0193			
			6	1200000	0.3000	0.0229			
10	-15.00	0.00	1	300000	0.3000	0.0111	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0196			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0202			
			6	1200000	0.3000	0.0235			
11	-13.00	0.00	1	300000	0.3000	0.0129	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0207			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0211			
			6	1200000	0.3000	0.0240			
12	-11.00	0.00	1	300000	0.3000	0.0147	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0217			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0218			
			6	1200000	0.3000	0.0245			
13	-9.00	0.00	1	300000	0.3000	0.0166	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0226			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0224			
			6	1200000	0.3000	0.0249			
14	-7.00	0.00	1	300000	0.3000	0.0184	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0233			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0229			
			6	1200000	0.3000	0.0252			
15	-5.00	0.00	1	300000	0.3000	0.0199	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0238			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0233			
			6	1200000	0.3000	0.0254			
16	-3.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0241			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0235			
			6	1200000	0.3000	0.0255			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
17	-1.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0243			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0235			
			6	1200000	0.3000	0.0255			
18	1.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0242			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0234			
			6	1200000	0.3000	0.0255			
19	3.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0238			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0232			
			6	1200000	0.3000	0.0253			
20	5.00	0.00	1	300000	0.3000	0.0200	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0233			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0228			
			6	1200000	0.3000	0.0250			
21	7.00	0.00	1	300000	0.3000	0.0185	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0225			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0222			
			6	1200000	0.3000	0.0247			
22	9.00	0.00	1	300000	0.3000	0.0167	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0216			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0215			
			6	1200000	0.3000	0.0242			
23	11.00	0.00	1	300000	0.3000	0.0148	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0205			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0207			
			6	1200000	0.3000	0.0237			
24	13.00	0.00	1	300000	0.3000	0.0131	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0193			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0198			
			6	1200000	0.3000	0.0231			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
25	15.00	0.00	1	300000	0.3000	0.0113	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0179			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0188			
			6	1200000	0.3000	0.0225			
26	17.00	0.00	1	300000	0.3000	0.0096	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0165			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0177			
			6	1200000	0.3000	0.0217			
27	19.00	0.00	1	300000	0.3000	0.0078	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0150			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0166			
			6	1200000	0.3000	0.0210			
28	21.00	0.00	1	300000	0.3000	0.0060	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0136			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0155			
			6	1200000	0.3000	0.0202			
29	23.00	0.00	1	300000	0.3000	0.0043	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0121			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0143			
			6	1200000	0.3000	0.0193			
30	25.00	0.00	1	300000	0.3000	0.0025	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0107			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0131			
			6	1200000	0.3000	0.0184			
31	27.00	0.00	1	300000	0.3000	0.0006	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0093			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0120			
			6	1200000	0.3000	0.0176			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	-33.00	0.00	-11.00	0.07	-11.07
2	-31.00	0.00	-11.00	0.08	-11.08
3	-29.00	0.00	-11.00	0.09	-11.09
4	-27.00	0.00	-11.00	0.11	-11.11
5	-25.00	0.00	-11.00	0.14	-11.14
6	-23.00	0.00	-11.00	0.17	-11.17
7	-21.00	0.00	-11.00	0.20	-11.20
8	-19.00	0.00	-11.00	0.23	-11.23
9	-17.00	0.00	-11.00	0.27	-11.27
10	-15.00	0.00	-11.00	0.32	-11.32
11	-13.00	0.00	-11.00	0.38	-11.38
12	-11.00	0.00	-11.00	0.43	-11.43
13	-9.00	0.00	-11.00	0.48	-11.48
14	-7.00	0.00	-11.00	0.52	-11.52
15	-5.00	0.00	-11.00	0.55	-11.55
16	-3.00	0.00	-11.00	0.57	-11.57
17	-1.00	0.00	-11.00	0.58	-11.58
18	1.00	0.00	-11.00	0.58	-11.58
19	3.00	0.00	-11.00	0.57	-11.57
20	5.00	0.00	-11.00	0.55	-11.55
21	7.00	0.00	-11.00	0.51	-11.51
22	9.00	0.00	-11.00	0.46	-11.46
23	11.00	0.00	-11.00	0.41	-11.41
24	13.00	0.00	-11.00	0.36	-11.36
25	15.00	0.00	-11.00	0.29	-11.29

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
26	17.00	0.00	-11.00	0.24	-11.24
27	19.00	0.00	-11.00	0.17	-11.17
28	21.00	0.00	-11.00	0.13	-11.13
29	23.00	0.00	-11.00	0.10	-11.10
30	25.00	0.00	-11.00	0.09	-11.09
31	27.00	0.00	-11.00	0.07	-11.07

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	-11.00	Quaternary Sand (A1)
2	1	0.00	-15.00	Quaternary Clay & Organic soil (A2/3)
3	1	0.00	-39.00	Quaternary Sand (A1)
4	1	0.00	-45.00	Quaternary Clay & Organic soil (A2/3)
5	1	0.00	-49.00	Quaternary Sand (A1)
6	1	0.00	-56.00	CG Yorktown (B1)

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TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embank. Soil #		Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	X1 = -33.51 [ft]	1	-33.50	-10.00	12" Maritime Matress
	X2 = 27.51 [ft]	2	27.50	-10.00	
2	X1 = -33.51 [ft]	1	-33.50	-10.00	Rip Rap
	X2 = 27.51 [ft]	2	-24.50	-4.00	
		3	-18.50	-4.00	
		4	-5.00	5.00	
		5	5.00	5.00	
		6	27.50	-10.00	

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HISTORY OF SETTLEMENT ANALYSES

Case #	Location of 1D Section : (X) [ft.]	(Y) [ft.]	Ultimate Settlement, Sc [ft.]	After... [days]	Actual Settlement, [ft.]	U-ave (min.for all consol.layers) [%]	USER'S DESCRIPTION
1	0.00	0.00	0.581	282.5	0.6	95.1	
2	---	---	---	---	---	---	
3	---	---	---	---	---	---	
4	---	---	---	---	---	---	
5	---	---	---	---	---	---	
6	---	---	---	---	---	---	
7	---	---	---	---	---	---	
8	---	---	---	---	---	---	
9	---	---	---	---	---	---	
10	---	---	---	---	---	---	
11	---	---	---	---	---	---	
12	---	---	---	---	---	---	
13	---	---	---	---	---	---	
14	---	---	---	---	---	---	
15	---	---	---	---	---	---	

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TemporaryTextJ

Wallops Island Breakwater 1
Calculated Secondary Compression (Creep)
Total Calculated Secondary Compression = 0.228 [ft]. 2.74 in

#	Layer Undegoing Consolidation	C-alpha over Cc	Cc	C-alpha	e-sub-0	H [ft]	t2/t1	Ss [ft]
1	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	YES	0.0300	0.1500	0.0045	N/A	24.00	64.7	0.196
3	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	YES	0.0300	0.1500	0.0045	N/A	4.00	64.7	0.033
5	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Results of Consolidation Settlement – 1D
Project Number: 18C13074
Wallops Island Breakwaters
Breakwater 2 (C-2, D-2, C-3, B-2, D-3)

Node #	X [ft]	Y [ft]	Original Z [ft]	Settlement Sc [ft]	Elastic Settlement [ft]	**Consolidation Settlement Due to New Embankment [in]**	**Elastic Settlement Due to New Embankment [in]**	**Total Settlement Due to New Embankment [in]**
1	-33.0	0.0	-11	0.11	0.02	**1.31**	**0.24**	**8.18**
2	-31.0	0.0	-11	0.13	0.02	**1.51**	**0.24**	**8.37**
3	-29.0	0.0	-11	0.14	0.02	**1.72**	**0.24**	**8.59**
4	-27.0	0.0	-11	0.20	0.02	**2.35**	**0.24**	**9.21**
5	-25.0	0.0	-11	0.23	0.03	**2.82**	**0.36**	**9.80**
6	-23.0	0.0	-11	0.28	0.03	**3.30**	**0.36**	**10.29**
7	-21.0	0.0	-11	0.31	0.03	**3.73**	**0.36**	**10.71**
8	-19.0	0.0	-11	0.35	0.03	**4.16**	**0.36**	**11.14**
9	-17.0	0.0	-11	0.40	0.03	**4.82**	**0.36**	**11.80**
10	-15.0	0.0	-11	0.46	0.04	**5.53**	**0.48**	**12.64**
11	-13.0	0.0	-11	0.52	0.04	**6.26**	**0.48**	**13.37**
12	-11.0	0.0	-11	0.59	0.04	**7.04**	**0.48**	**14.14**
13	-9.0	0.0	-11	0.64	0.05	**7.73**	**0.60**	**14.95**
14	-7.0	0.0	-11	0.69	0.05	**8.29**	**0.60**	**15.52**
15	-5.0	0.0	-11	0.73	0.05	**8.71**	**0.60**	**15.94**
16	-3.0	0.0	-11	0.75	0.05	**8.97**	**0.60**	**16.19**
17	-1.0	0.0	-11	0.76	0.05	**9.09**	**0.60**	**16.31**
18	1.0	0.0	-11	0.76	0.05	**9.07**	**0.60**	**16.30**
19	3.0	0.0	-11	0.74	0.05	**8.94**	**0.60**	**16.16**
20	5.0	0.0	-11	0.72	0.05	**8.65**	**0.60**	**15.87**
21	7.0	0.0	-11	0.68	0.05	**8.20**	**0.60**	**15.42**
22	9.0	0.0	-11	0.63	0.04	**7.58**	**0.48**	**14.68**
23	11.0	0.0	-11	0.57	0.04	**6.82**	**0.48**	**13.93**
24	13.0	0.0	-11	0.50	0.04	**6.01**	**0.48**	**13.12**
25	15.0	0.0	-11	0.43	0.04	**5.17**	**0.48**	**12.28**
26	17.0	0.0	-11	0.35	0.03	**4.25**	**0.36**	**11.23**
27	19.0	0.0	-11	0.29	0.03	**3.42**	**0.36**	**10.41**
28	21.0	0.0	-11	0.22	0.03	**2.61**	**0.36**	**9.59**
29	23.0	0.0	-11	0.16	0.02	**1.92**	**0.24**	**8.78**
30	25.0	0.0	-11	0.13	0.02	**1.62**	**0.24**	**8.48**
31	27.0	0.0	-11	0.12	0.02	**1.41**	**0.24**	**8.28**

Secondary Settlement = 6.6 [in]

Time to End of Primary (95% Consolidation) = 305 [days]

Time to End of Design Life = 50 [years]

t2/t1 = 59.8

Schnabel ENGINEERING

Wallops Island Breakwaters

Report created by FoSSA(2.0): Copyright (c) 2003-2012, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title: Wallops Island Breakwaters
Project Number: 18C13074 -
Client: USACE
Designer: K. Pocta
Station Number:

Description:
Breakwater 2

Company's information:

Name: Schnabel Engineering
Street: 9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
Telephone #: (804) 649-7035
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E-Mail:

Original file path and name: G:\2011 - ..... ts\02-Calcs\01-Geotech\Settlement\Breakwater 2.2ST
Original date and time of creating this file: Thu Aug 16 16:25:34 2018

GEOMETRY: Analysis of a 2D geometry

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INPUT DATA – FOUNDATION LAYERS -- 7 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	115.00	0.30	Quaternary Sand (A1)
2	100.00	0.30	Quaternary Clay & Organic soil (A2/3)
3	115.00	0.30	Quaternary Sand (A1)
4	110.00	0.30	Quaternary Clay & Organic soil (A2/3)
5	115.00	0.30	Quaternary Sand (A1)
6	110.00	0.30	Quaternary Clay & Organic soil (A2/3)
7	115.00	0.30	CG Yorktown (B1)

INPUT DATA – EMBANKMENT LAYERS – 2 layers

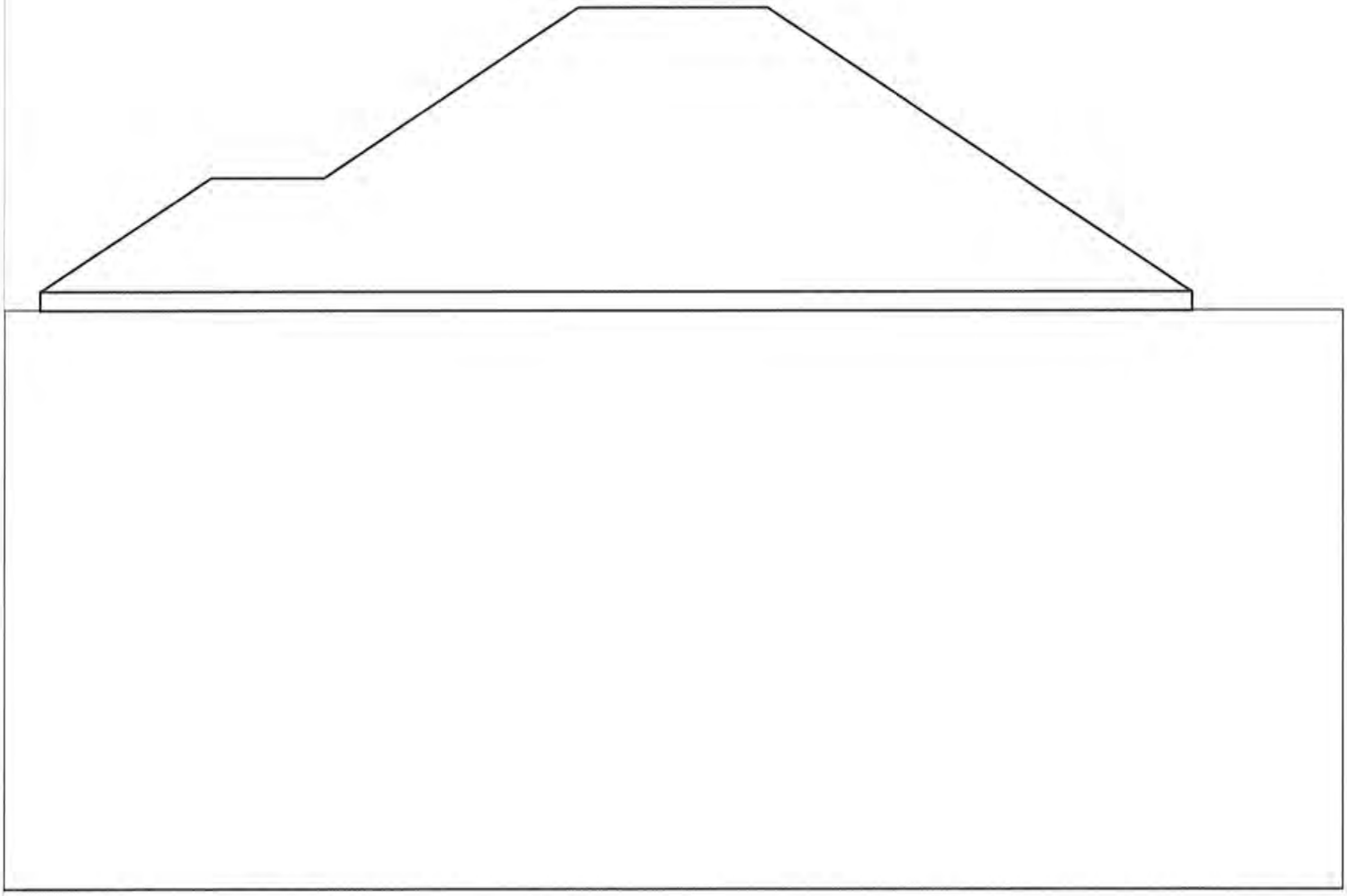
	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	115.00	12" Maritime Matress
2	150.00	Rip Rap

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	0.00

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DRAWING OF SPECIFIED GEOMETRY



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INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer #	Underging Consolidation [Yes/No]	OCR = Pc / Po	Cc / (1+e0)	Cr / (1+e0)	e0	Cv [ft ²/day]	Drains at :	CREEP Ca/Cc
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	3.50	0.150	0.011	N/A	0.5760	Top & Bot.	0.0300
3	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	Yes	3.50	0.150	0.011	N/A	0.5760	Top & Bot.	0.0300
5	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Yes	3.50	0.150	0.011	N/A	0.5760	Top & Bot.	0.0300
7	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Secondary Compression (Creep) : Settlement is calculated at t2/t1 = 59.8

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	-33.00	0.00	1	300000	0.3000	0.0006	-11.00	-11.02	0.02
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0077			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0035			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0032			
2	-31.00	0.00	1	300000	0.3000	0.0021	-11.00	-11.02	0.02
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0089			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0038			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0033			
3	-29.00	0.00	1	300000	0.3000	0.0035	-11.00	-11.02	0.02
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0102			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0040			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0034			
4	-27.00	0.00	1	300000	0.3000	0.0049	-11.00	-11.02	0.02
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0115			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0043			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0035			
5	-25.00	0.00	1	300000	0.3000	0.0062	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0129			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0045			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0036			
6	-23.00	0.00	1	300000	0.3000	0.0065	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0143			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0047			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0037			
7	-21.00	0.00	1	300000	0.3000	0.0063	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0157			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0050			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0038			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
8	-19.00	0.00	1	300000	0.3000	0.0062	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0171			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0052			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0039			
9	-17.00	0.00	1	300000	0.3000	0.0071	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0185			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0054			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0040			
10	-15.00	0.00	1	300000	0.3000	0.0085	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0197			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0056			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0040			
11	-13.00	0.00	1	300000	0.3000	0.0098	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0209			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0057			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0041			
12	-11.00	0.00	1	300000	0.3000	0.0112	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0220			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0059			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0041			
13	-9.00	0.00	1	300000	0.3000	0.0126	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0229			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0060			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			
14	-7.00	0.00	1	300000	0.3000	0.0140	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0237			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0061			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
15	-5.00	0.00	1	300000	0.3000	0.0152	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0242			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0061			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			
16	-3.00	0.00	1	300000	0.3000	0.0153	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0246			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0062			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			
17	-1.00	0.00	1	300000	0.3000	0.0153	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0247			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0062			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			
18	1.00	0.00	1	300000	0.3000	0.0153	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0246			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0061			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			
19	3.00	0.00	1	300000	0.3000	0.0153	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0242			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0061			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			
20	5.00	0.00	1	300000	0.3000	0.0152	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0237			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0060			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0042			
21	7.00	0.00	1	300000	0.3000	0.0140	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0229			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0059			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0041			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
22	9.00	0.00	1	300000	0.3000	0.0126	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0219			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0058			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0041			
23	11.00	0.00	1	300000	0.3000	0.0113	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0208			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0056			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0040			
24	13.00	0.00	1	300000	0.3000	0.0099	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0195			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0055			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0040			
25	15.00	0.00	1	300000	0.3000	0.0086	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0181			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0053			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0039			
26	17.00	0.00	1	300000	0.3000	0.0073	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0166			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0051			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0038			
27	19.00	0.00	1	300000	0.3000	0.0060	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0151			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0048			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0037			
28	21.00	0.00	1	300000	0.3000	0.0047	-11.00	-11.03	0.03
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0135			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0046			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0036			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
29	23.00	0.00	1	300000	0.3000	0.0034	-11.00	-11.02	0.02
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0120			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0043			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0035			
30	25.00	0.00	1	300000	0.3000	0.0020	-11.00	-11.02	0.02
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0105			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0041			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0034			
31	27.00	0.00	1	300000	0.3000	0.0005	-11.00	-11.02	0.02
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0091			
			4	999999999	0.3000	0.0000			
			5	300000	0.3000	0.0039			
			6	999999999	0.3000	0.0000			
			7	1200000	0.3000	0.0033			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	-33.00	0.00	-11.00	0.11	-11.11
2	-31.00	0.00	-11.00	0.13	-11.13
3	-29.00	0.00	-11.00	0.14	-11.14
4	-27.00	0.00	-11.00	0.20	-11.20
5	-25.00	0.00	-11.00	0.23	-11.23
6	-23.00	0.00	-11.00	0.28	-11.28
7	-21.00	0.00	-11.00	0.31	-11.31
8	-19.00	0.00	-11.00	0.35	-11.35
9	-17.00	0.00	-11.00	0.40	-11.40
10	-15.00	0.00	-11.00	0.46	-11.46
11	-13.00	0.00	-11.00	0.52	-11.52
12	-11.00	0.00	-11.00	0.59	-11.59
13	-9.00	0.00	-11.00	0.64	-11.64
14	-7.00	0.00	-11.00	0.69	-11.69
15	-5.00	0.00	-11.00	0.73	-11.73
16	-3.00	0.00	-11.00	0.75	-11.75
17	-1.00	0.00	-11.00	0.76	-11.76
18	1.00	0.00	-11.00	0.76	-11.76
19	3.00	0.00	-11.00	0.74	-11.74
20	5.00	0.00	-11.00	0.72	-11.72
21	7.00	0.00	-11.00	0.68	-11.68
22	9.00	0.00	-11.00	0.63	-11.63
23	11.00	0.00	-11.00	0.57	-11.57
24	13.00	0.00	-11.00	0.50	-11.50
25	15.00	0.00	-11.00	0.43	-11.43

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
26	17.00	0.00	-11.00	0.35	-11.35
27	19.00	0.00	-11.00	0.29	-11.29
28	21.00	0.00	-11.00	0.22	-11.22
29	23.00	0.00	-11.00	0.16	-11.16
30	25.00	0.00	-11.00	0.13	-11.13
31	27.00	0.00	-11.00	0.12	-11.12

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	-11.00	Quaternary Sand (A1)
2	1	0.00	-14.00	Quaternary Clay & Organic soil (A2/3)
3	1	0.00	-38.00	Quaternary Sand (A1)
4	1	0.00	-44.00	Quaternary Clay & Organic soil (A2/3)
5	1	0.00	-64.00	Quaternary Sand (A1)
6	1	0.00	-66.00	Quaternary Clay & Organic soil (A2/3)
7	1	0.00	-91.00	CG Yorktown (B1)

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TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embank. Soil #		Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	X1 = -33.51 [ft]	1	-33.50	-10.00	12" Maritime Matress
	X2 = 27.51 [ft]	2	27.50	-10.00	
2	X1 = -33.51 [ft]	1	-33.50	-10.00	Rip Rap
	X2 = 27.51 [ft]	2	-24.50	-4.00	
		3	-18.50	-4.00	
		4	-5.00	5.00	
		5	5.00	5.00	
		6	27.50	-10.00	

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HISTORY OF SETTLEMENT ANALYSES

Case #	Location of 1D Section : (X) [ft.]	(Y) [ft.]	Ultimate Settlement, Sc [ft.]	After... [days]	Actual Settlement, [ft.]	U-ave (min.for all consol.layers) [%]	USER'S DESCRIPTION
1	0.00	0.00	0.758	305.3	0.7	95.1	
2	---	---	---	---	---	---	
3	---	---	---	---	---	---	
4	---	---	---	---	---	---	
5	---	---	---	---	---	---	
6	---	---	---	---	---	---	
7	---	---	---	---	---	---	
8	---	---	---	---	---	---	
9	---	---	---	---	---	---	
10	---	---	---	---	---	---	
11	---	---	---	---	---	---	
12	---	---	---	---	---	---	
13	---	---	---	---	---	---	
14	---	---	---	---	---	---	
15	---	---	---	---	---	---	

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TemporaryTextJ

Wallops Island Breakwater 2
Calculated Secondary Compression (Creep)
Total Calculated Secondary Compression = 0.552 [ft]. 6.62 in

#	Layer Undegoing Consolidation	C-alpha over Cc	Cc	C-alpha	e-sub-0	H [ft]	t2/t1	Ss [ft]
1	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	YES	0.0300	0.1500	0.0045	N/A	24.00	59.8	0.192
3	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	YES	0.0300	0.1500	0.0045	N/A	20.00	59.8	0.160
5	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	YES	0.0300	0.1500	0.0045	N/A	25.00	59.8	0.200
7	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Results of Consolidation Settlement -- 1D
Project Number: 18C13074
Wallops Island Breakwaters
Breakwater 3 (C-4, B-3, D-4)

Node #	X [ft]	Y [ft]	Original Z [ft]	Settlement Sc [ft]	Elastic Settlement [ft]	**Consolidation Settlement Due to New Embankment [in]**	**Elastic Settlement Due to New Embankment [in]**	**Total Settlement Due to New Embankment [in]**
1	-33.0	0.0	-11	0.06	0.04	**0.72**	**0.48**	**3.55**
2	-31.0	0.0	-11	0.07	0.04	**0.86**	**0.48**	**3.69**
3	-29.0	0.0	-11	0.08	0.05	**0.99**	**0.60**	**3.95**
4	-27.0	0.0	-11	0.10	0.05	**1.21**	**0.60**	**4.16**
5	-25.0	0.0	-11	0.13	0.06	**1.62**	**0.72**	**4.69**
6	-23.0	0.0	-11	0.16	0.06	**1.92**	**0.72**	**4.99**
7	-21.0	0.0	-11	0.19	0.06	**2.25**	**0.72**	**5.32**
8	-19.0	0.0	-11	0.22	0.07	**2.66**	**0.84**	**5.85**
9	-17.0	0.0	-11	0.26	0.07	**3.12**	**0.84**	**6.31**
10	-15.0	0.0	-11	0.31	0.07	**3.74**	**0.84**	**6.93**
11	-13.0	0.0	-11	0.37	0.08	**4.38**	**0.96**	**7.69**
12	-11.0	0.0	-11	0.41	0.08	**4.98**	**0.96**	**8.29**
13	-9.0	0.0	-11	0.46	0.09	**5.58**	**1.08**	**9.01**
14	-7.0	0.0	-11	0.51	0.09	**6.09**	**1.08**	**9.52**
15	-5.0	0.0	-11	0.54	0.09	**6.48**	**1.08**	**9.91**
16	-3.0	0.0	-11	0.56	0.09	**6.72**	**1.08**	**10.15**
17	-1.0	0.0	-11	0.57	0.09	**6.83**	**1.08**	**10.26**
18	1.0	0.0	-11	0.57	0.09	**6.82**	**1.08**	**10.25**
19	3.0	0.0	-11	0.56	0.09	**6.69**	**1.08**	**10.12**
20	5.0	0.0	-11	0.53	0.09	**6.42**	**1.08**	**9.85**
21	7.0	0.0	-11	0.50	0.09	**6.00**	**1.08**	**9.43**
22	9.0	0.0	-11	0.45	0.08	**5.43**	**0.96**	**8.75**
23	11.0	0.0	-11	0.40	0.08	**4.83**	**0.96**	**8.15**
24	13.0	0.0	-11	0.35	0.08	**4.16**	**0.96**	**7.47**
25	15.0	0.0	-11	0.28	0.07	**3.38**	**0.84**	**6.58**
26	17.0	0.0	-11	0.23	0.07	**2.72**	**0.84**	**5.91**
27	19.0	0.0	-11	0.17	0.06	**1.98**	**0.72**	**5.06**
28	21.0	0.0	-11	0.12	0.06	**1.46**	**0.72**	**4.53**
29	23.0	0.0	-11	0.09	0.05	**1.08**	**0.60**	**4.04**
30	25.0	0.0	-11	0.08	0.04	**0.93**	**0.48**	**3.77**
31	27.0	0.0	-11	0.07	0.04	**0.78**	**0.48**	**3.61**

Secondary Settlement = 2.4 [in]

Time to End of Primary (95% Consolidation) = 282 [days]
Time to End of Design Life = 50 [years]

t2/t1 = 64.7

Schnabel ENGINEERING

Wallops Island Breakwaters

Report created by FoSSA(2.0): Copyright (c) 2003-2012, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title:	Wallops Island Breakwaters
Project Number:	18C13074 -
Client:	USACE
Designer:	K. Pocta
Station Number:	

Description:
Breakwater 3

Company's information:

Name:	Schnabel Engineering
Street:	9800 JEB Stuart Parkway, Suite 100 Glen Allen, VA 23059
Telephone #:	(804) 649-7035
Fax #:	(804) 264-3244
E-Mail:	

Original file path and name: G:\2011 - ..... ts\02-Calcs\01-Geotech\Settlement\Breakwater 3.2ST
Original date and time of creating this file:

GEOMETRY: Analysis of a 2D geometry

INPUT DATA – FOUNDATION LAYERS -- 4 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	115.00	0.30	Quaternary Sand (A1)
2	100.00	0.30	Quaternary Clay & Organic soil (A2/3)
3	115.00	0.30	Quaternary Sand (A1)
4	115.00	0.30	CG Yorktown (B1)

INPUT DATA – EMBANKMENT LAYERS – 2 layers

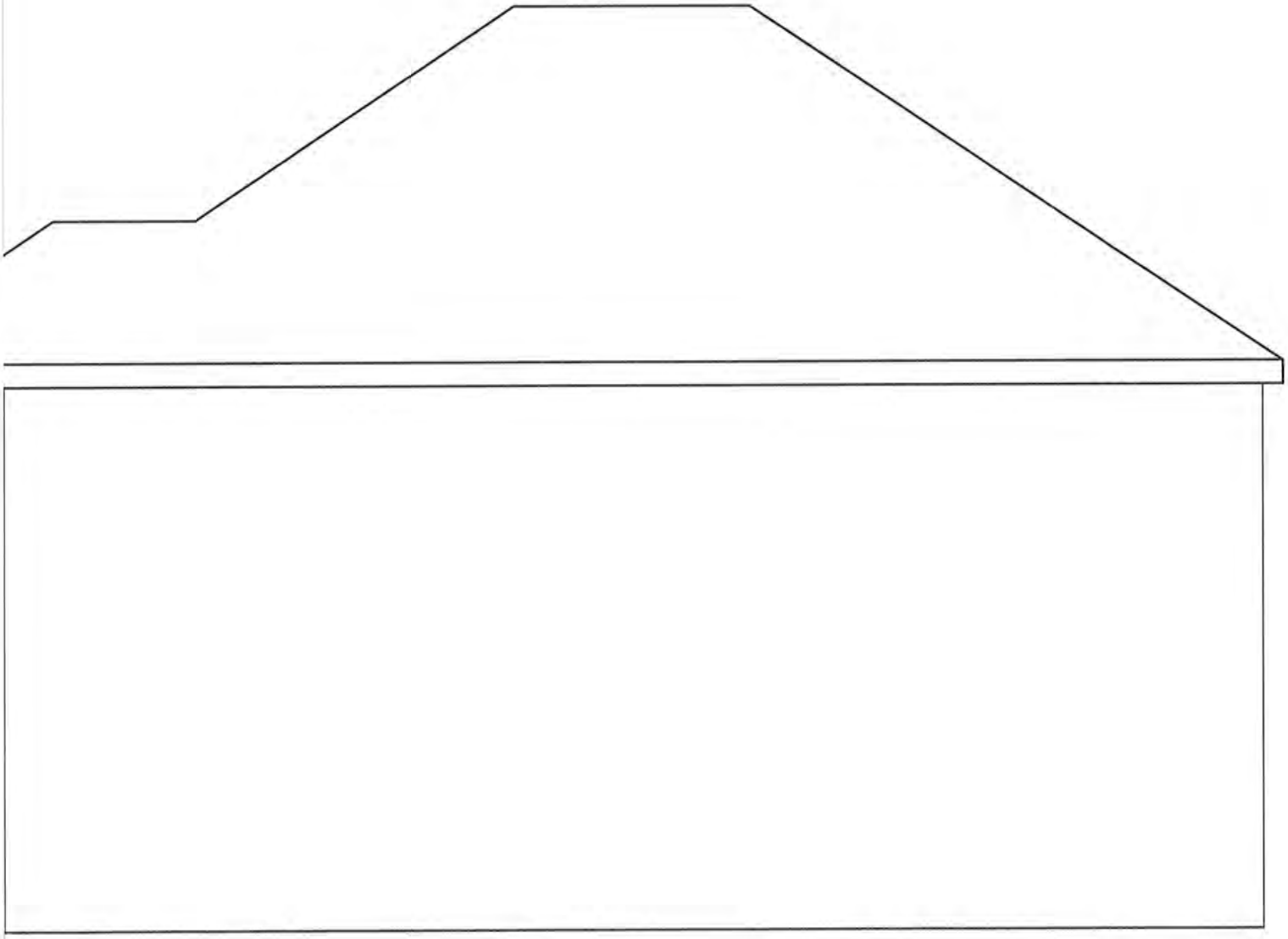
	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	115.00	12" Maritime Matress
2	150.00	Rip Rap

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	0.00

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DRAWING OF SPECIFIED GEOMETRY



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INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer #	Underging Consolidation [Yes/No]	OCR = Pc / Po	Cc / (1+e0)	Cr / (1+e0)	e0	Cv [ft ²/day]	Drains at :	CREEP Ca/Cc
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	3.50	0.150	0.011	N/A	0.5760	Top & Bot.	0.0300
3	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Secondary Compression (Creep) : Settlement is calculated at t2/t1 = 64.7

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	-33.00	0.00	1	300000	0.3000	0.0007	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0162			
			4	1200000	0.3000	0.0183			
2	-31.00	0.00	1	300000	0.3000	0.0026	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0183			
			4	1200000	0.3000	0.0193			
3	-29.00	0.00	1	300000	0.3000	0.0045	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0206			
			4	1200000	0.3000	0.0204			
4	-27.00	0.00	1	300000	0.3000	0.0063	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0230			
			4	1200000	0.3000	0.0214			
5	-25.00	0.00	1	300000	0.3000	0.0079	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0254			
			4	1200000	0.3000	0.0225			
6	-23.00	0.00	1	300000	0.3000	0.0083	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0278			
			4	1200000	0.3000	0.0234			
7	-21.00	0.00	1	300000	0.3000	0.0082	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0302			
			4	1200000	0.3000	0.0244			
8	-19.00	0.00	1	300000	0.3000	0.0082	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0325			
			4	1200000	0.3000	0.0253			
9	-17.00	0.00	1	300000	0.3000	0.0094	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0348			
			4	1200000	0.3000	0.0261			
10	-15.00	0.00	1	300000	0.3000	0.0111	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0369			
			4	1200000	0.3000	0.0269			
11	-13.00	0.00	1	300000	0.3000	0.0129	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0389			
			4	1200000	0.3000	0.0276			
12	-11.00	0.00	1	300000	0.3000	0.0147	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0406			
			4	1200000	0.3000	0.0282			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
13	-9.00	0.00	1	300000	0.3000	0.0166	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0421			
			4	1200000	0.3000	0.0287			
14	-7.00	0.00	1	300000	0.3000	0.0184	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0434			
			4	1200000	0.3000	0.0291			
15	-5.00	0.00	1	300000	0.3000	0.0199	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0443			
			4	1200000	0.3000	0.0293			
16	-3.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0448			
			4	1200000	0.3000	0.0295			
17	-1.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0450			
			4	1200000	0.3000	0.0295			
18	1.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0448			
			4	1200000	0.3000	0.0294			
19	3.00	0.00	1	300000	0.3000	0.0202	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0442			
			4	1200000	0.3000	0.0292			
20	5.00	0.00	1	300000	0.3000	0.0200	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0433			
			4	1200000	0.3000	0.0289			
21	7.00	0.00	1	300000	0.3000	0.0185	-11.00	-11.09	0.09
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0420			
			4	1200000	0.3000	0.0284			
22	9.00	0.00	1	300000	0.3000	0.0167	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0404			
			4	1200000	0.3000	0.0279			
23	11.00	0.00	1	300000	0.3000	0.0148	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0385			
			4	1200000	0.3000	0.0272			
24	13.00	0.00	1	300000	0.3000	0.0131	-11.00	-11.08	0.08
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0363			
			4	1200000	0.3000	0.0265			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
25	15.00	0.00	1	300000	0.3000	0.0113	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0340			
			4	1200000	0.3000	0.0257			
26	17.00	0.00	1	300000	0.3000	0.0096	-11.00	-11.07	0.07
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0315			
			4	1200000	0.3000	0.0248			
27	19.00	0.00	1	300000	0.3000	0.0078	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0290			
			4	1200000	0.3000	0.0238			
28	21.00	0.00	1	300000	0.3000	0.0060	-11.00	-11.06	0.06
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0264			
			4	1200000	0.3000	0.0228			
29	23.00	0.00	1	300000	0.3000	0.0043	-11.00	-11.05	0.05
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0238			
			4	1200000	0.3000	0.0218			
30	25.00	0.00	1	300000	0.3000	0.0025	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0213			
			4	1200000	0.3000	0.0207			
31	27.00	0.00	1	300000	0.3000	0.0006	-11.00	-11.04	0.04
			2	999999999	0.3000	0.0000			
			3	300000	0.3000	0.0188			
			4	1200000	0.3000	0.0196			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	-33.00	0.00	-11.00	0.06	-11.06
2	-31.00	0.00	-11.00	0.07	-11.07
3	-29.00	0.00	-11.00	0.08	-11.08
4	-27.00	0.00	-11.00	0.10	-11.10
5	-25.00	0.00	-11.00	0.13	-11.13
6	-23.00	0.00	-11.00	0.16	-11.16
7	-21.00	0.00	-11.00	0.19	-11.19
8	-19.00	0.00	-11.00	0.22	-11.22
9	-17.00	0.00	-11.00	0.26	-11.26
10	-15.00	0.00	-11.00	0.31	-11.31
11	-13.00	0.00	-11.00	0.37	-11.37
12	-11.00	0.00	-11.00	0.41	-11.41
13	-9.00	0.00	-11.00	0.46	-11.46
14	-7.00	0.00	-11.00	0.51	-11.51
15	-5.00	0.00	-11.00	0.54	-11.54
16	-3.00	0.00	-11.00	0.56	-11.56
17	-1.00	0.00	-11.00	0.57	-11.57
18	1.00	0.00	-11.00	0.57	-11.57
19	3.00	0.00	-11.00	0.56	-11.56
20	5.00	0.00	-11.00	0.53	-11.53
21	7.00	0.00	-11.00	0.50	-11.50
22	9.00	0.00	-11.00	0.45	-11.45
23	11.00	0.00	-11.00	0.40	-11.40
24	13.00	0.00	-11.00	0.35	-11.35
25	15.00	0.00	-11.00	0.28	-11.28

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
26	17.00	0.00	-11.00	0.23	-11.23
27	19.00	0.00	-11.00	0.17	-11.17
28	21.00	0.00	-11.00	0.12	-11.12
29	23.00	0.00	-11.00	0.09	-11.09
30	25.00	0.00	-11.00	0.08	-11.08
31	27.00	0.00	-11.00	0.07	-11.07

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	-11.00	Quaternary Sand (A1)
2	1	0.00	-15.00	Quaternary Clay & Organic soil (A2/3)
3	1	0.00	-39.00	Quaternary Sand (A1)
4	1	0.00	-51.00	CG Yorktown (B1)

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TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embank. Soil #		Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	X1 = -33.51 [ft]	1	-33.50	-10.00	12" Maritime Matress
	X2 = 27.51 [ft]	2	27.50	-10.00	
2	X1 = -33.51 [ft]	1	-33.50	-10.00	Rip Rap
	X2 = 27.51 [ft]	2	-24.50	-4.00	
		3	-18.50	-4.00	
		4	-5.00	5.00	
		5	5.00	5.00	
		6	27.50	-10.00	

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HISTORY OF SETTLEMENT ANALYSES

Case #	Location of 1D Section : (X) [ft.]	(Y) [ft.]	Ultimate Settlement, Sc [ft.]	After... [days]	Actual Settlement, [ft.]	U-ave (min.for all consol.layers) [%]	USER'S DESCRIPTION
1	0.00	0.00	0.570	282.0	0.5	95.1	
2	---	---	---	---	---	---	
3	---	---	---	---	---	---	
4	---	---	---	---	---	---	
5	---	---	---	---	---	---	
6	---	---	---	---	---	---	
7	---	---	---	---	---	---	
8	---	---	---	---	---	---	
9	---	---	---	---	---	---	
10	---	---	---	---	---	---	
11	---	---	---	---	---	---	
12	---	---	---	---	---	---	
13	---	---	---	---	---	---	
14	---	---	---	---	---	---	
15	---	---	---	---	---	---	

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TemporaryTextJ

Wallops Island Breakwater 3
Calculated Secondary Compression (Creep)
Total Calculated Secondary Compression = 0.196 [ft]. 2.35 in

#	Layer Undegoing Consolidation	C-alpha over Cc	Cc	C-alpha	e-sub-0	H [ft]	t2/t1	Ss [ft]
1	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	YES	0.0300	0.1500	0.0045	N/A	24.00	64.7	0.196
3	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Results of Consolidation Settlement -- 1D
Project Number: 18C13074
Wallops Island Breakwaters
Breakwater 4 (C-5, D-5, B-4, D-6, C-6)

Node #	X [ft]	Y [ft]	Original Z [ft]	Settlement Sc [ft]	Elastic Settlement [ft]	**Consolidation Settlement Due to New Embankment [in]**	**Elastic Settlement Due to New Embankment [in]**	**Total Settlement Due to New Embankment [in]**
1	-27.0	0.0	-7	0.05	0.03	**0.60**	**0.36**	**3.46**
2	-25.0	0.0	-7	0.06	0.04	**0.68**	**0.48**	**3.66**
3	-23.0	0.0	-7	0.06	0.04	**0.77**	**0.48**	**3.74**
4	-21.0	0.0	-7	0.07	0.05	**0.84**	**0.60**	**3.94**
5	-19.0	0.0	-7	0.08	0.05	**0.92**	**0.60**	**4.01**
6	-17.0	0.0	-7	0.08	0.05	**0.98**	**0.60**	**4.08**
7	-15.0	0.0	-7	0.09	0.05	**1.04**	**0.60**	**4.14**
8	-13.0	0.0	-7	0.09	0.06	**1.10**	**0.72**	**4.32**
9	-11.0	0.0	-7	0.10	0.06	**1.15**	**0.72**	**4.36**
10	-9.0	0.0	-7	0.10	0.06	**1.19**	**0.72**	**4.41**
11	-7.0	0.0	-7	0.11	0.07	**1.27**	**0.84**	**4.60**
12	-5.0	0.0	-7	0.12	0.07	**1.38**	**0.84**	**4.72**
13	-3.0	0.0	-7	0.12	0.07	**1.45**	**0.84**	**4.79**
14	-1.0	0.0	-7	0.12	0.07	**1.48**	**0.84**	**4.82**
15	1.0	0.0	-7	0.12	0.07	**1.47**	**0.84**	**4.81**
16	3.0	0.0	-7	0.12	0.07	**1.41**	**0.84**	**4.75**
17	5.0	0.0	-7	0.11	0.07	**1.31**	**0.84**	**4.64**
18	7.0	0.0	-7	0.10	0.07	**1.18**	**0.84**	**4.52**
19	9.0	0.0	-7	0.09	0.06	**1.13**	**0.72**	**4.34**
20	11.0	0.0	-7	0.09	0.06	**1.07**	**0.72**	**4.28**
21	13.0	0.0	-7	0.08	0.05	**0.99**	**0.60**	**4.09**
22	15.0	0.0	-7	0.08	0.05	**0.91**	**0.60**	**4.01**
23	17.0	0.0	-7	0.07	0.04	**0.83**	**0.48**	**3.80**
24	19.0	0.0	-7	0.06	0.04	**0.74**	**0.48**	**3.71**
25	21.0	0.0	-7	0.05	0.03	**0.65**	**0.36**	**3.50**

Secondary Settlement = 2.5 [in]

Time to End of Primary (95% Consolidation) = 355 [days]

Time to End of Design Life = 50 [years]

t2/t1 = 51.4

Schnabel ENGINEERING

Wallops Island Breakwaters

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PROJECT IDENTIFICATION

Title:	Wallops Island Breakwaters
Project Number:	18C13074 -
Client:	USACE
Designer:	K. Pocta
Station Number:	

Description:
Breakwater 4

Company's information:

Name:	Schnabel Engineering
Street:	9800 JEB Stuart Parkway, Suite 100 Glen Allen, VA 23059
Telephone #:	(804) 649-7035
Fax #:	(804) 264-3244
E-Mail:	

Original file path and name: G:\2011 - ..... ts\02-Calcs\01-Geotech\Settlement\Breakwater 4.2ST
Original date and time of creating this file:

GEOMETRY: Analysis of a 2D geometry

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INPUT DATA – FOUNDATION LAYERS -- 4 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	115.00	0.30	Quaternary Sand (A1)
2	100.00	0.30	Quaternary Clay & Organic soil (A2/3)
3	115.00	0.30	CG Yorktown (B1)
4	110.00	0.30	FG Yorktown (B2)

INPUT DATA – EMBANKMENT LAYERS – 2 layers

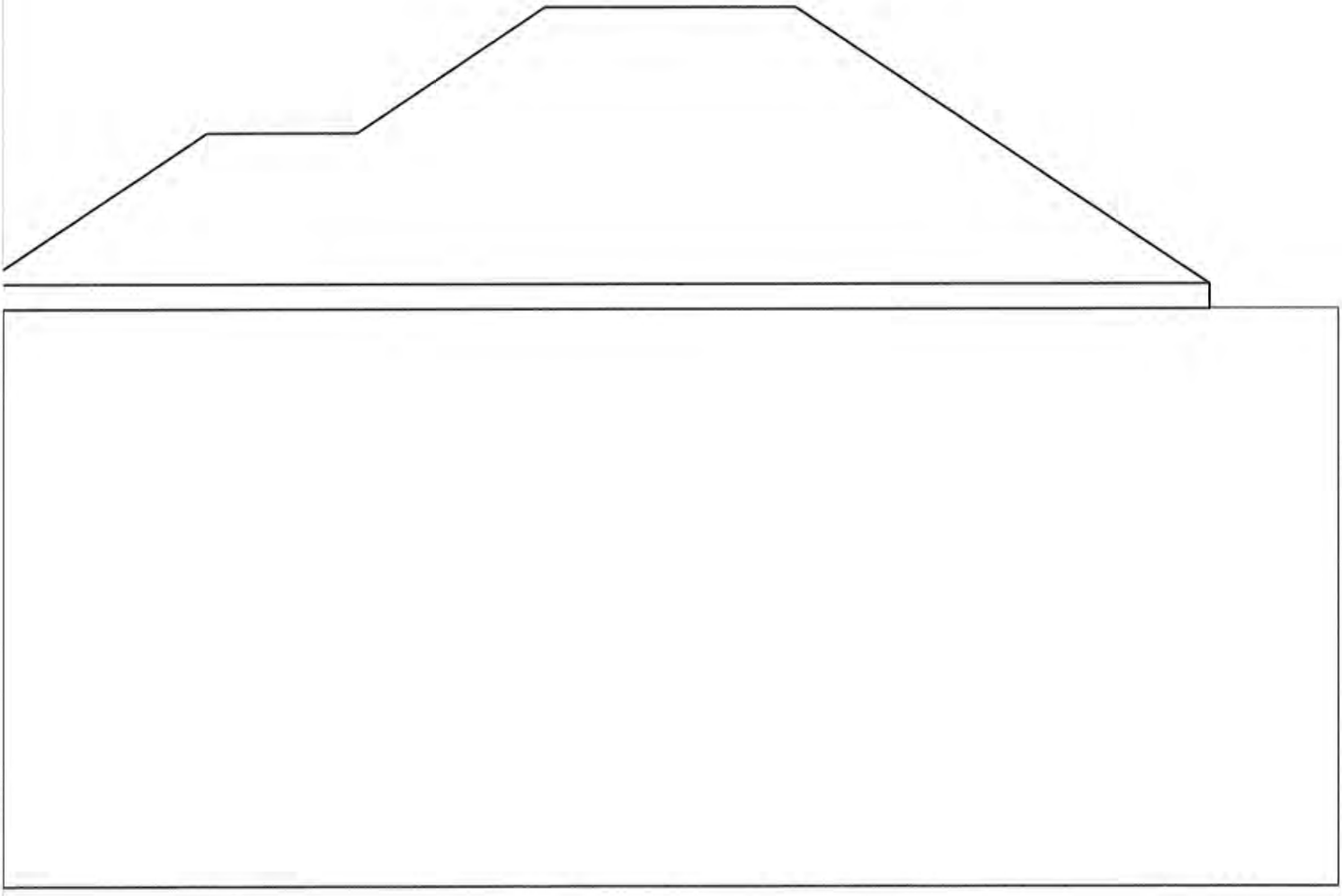
	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	115.00	12" Maritime Matress
2	150.00	VDOT Class y

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	0.00

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DRAWING OF SPECIFIED GEOMETRY



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INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer # Underging Consolidation [Yes/No]		OCR = Pc / Po	Cc / (1+e0)	Cr / (1+e0)	e0	Cv [ft ²/day]	Drains at :	CREEP Ca/Cc
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	3.50	0.150	0.011	N/A	0.5760	Top & Bot.	0.0300
3	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Secondary Compression (Creep) : Settlement is calculated at t2/t1 = 51.4

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	-27.00	0.00	1	300000	0.3000	0.0021	-7.00	-7.03	0.03
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0077			
			4	500000	0.3000	0.0203			
2	-25.00	0.00	1	300000	0.3000	0.0059	-7.00	-7.04	0.04
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0083			
			4	500000	0.3000	0.0210			
3	-23.00	0.00	1	300000	0.3000	0.0098	-7.00	-7.04	0.04
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0089			
			4	500000	0.3000	0.0216			
4	-21.00	0.00	1	300000	0.3000	0.0136	-7.00	-7.05	0.05
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0094			
			4	500000	0.3000	0.0223			
5	-19.00	0.00	1	300000	0.3000	0.0169	-7.00	-7.05	0.05
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0099			
			4	500000	0.3000	0.0229			
6	-17.00	0.00	1	300000	0.3000	0.0186	-7.00	-7.05	0.05
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0104			
			4	500000	0.3000	0.0234			
7	-15.00	0.00	1	300000	0.3000	0.0194	-7.00	-7.05	0.05
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0109			
			4	500000	0.3000	0.0239			
8	-13.00	0.00	1	300000	0.3000	0.0204	-7.00	-7.06	0.06
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0113			
			4	500000	0.3000	0.0243			
9	-11.00	0.00	1	300000	0.3000	0.0230	-7.00	-7.06	0.06
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0117			
			4	500000	0.3000	0.0247			
10	-9.00	0.00	1	300000	0.3000	0.0265	-7.00	-7.06	0.06
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0120			
			4	500000	0.3000	0.0250			
11	-7.00	0.00	1	300000	0.3000	0.0301	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0122			
			4	500000	0.3000	0.0252			
12	-5.00	0.00	1	300000	0.3000	0.0331	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0124			
			4	500000	0.3000	0.0253			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
13	-3.00	0.00	1	300000	0.3000	0.0343	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0124			
			4	500000	0.3000	0.0254			
14	-1.00	0.00	1	300000	0.3000	0.0347	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0124			
			4	500000	0.3000	0.0254			
15	1.00	0.00	1	300000	0.3000	0.0347	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0124			
			4	500000	0.3000	0.0253			
16	3.00	0.00	1	300000	0.3000	0.0344	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0122			
			4	500000	0.3000	0.0252			
17	5.00	0.00	1	300000	0.3000	0.0332	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0120			
			4	500000	0.3000	0.0249			
18	7.00	0.00	1	300000	0.3000	0.0302	-7.00	-7.07	0.07
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0117			
			4	500000	0.3000	0.0246			
19	9.00	0.00	1	300000	0.3000	0.0264	-7.00	-7.06	0.06
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0113			
			4	500000	0.3000	0.0242			
20	11.00	0.00	1	300000	0.3000	0.0224	-7.00	-7.06	0.06
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0109			
			4	500000	0.3000	0.0238			
21	13.00	0.00	1	300000	0.3000	0.0182	-7.00	-7.05	0.05
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0104			
			4	500000	0.3000	0.0233			
22	15.00	0.00	1	300000	0.3000	0.0140	-7.00	-7.05	0.05
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0099			
			4	500000	0.3000	0.0228			
23	17.00	0.00	1	300000	0.3000	0.0099	-7.00	-7.04	0.04
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0094			
			4	500000	0.3000	0.0222			
24	19.00	0.00	1	300000	0.3000	0.0058	-7.00	-7.04	0.04
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0088			
			4	500000	0.3000	0.0215			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
25	21.00	0.00	1	300000	0.3000	0.0020	-7.00	-7.03	0.03
			2	999999999	0.3000	0.0000			
			3	1200000	0.3000	0.0082			
			4	500000	0.3000	0.0208			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	-27.00	0.00	-7.00	0.05	-7.05
2	-25.00	0.00	-7.00	0.06	-7.06
3	-23.00	0.00	-7.00	0.06	-7.06
4	-21.00	0.00	-7.00	0.07	-7.07
5	-19.00	0.00	-7.00	0.08	-7.08
6	-17.00	0.00	-7.00	0.08	-7.08
7	-15.00	0.00	-7.00	0.09	-7.09
8	-13.00	0.00	-7.00	0.09	-7.09
9	-11.00	0.00	-7.00	0.10	-7.10
10	-9.00	0.00	-7.00	0.10	-7.10
11	-7.00	0.00	-7.00	0.11	-7.11
12	-5.00	0.00	-7.00	0.12	-7.12
13	-3.00	0.00	-7.00	0.12	-7.12
14	-1.00	0.00	-7.00	0.12	-7.12
15	1.00	0.00	-7.00	0.12	-7.12
16	3.00	0.00	-7.00	0.12	-7.12
17	5.00	0.00	-7.00	0.11	-7.11
18	7.00	0.00	-7.00	0.10	-7.10
19	9.00	0.00	-7.00	0.09	-7.09
20	11.00	0.00	-7.00	0.09	-7.09
21	13.00	0.00	-7.00	0.08	-7.08
22	15.00	0.00	-7.00	0.08	-7.08
23	17.00	0.00	-7.00	0.07	-7.07
24	19.00	0.00	-7.00	0.06	-7.06
25	21.00	0.00	-7.00	0.05	-7.05

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	-7.00	Quaternary Sand (A1)
2	1	0.00	-16.00	Quaternary Clay & Organic soil (A2/3)
3	1	0.00	-43.00	CG Yorktown (B1)
4	1	0.00	-68.00	FG Yorktown (B2)

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TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embank. Soil #		Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	X1 = -27.51 [ft]	1	-27.50	-6.00	12" Maritime Matress
	X2 = 21.51 [ft]	2	21.50	-6.00	
2	X1 = -27.51 [ft]	1	-27.50	-5.99	VDOT Class y
	X2 = 21.51 [ft]	2	-18.50	0.00	
		3	-12.50	0.00	
		4	-5.00	5.00	
		5	5.00	5.00	
		6	21.50	-5.99	

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HISTORY OF SETTLEMENT ANALYSES

Case #	Location of 1D Section : (X) [ft.]	(Y) [ft.]	Ultimate Settlement, Sc [ft.]	After... [days]	Actual Settlement, [ft.]	U-ave (min.for all consol.layers) [%]	USER'S DESCRIPTION
1	0.00	0.00	0.124	354.5	0.1	95.1	
2	---	---	---	---	---	---	
3	---	---	---	---	---	---	
4	---	---	---	---	---	---	
5	---	---	---	---	---	---	
6	---	---	---	---	---	---	
7	---	---	---	---	---	---	
8	---	---	---	---	---	---	
9	---	---	---	---	---	---	
10	---	---	---	---	---	---	
11	---	---	---	---	---	---	
12	---	---	---	---	---	---	
13	---	---	---	---	---	---	
14	---	---	---	---	---	---	
15	---	---	---	---	---	---	

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TemporaryTextJ

Wallops Island Breakwater 4
Calculated Secondary Compression (Creep)
Total Calculated Secondary Compression = 0.208 [ft]. 2.50 in

#	Layer Undegoing Consolidation	C-alpha over Cc	Cc	C-alpha	e-sub-0	H [ft]	t2/t1	Ss [ft]
1	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	YES	0.0300	0.1500	0.0045	N/A	27.00	51.4	0.208
3	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Results of Consolidation Settlement -- 1D
Project Number: 18C13074
Wallops Island Breakwaters
Breakwater 5 (D-7, C-7, B-5, D-8)

Node #	X [ft]	Y [ft]	Original Z [ft]	Settlement Sc [ft]	Elastic Settlement [ft]	**Consolidation Settlement Due to New Embankment [in]**	**Elastic Settlement Due to New Embankment [in]**	**Total Settlement Due to New Embankment [in]**
1	-29.0	0.0	-8	0.05	0.04	**0.56**	**0.48**	**4.42**
2	-27.0	0.0	-8	0.05	0.05	**0.63**	**0.60**	**4.61**
3	-25.0	0.0	-8	0.06	0.05	**0.69**	**0.60**	**4.68**
4	-23.0	0.0	-8	0.06	0.06	**0.76**	**0.72**	**4.86**
5	-21.0	0.0	-8	0.07	0.06	**0.82**	**0.72**	**4.93**
6	-19.0	0.0	-8	0.07	0.07	**0.88**	**0.84**	**5.11**
7	-17.0	0.0	-8	0.08	0.07	**0.94**	**0.84**	**5.16**
8	-15.0	0.0	-8	0.08	0.08	**0.99**	**0.96**	**5.34**
9	-13.0	0.0	-8	0.09	0.08	**1.04**	**0.96**	**5.38**
10	-11.0	0.0	-8	0.09	0.09	**1.08**	**1.08**	**5.54**
11	-9.0	0.0	-8	0.09	0.09	**1.12**	**1.08**	**5.58**
12	-7.0	0.0	-8	0.10	0.10	**1.14**	**1.20**	**5.73**
13	-5.0	0.0	-8	0.10	0.10	**1.17**	**1.20**	**5.75**
14	-3.0	0.0	-8	0.10	0.10	**1.18**	**1.20**	**5.76**
15	-1.0	0.0	-8	0.10	0.10	**1.18**	**1.20**	**5.77**
16	1.0	0.0	-8	0.10	0.10	**1.18**	**1.20**	**5.76**
17	3.0	0.0	-8	0.10	0.10	**1.17**	**1.20**	**5.75**
18	5.0	0.0	-8	0.10	0.10	**1.14**	**1.20**	**5.73**
19	7.0	0.0	-8	0.09	0.09	**1.11**	**1.08**	**5.57**
20	9.0	0.0	-8	0.09	0.09	**1.07**	**1.08**	**5.53**
21	11.0	0.0	-8	0.08	0.08	**1.02**	**0.96**	**5.36**
22	13.0	0.0	-8	0.08	0.08	**0.96**	**0.96**	**5.30**
23	15.0	0.0	-8	0.07	0.07	**0.90**	**0.84**	**5.12**
24	17.0	0.0	-8	0.07	0.06	**0.83**	**0.72**	**4.93**
25	19.0	0.0	-8	0.06	0.05	**0.75**	**0.60**	**4.74**
26	21.0	0.0	-8	0.06	0.05	**0.68**	**0.60**	**4.66**
27	23.0	0.0	-8	0.05	0.04	**0.61**	**0.48**	**4.47**

Secondary Settlement = 3.4 [in]

Time to End of Primary (95% Consolidation) = 127 [days]

Time to End of Design Life = 50 [years]

t2/t1 = 143.7

Schnabel ENGINEERING

Wallops Island Breakwaters

Report created by FoSSA(2.0): Copyright (c) 2003-2012, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title: Wallops Island Breakwaters
Project Number: 18C13074 -
Client: USACE
Designer: K. Pocta
Station Number:

Description:
Breakwater 5

Company's information:

Name: Schnabel Engineering
Street: 9800 JEB Stuart Parkway, Suite 100
Glen Allen, VA 23059
Telephone #: (804) 649-7035
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E-Mail:

Original file path and name: G:\2011 - ..... ts\02-Calcs\01-Geotech\Settlement\Breakwater 5.2ST
Original date and time of creating this file: Fri Aug 17 09:05:29 2018

GEOMETRY: Analysis of a 2D geometry

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INPUT DATA – FOUNDATION LAYERS -- 4 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	115.00	0.30	Quaternary Sand (A1)
2	100.00	0.30	Quaternary Clay & Organic soil (A2/3)
3	110.00	0.30	Quaternary Clay & Organic soil (A2/3)
4	110.00	0.30	FG Yorktown (B2)

INPUT DATA – EMBANKMENT LAYERS -- 2 layers

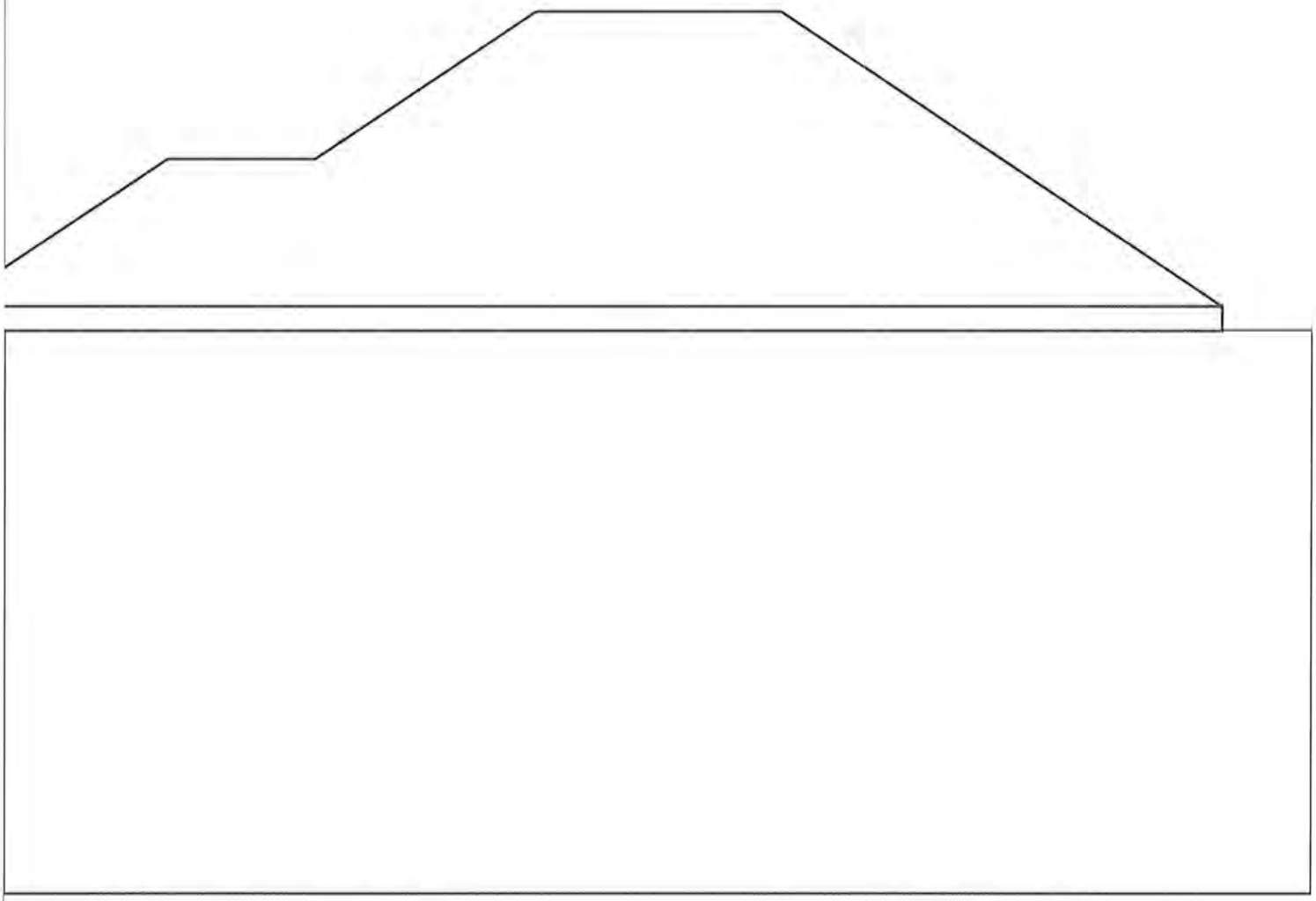
	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	115.00	12" Maritime Mattress
2	150.00	Rip Rap

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	0.00

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DRAWING OF SPECIFIED GEOMETRY



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INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer #	Underging Consolidation [Yes/No]	OCR = Pc / Po	Cc / (1+e0)	Cr / (1+e0)	e0	Cv [ft²/day]	Drains at :	CREEP Ca/Cc
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	3.50	0.150	0.011	N/A	0.5760	Top & Bot.	0.0300
3	Yes	3.50	0.150	0.011	N/A	0.5760	Top & Bot.	0.0300
4	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Secondary Comprassion (Creep) : Settlement is calculated at t2/t1 = 143.7

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	-29.00	0.00	1	300000	0.3000	0.0022	-8.00	-8.04	0.04
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0367			
2	-27.00	0.00	1	300000	0.3000	0.0068	-8.00	-8.05	0.05
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0386			
3	-25.00	0.00	1	300000	0.3000	0.0117	-8.00	-8.05	0.05
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0405			
4	-23.00	0.00	1	300000	0.3000	0.0165	-8.00	-8.06	0.06
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0423			
5	-21.00	0.00	1	300000	0.3000	0.0209	-8.00	-8.06	0.06
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0440			
6	-19.00	0.00	1	300000	0.3000	0.0239	-8.00	-8.07	0.07
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0456			
7	-17.00	0.00	1	300000	0.3000	0.0256	-8.00	-8.07	0.07
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0471			
8	-15.00	0.00	1	300000	0.3000	0.0273	-8.00	-8.08	0.08
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0485			
9	-13.00	0.00	1	300000	0.3000	0.0303	-8.00	-8.08	0.08
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0498			
10	-11.00	0.00	1	300000	0.3000	0.0347	-8.00	-8.09	0.09
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0508			
11	-9.00	0.00	1	300000	0.3000	0.0395	-8.00	-8.09	0.09
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0517			
12	-7.00	0.00	1	300000	0.3000	0.0440	-8.00	-8.10	0.10
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0524			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
13	-5.00	0.00	1	300000	0.3000	0.0478	-8.00	-8.10	0.10
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0528			
14	-3.00	0.00	1	300000	0.3000	0.0495	-8.00	-8.10	0.10
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0531			
15	-1.00	0.00	1	300000	0.3000	0.0501	-8.00	-8.10	0.10
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0531			
16	1.00	0.00	1	300000	0.3000	0.0501	-8.00	-8.10	0.10
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0529			
17	3.00	0.00	1	300000	0.3000	0.0495	-8.00	-8.10	0.10
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0524			
18	5.00	0.00	1	300000	0.3000	0.0478	-8.00	-8.10	0.10
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0518			
19	7.00	0.00	1	300000	0.3000	0.0439	-8.00	-8.09	0.09
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0509			
20	9.00	0.00	1	300000	0.3000	0.0391	-8.00	-8.09	0.09
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0499			
21	11.00	0.00	1	300000	0.3000	0.0339	-8.00	-8.08	0.08
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0486			
22	13.00	0.00	1	300000	0.3000	0.0284	-8.00	-8.08	0.08
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0472			
23	15.00	0.00	1	300000	0.3000	0.0229	-8.00	-8.07	0.07
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0457			
24	17.00	0.00	1	300000	0.3000	0.0174	-8.00	-8.06	0.06
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0440			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
25	19.00	0.00	1	300000	0.3000	0.0120	-8.00	-8.05	0.05
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0423			
26	21.00	0.00	1	300000	0.3000	0.0069	-8.00	-8.05	0.05
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0404			
27	23.00	0.00	1	300000	0.3000	0.0021	-8.00	-8.04	0.04
			2	999999999	0.3000	0.0000			
			3	999999999	0.3000	0.0000			
			4	500000	0.3000	0.0385			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	-29.00	0.00	-8.00	0.05	-8.05
2	-27.00	0.00	-8.00	0.05	-8.05
3	-25.00	0.00	-8.00	0.06	-8.06
4	-23.00	0.00	-8.00	0.06	-8.06
5	-21.00	0.00	-8.00	0.07	-8.07
6	-19.00	0.00	-8.00	0.07	-8.07
7	-17.00	0.00	-8.00	0.08	-8.08
8	-15.00	0.00	-8.00	0.08	-8.08
9	-13.00	0.00	-8.00	0.09	-8.09
10	-11.00	0.00	-8.00	0.09	-8.09
11	-9.00	0.00	-8.00	0.09	-8.09
12	-7.00	0.00	-8.00	0.10	-8.10
13	-5.00	0.00	-8.00	0.10	-8.10
14	-3.00	0.00	-8.00	0.10	-8.10
15	-1.00	0.00	-8.00	0.10	-8.10
16	1.00	0.00	-8.00	0.10	-8.10
17	3.00	0.00	-8.00	0.10	-8.10
18	5.00	0.00	-8.00	0.10	-8.10
19	7.00	0.00	-8.00	0.09	-8.09
20	9.00	0.00	-8.00	0.09	-8.09
21	11.00	0.00	-8.00	0.08	-8.08
22	13.00	0.00	-8.00	0.08	-8.08
23	15.00	0.00	-8.00	0.07	-8.07
24	17.00	0.00	-8.00	0.07	-8.07
25	19.00	0.00	-8.00	0.06	-8.06

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
26	21.00	0.00	-8.00	0.06	-8.06
27	23.00	0.00	-8.00	0.05	-8.05

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	-8.00	Quaternary Sand (A1)
2	1	0.00	-20.00	Quaternary Clay & Organic soil (A2/3)
3	1	0.00	-33.00	Quaternary Clay & Organic soil (A2/3)
4	1	0.00	-49.00	FG Yorktown (B2)

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TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embank. Soil #		Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	X1 = -29.01 [ft]	1	-29.00	-7.00	12" Maritime Mattress
	X2 = 23.01 [ft]	2	23.00	-7.00	
2	X1 = -29.01 [ft]	1	-29.00	-7.00	Rip Rap
	X2 = 23.01 [ft]	2	-20.00	-1.00	
		3	-14.00	-1.00	
		4	-5.00	5.00	
		5	5.00	5.00	
		6	23.00	-7.00	

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HISTORY OF SETTLEMENT ANALYSES

Case #	Location of 1D Section : (X) [ft.]	(Y) [ft.]	Ultimate Settlement, Sc [ft.]	After... [days]	Actual Settlement, [ft.]	U-ave (min.for all consol.layers) [%]	USER'S DESCRIPTION
1	0.00	0.00	0.099	127.2	0.1	95.2	
2	---	---	---	---	---	---	
3	---	---	---	---	---	---	
4	---	---	---	---	---	---	
5	---	---	---	---	---	---	
6	---	---	---	---	---	---	
7	---	---	---	---	---	---	
8	---	---	---	---	---	---	
9	---	---	---	---	---	---	
10	---	---	---	---	---	---	
11	---	---	---	---	---	---	
12	---	---	---	---	---	---	
13	---	---	---	---	---	---	
14	---	---	---	---	---	---	
15	---	---	---	---	---	---	

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TemporaryTextJ

Wallops Island Breakwater 5
Calculated Secondary Compression (Creep)
Total Calculated Secondary Compression = 0.282 [ft]. 3.38 in

#	Layer Undegoing Consolidation	C-alpha over Cc	Cc	C-alpha	e-sub-0	H [ft]	t2/t1	Ss [ft]
1	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	YES	0.0300	0.1500	0.0045	N/A	13.00	143.7	0.126
3	YES	0.0300	0.1500	0.0045	N/A	16.00	143.7	0.155
4	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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CALCULATION COVER SHEET

Project	Project Number
Wallops Island Breakwaters	18C13074

Title
Breakwater Global Stability Calculations

Computer Programs Used	Version/Release No.
GeoStudio (Slope/W)	2016

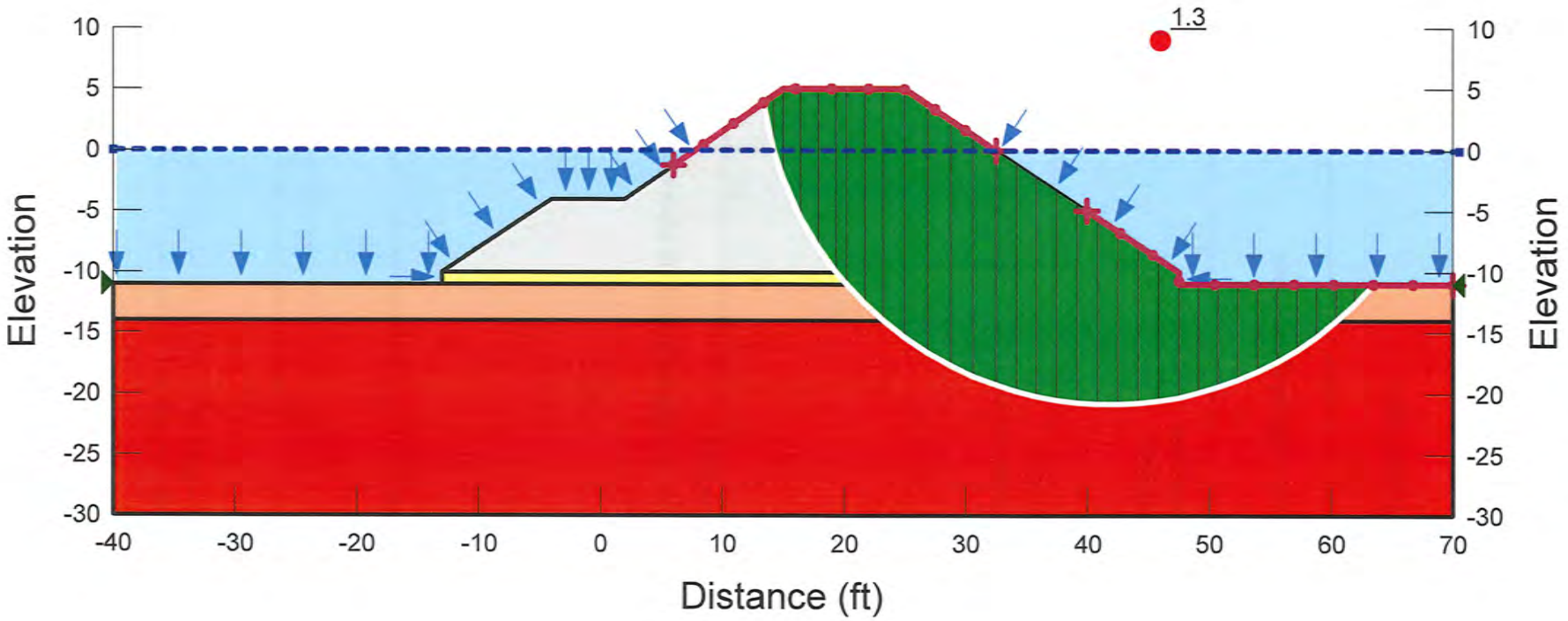
Purpose and Objective
Evaluate the global stability of the 3 critical breakwater sections (Breakwaters 2, 4 and 5) at Wallops Island.

Summary of Conclusions
Factors of safety for slope stability of the breakwater sections evaluated exceed 1.3.

Originator			
K. Pocta			Aug 17, 2018
	Print	Sign	Date
Checked			
J. Seli			Aug 21, 2018
	Print	Sign	Date

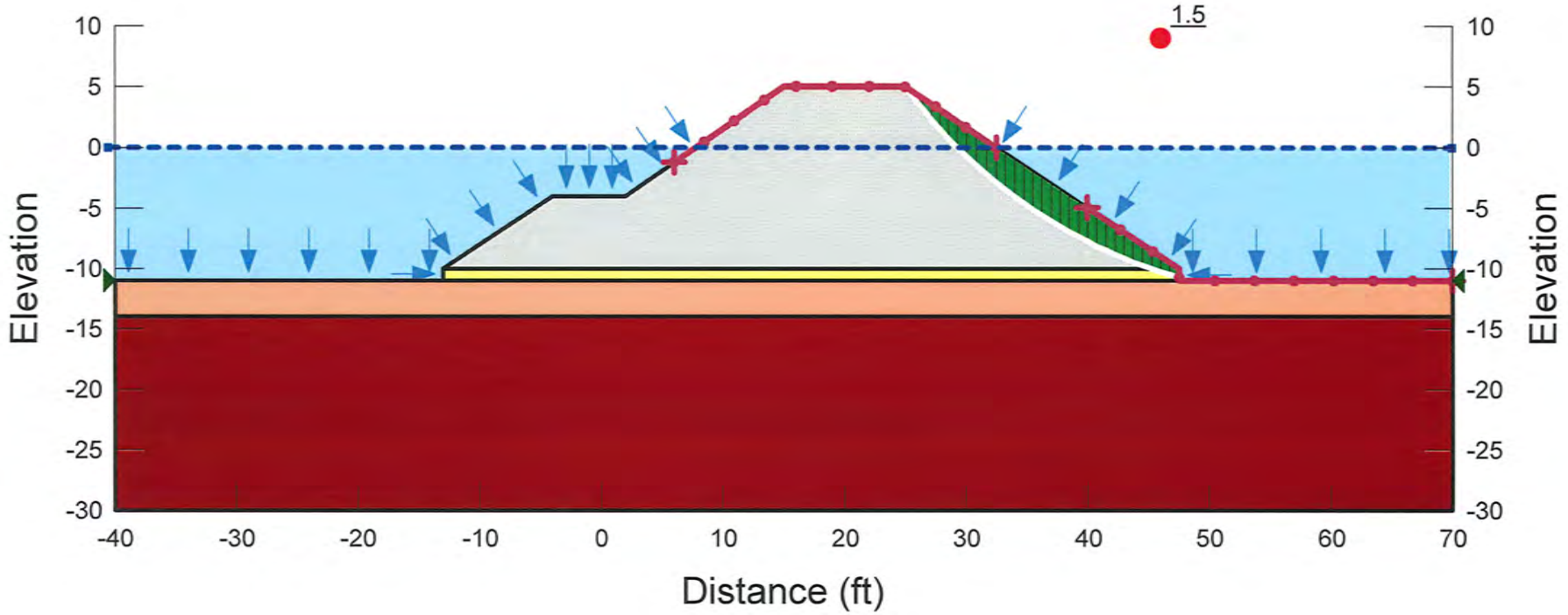
Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	A1	115	0	34
	A2/3 Effective	100	100	15
	Mattress Material	115	0	34
	Rip Rap	150	0	45

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 2 - Effective Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



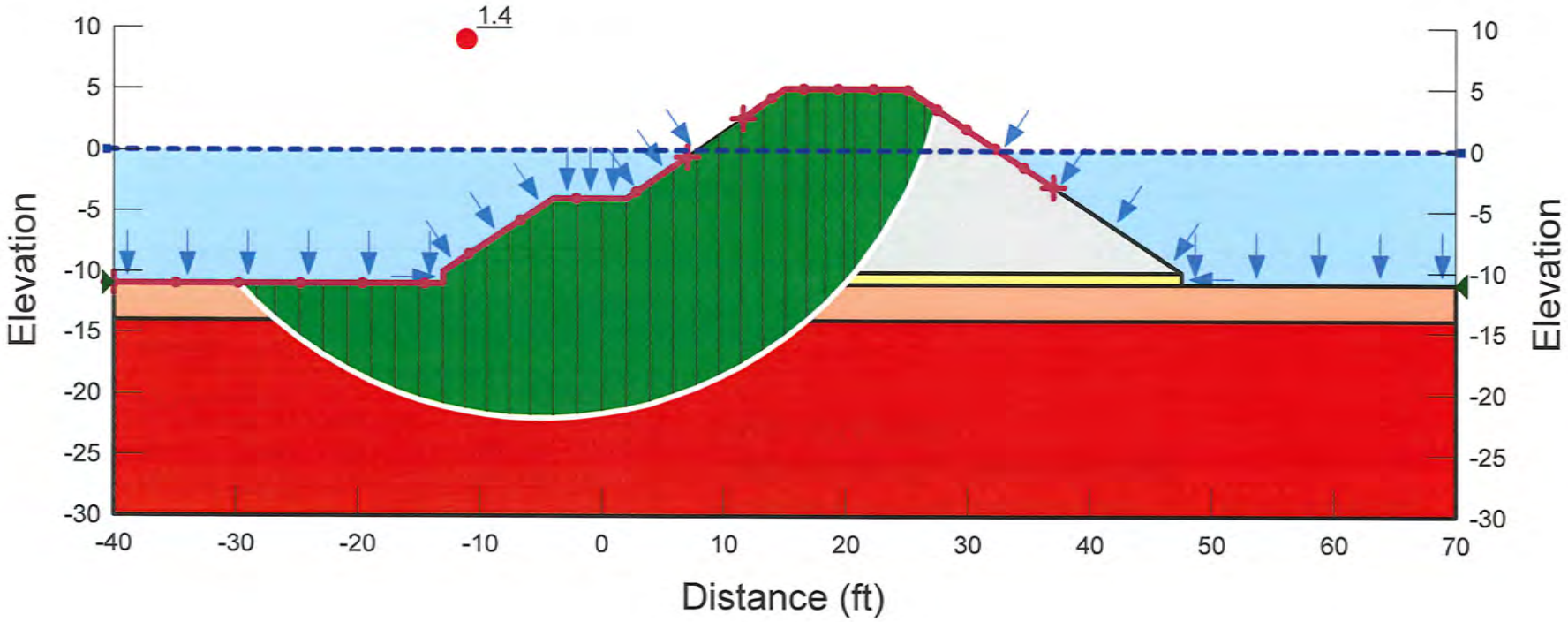
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	A1	115	0	34	
	A2/3 Total	100			600
	Mattress Material	115	0	34	
	Rip Rap	150	0	45	

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 2 - Total Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



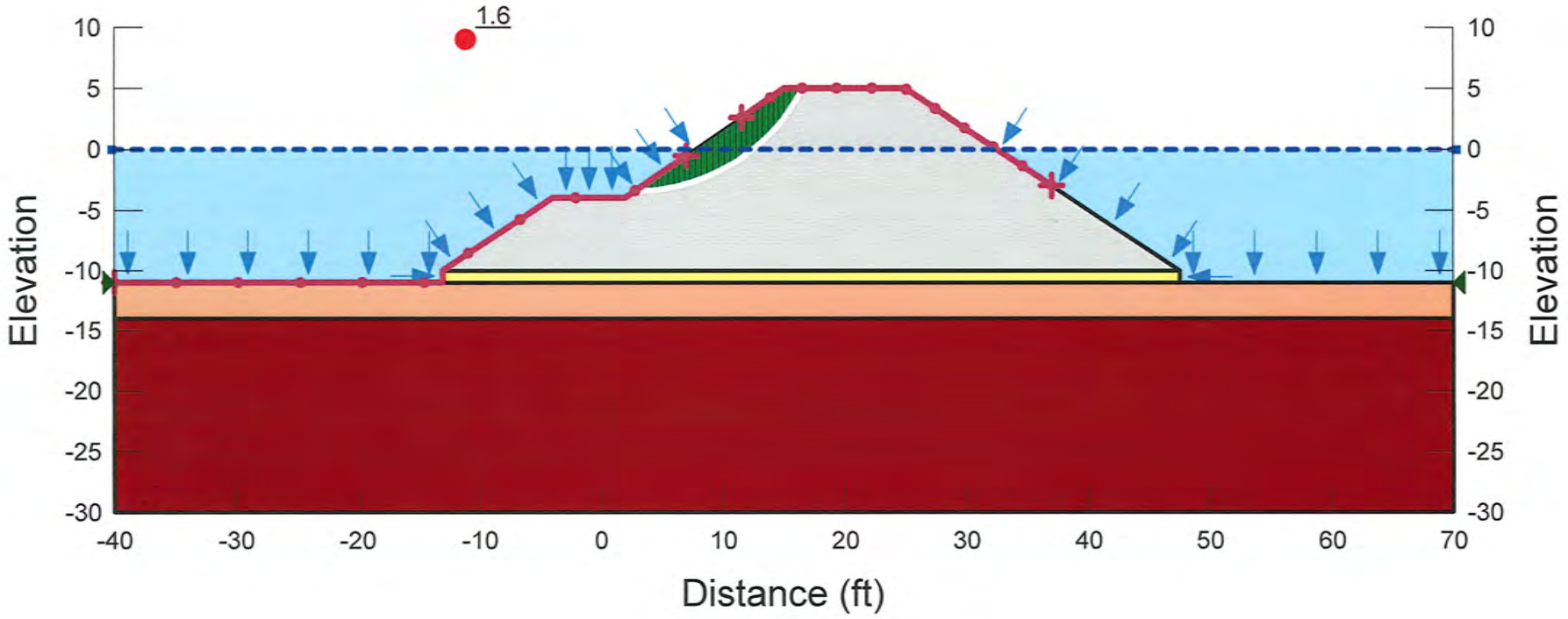
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	A2/3 Effective	100	100	15
	Mattress Material	115	0	34
	Rip Rap	150	0	45

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 2 (Step) - Effective Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



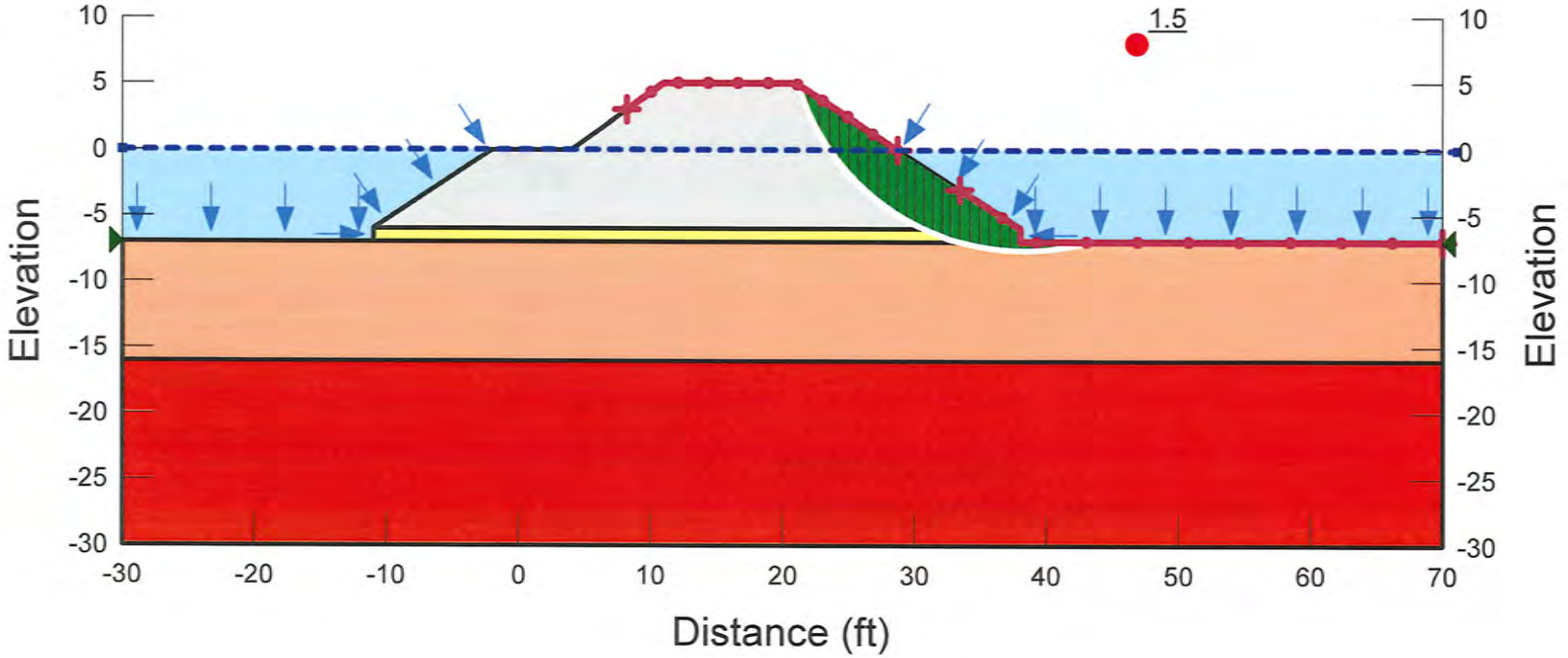
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	A2/3 Total	100			600
	Mattress Material	115	0	34	
	Rip Rap	150	0	45	

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 2 (Step) - Total Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



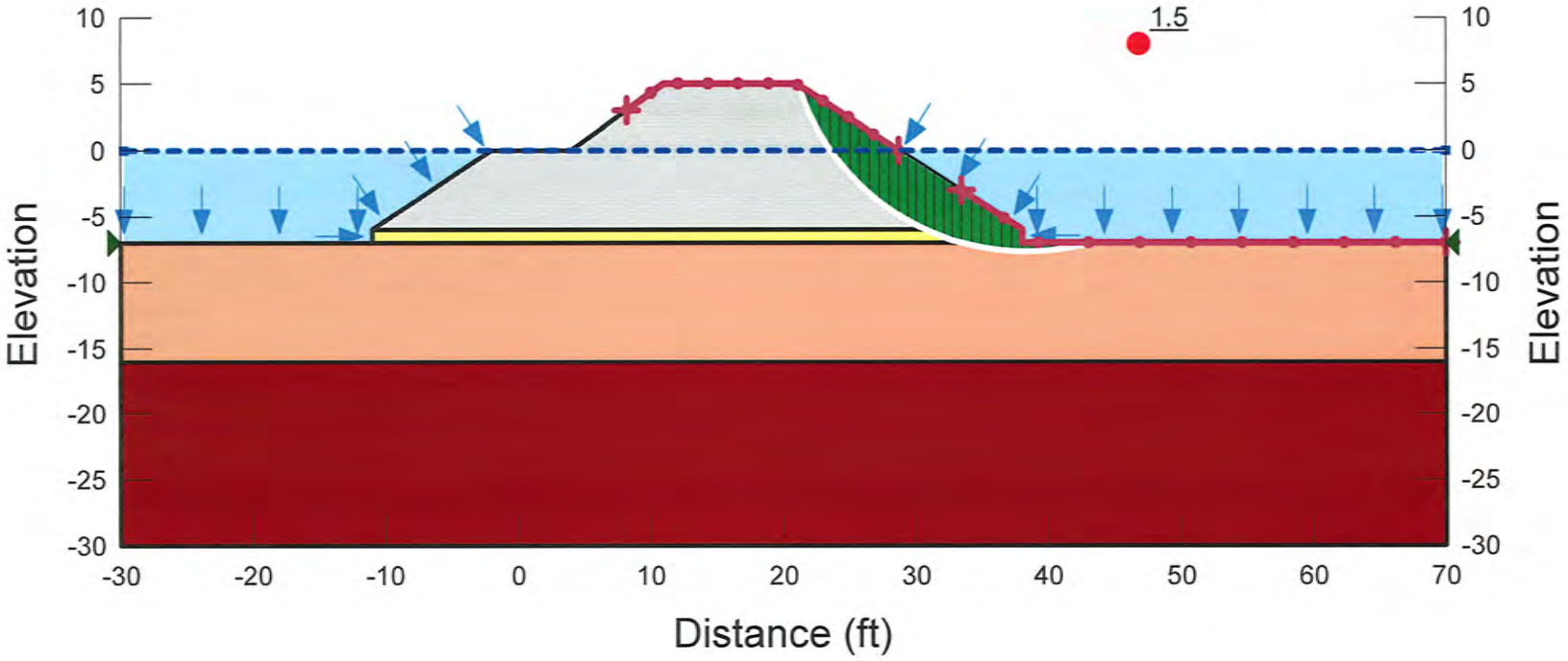
Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	A1	115	0	34
	A2/3 Effective	100	100	15
	Mattress Material	115	0	34
	Rip Rap	150	0	45

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 4 - Effective Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



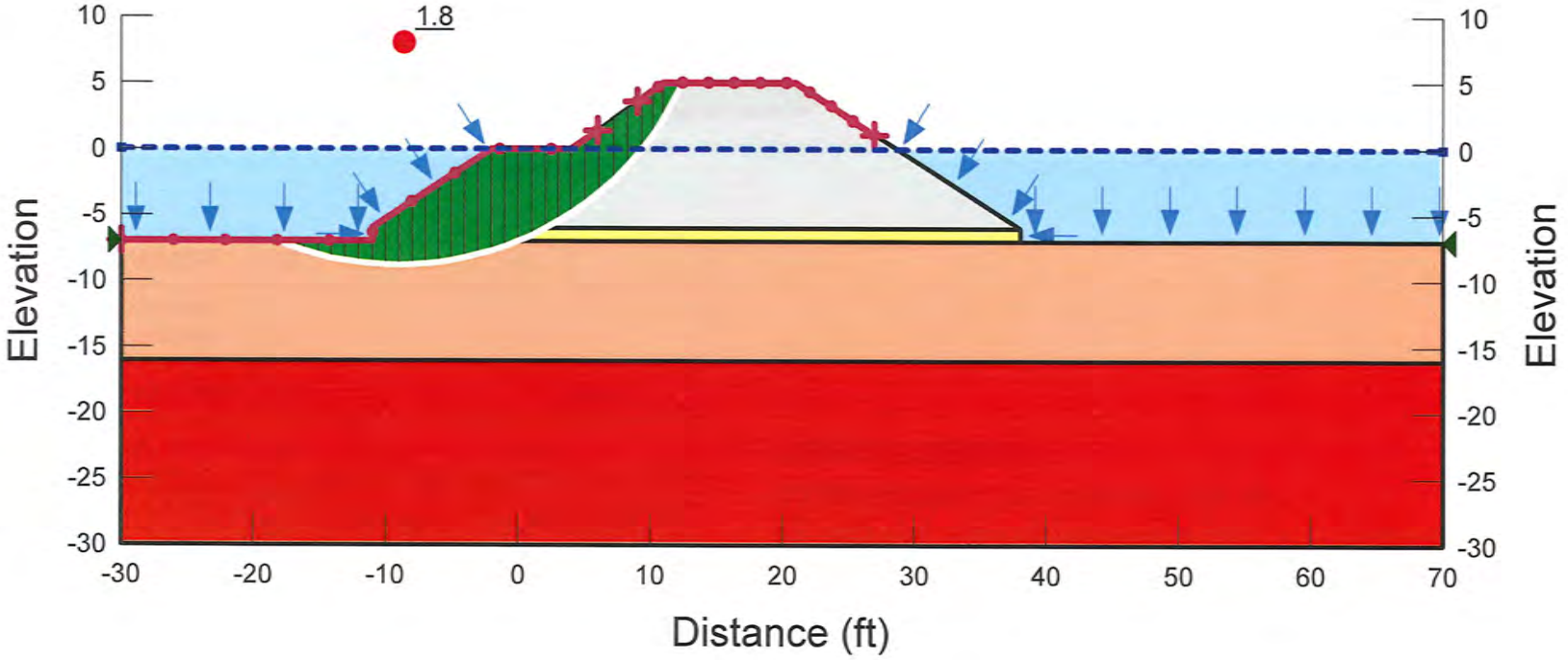
Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 4 - Total Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion (psf)
	A1	115	0	34	
	A2/3 Total	100			600
	Mattress Material	115	0	34	
	Rip Rap	150	0	45	



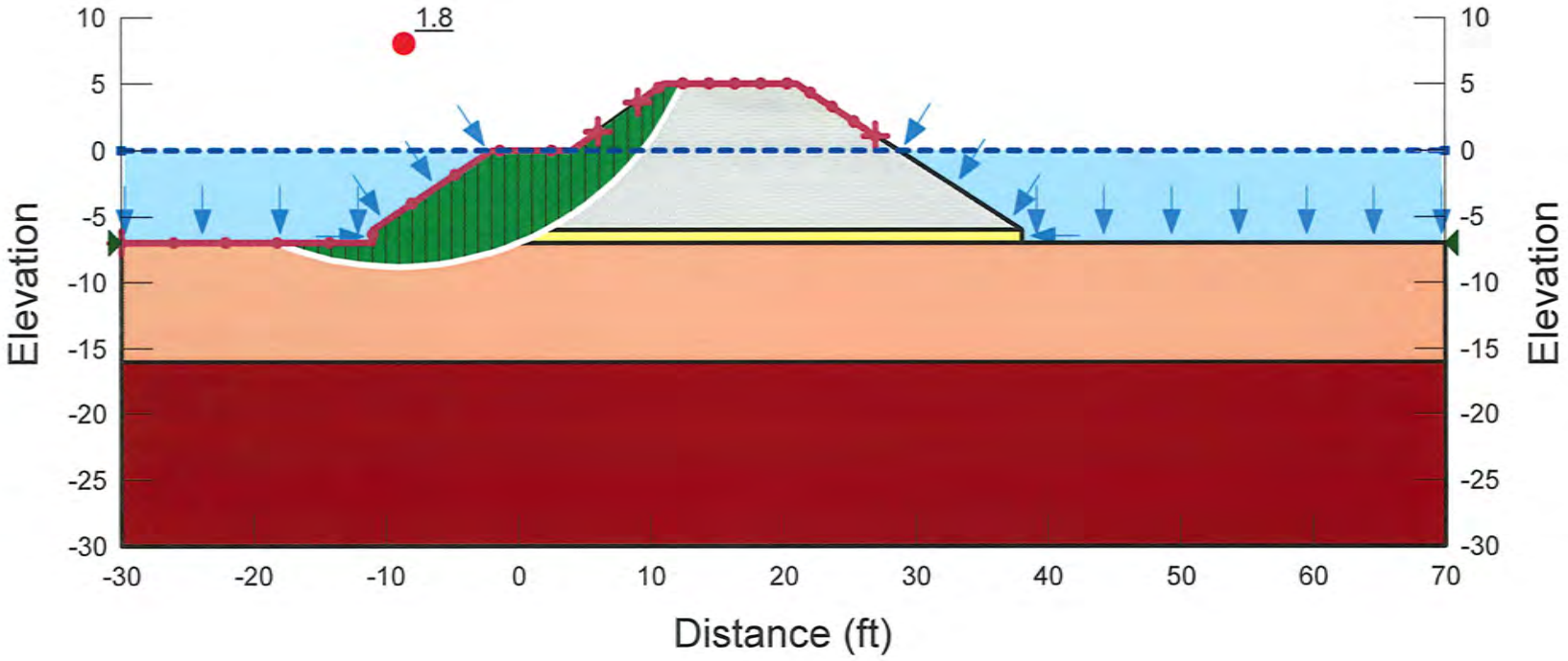
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	A2/3 Effective	100	100	15
	Mattress Material	115	0	34
	Rip Rap	150	0	45

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 4 (Step) - Effective Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



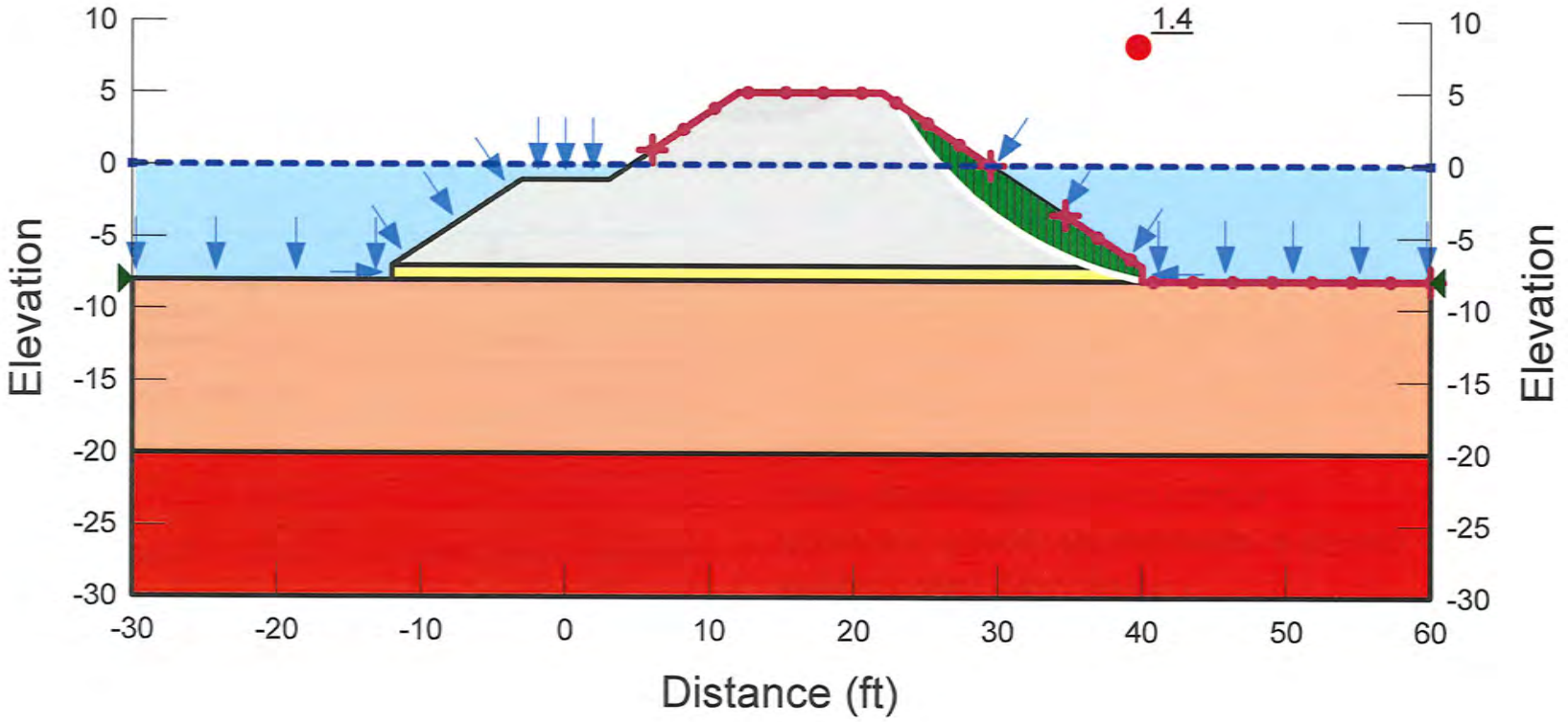
Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 4 (Step) - Total Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion (psf)
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	A2/3 Total	100			600
	Mattress Material	115	0	34	
	Rip Rap	150	0	45	



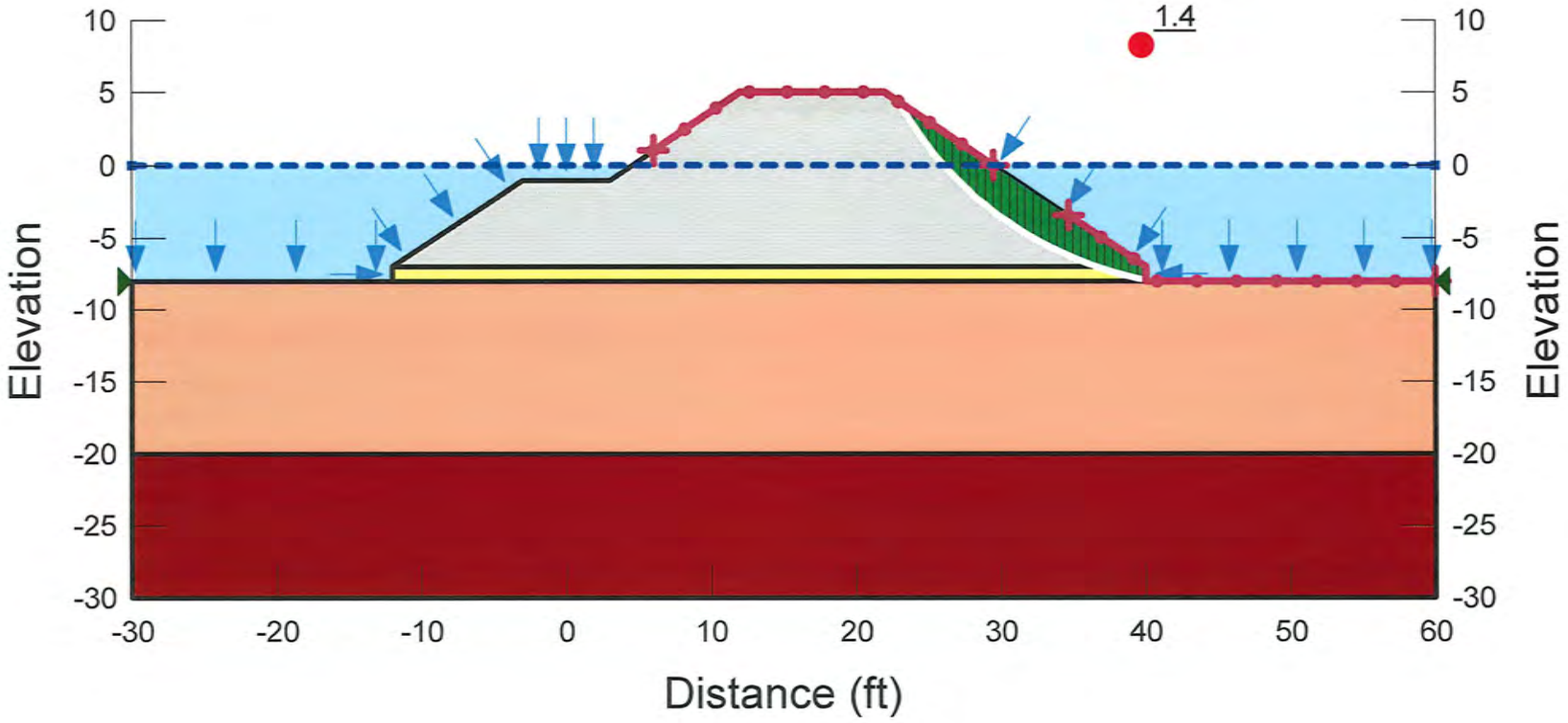
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	A1	115	0	34
	A2/3 Effective	100	100	15
	Mattress Material	115	0	34
	Rip Rap	150	0	45

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 5 - Effective Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



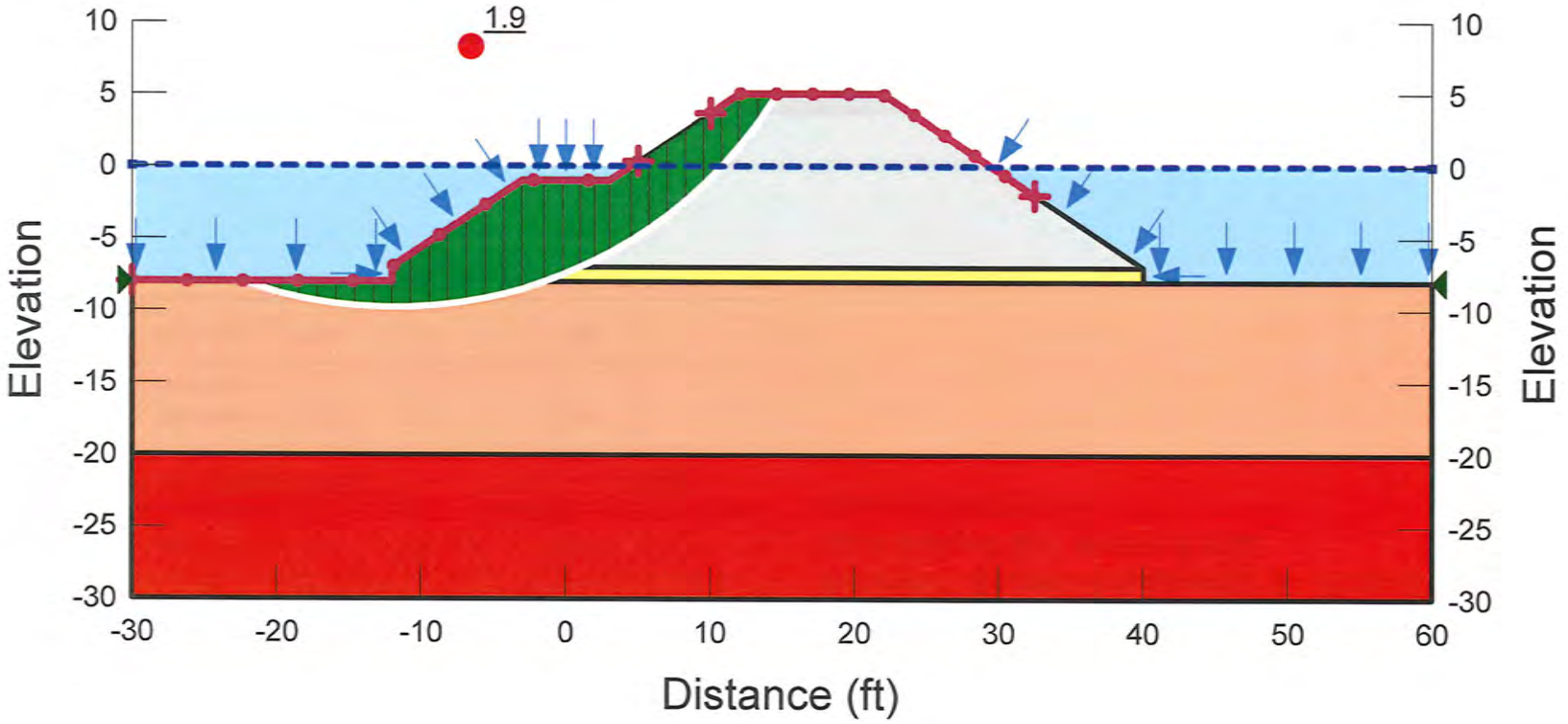
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	A2/3 Total	100			600
	Mattress Material	115	0	34	
	Rip Rap	150	0	45	

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 5 - Total Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



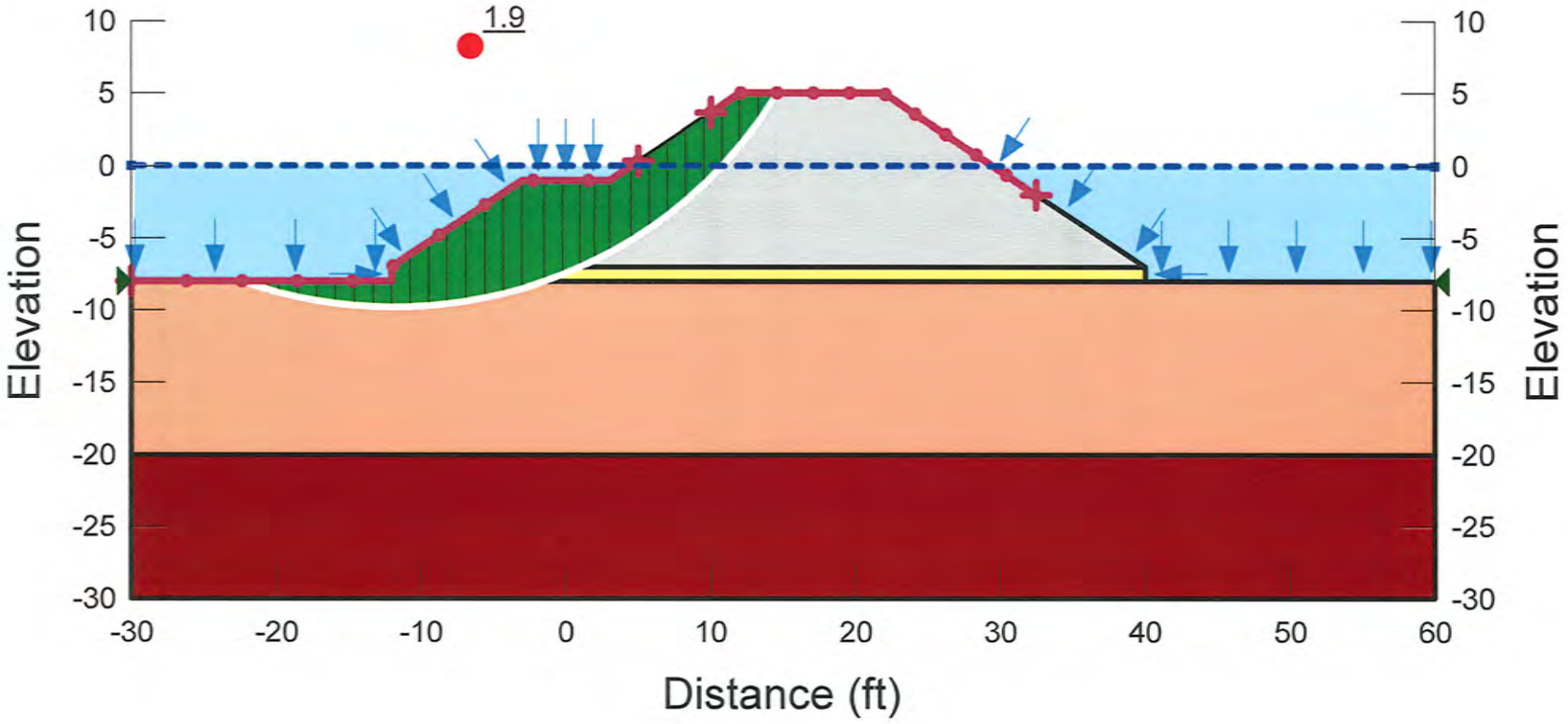
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	A2/3 Effective	100	100	15
	Mattress Material	115	0	34
	Rip Rap	150	0	45

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 5 (Step) - Effective Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion (psf)
	A1	115	0	34	
	A2/3 Total	100			600
	Mattress Material	115	0	34	
	Rip Rap	150	0	45	

Project: Wallops Island Breakwaters
Project No.: 18C13074
Analysis Name: Breakwater 5 (Step) - Total Stress
Last Edited By: Kevin Pocta
Date: 8/15/2018



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CALCULATION COVER SHEET

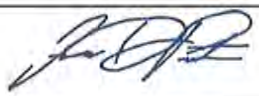
Project	Project Number
Wallops Island Breakwaters	18C13074

Title
Breakwater Bearing Capacity

Computer Programs Used	Version/Release No.
N/A	N/A

Purpose and Objective
Find the bearing resistance of the soils beneath the breakwaters.

Summary of Conclusions
The breakwater foundation soils have a bearing capacity of 2 ksf.

Originator		
K. Pocta		Aug 17, 2018
Print	Sign	Date

Checked		
J. Seli		Aug 21, 2018
Print	Sign	Date

Schnabel ENGINEERING

Project WALLOPS ISLAND BREAKWATER Page 1 of 1

Project No. 18C13074 By JS Date 7/18/18

Client _____ Checked _____ Date _____

Subject BEARING CAPACITY

GENERALLY HAVE 4' OF SAND OVER SOFT CLAY (s_u = 600 PSF ±)

USE A LOW ϕ TO ACCOUNT FOR SOFT CLAYS UNDERNEATH

USE $\phi = 25^\circ$ $\gamma_b = 53$ PCF

STRIP FOUNDATION B = 40' D = 0 (ON MUDLINE)

$$q_{ult} = \cancel{CN_c^{\,0}} + \gamma \cancel{DN_q^{\,0}} + \frac{\gamma B}{2} N_\gamma \qquad N_\gamma = 7 \qquad \text{(DM-7.2-131)}$$

$$q_{ult} = \frac{(53)(40)}{2}\, 7 = 7420 \text{ PSF} \qquad FS > 3 \text{ FOR } q = 2000 \text{ PSF}$$

APPENDIX E

2026 TERRACON BEACH

GRAB SAMPLE REPORT

NASA Wallops Flight Facility (WFF) Geotechnical Exploration

Beach Grab Sample Laboratory Testing Report R1

Wallops Island, Virginia

February 23, 2026 | Terracon Project No. K3322022

Prepared for:

BURNS McDONNELL

Burns & McDonnell
1317 Executive Blvd., 3rd Floor
Chesapeake, VA 23320

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February 23, 2026

Burns & McDonnell
1317 Executive Blvd., 3rd Floor
Chesapeake, VA 23320

Attn: Anat Mor, AIA, LEED AP
P: 757-916-4351
E: amor@burnsmcd.com

Re: Beach Grab Sample Laboratory Testing Report R1
NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Wallops Flight Facility
Wallops Island, Virginia
Terracon Project No. K3322022

Dear Ms. Mor:

We have completed the scope of Beach Grab Sample Laboratory Testing services for the above referenced project in general accordance with Terracon Proposal No. PK3322022 R1 dated July 29, 2025. This data report presents the findings of the subsurface exploration and laboratory testing results for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,

Terracon

COMMONWEALTH OF VIRGINIA
MARC S. NELLIS
Lic. No. 057541
PROFESSIONAL ENGINEER

Marc S. Nellis, PE
Senior Geotechnical Engineer
VA License No. 057541

Chris M. Caton, PE, PG, PMP
Senior Principal
VA License No. 046947

Table of Contents

Introduction 1
Project Description 1
Site Conditions 3
General Comments 3

Attachments

Exploration and Testing Procedures
Photography Log
Site Location and Exploration Plans
Beach Sample Laboratory Results
Supporting Information

Note: This report was originally delivered in a web-based format. **Blue Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the Terracon logo will bring you back to this page. For more interactive features, please view your project online at **client.terracon.com**.

Refer to each individual Attachment for a listing of contents.

Introduction

This report presents the results of our Beach Grab Sample Laboratory Testing services performed for the proposed beach renourishment to be located at Wallops Flight Facility on Wallops Island, Virginia. The purpose of these services was to provide information and laboratory testing relative to:

- Existing beach soil conditions

The geotechnical engineering Scope of Services for this project included the collection of beach grab samples, laboratory testing, and preparation of this data report.

Drawings showing the site and grab sample locations are shown on the **Site Location** and **Exploration Plan**, respectively. Our field exploration and laboratory testing procedures are detailed in the **Exploration and Testing Procedures** attachment. The results of the laboratory testing performed on soil samples obtained from the site during our field exploration are included as separate graphs in the **Beach Sample Laboratory Results** attachment.

Project Description

Our initial understanding of the project was provided in our proposal and was discussed during project planning. A period of collaboration has transpired since the project was initiated, and our final understanding of the project conditions is as follows:

Item	Description
Information Provided	An email request for proposal was provided by Ms. Anat Mor on 29 JAN 2025. The request included the following documents. ■ 'WFF Geotech_VE SOW_revised1_22NOV24' ■ 'Appendix A thru D' (not dated) ■ 'RFP NASA WFF Geotechnical and VE Study_FINAL_20250129' Additional information was provided by Burns & McDonnell via a phone call with Ms. Mor on 30 JAN 2025 and subsequent emails from Ms. Mor. An updated RFP and associated documents (dated 12 FEB 2025) were provided by Ms. Anat Mor on 12 FEB 2025. An email request for a revised proposal was provided by Ms. Anat Mor on 10 MAR 2025. The request included the following documents. ■ 'WFF Geotech_VE SOW_4MAR25_approved' ■ 'Appendix A thru D -revised 3-4-25' ■ 'NSA Questions' ■ 'NASA Wallops Flight Facility Proposal Geotech Exploration Assumptions final'
Project Description	As indicated by Ms. Mor on 31 JAN 2025, Terracon's scope of work was to perform the following 'Geotechnical Exploration' scoping item. ■ SAES Section 3.2.2.I.i, Beach Grab Sampling Perform a geotechnical exploration for use in the design and construction of a breakwater shoreline protection system and beach renourishment to address ongoing tidal erosion. Perform a Value Engineering Study on the design of breakwaters being constructed to protect key NASA infrastructure on WFF (VE services and breakwater shoreline protection system are not part of Terracon's scope).

Site Conditions

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and the project topographic maps.

Item	Description
Parcel Information	The project is located at Wallops Flight Facility at Wallops Island, Virginia. Latitude/Longitude (approximate) 37.8419° N, -75.4782° W See **Site Location**
Current Ground Cover	The beach shoreline consists of sand with dunes located to the west and the Atlantic Ocean to the east.
Existing Topography	**Beach Shoreline** Elevations range from approximately -5.5 feet to 13.5 feet (NAVD 88)

We also collected photographs at the time of our field exploration program. Representative photographs are provided in our **Beach Sample Photography Log**.

General Comments

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Attachments

Exploration and Testing Procedures

Field Exploration

Number of Grab Samples	Approximate Grab Sample Depth (feet)	Location
6	0 to 1	Dune (DS-1196-XX)
10	0 to 1	Mid-Berm (BS-1196-XX)
7	0 to 1	Swash Zone (SW-1196-XX)

Grab Sample Locating: Terracon personnel located the grab samples using a handheld Trimble TDC6 Data Collector with GNSS receiver (estimated horizontal accuracy of about ±3 feet) and referencing existing site features. The locations were shifted as needed to avoid any vegetation, deposits of shells, or other items on the beach that would impact the samples. Sample coordinates were collected in Lat/Long and converted to Northing and Easting utilizing the NGS NCAT website.

Grab Sample Exploration Procedures: We collected the beach grab samples using a manual hand auger with a 3.25 inch diameter "sand" bucket attachment. The hand auger was advanced from the existing ground surface to a maximum depth of 1 foot below existing ground surface. A continuous sample was collected over this entire depth. Samples were collected at the dune (DS), mid-berm (BS), and swash zone (SW) at each cross-shore location. The samples for each cross -shore location were placed in a clean, dry, plastic 5-gallon bucket and thoroughly mixed together to create a composite sample. The composite samples were then placed into a clean, dry, plastic quart size jar. The jars were sealed with a tight-fitting rubber gasket sealed lid to ensure that the moisture content remained consistent. Each jar was labeled with the composite sample ID (CMP-1196-01 through CMP-1196-03, and CMP-1196-07 through CMP-1196-10).

The only exception to this procedure was for the samples along the shore wall, (BS-1196-04, SW-1196-04, BS-1196-05, SW-1196-05, BS-1196-06, and SW-1196-06). Due to high tide and surf, only the mid-berm (BS) samples were able to be obtained. These samples were collected in the water using the same sample collection procedure outlined above. The jars for these samples were labeled with the sample location ID (BS-1196-04, BS-1196-05, and BS-1196-06).

Upon completion of each sample, the holes were backfilled and rough graded with the surrounding sand. Photographs and updated coordinated were captured using the handheld GPS were also obtained at each sample location. The photographs, coordinates, and beach grab sample notes are listed on the **Beach Grab Sample Photography Logs**.

The samples were then transported back to our Materials Testing Center (MTC) Certified Virginia Beach office for laboratory testing.

Laboratory Testing

The project engineer performed Munsell Soil Color classification on the as sampled, wet condition and then assigned laboratory tests. The laboratory testing program included the following types of tests:

- Moisture Content
- Sieve Analysis using the Wentworth Sieve Set with a wash over the No. 230 sieve
- Munsell Color Soil determination, as sampled wet condition, dry condition prior to wash, and dry condition after wash

The project SAES required Atterberg Limits testing and Hydrometer testing but due to the limited number of fines in each sample, these tests could not be performed.

The Munsell Color Book determination was performed by taking a portion of each sample and comparing it to each color chart. This was repeated until a close match was determined by the project engineer. The page number, value, and chroma were recorded for each sample at each stage listed above.

Upon completion of the laboratory testing program, the results were input into gINT and on to the Granularmetric Report example provided in the SAES. The results can be found in the **Beach Sample Laboratory Results** attachment.

Beach Grab Samples Photography Log

Sample Notes:

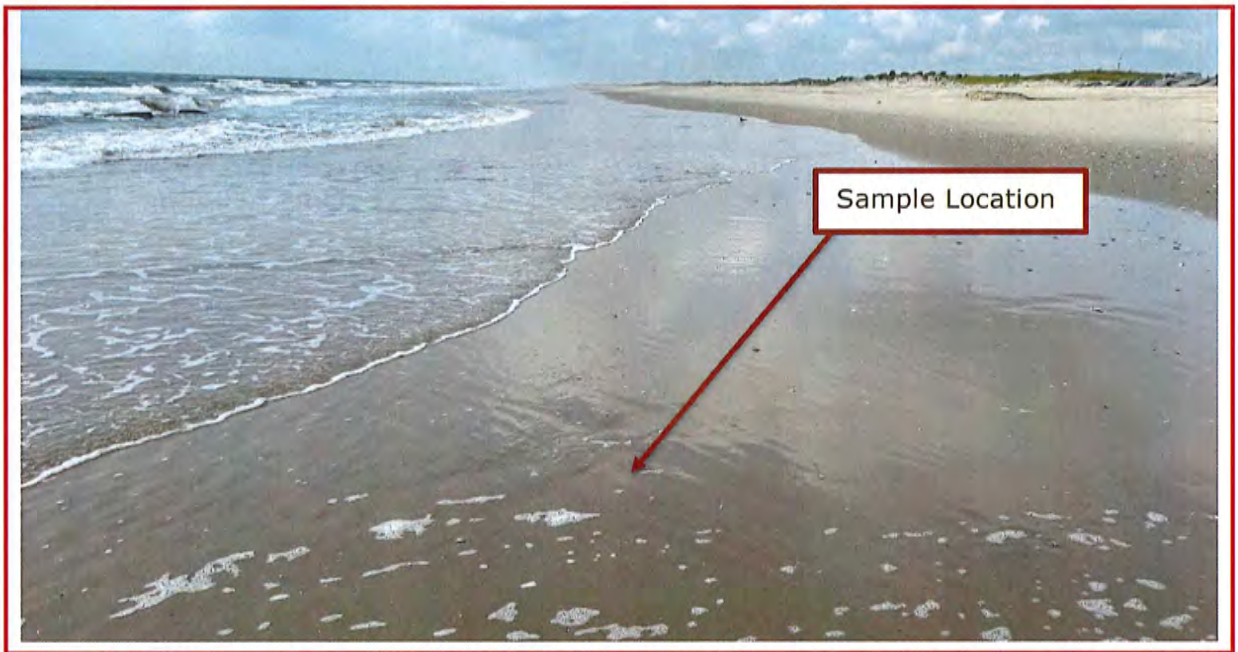
- The locations of the beach grab samples were provided by USACE and adjusted in the field to account for the Dune, Berm, and Swash zones. As sampled Northing and Easting coordinates are provided for each sample.
- All samples were collected using a hand auger from 0 to 1 foot below existing grades. The samples from each corresponding location (i.e. XX-1196-01) were placed in a clean and dry 5-gallon bucket, mixed and sealed in plastic quart mason jars.
- Sample Locations were surveyed in the field utilizing a Trimble TDC6 Data Collector with GNSS receiver. At the time of data collection, an accuracy of +/- 3 feet. Sample coordinates were collected in Lat/Long and converted to Northing and Easting (VA South Zone) utilizing the NGS NCAT website.
- Due to high tide and surf, samples SW-1196-04, SW-1196-05, and SW-1196-06 were unable to be obtained.
- Composite samples CMP-1196-04, CMP-1196-05, and CMP-1196-06 were only comprised of BS-1196-04, BS-1196-05, and BS-1196-06.
- Samples SW-1196-09 and SW-1196-10, were collected at low tide, making it difficult to gauge the extent of the swash zone at high tide, as such these samples may have been obtained from just outside of the high tide swash zone.
- Sample times are based on picture time stamps and should be considered an approximate time the sample was obtained.



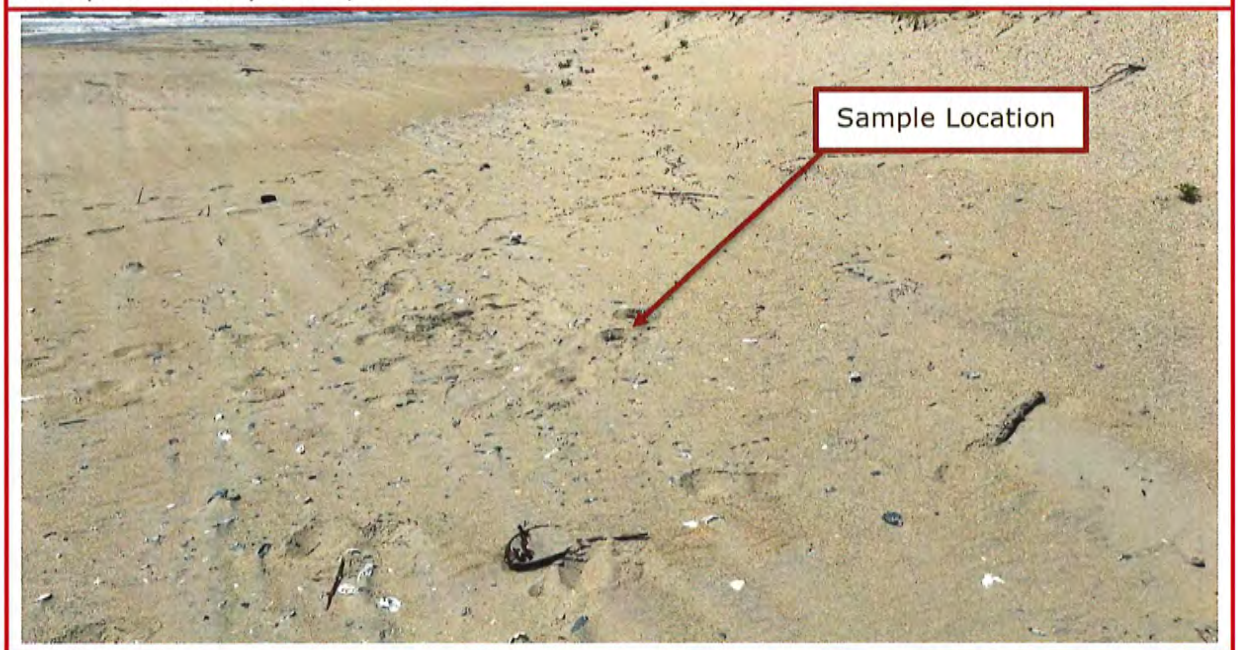
DS-1196-01 (N 3,837,062.674, E 12,349,909.553)
Sampled 09 July 2025, 11:10



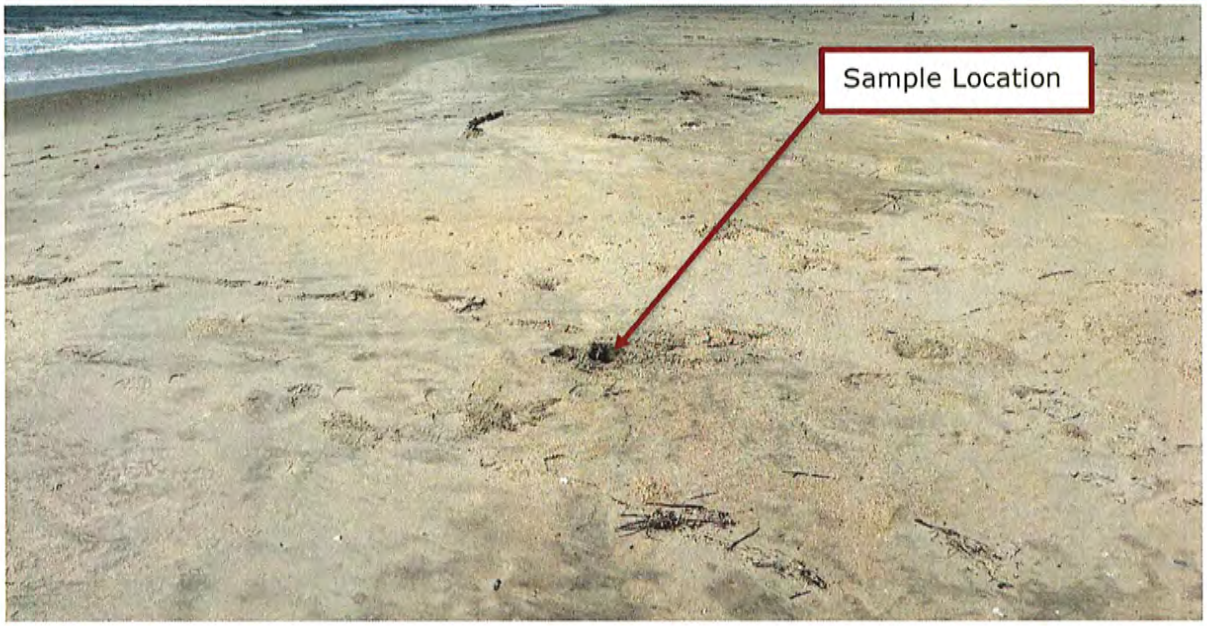
BS-1196-01 (N 3,837,026.99, E 12,349,966.438)
Sampled 09 July 2025, 11:11



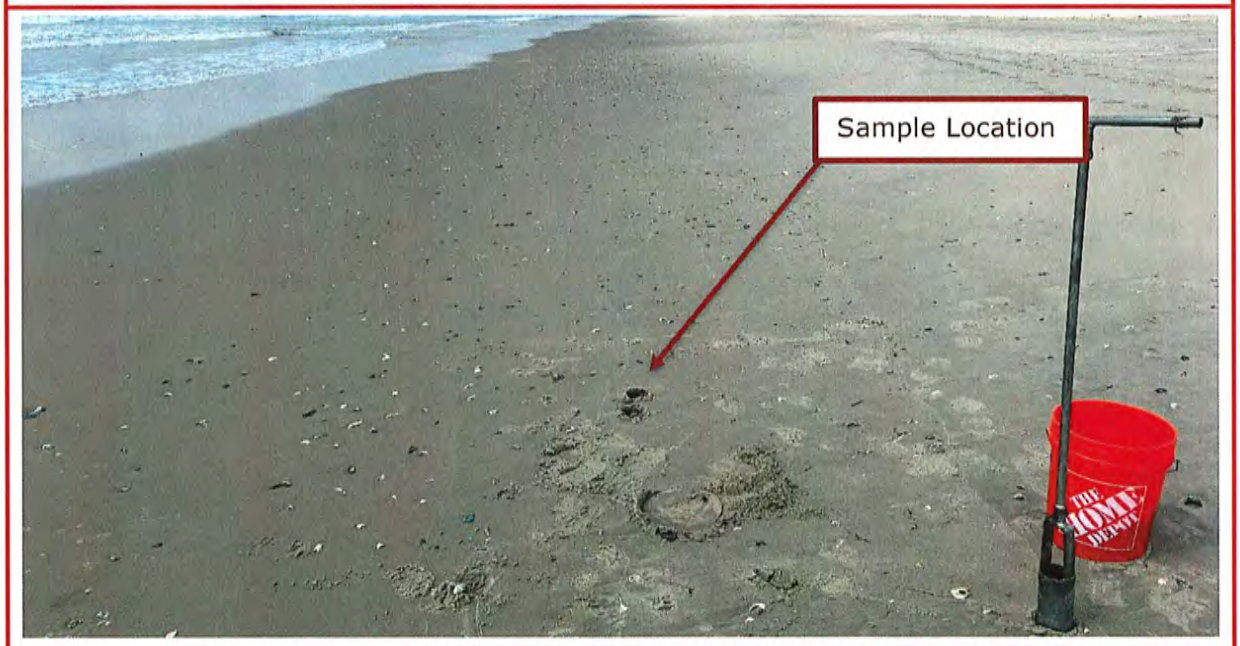
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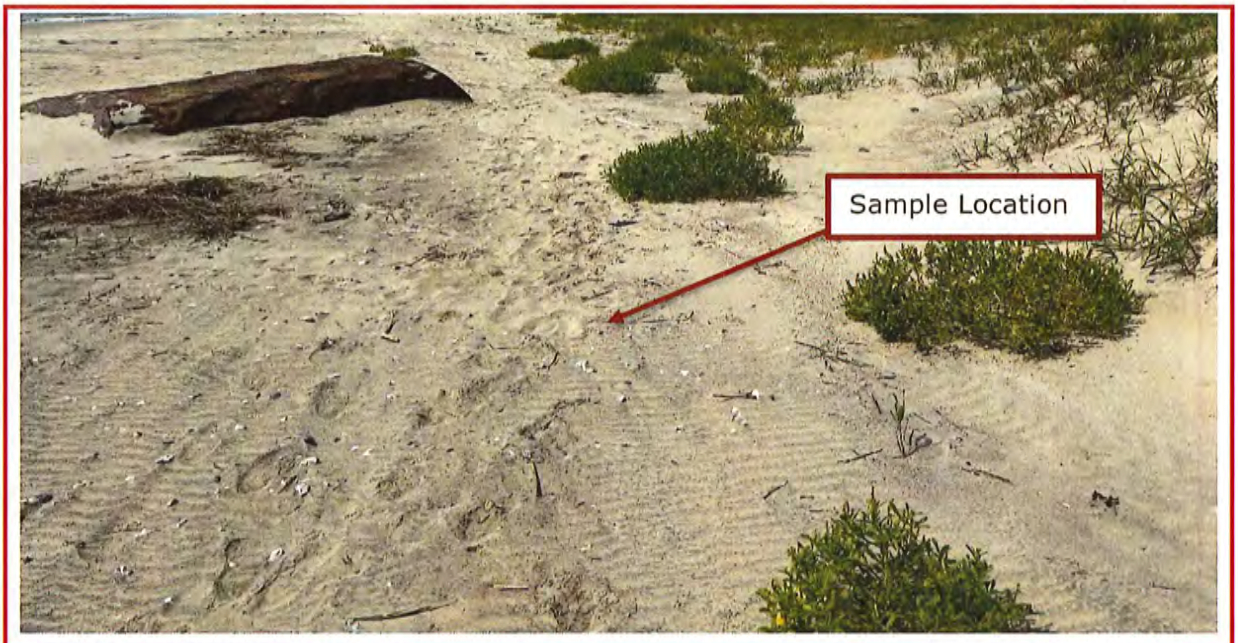
DS-1196-02 (N 3,838,528.634, E 12,350,955.284)
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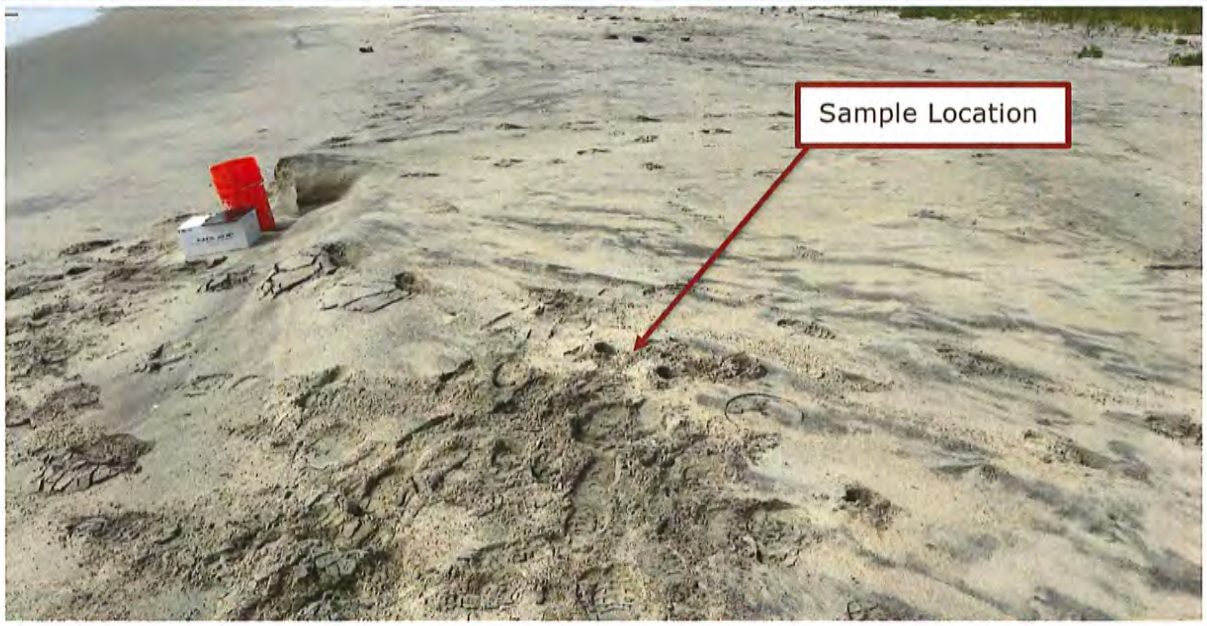
BS-1196-02 (N 3,838,490.673, E 12,351,010.934)
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SW-1196-02 (N 3,838,458.521, E 12,351,053.265)
Sampled 09 July 2025, 10:55



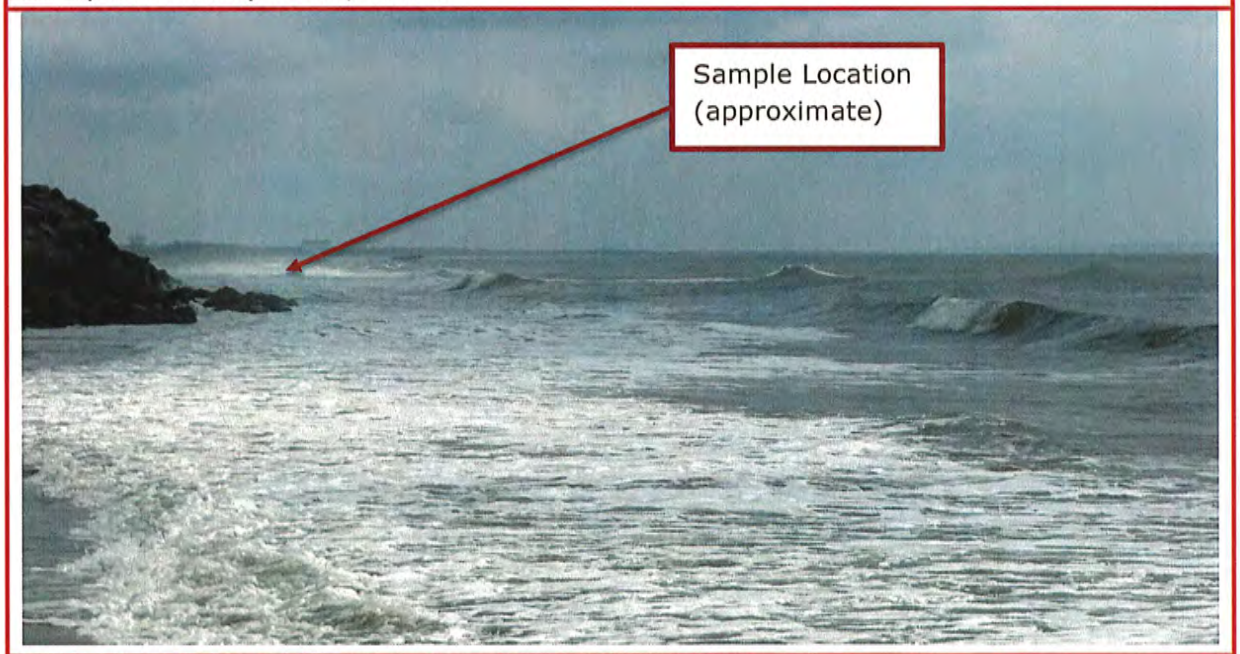
DS-1196-03 (N 3,840,120.459, E 12,352,161.610)
Sampled 09 July 2025, 10:05



BS-1196-03 (N 3,840,080.680, E 12,352,207.711)
Sampled 09 July 2025, 10:05



SW-1196-03 (N 3,840,055.788, E 12,352,236.318)
Sampled 09 July 2025, 10:09



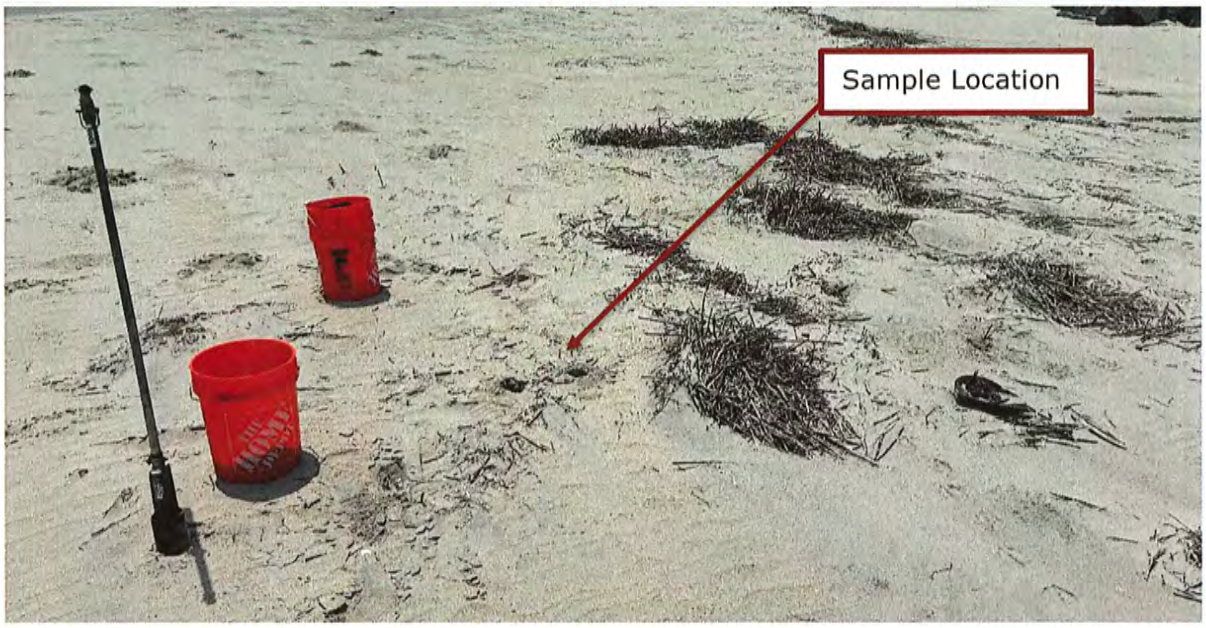
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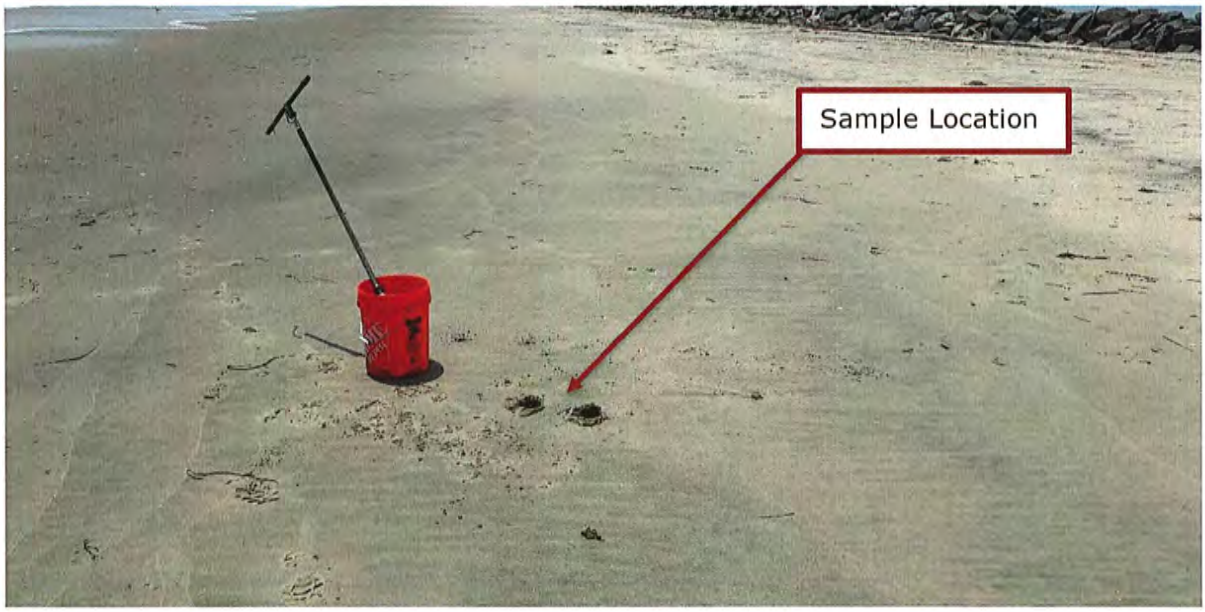
BS-1196-05 (N 3,842,068.327, E 12,353,860.527)
Sampled 09 July 2025, 13:21



BS-1196-06 (N 3,843,174.424, E 12,354,723.677)
Sampled 09 July 2025, 13:42



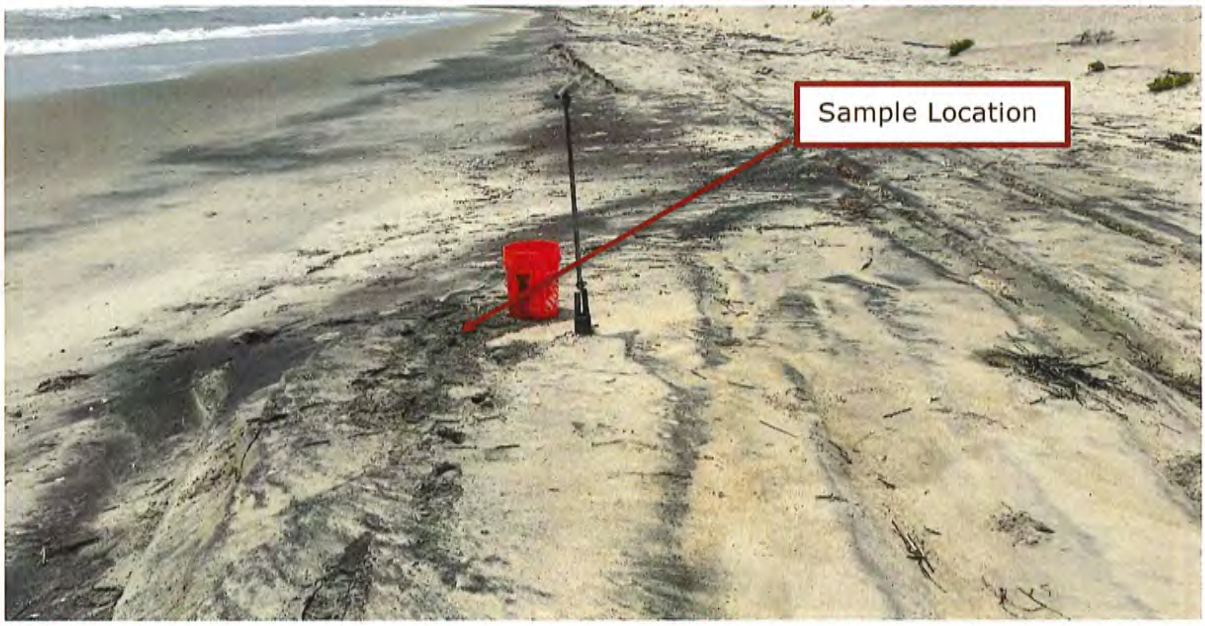
BS-1196-07 (N 3,844,731.801, E 12,355,975.188)
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SW-1196-07 (N 3,844,684.437, E 12,356,037.026)
Sampled 09 July 2025, 13:07



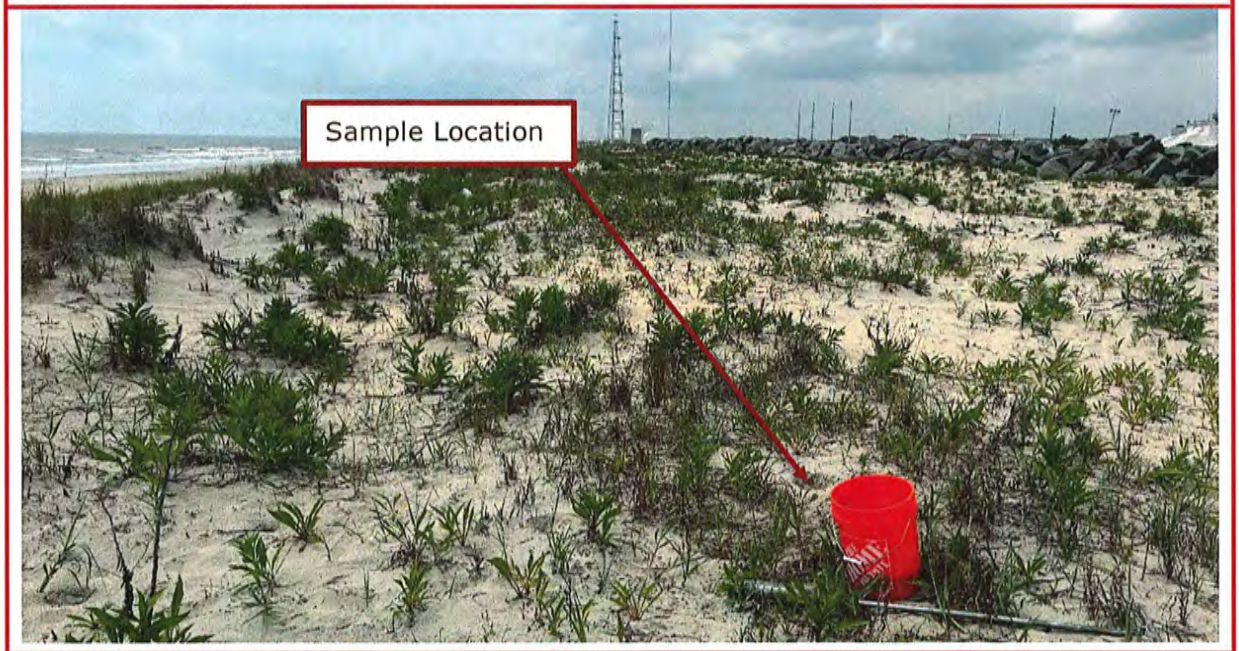
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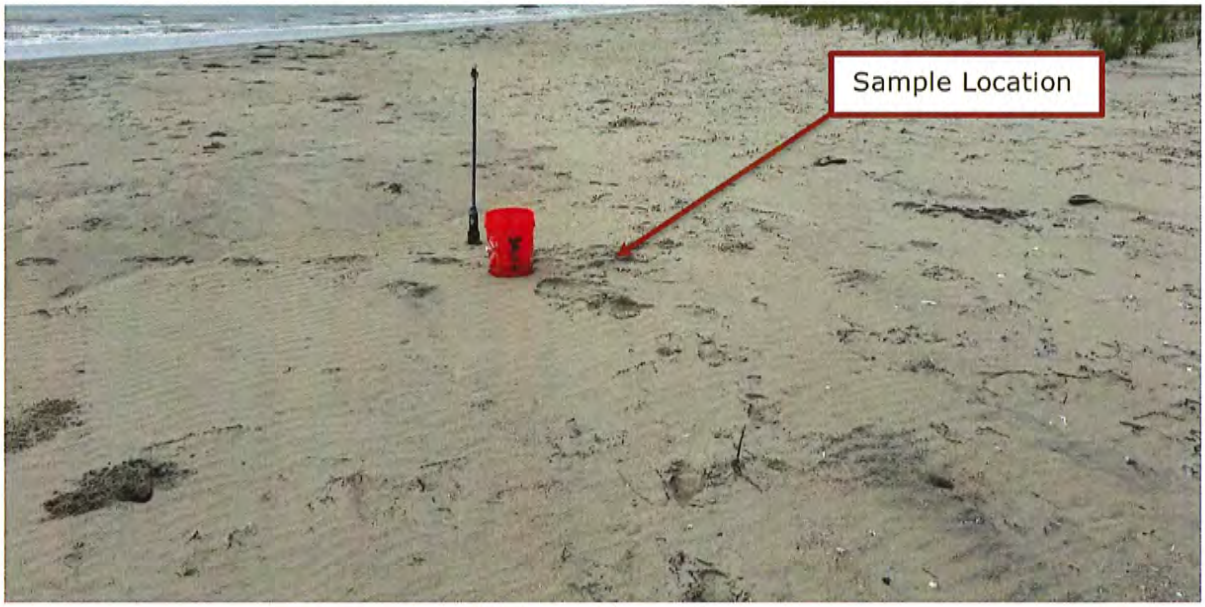
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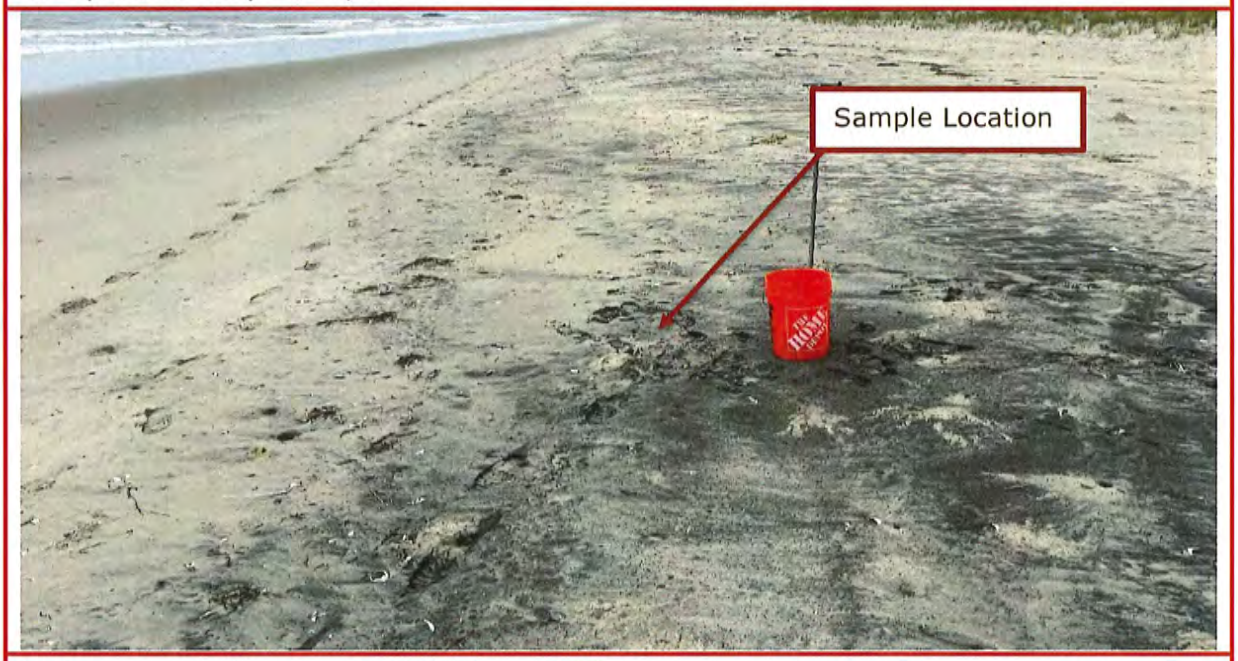
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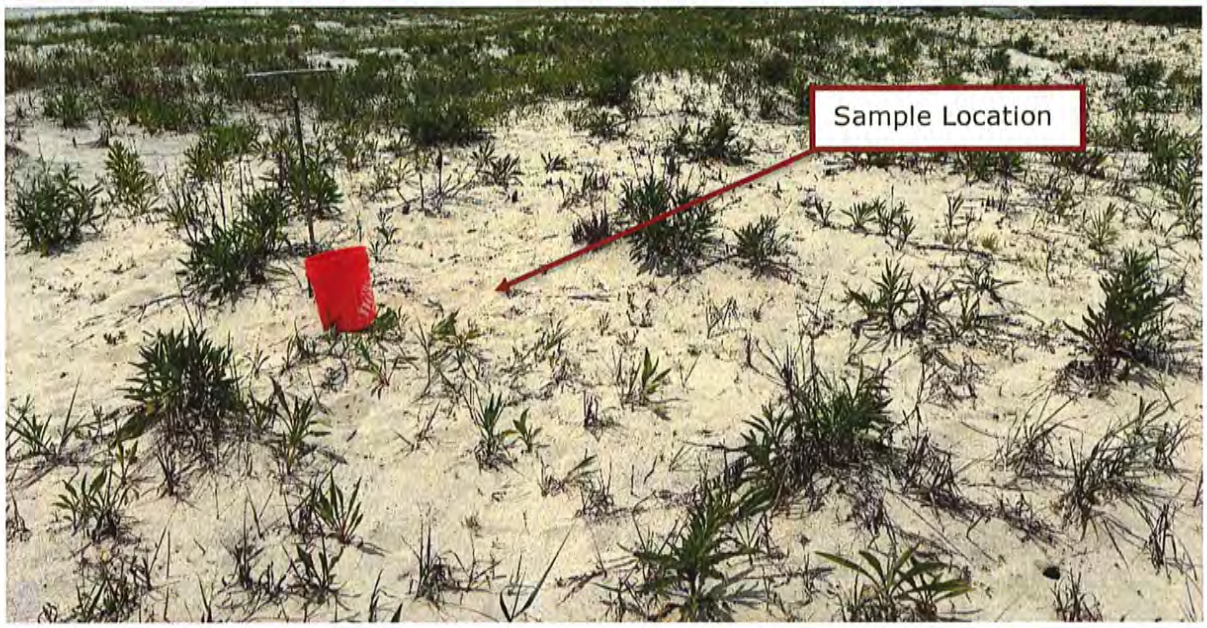
DS-1196-09 (N 3,847,480.633, E 12,358,142.292)
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BS-1196-09 (N 3,847,412.675, E 12,358,225.237)
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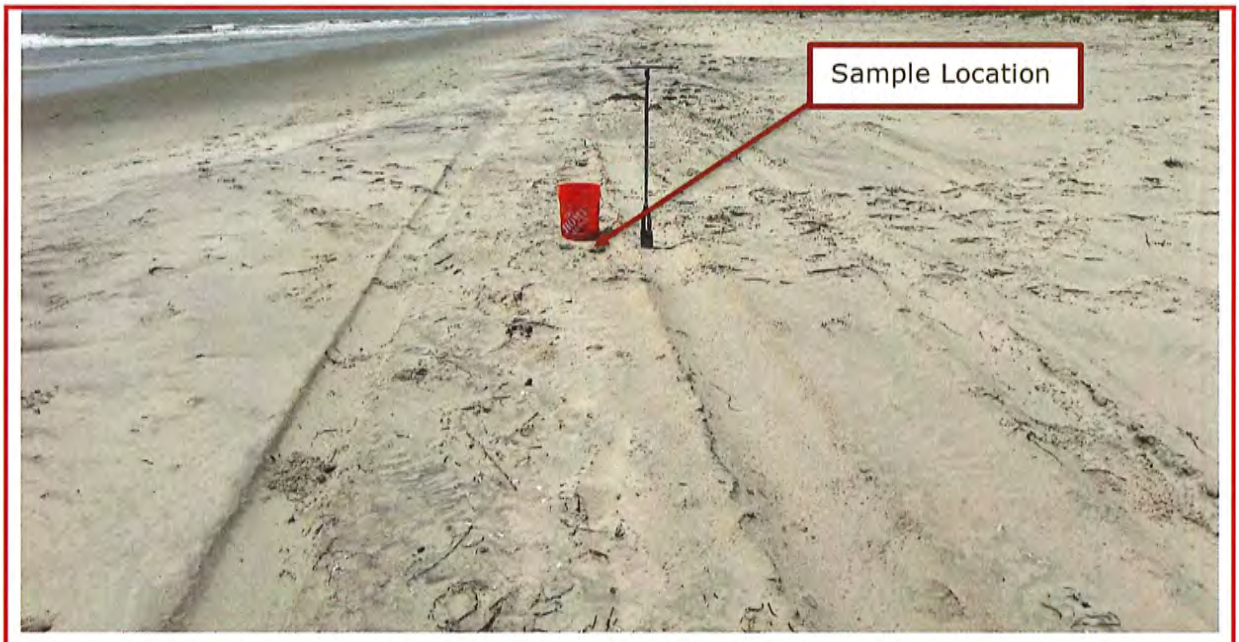
SW-1196-09 (N 3,847,374.063, E 12,358,272.411)
Sampled 09 July 2025, 12:21



DS-1196-10 (N 3,848,658.009, E 12,359,071.449)
Sampled 09 July 2025, 12:03



BS-1196-10 (N 3,848,579.477, E 12,359,173.155)
Sampled 09 July 2025, 12:04



SW-1196-10 (N 3,848,469.390, E 12,359,313.60)
Sampled 09 July 2025, 12:07

Site Location and Exploration Plans

Contents:

Site Location Plan
Exploration Plan (2 pages)

Note: All attachments are one page unless noted above.

Site Location



DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

Exploration Plans

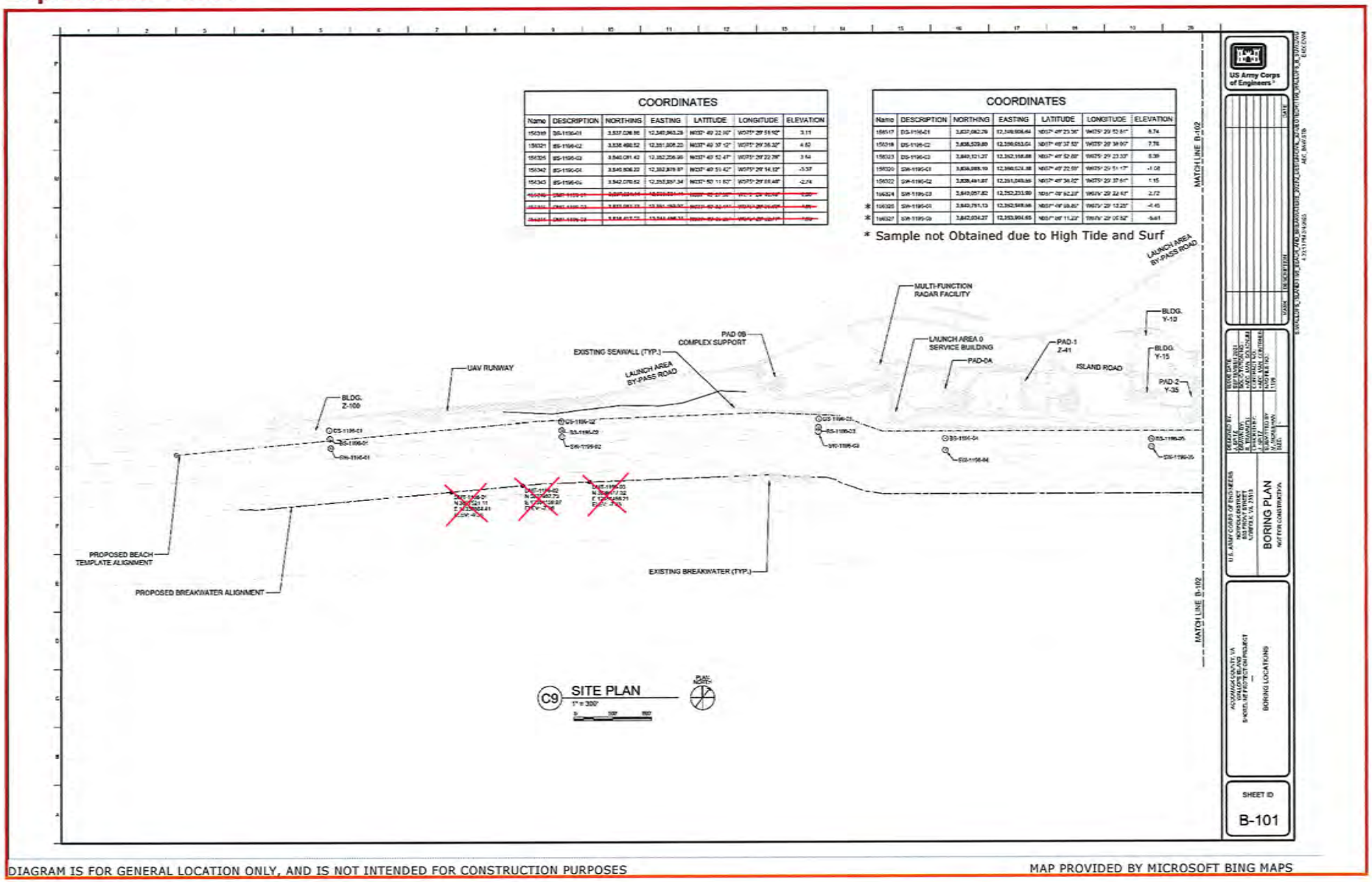


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

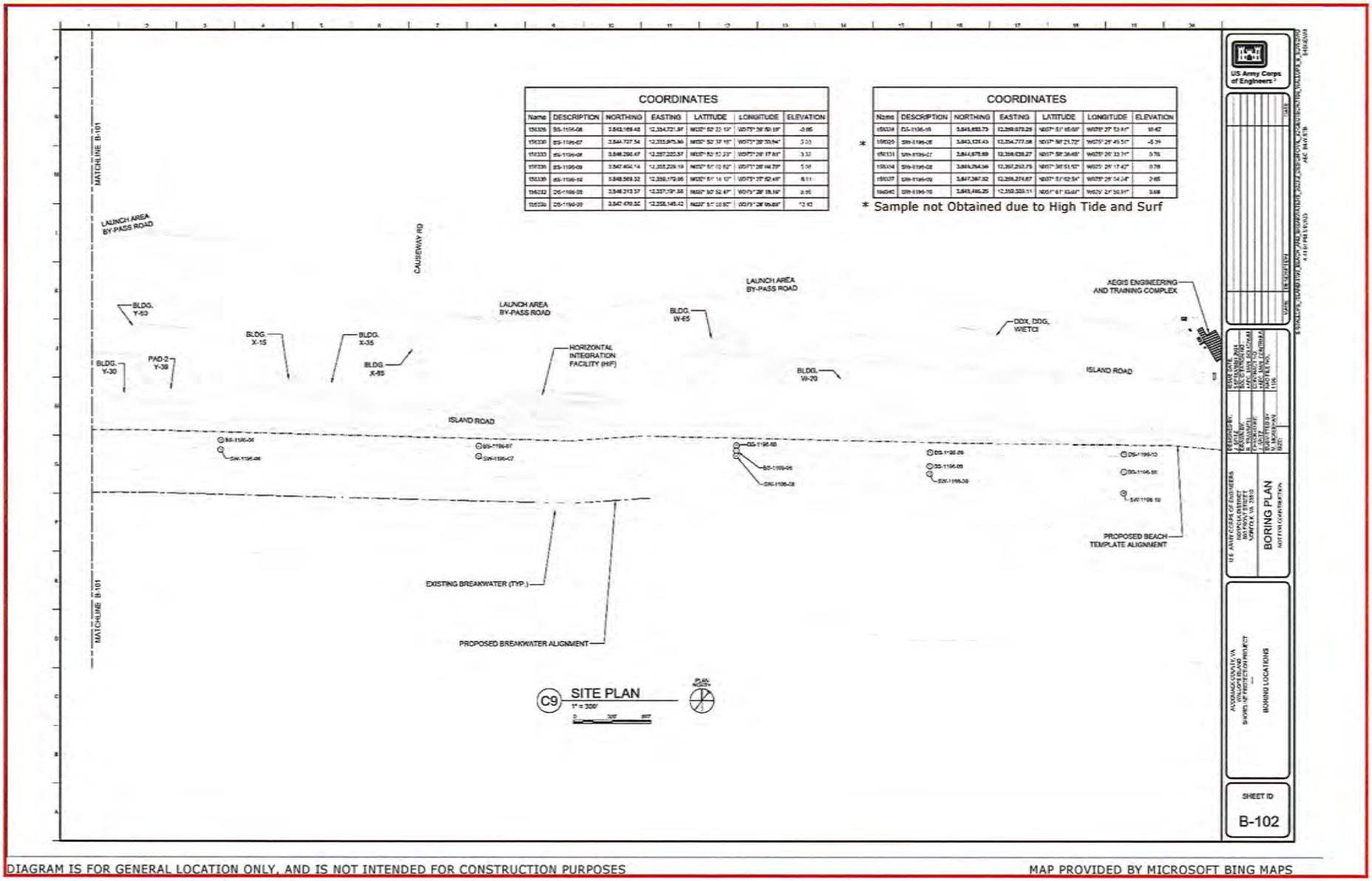


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

Beach Sample Laboratory Results

Contents:

Grain Size Distribution (10 pages)
Granularmetric Reports (10 pages)

Note: All attachments are one page unless noted above.

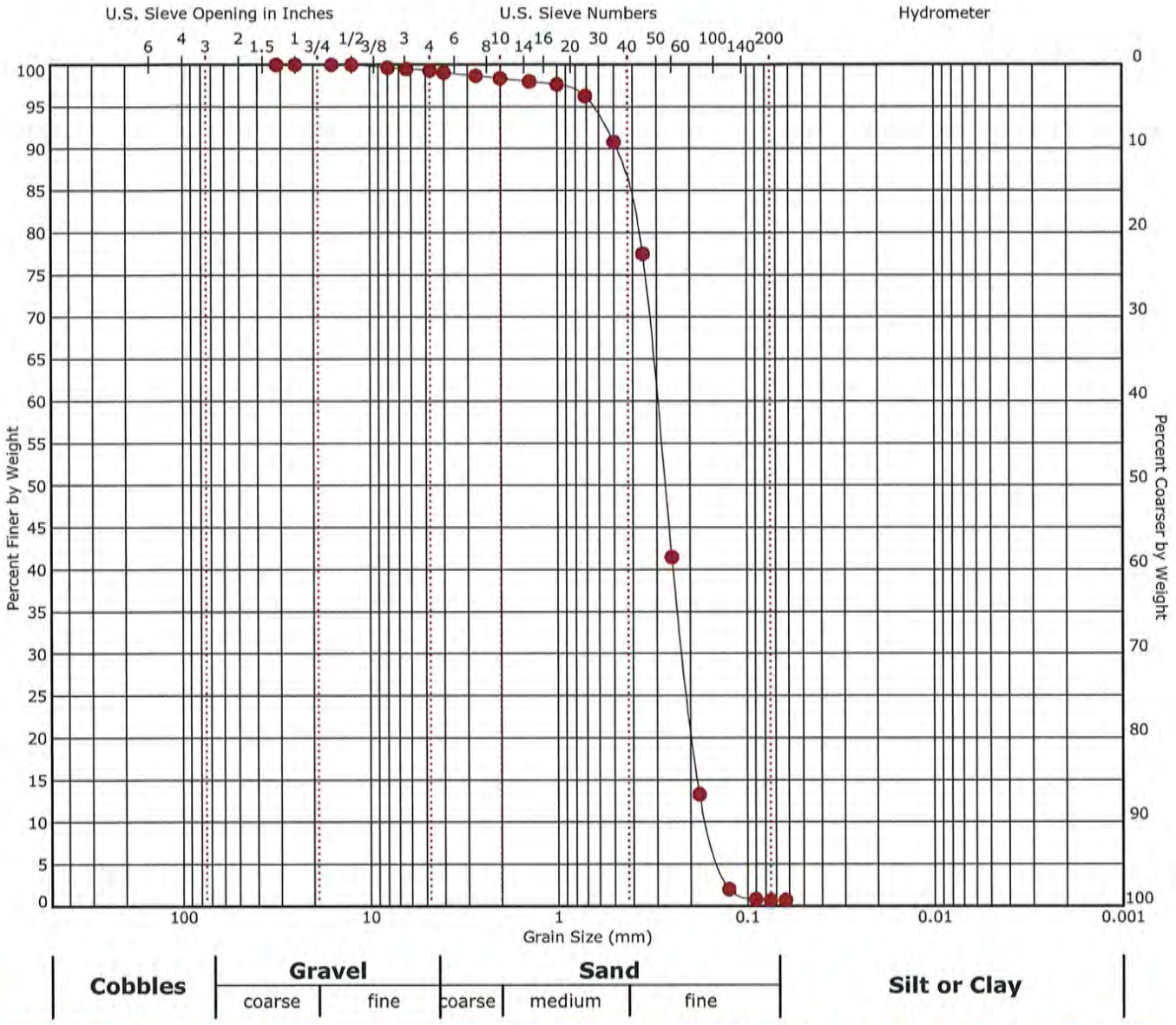
Grain Size Distribution

NASA WFF Geotechnical Exploration
Wallops Flight Facility | Wallops Island, VA
Terracon Project No. K3255022

Terracon
5465 Greenwich Rd
Virginia Beach, VA

Grain Size Distribution

ASTM D6913



Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
CMP-1196-01	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				0.99	1.85

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
CMP-1196-01	0 - 1	31.5	0.299	0.219	0.162	0.0	0.7	98.6	0.7

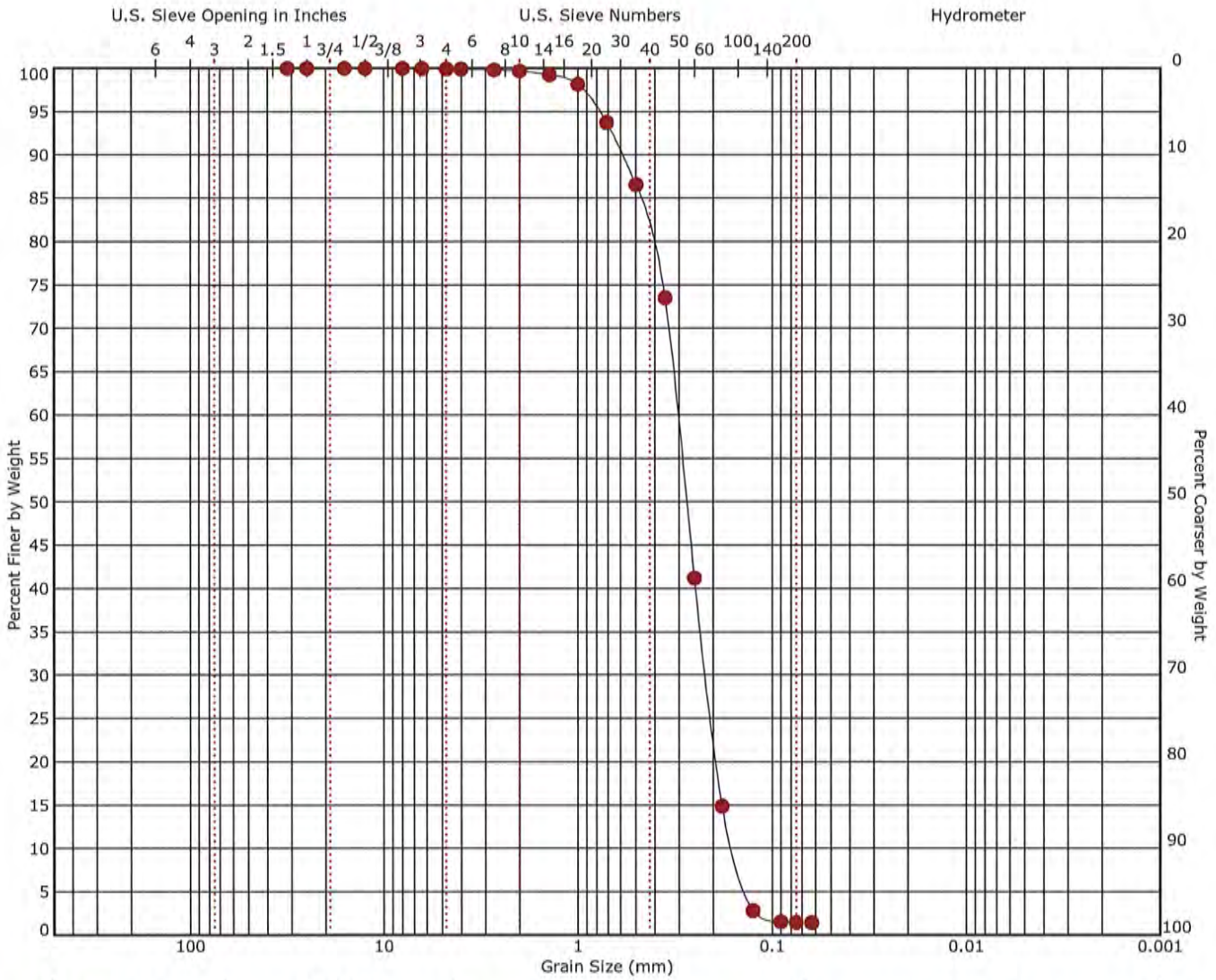
Laboratory tests are not valid if separated from original report.

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Terracon Project No. K3255022

Terracon
5465 Greenwich Rd
Virginia Beach, VA

Grain Size Distribution

ASTM D6913



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
CMP-1196-02	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				0.99	1.97

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
CMP-1196-02	0 - 1	31.5	0.306	0.217	0.155	0.0	0.1	98.4	1.5

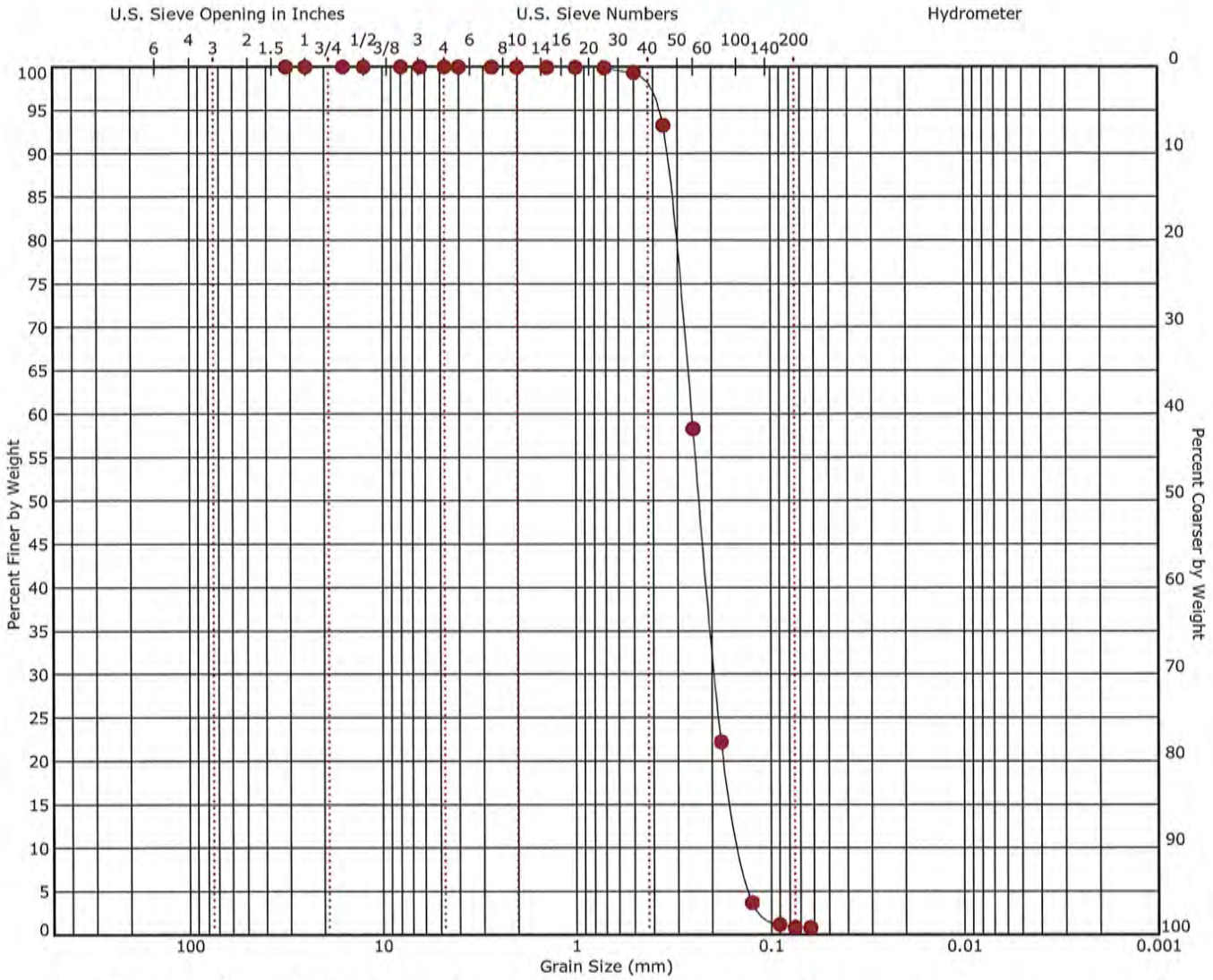
Laboratory tests are not valid if separated from original report.

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Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
CMP-1196-03	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				1.04	1.80

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
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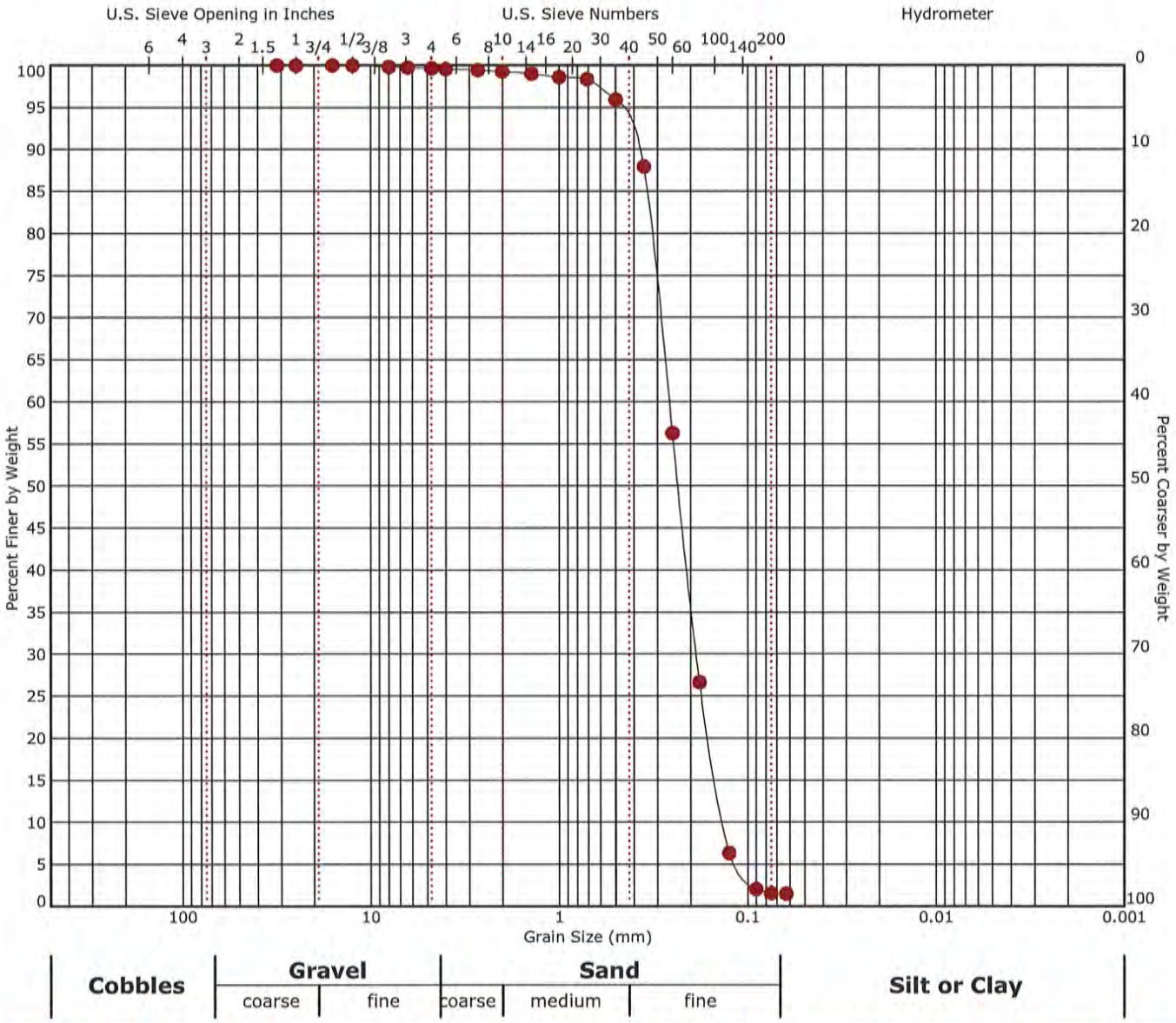
Laboratory tests are not valid if separated from original report.

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Virginia Beach, VA

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Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
BS-1196-04	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				1.00	1.95

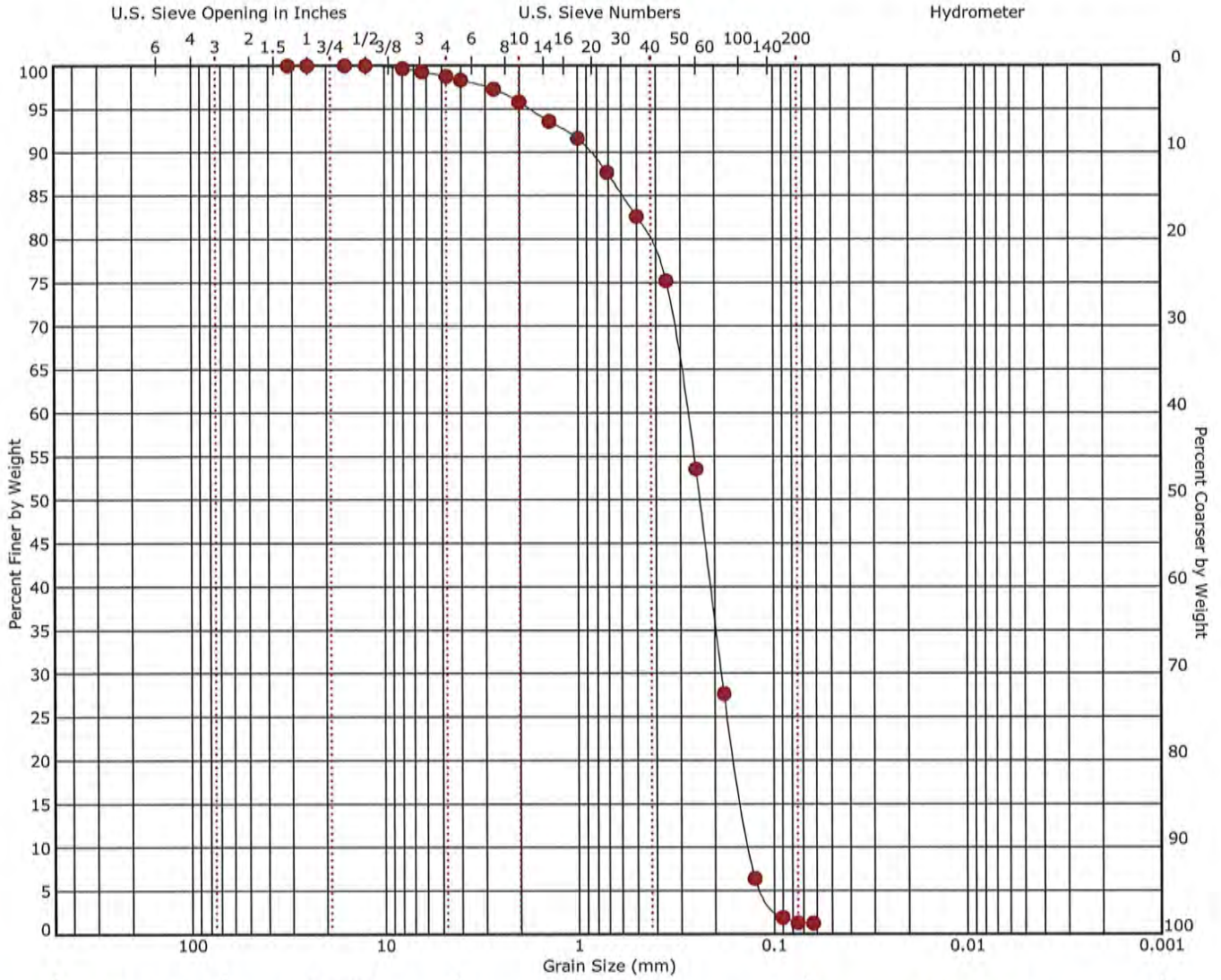
Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
BS-1196-04	0 - 1	31.5	0.26	0.187	0.133	0.0	0.4	98.0	1.6

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Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
BS-1196-05	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				0.93	2.09

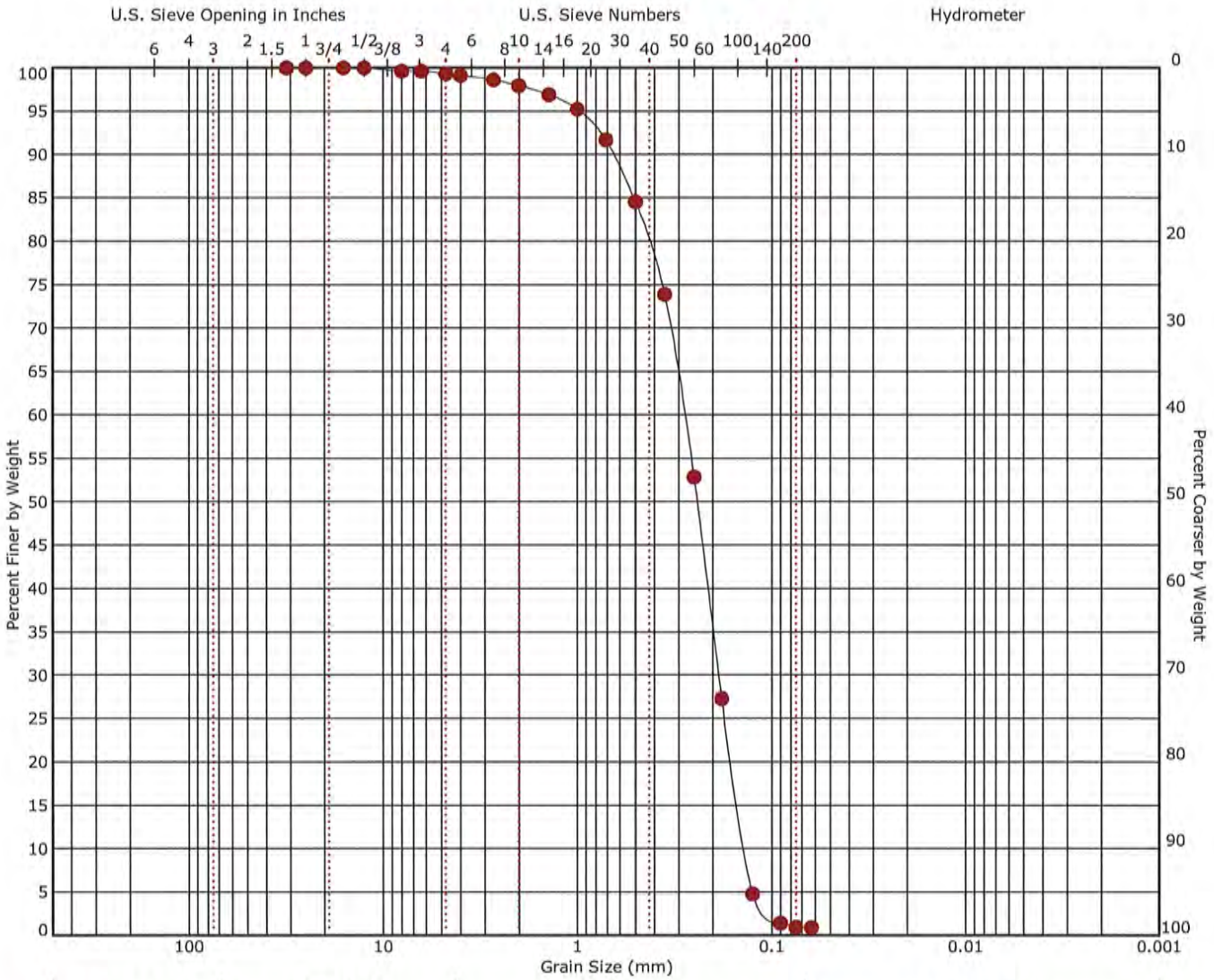
Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
BS-1196-05	0 - 1	31.5	0.277	0.185	0.133	0.0	1.3	97.4	1.3

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Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
BS-1196-06	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				0.91	2.07

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
BS-1196-06	0 - 1	31.5	0.282	0.186	0.136	0.0	0.7	98.3	1.0

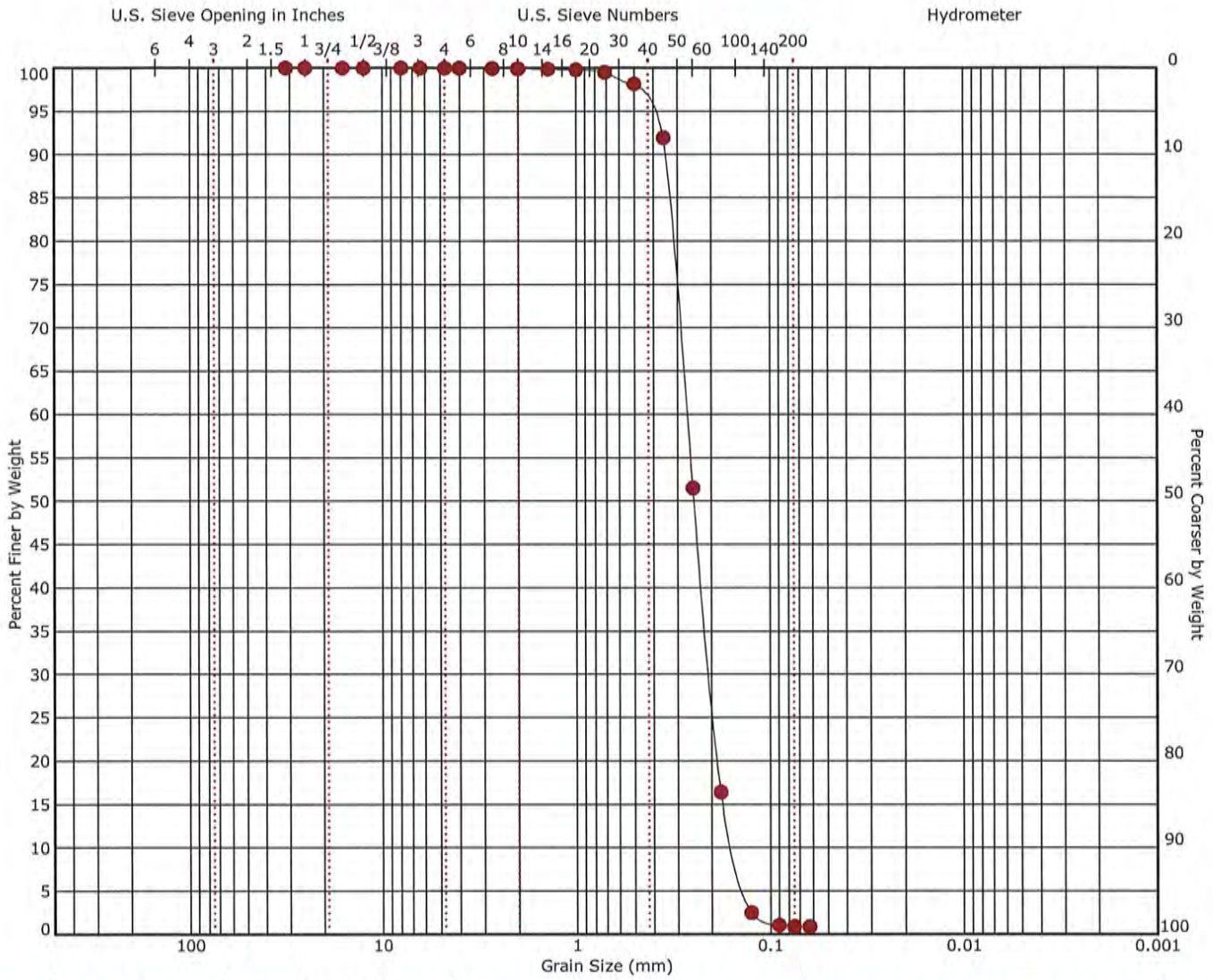
Laboratory tests are not valid if separated from original report.

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Grain Size Distribution

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Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
CMP-1196-07	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				1.02	1.77

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
CMP-1196-07	0 - 1	31.5	0.269	0.204	0.152	0.0	0.0	99.1	0.9

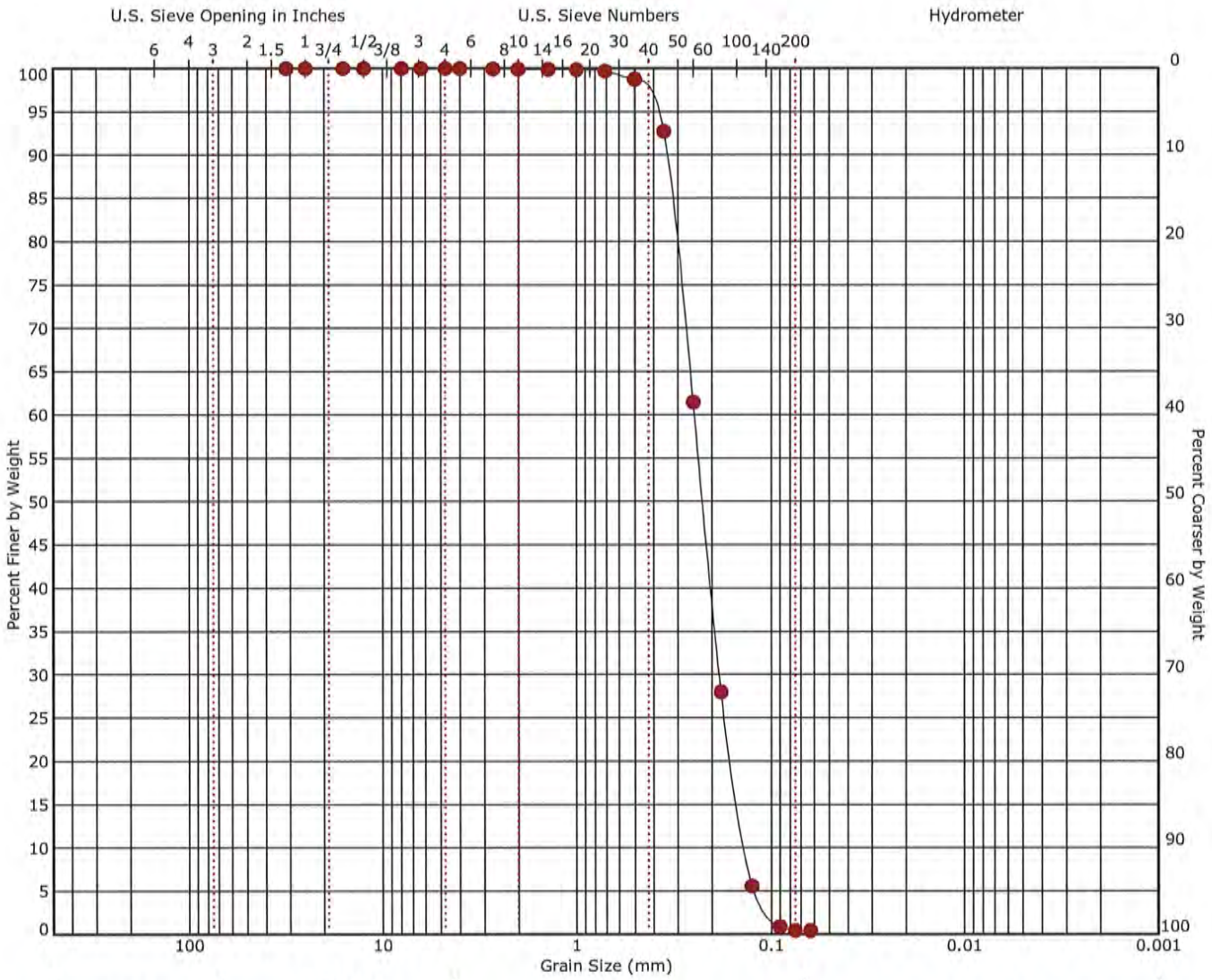
Laboratory tests are not valid if separated from original report.

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Terracon
5465 Greenwich Rd
Virginia Beach, VA

Grain Size Distribution

ASTM D6913



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
CMP-1196-08	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				1.02	1.83

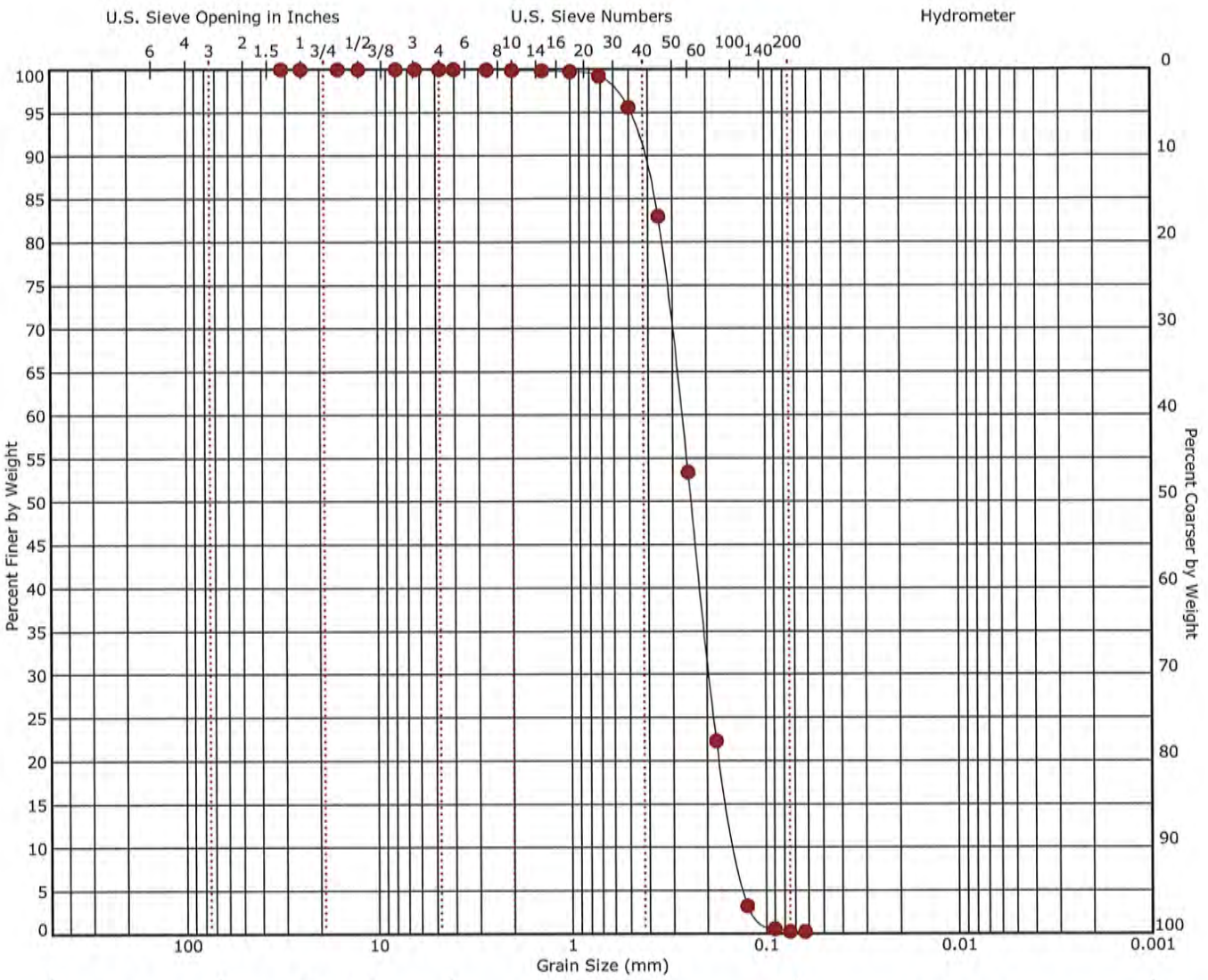
Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
CMP-1196-08	0 - 1	31.5	0.246	0.184	0.134	0.0	0.0	99.5	0.5

Laboratory tests are not valid if separated from original report.

Terracon
5465 Greenwich Rd
Virginia Beach, VA

Grain Size Distribution

ASTM D6913



Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
CMP-1196-09	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				0.99	1.90

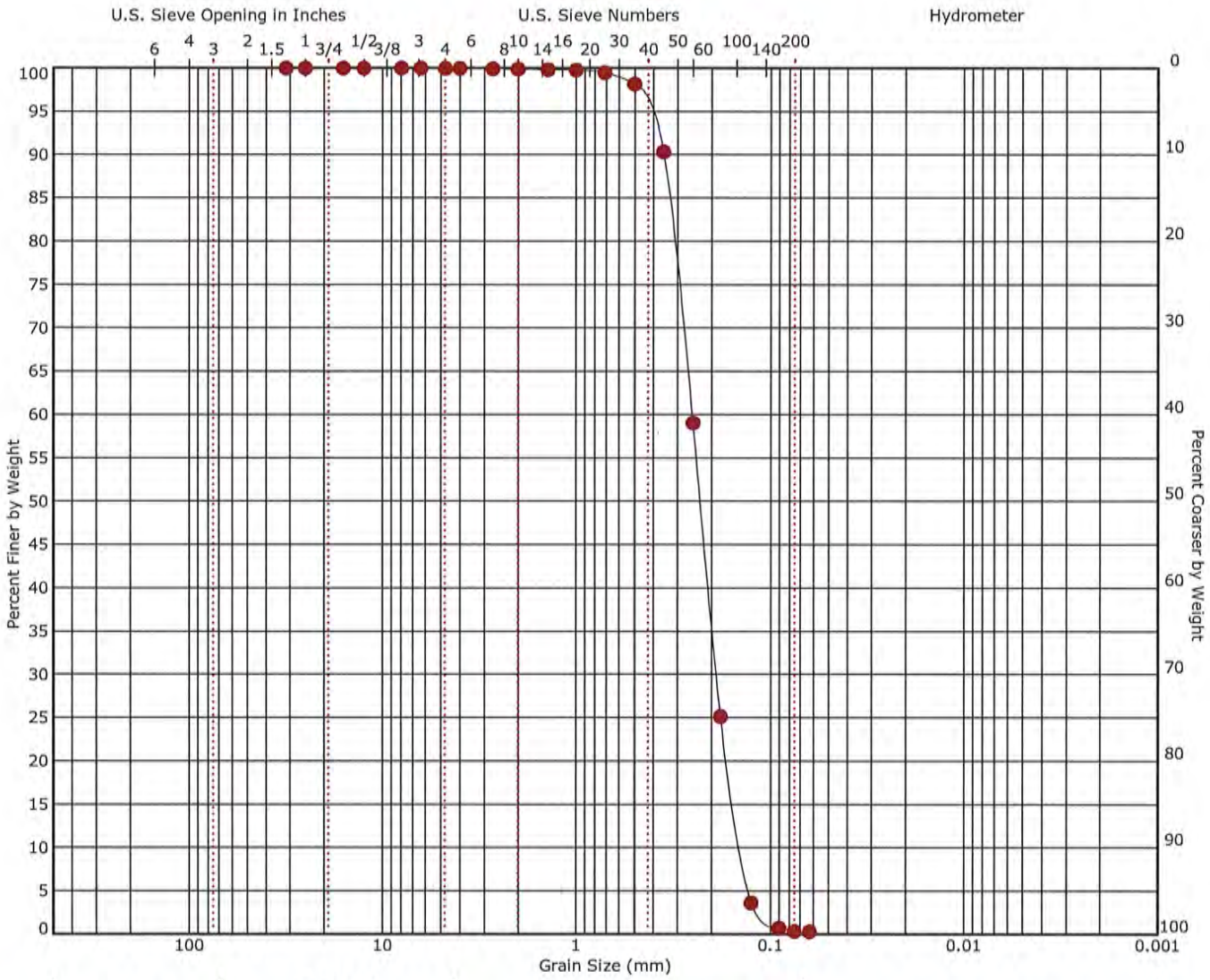
Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
CMP-1196-09	0 - 1	31.5	0.27	0.195	0.142	0.0	0.0	99.7	0.3

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Virginia Beach, VA

Grain Size Distribution

ASTM D6913



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	Description	USCS	Test Method	LL	PL	PI	Cc	Cu
MP-1196-010	0 - 1	POORLY GRADED SAND(SP)	SP	Method B				1.01	1.81

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines
MP-1196-010	0 - 1	31.5	0.253	0.189	0.139	0.0	0.0	99.6	0.4

Granularmetric Report

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	CMP-1196-01
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

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Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
DS-1196-01 - 3,837,062.674 BS-1196-01 - 3,837,026.99 SW-1196-01 -3,836,987.428	DS-1196-01 - 12,349,909.553 BS-1196-01 - 12,349,966.438 SW-1196-01 - 12,350,026.414	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 5 2 Dry Before Wash: 10 YR 6 2 Dry After Wash: 10YR 7 2	Natural Moisture Content: 8.8%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
812.52	809.6	0.15	0.37	No. 200 = 0.7% No. 230 = 0.7%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	3.02	0.4	3.02	0.4
1/4-inch	-2.7	6.35	1.32	0.2	4.34	0.5
4	-2.2	4.75	1.37	0.2	5.71	0.7
5	-2.0	4	1.91	0.2	7.62	0.9
7	-1.4	2.7	3.18	0.4	10.8	1.3
10	-1.0	2	2.46	0.3	13.26	1.6
14	-0.5	1.4	3.03	0.4	16.29	2.0
18	0.0	1	2.86	0.4	19.15	2.4
25	0.5	0.71	11.05	1.4	30.2	3.7
35	1.0	0.5	44.35	5.5	74.55	9.2
45	1.5	0.355	108.05	13.3	182.6	22.5
60	2.0	0.25	292.73	36.0	475.33	58.5
80	2.5	0.18	229.01	28.2	704.34	86.7
120	3.0	0.125	91.61	11.3	795.95	98.0
170	3.5	0.09	9.74	1.2	805.69	99.2
200	3.7	0.075	0.74	0.1	806.43	99.3
230	4.0	0.0625	0.04	0.0	806.47	99.3

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.74	2.64	2.47	1.89	1.79	1.60	1.32

Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	2.04	0.24	0.27	-0.50	-0.32	0.84

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	CMP-1196-02
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

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Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
DS-1196-02 - 3,838,528.634 BS-1196-02 - 3,838,490.673 SW-1196-02 -3,838,458.521	DS-1196-02 - 12,350,955.284 BS-1196-02 - 12,351,010.934 SW-1196-02 - 12,351,053.265	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 5 2 Dry Before Wash: 10 YR 6 2 Dry After Wash: 10YR 7 2	Natural Moisture Content: 11.7%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
819.56	816.35	0.06	1.07	No. 200 = 1.5% No. 230 = 1.5%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	0	0.0	0	0.0
1/4-inch	-2.7	6.35	0	0.0	0	0.0
4	-2.2	4.75	0.64	0.1	0.64	0.1
5	-2.0	4	0.08	0.0	0.72	0.1
7	-1.4	2.7	0.88	0.1	1.6	0.2
10	-1.0	2	0.99	0.1	2.59	0.3
14	-0.5	1.4	3.55	0.4	6.14	0.7
18	0.0	1	8.97	1.1	15.11	1.8
25	0.5	0.71	36	4.4	51.11	6.2
35	1.0	0.5	58.79	7.2	109.9	13.4
45	1.5	0.355	106.97	13.1	216.87	26.5
60	2.0	0.25	264.64	32.3	481.51	58.8
80	2.5	0.18	215.89	26.3	697.4	85.1
120	3.0	0.125	98.88	12.1	796.28	97.2
170	3.5	0.09	10.43	1.3	806.71	98.4
200	3.7	0.075	0.76	0.1	807.47	98.5
230	4.0	0.0625	0.09	0.0	807.56	98.5

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.18	2.40	2.32	1.79	1.40	1.15	0.32

Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	1.78	0.29	0.29	-0.79	0.02	1.27

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	CMP-1196-03
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

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Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
DS-1196-03 - 3,840,120.459 BS-1196-03 - 3,840,080.680 SW-1196-03 -3,840,055.788	DS-1196-03 - 12,352,161.610 BS-1196-03 - 12,352,207.711 SW-1196-03 - 12,352,236.318	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 5 2 Dry Before Wash: 10 YR 6 1 Dry After Wash: 10YR 7 2	Natural Moisture Content: 11.8%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
798.58	794.14	0.2	0.28	No. 200 = 0.9% No. 230 = 0.9%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	0	0.0	0	0.0
1/4-inch	-2.7	6.35	0	0.0	0	0.0
4	-2.2	4.75	0	0.0	0	0.0
5	-2.0	4	0	0.0	0	0.0
7	-1.4	2.7	0.25	0.0	0.25	0.0
10	-1.0	2	0.11	0.0	0.36	0.0
14	-0.5	1.4	0.05	0.0	0.41	0.1
18	0.0	1	0.15	0.0	0.56	0.1
25	0.5	0.71	0.3	0.0	0.86	0.1
35	1.0	0.5	4.36	0.5	5.22	0.7
45	1.5	0.355	48.31	6.0	53.53	6.7
60	2.0	0.25	279.36	35.0	332.89	41.7
80	2.5	0.18	288.13	36.1	621.02	77.8
120	3.0	0.125	147.83	18.5	768.85	96.3
170	3.5	0.09	20.17	2.5	789.02	98.8
200	3.7	0.075	2.54	0.3	791.56	99.1
230	4.0	0.0625	0.12	0.0	791.68	99.1

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.94	2.64	2.47	2.25	1.79	1.69	1.40
Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	2.20	0.22	0.21	-0.50	0.14	0.92

Granularmetric Report

Depths and elevations based on measured values

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Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	BS-1196-04
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
BS-1196-04 - 3,840,805.152	BS-1196-04 - 12,352,878.286	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 4 2 Dry Before Wash: 10 YR 6 2 Dry After Wash: 10YR 7 2	Natural Moisture Content: 20.3%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
753.82	746.76	0.12	0.59	No. 200 = 1.6% No. 230 = 1.5%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	1.38	0.2	1.38	0.2
1/4-inch	-2.7	6.35	0.58	0.1	1.96	0.3
4	-2.2	4.75	0.8	0.1	2.76	0.4
5	-2.0	4	0.59	0.1	3.35	0.4
7	-1.4	2.7	0.99	0.1	4.34	0.6
10	-1.0	2	1.24	0.2	5.58	0.7
14	-0.5	1.4	1.91	0.3	7.49	1.0
18	0.0	1	3.03	0.4	10.52	1.4
25	0.5	0.71	1.9	0.3	12.42	1.6
35	1.0	0.5	18.2	2.4	30.62	4.1
45	1.5	0.355	59.95	8.0	90.57	12.0
60	2.0	0.25	238.78	31.7	329.35	43.7
80	2.5	0.18	223.39	29.6	552.74	73.3
120	3.0	0.125	153.08	20.3	705.82	93.6
170	3.5	0.09	32.34	4.3	738.16	97.9
200	3.7	0.075	3.65	0.5	741.81	98.4
230	4.0	0.0625	0.42	0.1	742.23	98.5

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.18	2.64	2.47	2.25	1.74	1.51	1.12

Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	2.14	0.23	0.21	-0.63	0.20	1.15

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	BS-1196-05
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

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Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
BS-1196-05 - 3,842,068.327	BS-1196-05- 12,353,860.527	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 5YR 4 1 Dry Before Wash: 10 YR 7 1 Dry After Wash: 10YR 7 2	Natural Moisture Content: 18.9%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
782.58	777.07	0.15	0.56	No. 200 = 1.3% No. 230 = 1.3%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	2.72	0.3	2.72	0.3
1/4-inch	-2.7	6.35	2.87	0.4	5.59	0.7
4	-2.2	4.75	4.23	0.5	9.82	1.3
5	-2.0	4	3.12	0.4	12.94	1.7
7	-1.4	2.7	8.21	1.0	21.15	2.7
10	-1.0	2	11.43	1.5	32.58	4.2
14	-0.5	1.4	17.64	2.3	50.22	6.4
18	0.0	1	15.2	1.9	65.42	8.4
25	0.5	0.71	30.64	3.9	96.06	12.3
35	1.0	0.5	39.72	5.1	135.78	17.4
45	1.5	0.355	57.95	7.4	193.73	24.8
60	2.0	0.25	169.53	21.7	363.26	46.4
80	2.5	0.18	202.53	25.9	565.79	72.3
120	3.0	0.125	166.44	21.3	732.23	93.6
170	3.5	0.09	35.19	4.5	767.42	98.1
200	3.7	0.075	4.67	0.6	772.09	98.7
230	4.0	0.0625	0.44	0.1	772.53	98.7

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.18	2.64	2.47	2.12	1.51	0.52	-0.93
Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	1.76	0.29	0.23	-1.21	0.49	1.76

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	BS-1196-06
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

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Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
BS-1196-06 - 3,843,174.424	BS-1196-06 - 12,354,723.677	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 5YR 4 1 Dry Before Wash: 10 YR 7 1 Dry After Wash: 10YR 7 2	Natural Moisture Content: 18.6%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
741.04	736.62	0.07	0.33	No. 200 = 1.0% No. 230 = 0.9%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	2.86	0.4	2.86	0.4
1/4-inch	-2.7	6.35	0	0.0	2.86	0.4
4	-2.2	4.75	2.2	0.3	5.06	0.7
5	-2.0	4	1.47	0.2	6.53	0.9
7	-1.4	2.7	3.82	0.5	10.35	1.4
10	-1.0	2	4.88	0.7	15.23	2.1
14	-0.5	1.4	7.73	1.0	22.96	3.1
18	0.0	1	12.33	1.7	35.29	4.8
25	0.5	0.71	26.15	3.5	61.44	8.3
35	1.0	0.5	52.9	7.1	114.34	15.4
45	1.5	0.355	78.95	10.7	193.29	26.1
60	2.0	0.25	155.88	21.0	349.17	47.1
80	2.5	0.18	189.45	25.6	538.62	72.7
120	3.0	0.125	166.83	22.5	705.45	95.2
170	3.5	0.09	25	3.4	730.45	98.6
200	3.7	0.075	3.33	0.4	733.78	99.0
230	4.0	0.0625	0.37	0.0	734.15	99.1

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.18	2.74	2.56	2.12	1.47	1.03	0.00

Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	1.96	0.26	0.23	-0.96	0.30	1.21

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	CMP-1196-07
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

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Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
BS-1196-07 - 3,844,731.801 SW-1196-07 -3,844,684.437	BS-1196-07 - 12,355,975.188 SW-1196-07 - 12,356,037.026	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 5 2 Dry Before Wash: 10 YR 7 1 Dry After Wash: 10YR 7 2	Natural Moisture Content: 12.1%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
810.26	806.74	0.06	0.49	No. 200 = 0.9% No. 230 = 0.9%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	0	0.0	0	0.0
1/4-inch	-2.7	6.35	0	0.0	0	0.0
4	-2.2	4.75	0	0.0	0	0.0
5	-2.0	4	0	0.0	0	0.0
7	-1.4	2.7	0.43	0.1	0.43	0.1
10	-1.0	2	0.31	0.0	0.74	0.1
14	-0.5	1.4	0.25	0.0	0.99	0.1
18	0.0	1	0.64	0.1	1.63	0.2
25	0.5	0.71	2.43	0.3	4.06	0.5
35	1.0	0.5	10.91	1.3	14.97	1.8
45	1.5	0.355	50.18	6.2	65.15	8.0
60	2.0	0.25	327.49	40.4	392.64	48.5
80	2.5	0.18	284.44	35.1	677.08	83.6
120	3.0	0.125	112.83	13.9	789.91	97.5
170	3.5	0.09	11.6	1.4	801.51	98.9
200	3.7	0.075	1.14	0.1	802.65	99.1
230	4.0	0.0625	0.08	0.0	802.73	99.1

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
2.94	2.47	2.32	1.94	1.74	1.69	1.36

Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	2.04	0.24	0.26	-0.46	-0.31	1.11

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	CMP-1196-08
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

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Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
DS-1196-08 - 3,846,321.237 BS-1196-08 - 3,846,299.413 SW-1196-08 -3,846,273.380	DS-1196-08 - 12,357,190.020 BS-1196-08 - 12,357,220.665 SW-1196-08 - 12,357,254.354	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 6 2 Dry Before Wash: 10 YR 6 1 Dry After Wash: 10YR 7 2	Natural Moisture Content: 7.7%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
850.39	848.26	0.04	0.20	No. 200 = 0.5% No. 230 = 0.5%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	0	0.0	0	0.0
1/4-inch	-2.7	6.35	0	0.0	0	0.0
4	-2.2	4.75	0	0.0	0	0.0
5	-2.0	4	0	0.0	0	0.0
7	-1.4	2.7	0.51	0.1	0.51	0.1
10	-1.0	2	0.32	0.0	0.83	0.1
14	-0.5	1.4	0.11	0.0	0.94	0.1
18	0.0	1	0.27	0.0	1.21	0.1
25	0.5	0.71	1.46	0.2	2.67	0.3
35	1.0	0.5	7.97	0.9	10.64	1.3
45	1.5	0.355	50.99	6.0	61.63	7.2
60	2.0	0.25	265.75	31.3	327.38	38.5
80	2.5	0.18	284.7	33.5	612.08	72.0
120	3.0	0.125	190.8	22.4	802.88	94.4
170	3.5	0.09	39.77	4.7	842.65	99.1
200	3.7	0.075	3.74	0.4	846.39	99.5
230	4.0	0.0625	0.1	0.0	846.49	99.5

	Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
	3.18	2.64	2.47	2.25	1.79	1.71	1.36
Moment Statistics		Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
		2.20	0.22	0.21	-0.54	0.07	1.09

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	CMP-1196-09
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

Terracon
Explore with us
5465 Greenwich Road
Virginia Beach, Virginia 23462
Phone (757) 518-1703

Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
DS-1196-09 - 3,847,480.633 BS-1196-09 - 3,847,412.675 SW-1196-09 -3,847,374.063	DS-1196-09 - 12,358,142.292 BS-1196-09 - 12,358,225.237 SW-1196-09 - 12,358,272.411	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 6 2 Dry Before Wash: 10 YR 6 1 Dry After Wash: 10YR 7 2	Natural Moisture Content: 3.1%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
875.9	874.52	0.07	0.11	No. 200 = 0.3% No. 230 = 0.3%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	0	0.0	0	0.0
1/4-inch	-2.7	6.35	0	0.0	0	0.0
4	-2.2	4.75	0	0.0	0	0.0
5	-2.0	4	0	0.0	0	0.0
7	-1.4	2.7	0.45	0.1	0.45	0.1
10	-1.0	2	0.49	0.1	0.94	0.1
14	-0.5	1.4	0.48	0.1	1.42	0.2
18	0.0	1	0.95	0.1	2.37	0.3
25	0.5	0.71	4.52	0.5	6.89	0.8
35	1.0	0.5	31.74	3.6	38.63	4.4
45	1.5	0.355	110.22	12.6	148.85	17.0
60	2.0	0.25	259.21	29.6	408.06	46.6
80	2.5	0.18	272.24	31.1	680.3	77.7
120	3.0	0.125	167.22	19.1	847.52	96.8
170	3.5	0.09	23.14	2.6	870.66	99.4
200	3.7	0.075	2.66	0.3	873.32	99.7
230	4.0	0.0625	0.15	0.0	873.47	99.7

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.18	2.56	2.47	2.25	1.69	1.36	1.03

Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	2.06	0.24	0.21	-0.66	0.31	1.13

Granularmetric Report

Depths and elevations based on measured values

Project Name:	NASA Wallops Flight Facility (WFF) Geotechnical Exploration
Sample Name:	CMP-1196-10
Analysis Date:	23-Jul-2025
Analyzed By:	Terracon

Terracon
Explore with us
5465 Greenwich Road
Virginia Beach, Virginia 23462
Phone (757) 518-1703

Northing (ft)	Easting (ft)	Coordinate System:	Elevation (ft):
DS-1196-10 - 3,848,658.009 BS-1196-10 - 3,848,579.477 SW-1196-10 -3,837,062.674	DS-1196-10 - 12,359,071.449 BS-1196-10 - 12,359,173.155 SW-1196-10 - 12,349,909.553	Virginia South Zone	N/A

USCS	Munsell:	Comments:
SP	Wet: 2.5YR 6 2 Dry Before Wash: 10 YR 6 1 Dry After Wash: 10YR 7 2	Natural Moisture Content: 2.8%

Dry Weight (g):	Wash Weight (g):	Pan Retained (g):	Sieve Loss (%):	Fines (%):	Organics (%):	Carbonates (%):	Shells (%):
876.68	875.72	0.15	0.20	No. 200 = 0.4% No. 230 = 0.3%	N/A	N/A	N/A

Sieve Number	Sieve Size (Phi)	Sieve Size (Millimeters)	Grams Retained	% Weight Retained	Cumulative Grams Retained	Cumulative % Weight Retained
1-1/4 inch	-5.0	31.5	0	0.0	0	0.0
1-inch	-4.6	25	0	0.0	0	0.0
5/8-inch	-4.0	16	0	0.0	0	0.0
1/2-inch	-3.6	12.5	0	0.0	0	0.0
5/16-inch	-3.0	8	0	0.0	0	0.0
1/4-inch	-2.7	6.35	0	0.0	0	0.0
4	-2.2	4.75	0.36	0.0	0.36	0.0
5	-2.0	4	0	0.0	0.36	0.0
7	-1.4	2.7	0.34	0.0	0.7	0.1
10	-1.0	2	0.32	0.0	1.02	0.1
14	-0.5	1.4	0.54	0.1	1.56	0.2
18	0.0	1	0.45	0.1	2.01	0.2
25	0.5	0.71	2.58	0.3	4.59	0.5
35	1.0	0.5	11.54	1.3	16.13	1.8
45	1.5	0.355	68.42	7.8	84.55	9.6
60	2.0	0.25	274.22	31.3	358.77	40.9
80	2.5	0.18	297.25	33.9	656.02	74.8
120	3.0	0.125	188.75	21.5	844.77	96.4
170	3.5	0.09	25.51	2.9	870.28	99.3
200	3.7	0.075	3.19	0.4	873.47	99.6
230	4.0	0.0625	0.33	0.0	873.8	99.7

Phi 5	Phi 16	Phi 25	Phi 50	Phi 75	Phi 84	Phi 95
3.18	2.56	2.47	2.25	1.74	1.69	1.32

Moment Statistics	Mean Phi	Mean (mm)	D50	Sorting	Skewness	Kurtosis
	2.17	0.22	0.21	-0.53	0.15	1.04

Supporting Information

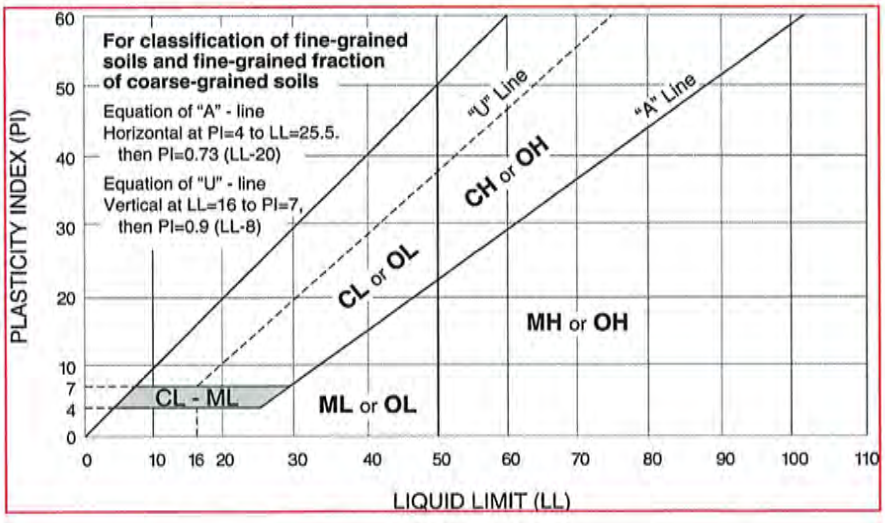
Contents:

Unified Soil Classification System

Unified Soil Classification System

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification	
				Group Symbol	Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu≥4 and 1≤Cc≤3 [E]	GW	Well-graded gravel [F]
			Cu<4 and/or [Cc<1 or Cc>3.0] [E]	GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu≥6 and 1≤Cc≤3 [E]	SW	Well-graded sand [I]
			Cu<6 and/or [Cc<1 or Cc>3.0] [E]	SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G, H, I]
			Fines classify as CL or CH	SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots above "A" line [J]	CL	Lean clay [K, L, M]
			PI < 4 or plots below "A" line [J]	ML	Silt [K, L, M]
		Organic:	$(LL\ oven\ dried)/(LL\ not\ dried) < 0.75$	OL	Organic clay [K, L, M, N] / Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K, L, M]
			PI plots below "A" line	MH	Elastic silt [K, L, M]
		Organic:	<	OH	Organic clay [K, L, M, P] / Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.
[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.
[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
[F] If soil contains ≥ 15% sand, add "with sand" to group name.
[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H] If fines are organic, add "with organic fines" to group name.
[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.
[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 4 and plots on or above "A" line.
[O] PI < 4 or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.



Shoreline Protection Program

Joint Permit Application

Pre-Application Meeting

NASA Wallops Flight Facility

April 28, 2025

Introductions

NASA

Corps of Engineers

BOEM

USFWS

NOAA Fisheries

EPA

VDCR

VDEQ

VMRC

VIMS

Accomack County

Stantec

Meeting Agenda

- Introduction to Wallops Flight Facility
- Setting
- Background
- Program History
- Existing Conditions/Current Scenario
- Current Project
- Agency Coordination
- Permitting
- Project Schedule

Risk Posed by Shoreline Deterioration

- Rocket launches could be affected by shoreline deterioration, including International Space Station resupply; numerous Department of Defense (DOD), commercial, and academic sounding rocket campaigns; and multiple DOD research and test missions.
- Missions are impacted by loss of support infrastructure and/or loss of employee time.
    - Employees are not allowed on the island during or immediately after severe storm events, in infrastructure has been compromised.
    - Employee time is diverted from mission support to clean up and restoration of island and infrastructure.
- The beach berm and dune system that protects launch range infrastructure has been subject to erosion through storm wind and wave damage.
- The original beach system, designed and constructed in 2009 – 2012 and re-established in 2014 and again in 2021, served its intended purpose of reducing physical damage to the range assets.
- A sizable portion of surface sand is constantly eroded by storms, wind, and waves.
- Physical real estate would continue to be lost without renourishment events.



History of WFF Shoreline Stabilization Actions

NACA (1945 - 1959 and NASA (1959 -present) attempted to stabilize the Wallops Island shoreline using a variety of methods



1946 – Metal bulkhead (buried)



1969 – Wooden groins



1958 – Metal bulkhead



1992 – Seawall and relict bulkhead and groins.



2008 – Geotubes



1962 – Metal bulkhead



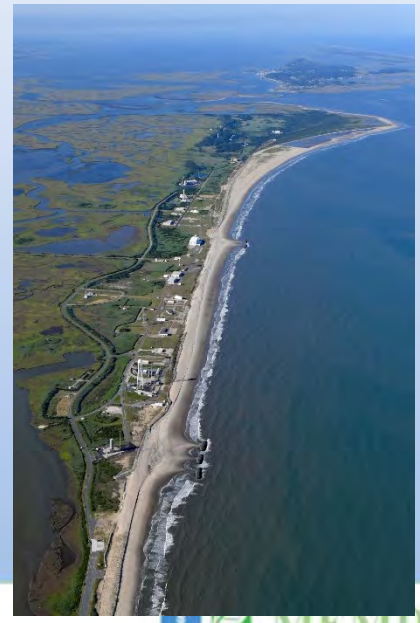
2003 – Christmas trees to promote sand accretion.



2012 – Beach nourishment
(note pilings from historical groins)



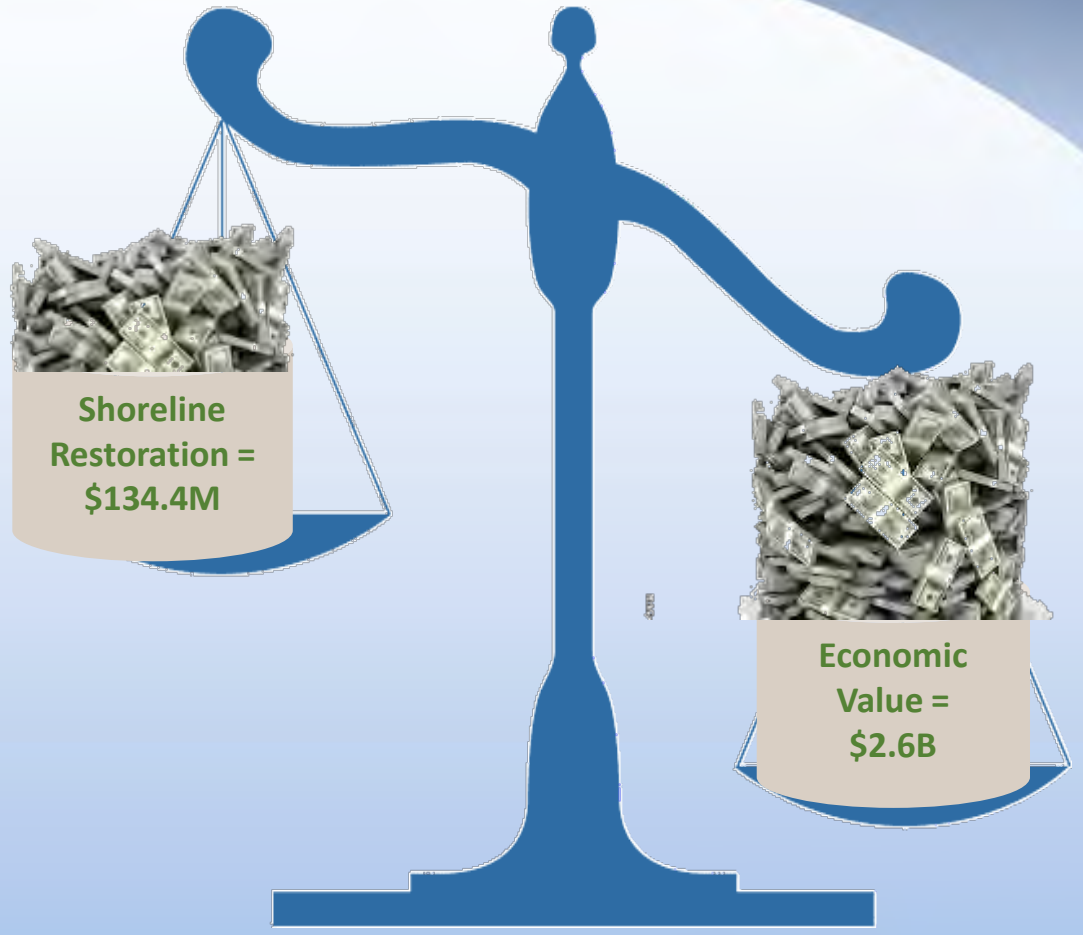
2014 – Post-Sandy renourishment



2021 – Breakwaters & renourishment

Financial Benefit of WFF Shoreline Stabilization

- Total Replacement Cost Value of assets on Wallops Island is $1.3B
- Total annual economic impact of Wallops Island* is estimated at $1.37B
  - Direct impacts are estimated at $820M
    - $46.5M in NASA programs
    - $50 Million in Navy programs
    - $1.9B CRS (Commercial Resupply Services for the ISS) program.
  - Indirect impacts are estimated at $284M
  - Induced impacts are estimated at $265M
- Shoreline Restoration costs
  - 2010 – 2023
  - TOTAL $134.4M



*The installations and organizations currently associated with the Wallops Island Aerospace Cluster are NASA WFF, the U.S. NAVY SCSC, NOAA, the U.S. Coast Guard, Virginia Space, Northrop Grumman Innovation Systems, and Rocket Lab USA

Setting

- Wallops Island is part of a dynamic barrier island system including Assateague island to the north and Assawoman Island to the south
- Since the 1850s, parts of Wallops Island have been subject to continual erosion, while others have experienced significant growth



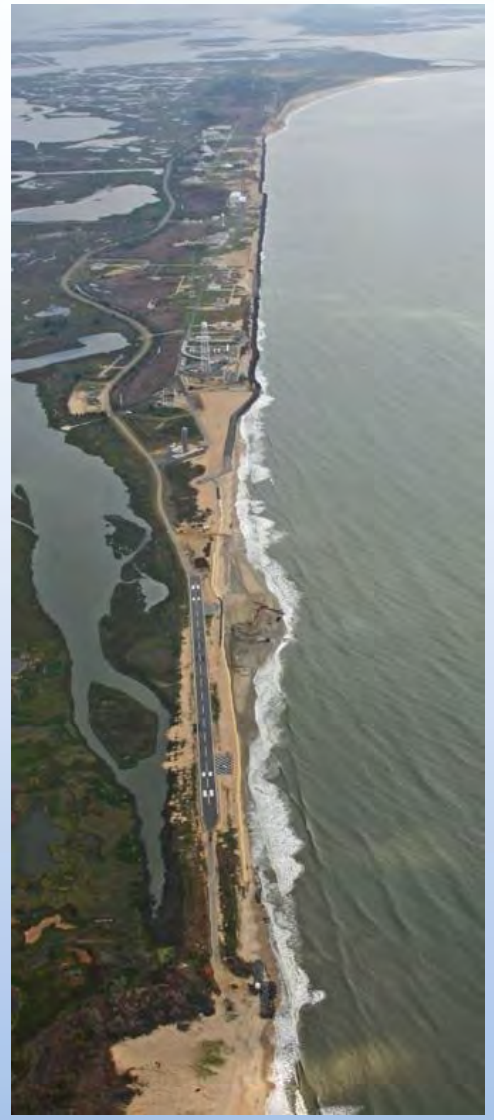
Source: TNC Coastal Resilience tool (http://maps.coastalresilience.org/virginia/#)

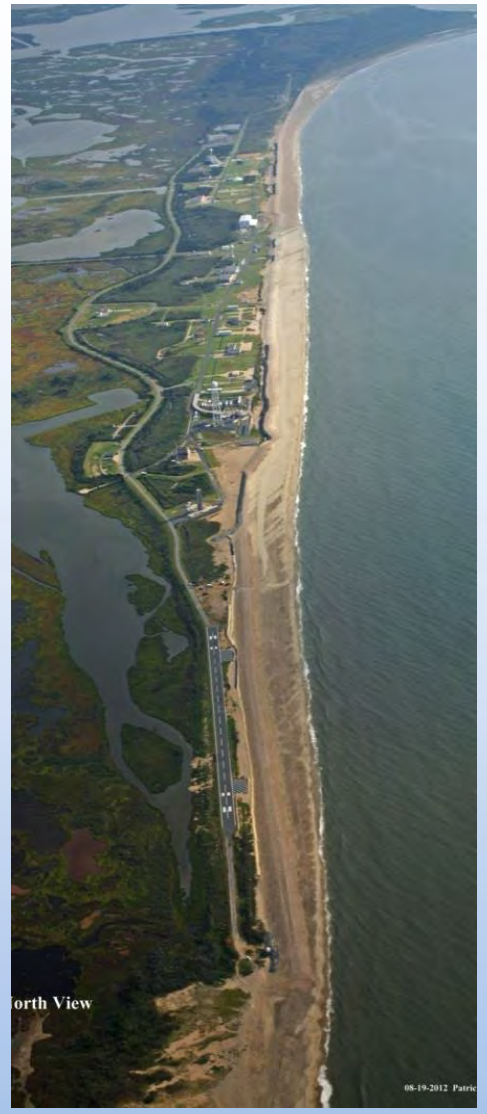
Wallops Island Sand Movement

- Extreme north Wallops Island gaining sediment
- Nodal point is located approximately in the center of island where sediment transport diverges in two directions
- High value south end launch areas drastically losing sediment



2012 Wallops Shoreline Protection Project

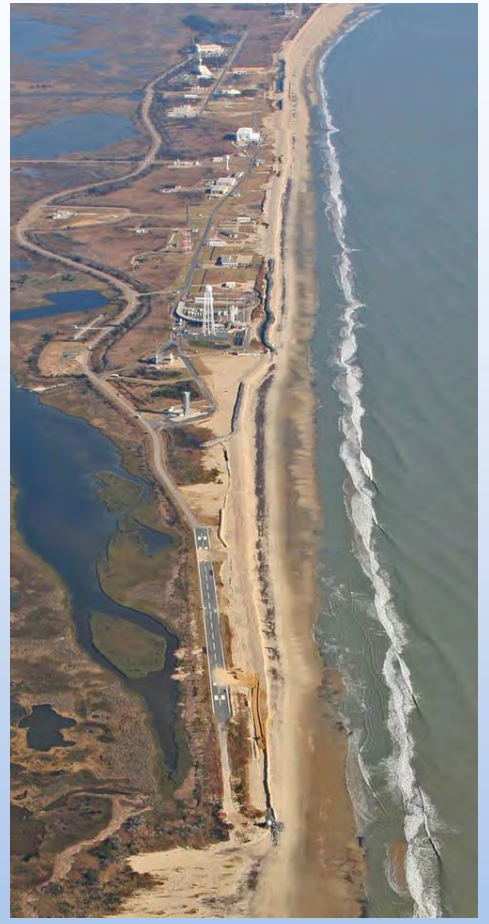




- 1,700 ft seawall extension
- 3.2 million cubic yards of sand
- $40 million investment protecting $1.2 billion in assets

MEMD
Medical and Environmental Management Division

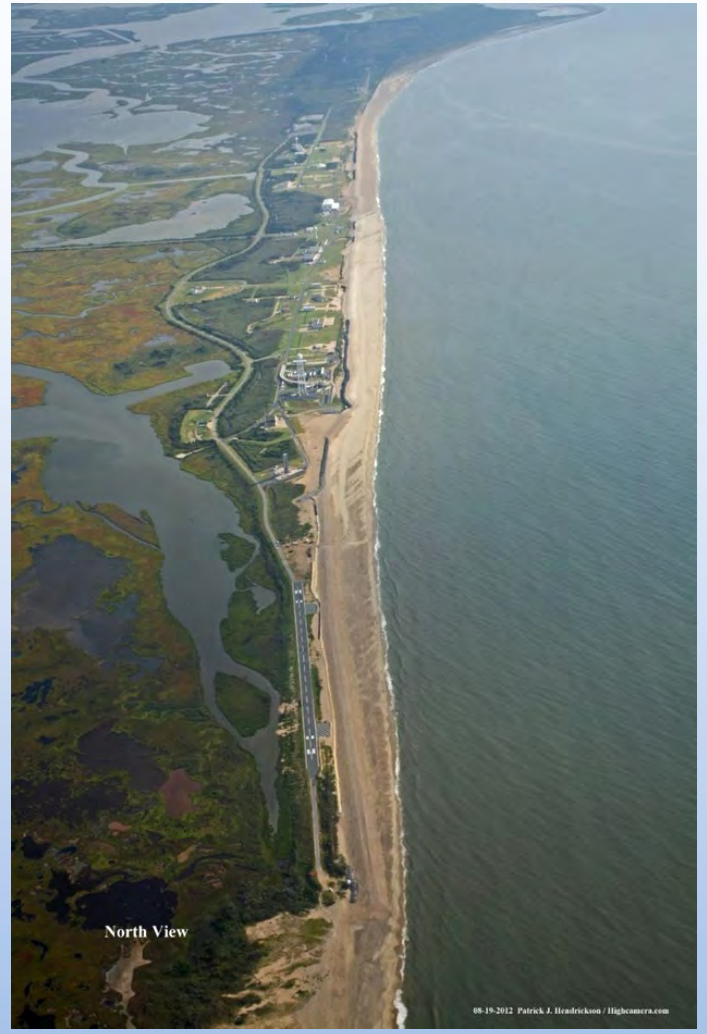
2014 Post-Hurricane Sandy Replenishment



- About 20 percent of the beach lost
- $11.34 million for an out-of-cycle replenishment
- 650,000 cubic yards of sand



Post-2012 Beach Replenishment vs Pre-2020 Beach Replenishment





Post 2020/2021 Beach Replenishment vs October 2023





Current Shoreline Protection Program

NASA Proposes over the next 5 years:

- to utilize 3 million cubic yards of sand from Unnamed Shoal A To renourish 15,000 feet of beach;
- to build up to twelve offshore breakwaters;
- to extend the seawall by 3,170 feet.

Current Shoreline Protection Program



Agency Coordination

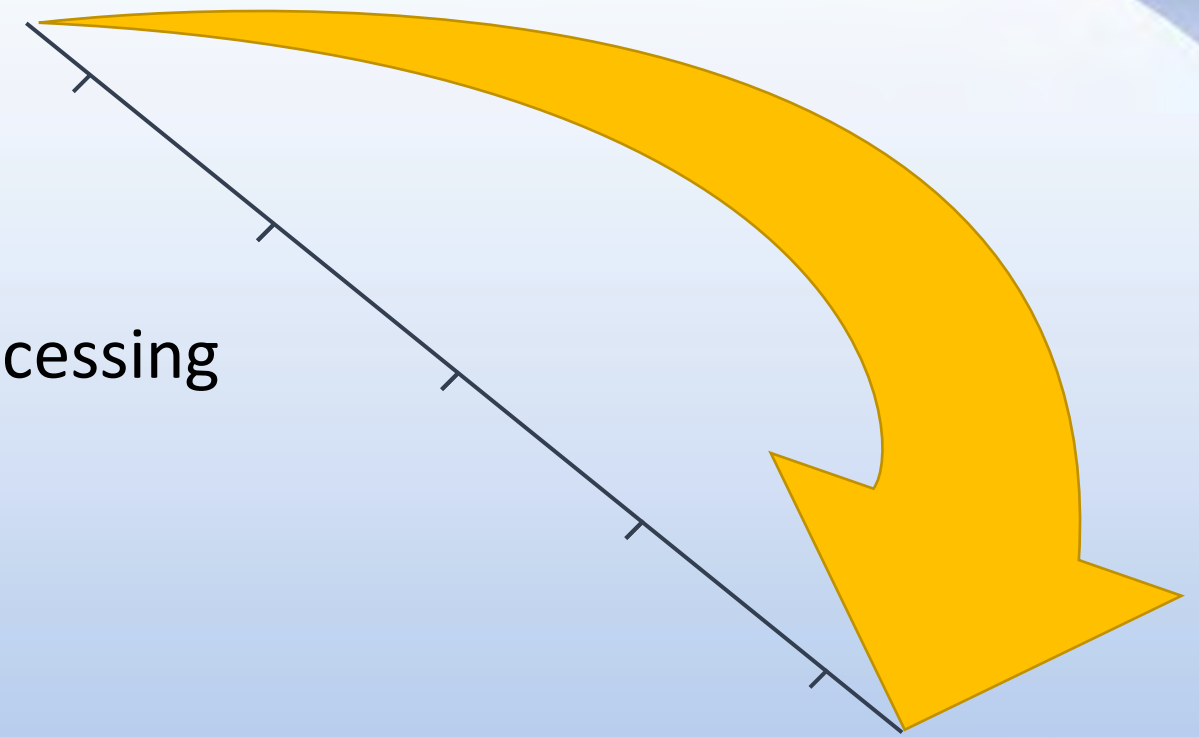
- SHPO - Letter of Concurrence for “no effect on historic resources” coordination in process
- NMFS - Currently preparing EFH Assessment
- NMFS - Currently preparing Biological Evaluation
- USFWS – Currently preparing Biological Evaluation

Permitting

- VMRC
  - Primary Dune/Barrier Island Policy
  - Permit
- USACE- RP 19 (Previously Used to Permit Shoreline Enhancement)
- VDEQ – Waiver with RP 19

Schedule

- 04/28/25 – Pre-Application Meeting
- 06/25 – JPA Submittal (65% Design)
- Summer 25 – VMRC PN/Hearing
- Summer/Fall/Winter 25 – USACE Processing
- 08/07/26 – All Permits Secured
- 08/21/26 – Project Bid Date
- 02/22/27 – Construction Award
- Summer 27 – Construction Commences



Enjoy your visit!







MEMD
Medical and Environmental Management Division