Feasibility Assessment for an Offshore Wind Marshalling Port in the Delaware Bay

June 2020

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ABOUT THIS PROJECT

This project was commissioned and funded as part of the Spin-In program through the University of Delaware. The project was led by Dr. Willett Kempton, who knew of the coming need for offshore wind ports, and thought analysis of specific sites would help industry and investors to evaluate options on the eastern seaboard. The sector is fast growing, with states signing power purchase contracts for offshore wind power warranting investment in infrastructure to support that construction. This report is a feasibility analysis of two sites for an offshore wind marshalling port in the US Northeast.

ACKNOWLEDGMENTS

This assessment was made all the more accurate thanks to the many individuals who were consulted or otherwise contributed to the analyses for this report. Thank you to Jesper Bank of Port of Esbjerg, Tim Kelly from the Army Corps of Engineers, Laura Mensch from the Delaware Department of Natural Resources and Environmental Control, Dr. John Madsen of UD, Eric Casey and Gene Bailey from Gulftainer, for their advisement, and to many others who contributed information and advice. Additional thanks to Emily Tino, Renee Hetrick, Christina Clark, Dr. Helen Bowers, Andrew Ames, and Cheryl Honaker for their participation earlier in the project. Thanks for financial and logistical support to the Spin-in program at UD Office of Economic Development and Partnerships, especially to Amalea Rassias, and the OEIP team. Special thanks to Willett Kempton and Sara Parkison for their guidance and revisions throughout this project.

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Executive Summary

The wind energy sector in the United States is growing rapidly. States along the eastern seaboard from Maine to Virginia are soliciting contracts to procure offshore wind power and meet their ambitious offshore wind procurement targets. These targets amount to a cumulative regional acquisition of nearly 25 gigawatt (GW) of offshore wind power capacity installed by the year 2035 (Market Analysis, Table 2). This report evaluates the viability and logistics of developing additional marshalling ports in the Delaware Bay to service the offshore wind sector.

Drawing from the projections published by the University of Delaware Special Initiative on Offshore Wind (SIOW) in their March 2019 white paper titled "Supply Chain Contracting Forecast for U.S. Offshore Wind Power", this report begins with a market analysis of projected development requirements along the east coast. Results from the analysis project an annual deployment of at least 1 GW from 2022-2035. (Market Analysis, Table 5) This indicates a significant need for development infrastructure.

Currently there is only one operating offshore wind marshalling port in the region that meets the necessary requirements for turbine deployment. In addition, three more are planned or proposed (Market Analysis, Table 6). These existing or planned port facilities, if they were all built, would have a collective capacity to deploy 916 MW annually. However, current contracts and requirements project an annual deployment of 1 to 2 GW from 2022 through 2035. Thus, market demand will exceed all existing and projected port capacity over the next 15 years (Market Analysis, Table 5), even if no further offshore wind projects are planned beyond existing requirements. The annual demand created by upcoming state-committed wind deployment projects will therefore require additional port capacity for suitable marshalling ports.

To this end, this report evaluates the potential for developing an additional marshalling port in the Delaware Bay. This Delaware Bay was selected based on several criteria, including sufficient overhead clearance from the port to the sea, sufficient quayside and channel draft, and sizable laydown area. This report provides an analysis of two site opportunities in the Delaware Bay that are suitable candidates for marshalling port developments based on these criteria.

The two proposed site locations are situated on opposing sides of the Delaware River, a river that defines part of the New Jersey / Delaware border. Hereafter referred to as the Delaware site and the New Jersey site, the locations chosen have a number of advantages, including having the necessary space to build a port capable of deploying at least 500 MW each build season, with ample potential to expand. Their geographic locations are unhindered by bridges, overhead cables or other blockages, thus allowing vessels to install projects throughout the mid-Atlantic and potentially beyond. Both also have areas with a self-scouring channel, further reducing maintenance dredging and maintenance cost.

To assess the viability of each site to fill the coming shortfall in port capacity, as well as to explore the steps a port developer will need to take to construct the port, this report provides detailed permitting and engineering analysis and recommendations for each location. The key takeaways of these analyses are as follows:

- From our projections based on existing power purchase contracts, new offshore wind build will have to exceed 2000 MW annually for the region starting in 2022 and 2023 (Market Analysis, table 5), and will outpace the deployment abilities of current and planned marshalling facilities. Existing and proposed facilities which can serve as a marshalling port for the region have a collective maximum deployment capacity of 916 MW annually (table 6).
- For example, a port design we outline in the Delaware bay, of 54 acres, could deploy at least 500 MW each build season, raising the annual deployment capacity for this regional sector to around 1.4 GW. The regional demand is projected to exceed even this greater capacity in four of the next five years. (Market Analysis, table 6).
- The example 54 acre design would only use part of either of the two properties studied. The property for the two potential sites are 831 acres for the Delaware site and 265 acres for the New Jersey site.
- Based on our analysis of permitting procedures for each state, it is estimated that the permitting process would take about 2 years from the data collection of pre-application feasibility studies to beginning construction , on either of the sites.The pre application studies is estimated to take 12-18 months and the permitting decision would occur within 9 months following a completed application.
- The Delaware site would require a Coastal Zone Act (CZA) permit, a Wetlands and Subaqueous Lands Lease, an NPDES permit, and a feasibility cost-sharing agreement with the US Army Corps of Engineers to coordinate dredging. It is estimated to take 12-18 months to gather the information necessary to complete the application. Once a completed application is submitted, it is estimated to take 7-9 months for a decision to be made by regulatory authorities in Delaware.
- The New Jersey site would require a Coastal Area Facilities Review Act (CAFRA) permit, an NJPDES permit, and an agreement with the US Army Corp of Engineer (USACE.) Similarly, it is estimated to take 12-18 months to gather the information necessary to complete the application. The regulatory process associated with the New Jersey site should be able to be completed within 7-9 months following a completed permit application decision.
- The largest unknown variable in the entire permitting process is the time it will take to collect the data necessary to complete the pre-application studies for both the Delaware and the New Jersey sites. This is a preliminary step needed to file the permit application. USACE guidelines estimate the pre-application process takes between 12-18 months. Following this, both sites render permitting decisions within 9 months. Thus, the total length of time needed to complete all permitting is 2 years.
- New Jersey has made strong commitments to offshore wind power purchases via Executive Order. Delaware does not have any similar commitment for offshore wind. Industry feels pressed to locate manufacturing and ports within states that are purchasing offshore wind power.
- The Delaware site is currently zoned for industrial use and provides access to roads and railways. The New Jersey site is also zoned for industrial use, but has less access to roads and rail, with a large wetland area between the site and the nearest transportation corridors..
- Based on presumptive load bearing values for soil materials present on the site, it is our interpretation that the load bearing capacities of the Delaware and the New Jersey sites are within the range of 1,000 to 2,000 psf (pounds per square foot), although these estimates are first-order and will need to be determined based on direct soil sampling and subsequent laboratory measurements of physical soil properties. For the requirements of a major offshore wind port, the

ground bearing pressure of the laydown area and quay or lift area with crane loads are required to be 1,200 psf (6 tons/m^2) and 6,000 psf (30 tons/m^2), respectively. Preliminary analysis of these sites have determined that they are appropriate for a high load bearing deployment port once civil engineering strategies to increase the bearing capacity of the soil are implemented.

- Based on technical analysis of land for high load bearing areas and appropriate channel depth to ensure installation vessels accessibility, several quay design mockups are presented for both sites (Preliminary Engineering Design, Section IIIA).
- Rising sea levels predicted by climate change models and extreme flood events are expected to increase the inundation of coastal areas including the Delaware Bay. Analysis of the area's floodplains has found that the Delaware site is expected to experience minor inundation due to surrounding the canals, while the New Jersey site is predicted to experience more substantial inundation encroaching further inland due to the surrounding wetlands system (Current Conditions Report, Section IE). Much of the present coastline and surrounding wetland area along the New Jersey site is predicted to be permanently inundated due to sea level rise by the year 2050, as would be the adjacent wetlands and future roads or rail for access.

Based on our analysis of existing power purchase contracts solicited by states from Virginia to Maine seeking to add offshore wind to their renewable portfolio, market demand is expected to exceed the service abilities of comparable marshalling ports (both existing and proposed). Our example analysis of an additional 54 acre offshore wind marshalling port in the Delaware Bay would raise the regional annual capacity to around 1.4 GW, which still falls short of projected demand. Both the NJ and DE sites analyzed have the potential for expansion to better match the projected market, up to 265 and 831 acres respectively. From an engineering and permitting standpoint, both the Delaware and New Jersey sites have been determined to be feasible to develop an offshore wind marshalling port. If further investigation is made subsequent to this feasibility assessment, analysis of environmental aspects of the sites including characteristics of the watershed, flood patterns, and geologic composition would need to be conducted as a basis for permitting and for a complete port design.

Section 1:

Regional Market Analysis for Offshore Wind Energy Sector

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I. Introduction

Based on the projections published by the University of Delaware Special Initiative on Offshore Wind (SIOW) white paper in March 2019[1], we have developed a market forecast depicting the annual offshore wind turbine deployment along the east coast. This market forecast is derived from SIOW's compilation of existing power contracts and forecasted contracts through 2035. Those quantities and dates are based on state laws, executive orders and similar policy commitments. The wind energy sector is fast growing, and states have been quickly moving through the bid solicitation process in order to secure contracts, the overall result being a sequence or "pipeline" of projects sequenced over the next 15 years.

In addition to the SIOW forecast, the following analysis is based on the most up-to-date press releases and other announcements from wind developers and states as of the writing of the report. These documents often offer proposed and bidded construction timeframes. In some cases, such as the Virginia Dominion energy project, wind developers have made announcements for wind farm projects outside of the state's internal process and without a state policy directive to do so.

The following two sections analyze existing power purchase agreements (PPAs). Section III then summarizes state requirements that have not yet gotten to the point of a contract. Both of these components are used later in the report to derive year by year construction projections (table 5) relevant to the deployment of offshore wind energy.

II. State power purchase agreements

Table 1 details the projects with PPAs or similar firm commitments. Dates in black are taken from power-on dates or start construction dates announced by wind developers and state press releases. Our team's projections are in red. We used established data on the state totals (as noted above), but projected unknowns as follows: Our projections match the start construction date with the power-on date based on a typical two-season construction duration, to complete marshalling, deployment and installation of an 800 MW to 1.2 GW project. Due to a difference in technology, the Maine Aqua Ventus project (which will be using floating turbines as opposed to turbines on foundations mounted on the ocean floor) we assumed a single-season build cycle.

[1] McClellan, S. (March 2019). *Supply Chain Contracting Forecast for U.S. Offshore Wind Power* [White Paper]. Retrieved from University of Delaware Special Initiative on Offshore Wind. *https://cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/e/10028/files/2020/01/SIOW-White-Paper-Supply-Chain-Contracting-Forecast-for-US-Offshore-Wind-Power-FINAL.pdf*

Table 1: Offshore wind power purchase agreements, by state and date

State	Project Announced	Wind Developer	Construction Start Date	Power-on Date	MW Deployed
Virginia	September 2019[1]	Dominion Energy	2022	2024	880
			2023	2025	860
			2024	2026	860
	August 2018[2]	Coastal Virginia Offshore Wind Farm Demonstration Project (Dominion Energy)	2020	2022	12
New York	June 2019[3]	Bay State Wind (Orsted)	2022	2024	880
		Empire Wind (Equinor)	2022	2024	816
New Jersey	June 2019[4]	Ocean Wind (Orsted)	2022	2024	1100
Massachusetts	May 2018[5]	Vineyard Wind (Avangrid Renewables and Copenhagen Infrastructure Partners)	2020	2022	800
	October 2019[12]	Mayflower Wind	2020	2020	800
Connecticut	December 2018[6]	Revolution wind (Deepwater Wind)	2022	2023	200
			2023	2024	104
Rhode Island[7]	May 2019	Revolution Wind	2020	2023	400
Maryland	September 2019[8]	Skipjack (Orsted)	2021	2022	120
	January 2018[9 10]	US Wind	2021	2023	270
Maine	November 2019[11]	Maine Aqua Ventus	2019	2020	12
				Total MW awarded in contract	**8114**

[1]https://www.seattletimes.com/business/dominion-energy-plans-220-turbine-offshore-wind-project/
[2]https://www.offshorewind.biz/2018/08/09/siemens-gamesa-and-orsted-ink-first-us-offshore-wind-turbine-deal/
[3]https://www.offshorewind.biz/2019/07/19/orsted-and-equinor-share-new-york-offshore-wind-spoils/
[4]https://www.offshorewind.biz/2019/06/24/orsted-wins-1-1gw-new-jersey-offshore-wind-solicitation/
[5]https://www.bloomberg.com/news/articles/2019-08-09/u-s-is-said-to-extend-review-of-first-major-offshore-wind-farm
[6]https://orsted.com/en/Media/Newsroom/News/2018/12/Connecticut-Regulators-Approve-Revolution-Wind-Power-Contract
[6]https://www.nsenergybusiness.com/projects/revolution-wind-project/
[7]https://www.offshorewind.biz/2019/05/29/revolution-wind-gets-rhode-island-power-contract/
[8]https://www.ge.com/reports/the-coast-with-the-most-two-new-u-s-offshore-wind-farms-will-use-the-worlds-most-powerful-turbines/
[9]http://www.uswindinc.com/maryland-offshore-wind-project/
[10]http://www.uswindinc.com/news/press-release/
[11]https://www.offshorewind.biz/2019/11/06/maine-aqua-ventus-gets-power-contract/?utm_source=offshorewind&utm_medium=email&utm_campaign=newsletter_2019-11-07
[12]https://www.masslive.com/news/2019/10/mayflower-wind-wins-massachusetts-second-offshore-wind-contract.htm

III. State Targets

In addition to the PPAs and contracts, seven eastern states have made offshore wind procurement targets through 2035 (Table 2). Although many of these targets have not yet been cemented by a power purchase agreement, they represent a commitment to utility purchase of offshore wind power, most legally binding.

These state targets are itemized in *Table 2* and have been used along with the PPAs to derive our market projections for construction through 2035 later in this report. In the cases where states have announced a certain MW of offshore wind acquisition by a certain year, the announced goal was extrapolated to the present on a year-by-year basis to illustrate a possible roadmap that defines the annual construction needs to reach the given target (table 4). These extrapolations were further refined by integrating the timelines of announced power purchase contracts into the final construction estimates.

Table 2: State requirements for offshore wind power solicitations

State	Initiator	MW Committed	By Date	Form	Last Updated
Virginia[1]	Gov. Ralph Northam	2500	2026	Executive order Forty-Three	Sep 2019
New York[2]	Gov. Andrew Cuomo	9000	2035	Public service commission order	July 2018
New Jersey[3]	Gov. Phil Murphy	7500	2035	Executive order	Nov 2019
Massachusetts[4]	Legislature	1600	-	Renewable energy law	2016
Connecticut[5]	Gov. Ned Lamont	2000	2030	Bill: Offshore Wind Mandate	July 2019
Rhode Island[6*]	Gov. Gina M. Raimondo	1000	2020	Strategic goal for clean energy*	2016
Maryland[7]	Legislature	480	2020	Maryland Offshore Wind Energy Act	2013

**Rhode Island's commitment is nonspecific to offshore wind*

[1]https://www.offshorewind.biz/2019/09/17/virginia-increases-offshore-wind-ambitions/
[2]https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Offshore-Wind-Solicitations
[3]https://www.bnnbloomberg.ca/new-jersey-doubles-down-on-offshore-wind-for-half-its-power-1.1350401
[4]https://apnews.com/508e0ed06bcc47a488a3e388e19c933f
[5]https://www.cleanenergyfinanceforum.com/2019/07/31/connecticut-looks-before-it-leaps-on-offshore-wind
[6]https://www.ri.gov/press/view/29766
[7]https://energy.maryland.gov/Pages/Info/renewable/offshorewind.aspx

IV. Construction estimates

The next step in our market forecast draws on a state by year table (drawn from the SIOW Supply Chain Analysis), with MW size. That SIOW table is reproduced here as Table 3.

Table 3: Offshore Wind Power Forecast, by State and MW size[1]

	MD	RI	CT	MA	NY	NJ	VA	**Total**
2018	368	400	200	800	130		12	**1910**
2019			100		800	1100		**2000**
2020		400		800	800			**2000**
2021			300			1200		**1500**
2022				800	1200			**2000**
2023			300			1200		**1500**
2024				800	1200			**2000**
2025	432	200	300					**932**
2026					1200			**1200**
2027	400		400					**800**
2028					1200			**1200**
2029			400					**400**
2030					1200			**1200**
total	**1200**	**1000**	**2000**	**3200**	**7730**	**3500**	**12**	**18642**

[1] *This table is reproduced from the Special Initiative on Offshore Wind (SIOW) White Paper published in March 2019*

This report has updated the above estimates offered by the SIOW paper to reflect recent negotiations for power purchase contracts as well as revised renewable energy targets by the state. In *Table 4* we have projected (in red) updated estimates for the annual MW deployed at the start of the construction phase through 2035. These projections are based on analysis of PPAs and state targets as summarized above. To provide an illustration of annual MW demand, this is later extrapolated into a year by year estimation of the buildout in Table 5. Each project deployment is divided over two years, based on a 2-year buildout typical for an 800 to 1,000 MW-project.

The estimates in the following tables tabulate the construction needs of eight states on the east coast that have completed or required power purchase agreements and otherwise demonstrated commitments to offshore wind energy. We will primarily focus on the right hand column that estimates a year-by-year timeline of MW deployed. This is directly translatable to construction needs and represents market potential for a port that can handle and ship large scale offshore wind technology.

Table 4: Projects contracted or committed by state and year

	NJ	MD	VA	NY	CT	MA	RI	ME	**Annual MW deployed**
2018									0
2019									0
2020			12			1600	400	12	2024
2021		390							390
2022	1100		880	1696	200		400		4276
2023			860	534	104				1498
2024	1100		860			800			2760
2025				1100	296				1396
2026	1100					800			1900
2027				1100	300		200		1600
2028	1100	410							1510
2029				1100	300				1400
2030	1100	400							1500
2031				1100	400				1500
2032	1100								1100
2033				1100	400				1500
2034	900								900
2035				1270					1270
Total constructed by year 2038	**7500**	**1200**	**2612**	**9000**	**2000**	**3200**	**1000**	**12**	**26524**

**all figures are in MW*
**VA based on executive and private procurement by utilities and estimates by Dominion Energy*

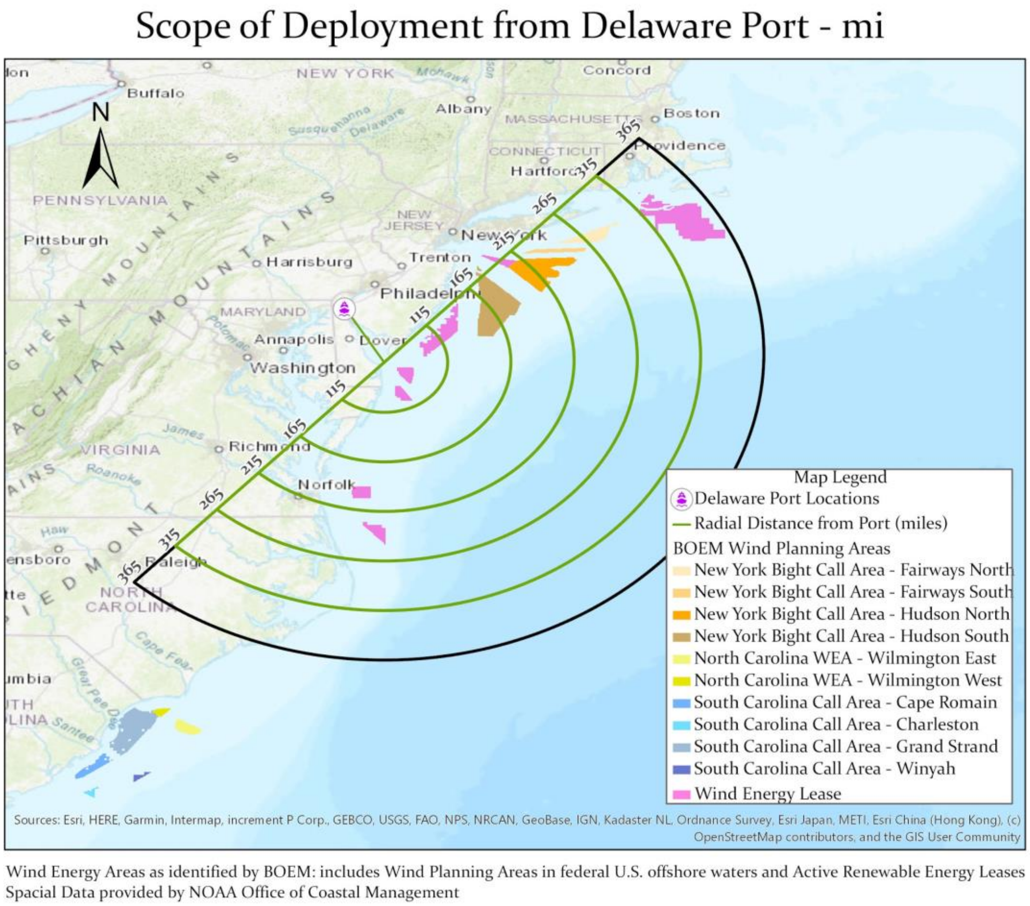

Figure 1: Visual representation of the scope of potential deployment to wind energy areas from the proposed Delaware Bay location. Distances shown on the map represent the radial distance from the port location, including the approximately 65 mile distance on the Delaware River, to each radius.

Table 5 is a tabulation by year, of states and the total deployments, based on the start construction dates summarized in *Table 4*. *Table 5* also separates in green the regional market that would be a primary target for a proposed port in the Delaware Bay. The geographical range of this market was determined from industry experience which demonstrates that typical vessel trips are more cost effective up to 200 miles (320 km). Greater distances may be less competitive compared to existing or planned marshalling ports further north. However, it should be noted that this boundary is not fixed and that the port could still be used to service projects up and down the coast in response to increases in demand for larger laydown areas and to changes in turbine and vessel technology. Our estimates, based on existing state commitments and contracts with wind developers, project a total buildout for this regional sector of 19,679 MW by the year 2035.

Table 5: Annual deployments, by region

	NJ	MD	VA	NY	CT	MA	RI	ME	Total MW deployed per year	annual MW deployed in regional zone
2018									0	**0**
2019									0	**0**
2020			**6**			**400**	**200**	**12**	618	**6**
2021		**195**	**6**			**400**	**200**		801	**201**
2022	**550**	**195**	**440**	**848**	**100**	**400**	**200**		2733	**2033**
2023	**550**		**870**	**1115**	**152**	**400**	**200**		3287	**2535**
2024	**550**		**860**	**267**	**52**	**400**			2129	**1677**
2025	**550**		**430**	**550**	**148**	**400**			2078	**1530**
2026	**550**			**550**	**148**	**400**			1648	**1100**
2027	**550**			**550**	**150**	**400**	**200**		1850	**1100**
2028	**550**	**410**		**550**	**150**				1660	**1510**
2029	**550**			**550**	**150**				1250	**1100**
2030	**550**	**400**		**550**	**150**				1650	**1500**
2031	**550**			**550**	**200**				1300	**1100**
2032	**550**			**550**	**200**				1300	**1100**
2033	**550**			**550**	**200**				1300	**1100**
2034	**450**			**550**	**200**				1200	**1000**
2035	**450**			**635**					1085	**1085**
Total/State	**7500**	**1200**	**2612**	**8365**	**1800**	**3200**	**1000**	**12**	25889	**19679**

There is industry precedent for the service range proposed here for a marshalling port located in the Delaware Bay. Upcoming wind deployment projects slated to be built within the Mid-Atlantic Wind Energy Areas leased by the Bureau of Ocean Energy Management (BOEM Lease Areas), shown on Figure 11 as multi-colored ocean areas are within the serviceable radius of the Delaware Bay location (figure 1). The BOEM lease areas for 7 out of the 8 states analyzed in this report (excluding Maine) are all within a 300 mile radius. Comparatively, the port of Esbjerg, a well established wind deployment port based out of Denmark, has a service radius extending over 500 km (equivalent to 300 miles). In Figure 1, the radii within 300 miles are portrayed in green, indicating that the ideal location of this proposed port could compete to bid on a large portion of U.S. Mid-Atlantic offshore wind projects.

V. Restrictions on Delaware Bay Port Usability

The Maine Aqua Ventus project slated to occur off the coast of the state may be out of the range of our port, both in terms of geography and technology. The project in the upper peninsula will be utilizing an experimental flotation-based technology for the turbines as opposed to the more common bottom anchored techniques that are utilized in more shallow sections on the continental shelf in the other BOEM lease areas.

Connecticut's first 200 MW procurement from Revolution Wind, estimated to begin construction in 2022, has a requirement to utilize the planned port in New London, however other ports can be utilized if necessary. By our estimations, the limited capacity of the New London port may warrant additional contracts with port developers.

Maryland's 120 MW acquisition fulfilled by Orsted includes a requirement to use the Sparrow's Point port in Maryland. However, Sparrows Point does not meet the needs for a marshalling port for wind deployment--it is both blocked by low bridges and is far from the sea. Our judgement is that it will be used for receiving and transferring shipped parts, but the marine construction contractor will either do barge transfer or transfer at a deployment port, in either case at a downstream location with no overhead obstructions. So, Sparrows Point will be used (as required) but not as a marshalling port.

VI. Meeting Market Capacity Needs

Based on analysis using confidential technical specifications provided by a major turbine OEM, we have calculated estimations of the area of land necessary to deploy a 1GW project. Each 1GW wind farm project (1GW = 1000 MW) would demand a 54 acre wind deployment port in operation through an 18 month build cycle (two construction seasons.) We consider that a capacity of 500MW per year. This assumption is informed by an analysis of the size of current turbine technology (over 10 MW) with consideration of the laydown area necessary to maneuver components. The 1 GW, 54 acre calculation is an example calculation and could be a first-tier build, but both Delaware Bay sites could expand considerably based on their land area. (The other three sites in the table could not easily expand, they are limited by other facilities or water.)

Comparing the first three sites in Table 6 with market demand in Table 5, even with New Bedford and Arthur Kill in operation, there are not sufficient marshalling ports in the region with the necessary characteristics required for wind deployment operations. These characteristics have been determined by consultations with industry experts and are as follows: a lack of overhead obstructions between the port and deployment area, sufficient quayside draft, distance to the channel, heavy lift capacities, and sizable laydown area.

Table 6: Capacities of Regional Ports

Marshalling Port	Acreage	Annual deployment capacity (MW)
New Bedford	29	268
New London (planned)	35	324
Arthur Kill (proposed)	35	324
Delaware Bay (conceptual)	54	500

Currently the port of New Bedford is the only operating offshore wind deployment port in the region that meets the necessary requirements for turbine deployment. The port of New London and Arthur Kill are not yet in service for wind deployment but have received investor interest. The port of New London in particular is expected to go online to meet future demand of the region.

From our projections based on existing power purchase contracts, MW demanded, exceeding 2000 MW annually for the region in 2022 and 2023 alone *(Table 5)*, will outpace the service abilities of these current ports. Existing and proposed facilities which can serve as a marshalling port for the region have a collective maximum deployment capacity of approximately 916 MW annually *(table 6)*. In 2022 and 2023, that is a gap in port service supply of over 1 GW. From 2024 to 2033, port availability still falls short by at least 100 MW annually. In light of the deficit between demand and current capacity, there is a clear need to pursue additional port opportunities on the eastern seaboard.

A proposed port in the Delaware bay built to 54 acres would be able to serve at least 500 MW each build season, raising the annual deployment capacity for this regional sector to around 1.4 GW. The regional demand is projected to exceed even this greater capacity in four of the next five years. (table 6).

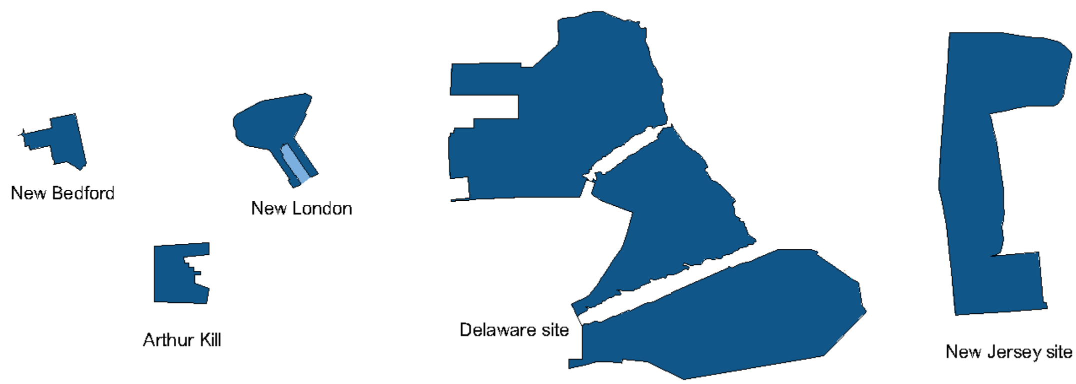

Figure 2: Comparable port sizes (New Bedford, New London, Arthur Kill, Delaware Bay conceptual sites) Delaware site and New Jersey sites are depicted in Figure 2 with an area greater than 54 acres, illustrating the potential laydown area based on the property size. (DE site: 831 acre NJ site: 265 acre)

It is important to note that both the New Jersey site and Delaware site have ample space to expand beyond our example design of 54 acres for these sites, thereby able to serve more than 500 MW annually with an expanded area and quay (*figure 2*). The property at the two potential sites total 831 acres for the Delaware site and 265 acres for the New Jersey site (although not all this is currently available for sale) Either location in the Delaware Bay would have the geographical range to service projects from Virginia to Massachusetts (*figure 1*), feasibly filling the gap we have identified in regional port capacity, even if the market grows well beyond current contracts and state offshore wind requirements.

Section 2:

Necessary Permits and Regulatory Analysis of the Delaware and New Jersey Port Locations

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Table of Contents

I. Overview

This policy report outlines the necessary permitting processes for the development of an additional marshalling port in the Delaware Bay. The two potential sites being evaluated are located in two separate states, Delaware and New Jersey, and so have different permitting requirements and regulatory timelines. This report compares the viability of the sites from a regulatory point of view.

The Delaware site would require a Coastal Zone Act (CZA) permit, a Wetlands and Subaqueous Lands Lease, an National Pollutant Discharge Elimination System Permit (NPDES) permit, and a feasibility cost sharing agreement with the US Army Corps of Engineers (USACE) to coordinate dredging. The entire permit process for the Delaware site will take about 2 years from pre-application feasibility studies to construction.

The New Jersey site would require a Coast Area Facilities Review Act (CAFRA) permit, a New Jersey Pollutant Discharge Elimination System Permit (NJPDES) permit, and an agreement with the USACE. The entire process for the New Jersey site will take about 2 years from pre-application feasibility studies to construction. The regulatory process should be complete within 7-9 months for both Delaware and New Jersey. The largest unknown variable is the time it will take to complete the pre-application studies for either site, and thus gather the necessary information to complete the permit application. USACE guidelines estimate the pre-application process takes between 12-18 months.

The Delaware site is currently zoned for industrial use and provides greater access to roads and railways. The Delaware site is expected to receive less backlash during the public comment period, since the development would repurpose current industrial sites, namely the Delaware City refinery and Oxychem property in New Castle county. Throughout our research period we have been in greater contact with the regulatory authorities in Delaware, specifically, the Department of Natural Resources and Environmental Control (DNREC) and the Philadelphia Office of the USACE. The greatest drawback for the Delaware site is Delaware's current lack of wind energy commitment in the political realm. Lack of support from the state may push wind developers to pursue an investment in a state with a further commitment.

The New Jersey site has little access to roads and rail. It is currently a dredge management spoils area owned by the USACE. We have had little contact with the NJ Department of Environmental Protection (DEP) or the New York Office of the USACE. However, the state has made strong commitments to energy from offshore wind.

II. Permitting Timeline

Table 1: Permitting Timeline

	Months						
Permit	1	2	3	4	5	6	7
DE CZA Permit							
Notice of Completeness	■						
Public Hearing Set		■					
Comment Period			■	■			
Final Decision					■	■	■
NJ CAFRA Permit							
Notice of Completeness	■						
Review for Compliance		■	■				
Public Hearing Set				■	■		
Comment Period						■	
Final Decision							■
DE Wetlands Land Permit							
Comment Period	■						
Initial DNREC Reivew		■					
Subaqueous Lands Lease			■				
Second Comment Period				■			
Final Decision					■		
DE NPDES Permit							
Notice of Completeness	■						
Public Hearing Set		■					
Comment Period			■				
Comment from Outside Agencies			■	■			
Section 401 Certification					■	■	
NJPDES Permit							
SESCP Plan Approved	■	■	■				
Notice of Completeness	■						
Review for Compliance		■					
Public Hearing Set			■				
Comment Period				■			
Final Decision					■	■	

The above timeline depicts the length of the regulatory process for various permits. The permitting times for “land use” and “National Pollutant” permits is very similar for both states. However, this visual does not account for the time necessary for pre-application studies. The visual shows only how long the regulatory process will take following a submitted application.

The pre-application process may take at least 6 months per permit prior to application submission. However, the information required to complete pre-application studies may be applicable to multiple permits. Additionally, some portions of the regulatory process can occur concurrently. This is specifically shown in the comment periods within the “DE NPDES” permit. There is one month of public comment and two months of comment from other state and federal organizations during the same period. This is depicted in figure 1 by stacks of blocks. The regulatory timelines of all applicable permits shown in figure 1 are detailed further throughout this report.

IV. Land Use Permits

A. Delaware

The Delaware Coastal Zone Act was signed into law in 1971 to "Protect the natural environment of Delaware's coastal areas from the destructive impacts of heavy industrialization and offshore bulk product transfer and safeguard their use primarily for recreation and tourism."[2] In 2017, it was updated to the Coastal Zone Act conversion permit (CZA). This permit is necessary for any additional or alternative heavy industry activity proposed in one of 14 grandfathered sites of industrial activity.[3] All of the potential sites in Delaware are grandfathered sites of the Coastal Zone Act and thus can support the development of a port. The CZA permit is traditionally only required for bulk products transfers. In the current regulations 'bulk product' "means loose masses of cargo such as oil, grain, gas and minerals, which are typically stored in the hold of a vessel.[4] Break bulk cargo does not use standard shipping containers.[5]

According to conversations with DNREC's Regulatory Programs Manager, Laura Mensch, our site would require a Coastal Zone Conversion Act Permit despite shipping break bulk products. The permit is necessary for any change in industrial activity that takes place in one of 14 grandfathered locations[6]. Since our port would signify a change from the current type of industrial activity, a CZA permit is required. The CZApermit costs $15,000 as an initial application with a $1,500 annual fee. We have estimated it would take one year to complete the application, as confirmed via personal correspondence with officials from DNREC. The application must include the following sections: the net environmental impacts and economic effects of the port, a project summary, compliance with Delaware Hazardous Substance Cleanup Act, a plan to prepare for sea level rise & storm impact, an offset proposal to combat negative environmental effects, the timeframe for construction, and evidence of financial assurance[7].

Once the CZA permit application is submitted, the application is either complete or insufficient. This decision is made within 30 days of submission. If the application is complete, a public hearing is set within 20 days. There is then a two-month period for comment before a final decision is reached. A final decision is made regarding the application's approval within three months of the hearing. Once the permit is submitted a final decision is made in about 7 months. The total timeline from pre-application studies to a final verdict on approval for the permit is estimated to be 15 - 18 months.

B. New Jersey

The New Jersey site would require a "Coastal Area Facility Review Act Individual"Permit (CAFRA) from the New Jersey Department of Environmental Protection (DEP) Division of Land Use Regulation. The total cost of the permit for development of the New Jersey site is estimated to be $27,000. The permit cost is $3,000 per acre, but the total cost may be larger. This cost may come from

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2 https://dnrec.alpha.delaware.gov/coastal-zone-act/history/
3 https://dnrec.alpha.delaware.gov/coastal-zone-act/conversion-permits/
4http://www.dnrec.delaware.gov/Admin/CZA/Coastal%20Zone%20Act%20Documents/CZCPA%20RAC%20Meetings/Meeting%203%20-%202018%20August/Examples%20of%20Bulk%20Product%20Transfer%20Scenarios.pdf
5 http://www.crowley.com/blog/services/what-is-breakbulk-shipping/
6 https://dnrec.alpha.delaware.gov/coastal-zone-act/conversion-permits/
7 https://dnrec.alpha.delaware.gov/coastal-zone-act/

addendums like a letter of interpretation to determine if wetlands are present or absent. These cost $1,000 per letter.

The New Jersey “CAFRA Permit” is much more comprehensive than the “Delaware CZA” permit. New Jersey does not have the equivalent of a Delaware Subaqueous Lands Permit, and instead requires the information to be included in the CAFRA Permit.

The timeline for the CAFRA Permit is as follows. The total from pre-application studies to a final verdict on approval for the permit is estimated to be two years. This is based on the regulatory procedure set out by NJDEP and pre-application estimates from USACE.[8][9] Once the pre-applications studies are complete, the regulatory process takes about 9 months. Thus, the largest time variable is gathering the information necessary to file the permit application.Once the information is prepared, a pre-application meeting is required with the DEP. Following this meeting, it will take several months to complete the application’s required sections. The CAFRA application includes: a Property Owner Certificate Form, a public notice to newspapers and clerks, a description of the project, other permits necessary, and environmental impact statement, site plans, specified soil erosion and sediment control measures, existing water information, dredging specifications, photos of the area, and a mitigation proposal[10][11][12].

Once the application is submitted, the applicant receives a notice of completeness within 20 days of hearing. If the application is complete, there is then a two-month period of review for compliance and content. The notice of public hearing is set within two months of a complete and correct application, with one full month of comments to be heard and or posted. A decision is made within a month after the comment window has closed. An appeal process may occur if the application is denied. The permit is valid for 5 years.

C. Comparison

The total length of the regulatory process once applications are submitted is negligible, around 7 months for both Delaware and New Jersey site locations. The difference between Delaware and New Jersey application process is small (no longer than 3 months difference) as Delaware as a slightly longer pre-application study and a longer period of time before a final verdict on the permit is made. From pre-application studies to a final permitting decision the overall timeline is estimated to take 2 years for both sites.

VII. State Specific Permits

A. Delaware

In Delaware, the port would require a “Wetlands and Subaqueous Lands Permit” from DNREC. This permit is needed for activities in tidal wetlands or tidal and non-tidal waters. After the permit is received, it is reviewed by a DNREC scientist. Including the 2 public hearings needed for the permit, the

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[8] https://www.nj.gov/dep/landuse/coastal/cp_main.html
[9] https://www.lrl.usace.army.mil/Portals/64/docs/regulatory/Permitting/PermittingProcessInformation.pdf
[10] https://nj.gov/dep/landuse/download/lur_021.pdf
[11] https://nj.gov/dep/landuse/coastal/cp_ip.html#cafra
[12] https://www.nj.gov/dep/landuse/download/cp_011.pdf

permit is completed within 4-6 months[13]. The estimated costs of the permit is dependent on the area of the site but should be under $10,000 total ($225 for the permit aline, $5,000 for the marina plus $1.50/yd3 for dredging and 1.50-2.00/linear ft of utility lines)[14] The permit has minimal requirements. They are as follows:description of location boundaries, a scaled plan and section view drawings of the proposed project, a copy of the deed, and a property survey. The proposed development will require several appendices filed with the Subaqueous Lands Permit. The port would require Appendix A for Boat Docking Facilities to describe land ownership, and vessel information. If the port would consist of more than four vessels it would be considered a marina facility.[15] From our conversations with DNREC, anything with Coast Guard certification is a vessel. If the site is to have more than four vessels at one time, we would also need Appendix N for preliminary Marina Screening and Appendix O for Marinas[16]. These appendices are much longer and require details of existing facilities, shoreline protection, and stormwater management[17].

Appendix E is required for utility installation of water, gas, and electric lines and methods of installation for the crossings[18]. We also may need Appendix G for bulkheads to ensure that the shoreline to maintain the current condition of the shoreline[19]. Finally, several appendices will be required for dredging. Appendix S is necessary for new dredging and requires an overall description of the dredging methods, purpose, and amount), the environmental impacts of the dredging (on the biological community, impact of bottom contours, the chemical composition of the dredged material, and the underlying substrate), and the disposal of the dredged material (method, location and characteristics of the disposal site). All new dredging also requires a sampling plan of particle size distribution, benthic invertebrate survey based on a minimum of three surface grab samples, elutriate analysis, surface water analysis, and a description of emergent and submerged vegetation in or adjacent to proposed dredging areas.[20] Appendix R is necessary for maintenance dredging and would be completed in conjunction with the permit for new dredging. This appendix requires Appendix R is used to permit the areas that have previously been dredged, by a former owner, while Appendix S is specifically for the new area of dredging. Appendix R details the amount of material dredged, the dimensions of dredged area relative to water levels, methods of dredging, and disposal information. The appendix for maintenance is overall less detailed than the appendix for new dredging.

Finally, our port would require a Subaqueous Lands Lease. It is renewable on a 10-year term and required for a dock, pier, or any fill project that is placed in underwater lands. It is then signed by the applicant and then returned to the Dept. of Cabinet Secretary, then recorded at the Recorder of Deeds Office in New Castle County.[21]The process is estimated to take 5 months to acquire a new lease.

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[13] https://dnrec.alpha.delaware.gov/water/wetlands-subaqueous/permits/
[14] http://www.dnrec.delaware.gov/wr/Documents/WSLS%20Fee%20Sheet.pdf
[15] http://www.dnrec.delaware.gov/wr/Documents/Appendix%20A%20Boat%20Docking%20Facilities.pdf
[16] http://www.dnrec.delaware.gov/wr/Documents/WSLS/Marinas.pdf
[17] http://www.dnrec.delaware.gov/wr/Documents/Appendix%20N%20Marina%20Checklist.pdf
[18] http://www.dnrec.delaware.gov/wr/Documents/Appendix%20E%20Utility%20Crossing.pdf
[19] http://www.dnrec.delaware.gov/wr/Documents/Appendix%20G%20Bulkheads.pdf
[20] http://www.dnrec.delaware.gov/wr/Documents/WSLS/New%20Dredging%20Projects.pdf
[21] https://dnrec.alpha.delaware.gov/water/wetlands-subaqueous/permits/

B. New Jersey

New Jersey does not have the same process as Delaware for its additional permits. The supplemental documents are placed within the overarching CAFRA permit.

VIII. NPDES Permit

The National Pollutant Discharge Elimination System (NPDES) Permit is required by the Environmental Protection Agency (EPA) for development in both Delaware and New Jersey. The NPDES permit limits water pollution by regulating point sources that discharge to US waters[22]. It is maintained under the Clean Water Act. The discharge limitations are based on water quality standards and effluent limitations.

Development of the marshalling port would require an individual permit consisting of specifics of our site. It is expected to take at least six months for both Delaware and New Jersey sites.[23]

A. Delaware

On the Delaware site, the development of a deployment port would require an individual NPDES permit issued by the EPA, but would be regulated by the DNREC division of Water and the Delaware River Basin Commission (DRBC). To apply for an NPDES individual permit, two forms are be required in Delaware[24].

The General Information Form 1:[25] describes the site, nature of the business, other environmental permits, and logistics of ownership.

Form 2D: required for new industrial facilities. This form must include a schematic of water flow, expected amounts of discharge (from rain) and the amount, if any pollutants will be discharged into US waters[26]. The permitting process may be faster than the standard 6 months to acquire a NPDES permit since we would not be discharging pollutants on the scale industrial facilities currently are.

The application process for the NPDES permit is as follows. An application for a NPDES permit must be done at least 6 months before construction will begin[27]. The permit application must contain the name of the permit applicant, a description of the activities that will result in the discharge, the type of discharge, the name of the receiving body of water. Public notice shall be given once an application for a permit is complete. The Secretary shall provide a 30-day period of public comment. The public notice will include all of the above details and will additionally provide a tentative determination of the permit and include the procedure by which the public may be involved with the final determination of the permit. The determination and procedure will come from the Secretary. The Secretary will also inform other appropriate government agencies of a completed application. This includes the appropriate District Engineer of the USACE; the US Fish and Wildlife Service; the National Marine Fisheries Service; the Advisory Council on Historic Preservation; the State Historic Preservation Officer; the State of Delaware

[22] https://www.epa.gov/npdes/about-npdes#overview
[23] https://www3.epa.gov/npdes/pubs/publicparticipation.pdf
[24] https://dnrec.alpha.delaware.gov/water/surface-water/npdes/individual-permits/
[25] https://www.epa.gov/sites/production/files/2019-05/documents/form_1_epa_form_3510-1.pdf
[26] https://www.epa.gov/sites/production/files/2019-05/documents/form_2d_epa_form_3510-2d.pdf
[27]https://regulations.delaware.gov/register/july2012/proposed/16%20DE%20Reg%2050%2007-01-12.htm

Department of Natural Resources and Environmental Control Division of Fish and Wildlife; the county or local government where the facility is located. These entities will be provided an opportunity to respond, comment, and request a public hearing for the permit application. Each agency will have at least 30 days from the receipt of the notice. During the comment period, any persons may submit written comments on the draft permit[28]. The Secretary may hold a public hearing at his or her discretion whenever there is significant public interest. If the USACE or any State or Federal agency advises the Secretary, in writing, regarding the permit, these provisions are included in the permit final decision. If the permit is approved, it will become effective on the first day of the month following the issuance date unless the issuance date is the 16th day of the month or after. The final NPDES permit shall become effective on the first day of the second month following the issuance date.[29] Permits must be reissued every 5 years.

B. New Jersey

The EPA has delegated authority to issue NPDES permits in New Jersey to the New Jersey Dept. of Environmental Protection. It is regulated by the Division of Water Quality within the NJDEP. Once an application is submitted to the NJDEP for the NPDES permit, the Department shall send written notice to the applicant as to whether the application and supporting documents are administratively complete.[30]

The permit for our port would require NJPDES permit application Form 1[31] and the NJPDES Form RFC[32]. Additionally, all NJPDES permit applications must include a Soil Erosion and Sediment Control Plan (SESCP) at least 90 days prior to construction. All construction permits must include a certification of a Stormwater Pollution Prevention Plan (SPPP)[33]. This is made up of the SESCP and the construction site waste control component. The SESCP is governed by the local requirements of the regional Sediment Control Department. most permits take 6 months to review[34] according to the Permitting Dashboard on the NJDEP website. It would therefore be expected to take 6 months or less to permit as the marshalling port will not be discharging a large amount of pollutants within the waterways.

[28] https://dnrec.alpha.delaware.gov/coastal-zone-act/conversion-permits/
[29] https://dnrec.alpha.delaware.gov/water/surface-water/npdes/
[30] https://www.nj.gov/dep/dwq/7_14a/sub15rule.pdf 7:14A-15.4
[31] https://www.nj.gov/dep/dwq/pdf/njpdes1f.pdf
[32] https://www.nj.gov/dep/dwq/pdf/formrfc.pdf
[33] https://www.epa.gov/npdes/developing-stormwater-pollution-prevention-plan-swppp
[34] https://www13.state.nj.us/DataMiner/Home/Documents?isExternal=y

IX. State Support:

A. Delaware

Delaware does not currently have any state commitment to wind as part of its energy portfolio. In 2011, the Delaware Offshore Wind Farm was proposed by Bluewater Wind offshore Rehoboth Beach. This would have been the first power purchase agreement for wind in the nation[35]. The contract was terminated because of the economic downturn and a decrease in natural gas prices. In 2017, Governor Carney established the Offshore Wind Working Group, and a final report was published by the group in 2018.[36] Originally, the report was meant to evaluate the economic and environmental dimensions related to offshore wind (OSW) generation for Delaware, and to make specific recommendations for the state on whether or not to move forward in offshore wind. The conclusions of this report did not give a specific recommendation to invest in offshore wind within Delaware. Instead, the report recommends to wait on other state's OSW commitments and procurements, to consider large purchases of renewables from other states, and to consider incremental commitments to future projects instead of a large-scale purchase upfront[37].

B. New Jersey

New Jersey is poised to become a national leader in offshore wind. [38] Executive Order No. 8 signed by Murphy in January 2018 was a signal from the start of his administration that NJ will push forward on offshore wind. This commitment of offshore wind was doubled in 2019 with Executive Order No. 92. New Jersey maintains a commitment to acquire 7,500 MW of offshore wind by 2035 to reach 100% clean energy by 2050[39]. The next solicitation for 1200 MW of will be opened by September 2020 and will be awarded in the second quarter of 2021. [40]

We have not directly met with the NJDEP. Therefore, we cannot speak to their level of willingness to support the development of an offshore wind deployment port despite their wind commitment. We can say, based on the NJ administration's efforts, that the level of political favorability and feasibility within the state is high.

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35 https://www.capegazette.com/article/bluewater-cancels-wind-power-contract/21352

36 https://dnrec.alpha.delaware.gov/climate-coastal-energy/renewable/offshore-wind-working-group/

37 Http://www.dnrec.delaware.gov/energy/Documents/Offshore%20Wind%20Working%20Group/Offshore%20Wind%20Working%20Group%20Report%20June%2029%202018.pdf

38 https://rtoinsider.com/nj-sets-schedule-offshore-wind-procurements-156612/

39 https://www.windpowerengineering.com/nj-calls-for-first-1-2-gw-of-offshore-wind-proposals-by-september-2020

40 https://www.greentechmedia.com/articles/read/new-jersey-governor-more-than-doubles-offshore-wind-target-to-7-5gw

X. USACE Oversight

A. The Process

The US Army Corps of Engineers (USACE) is responsible for maintaining and improving coastal, inland, and intracoastal waterways. For this development, the waterway of interest is the Delaware Bay. Any dredging on federal waterways must be completed in conjunction with the USACE. The New Jersey site is under the jurisdiction of the New York Office of the USACE while the Delaware site is regulated by the Philadelphia Office. Both sites would require the same cost sharing agreement and will take a similar amount of time, but feasibility of creating a cost-sharing agreement with an additional third partner may differ between states.

The process for partnering with the USACE is a multiyear, six-phase series of analyses that become progressively more detailed as the process moves forward. The end result is the creation of a Project Cooperation Agreement pursuant to Section 204 of the Water Resources Development Act of 1986[41]. The process is as follows:

The first phase is the Reconnaissance Phase. This phase defines the problem, identifies potential solutions, and creates a cost sharing agreement. It can take less than 12 months but no more than 18 and is paid for entirely by the government.

The second phase is the Feasibility Phase. This begins with the signing of a Feasibility Cost Sharing Agreement (FCSA).This document consists of specifications of the problems and opportunities associated, formulations of alternative plans, evaluations of the economic and environmental costs and benefits, a Real Estate Plan (REP), and the selection of the National Economic Development Plan (NED)[42]. The National Economic Development objective is to maximizes net economic benefit while protecting the environment. USACE is required to select this plan while considering environmental restoration. The “Federal Standard” is the least costly method consistent with federal environmental requirements (it is a baseline minimum for dredging). The option chosen by the USACE should maximize the sum of economic development and national environmental restoration benefits. The costs of the Feasibility Phase is split 50/50 between the USACE and the non-federal sponsor of the project.[43] In this case, the non-federal sponsor is the site developer.

The third phase is the Pre-Construction Engineering and Design Phase. This phase begins when the USACE receives funds from Congress. This may be able to occur through the America’s Water Infrastructure Act of 2018 (AWIA) for its study on innovative ports for offshore wind deployment or Section 1204 of the American Energy Innovation Act. This will happen concurrently with the completion of the Feasibility Phase. The Project Cooperation Agreement will be prepared by the end of this phase along with an updated REP. The costs are shared in the same proportions as in the construction costs.

The fourth phase is the Real Estate Acquisition Phase, which is entirely the responsibility of the non-federal entity (i.e., the site developer). This phase is mainly concerned with securing the land and the creation of Real Estate drawings of the property. These costs are determined by the expense to acquire the land and then create these documents. The time it takes to acquire the land is dependent on the current owner’s willingness to sell. The land is typically owned by the non-federal sponsor but it may be acquired

[41] https://www.usace.army.mil/Missions/Civil-Works/Project-Partnership-Agreements/ppa_forms/
[42] http://cdm16021.contentdm.oclc.org/utils/getfile/collection/p16021coll11/id/1784
[43] https://www.mvr.usace.army.mil/Portals/48/docs/RE/Guide/WhoPays.pdf

by the USACE to be used as a LERRDS offset. LERRDS offsets are the waiver of lands, easements, right-of-way, relocation or disposal areas to be used in place of direct cash contribution. The non-federal share of a cost sharing agreement usually consists of a cash contribution and real estate interests via the donations of LERRDS.

The Construction Phase of the process includes the largest unknowns of the project overall. Following funding, this phase begins once contracts are awarded. The USACE completes the required construction and dredging. The costs are shared depending on the depth of dredging required for the project. The table below shows the percentage paid by the non-federal share of dredging from the USACE Beneficial Use Planning Manual.[44]

New Navigation Projects

(deepening or widening of an existing federal navigation channel or creation of a new federal navigation channel)

For the portion of the project with a depth:	The non-federal share is:
Up to 20 ft	20% (10% during construction + 10% over 30 years)*
Over 20 ft and up to 45 ft	35% (25% during construction + 10% over 30 years)*
Over 45 ft	60% (50% during construction + 10% over 30 years)*

Operation and Maintenance of Existing Navigation Projects

1. Operation and Maintenance Dredging: Federal share is 100% (except for harbors greater than 45 feet, where the non-federal share is 50% of the costs beyond those which would be incurred for a project with a depth of 45 ft or less).

2. Constructing land-based and aquatic disposal facilities:

For the portion of the project with a depth:	The non-federal share is:
Up to 20 ft	20% (10% during construction + 10% over 30 years)*
Over 20 ft and up to 45 ft	35% (25% during construction + 10% over 30 years)*
Over 45 ft	60% (50% during construction + 10% over 30 years)*

3. Operating and maintaining land-based and aquatic disposal facilities: Federal share is 100%.†

** The non-federal share includes 10%, 25%, or 50% to be paid during construction. It may include an additional 10% share of the total project costs to be paid over 30 years. The value of lands, easements, rights-of-way, and relocations required for the project is credited to this 10%, which is to be paid over 30 years.*

† In some cases, the federal cost may be determined by legislation authorizing construction and maintenance of the confined disposal facility.

Figure 1:

The Feasibility and Pre-Construction phases will determine the depth of dredging required and thus show the portion necessary to be paid to the non federal sponsor.

Finally, following completion of construction, the final phase, Operations and Maintenance Phase of the Project, is typically covered fully by the non-federal sponsor. It begins once the project turns over to the Non-Federal sponsor and continues indefinitely. However, in projects that will support commercial navigation and will reach no more than a depth of 45 feet, the USACE will pay for 100% of the costs.[45] For depths greater than 45 ft, the USACE will pay for 50% of increased operation costs. This is also determined in the Project Cooperation Agreement prior to construction.

[44] https://www.epa.gov/sites/production/files/2015-08/documents/identifying_planning_and_financing_beneficial_use_projects.pdf - Appendix B

[45] https://www.mvr.usace.army.mil/Portals/48/docs/RE/Guide/WhoPays.pdf

B. October 2019 Meeting

According to a conversation with USACE personnel (Dan Kelly, Tim Kelly, and Jeff Gebber) from the Philadelphia District of the USACE in October 2019, a cost sharing agreement between the developer and the government of Delaware may apply. The cost would be split with 75% of the construction costs of dredging paid for by the non-federal sponsor and all costs for operation and maintenance paid for by the government. More research is required to determine if a federalized channel would have different steps required to partner with the USACE. This would include demonstrating the permanent economic return to the local economy via locational context and labor access.

C. USACE partnership comparison by site

The permitting and regulatory process is nearly identical between the New Jersey and Delaware Sites. Both would go through the six-phase process to partner with the USACE. However, the Delaware site has an advantage compared to the New Jersey site. Overall, we know that the owner of the Oxychem property on the Delaware Site is willing to sell while the owners of the Delaware City Refinery property are open to the discussion of selling. We have not approached the USACE to determine their willingness to sell the New Jersey site. However, it is noted that buying typically takes longer when buying from a federal entity instead of a private party. The USACE officials explained it took several years before the USACE sold land to PSE&G Nuclear as a dredge spoils site. Therefore, it may take at least a year before the USACE will sell the land for the New Jersey site. If a Delaware site is chosen, the overall costs of the non-federal sponsor may be split between the developer of the Wind Deployment Port and the Oxychem or the Delaware City Refinery. Specifically, costs within the Feasibility, Pre-Construction, and Construction phases of the USACE process will be reduced.

Table 2: USACE Dredging Timeline

Phase	Months										
	3	6	9	12	15	18	21	24	27	30	33
USACE Dredging DE											
Reconnaisance Phase											
Feasibilty Phase											
Pre-Construction Phase											
Real Estate Aquistion Phase											
USACE Dredging NJ											
Reconnaisance Phase											
Feasibilty Phase											
Pre-Construction Phase											
Real Estate Aquistion Phase											

Each cell pictured in Figure 3 represents three months. Both the Delaware site and the New Jersey site will take a similar amount of time to. However, it would be expected to take longer to acquire the land from the USACE on the New Jersey site than it would take to acquire land from a private party on the Delaware sites. Both sites are expected to take a similar amount of time, however the New Jersey site is expected to have a longer Real Estate Acquisition phase. This is because the land would be sold from a private entity instead of a public entity.

III. Zoning

All prospective sites in Delaware are zoned for heavy industry use under the Coastal Zone Act.[46][47] The NJ site is zoned for industrial use based on the 2014 Lower Alloways Creek township zoning.[48] Thus, industrial activities can occur in all potential sites.

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[46] https://dnrec.alpha.delaware.gov/coastal-zone-act/conversion-permits/

[47] http://www.dnrec.delaware.gov/Admin/CZA/Documents/2017%20CZA%20Remediation%20Status%20Baseline%20Report_Sept%202017.pdf

[48] https://www.lowerallowayscreek-nj.gov/sites/lowerallowayscreeknj/files/uploads/p_28000-28499_28081.00_cadd_dwg_28081.00_zoning_map_color_1.pdf

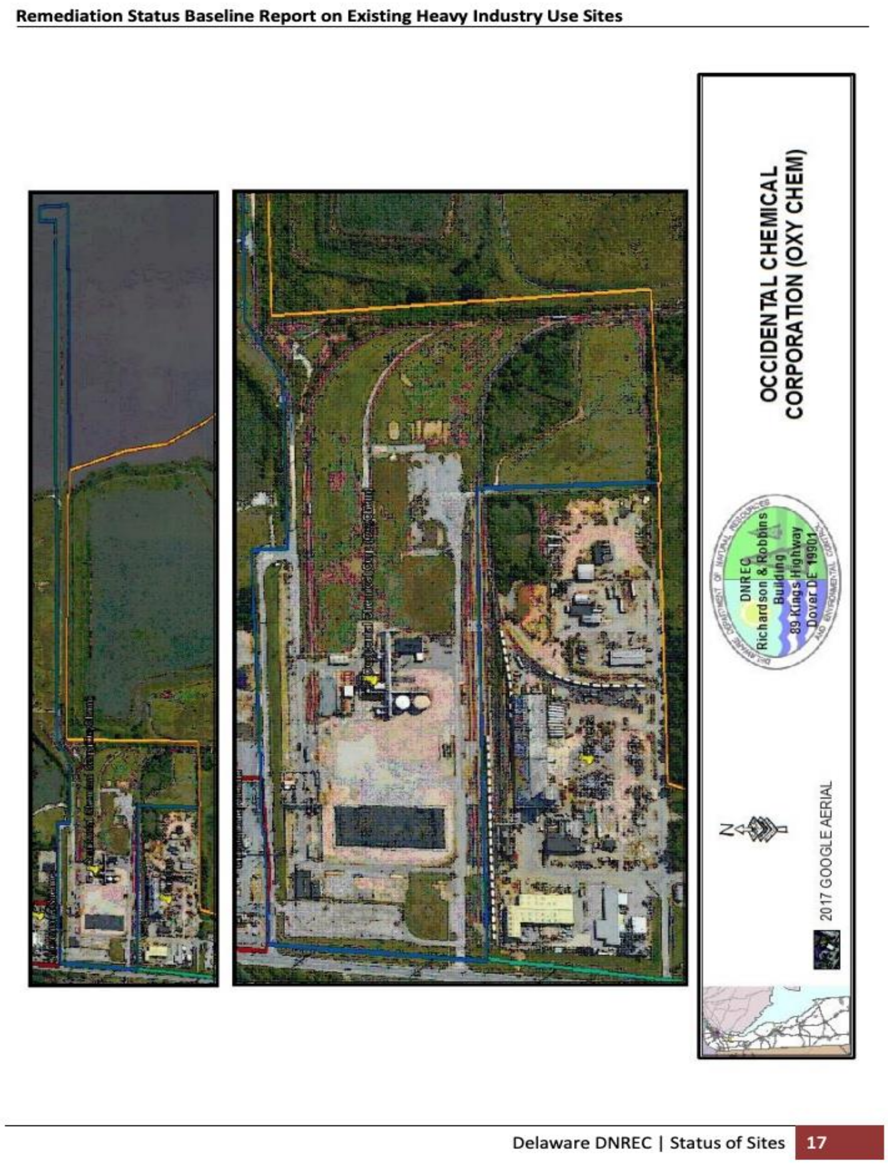

Figure 2:
The above image shows the Delaware Oxychem site from the DNREC Remediation Status Baseline Report on Existing Heavy Industry Sites. Thus, this site is fit for heavy industrial use[49].

[49]http://www.dnrec.delaware.gov/Admin/CZA/Documents/2017%20CZA%20Remediation%20Status%20Baseline%20Report_Sept%202017.pdf

Figure 3:
The above image shows the Delaware City Refinery site from the DNREC Remediation Status Baseline Report on Existing Heavy Industry Sites. It shows the site is fit for heavy industrial use.[50]

[50]http://www.dnrec.delaware.gov/Admin/CZA/Documents/2017%20CZA%20Remediation%20Status%20Baseline%20Report_Sept%202017.pdf

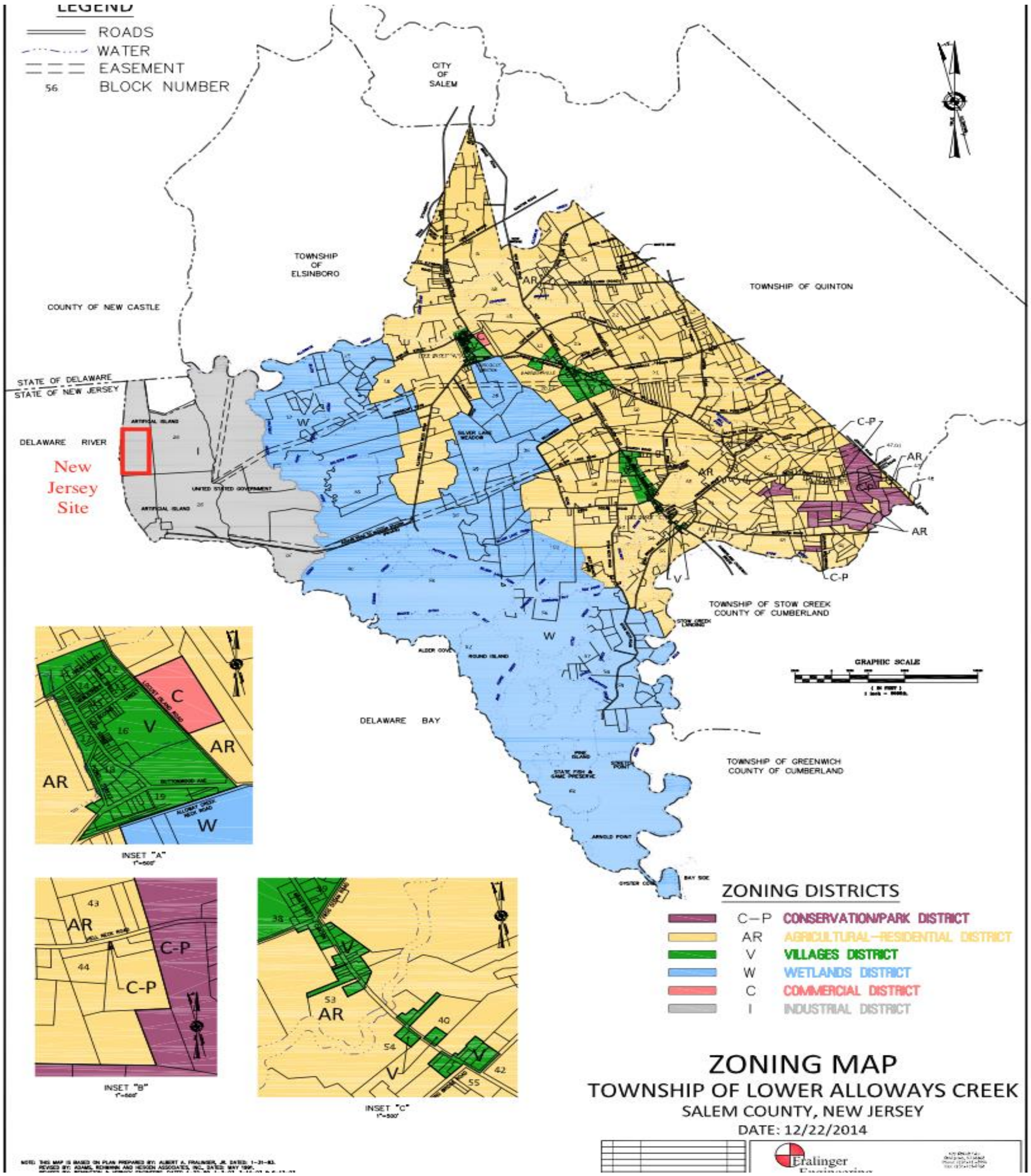

Figure 4:
The above figure shows the zoning districts of Lower Alloways Creek Township. The New Jersey site is boxed in red in the industrial district. This shows the New Jersey site is fit for industrial activity[51]*.*

[51] http://www.dnrec.delaware.gov/Admin/CZA/Documents/2017%20CZA%20Remediation%20Status%20Baseline%20Report_Sept%202017.pdf

IX. Accessibility

The Delaware sites have greater accessibility for service roads and railways than the New Jersey site. All of the Delaware sites are currently industrial properties that are just off of Delaware state Route 1. Oxychem and Delaware City Refinery are currently in operation and thus can support an influx of workers and traffic. The New Jersey site only has one service road that leads directly to the Salem Nuclear Plant. If this site is chosen, it will require a much larger investment in infrastructure mainly in supporting roads or rail that can hold the weight of the breakbulk components for the turbines. This may result in a longer construction period overall.

X. Property Ownership/Public Opinion

The Delaware site is expected to have a faster overall processing time in pre-application studies than the New Jersey site. Additionally, Oxychem is available for sale. The Delaware City Refinery is not using some of their dredge spoils areas, but is not currently offering lands on this site any for sale or lease.

The United States Army Corps of Engineers (USACE) currently owns the New Jersey site. If the state of New Jersey was to purchase this area, the time it will take to acquire this land for development of a marshalling port for an outside developer will be longer. This conclusion is based on information shared by USACE concerning the transfer of a smaller area of USACE land in New Jersey which took several years.[52] As more government agencies are involved with purchasing, the timeline typically takes longer compared to buying land from a non-federal entity.. Purchasing lands therefore will take longer with the New Jersey site since the site developer would be buying from a federal agency.

Additionally, the timeline of permitting the land in the New Jersey site may take longer due to the environmentalist movement in the state. The New Jersey site is currently being used as a dredge spoil management area (DMSA) by the USACE. While this land is barren, it is still a wetland and wildlife habitat. We expect New Jersey environmentalists to be more vocal than those in Delaware If this site is converted into an industrial port. This may delay the state from permitting the area.

There may also be some opposition within the public opinion of Delaware. Based on conservation with USACE, we believe the Partnership for the Delaware Estuary and the River Keepers Network may oppose our port for a variety of reasons, but specifically due to the breeding ground for Atlantic Sturgeon. We recommend having several public presentations with these groups to understand the priorities of each group.

This report only includes speculation of public opinion based on previous conversations with the USACE and Delaware state agencies. A more in depth analysis is recommended to determine the potential public opposition to development.

XI. Federal Support

We expect the renewable energy industry to bloom over the next decade[53]. This will be a result of several federal programs providing support. Under the America's Water Infrastructure Act of 2018 (AWIA), a study on innovative ports for offshore wind deployment was funded out and will be carried[54].

[52] Personal Conversations with Philadelphia Office of USACE

[53] https://sites.udel.edu/ceoe-siow/

[54] https://www.epa.gov/ground-water-and-drinking-water/americas-water-infrastructure-act-2018-awia

Section 1207 describes the implementation of a study to determine wind port viability[55]. The study will create a list of ports that would be feasible for offshore deployment including “port or harbor that can accommodate offshore wind including through retrofitting” and therefore future funding. This demonstrates that there is congressional support for offshore wind and the developer may be able to receive additional funding for the development of port infrastructure. The report of this study is expected within the upcoming months. There may be additional federal support for renewables, specifically with the American Energy Innovation Act, Section 1204[56]. This will encourage the greater development of the renewable energy industry.

[55] https://www.congress.gov/115/bills/s3021/BILLS-115s3021enr.pdf
[56]https://www.energy.senate.gov/public/index.cfm/2020/2/murkowski-manchin-introduce-american-energy-innovation-act

Section 3:

Current Conditions Analysis of the Delaware and New Jersey Offshore Wind Port Locations

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OEIP Spin In Team

University of Delaware
June 2020

Supervised by:
Willett Kempton and Sara Parkison

Table of Contents

Introduction

The purpose of this report is to provide an assessment of the environmental conditions relevant to the development of two potential port locations in the Delaware Bay for the deployment of offshore wind turbines in the US Mid-Atlantic region. An understanding of current site conditions is imperative for any investors seeking to make informed design decisions in the construction of a marshalling port for offshore wind. To this end, this report examines two aspects of each potential port location in the Delaware Bay: hydrology and geology.

Hydrology in coastal areas gives critical information on watershed characteristics, topography, rainfall, and flood trends which is useful for determining the characteristics and necessary remediations of the site prior to construction. Stormwater management and quay placement decisions must be made with consideration to these hydrological attributes in order to create a sustainable design that reduces the impact of storms and floods on port operations.

Understanding the geological aspects of a site is necessary to make sound geotechnical decisions prior to construction. Geotechnical engineers can reference the preliminary analysis in this report when designing foundations for the pier and the port laydown area. However, more tests may be needed to gain a complete understanding of the geological conditions of these sites. There is limited field data that exists in these coastal areas that provide information about the depths or qualitative descriptions about the soil. Further analysis will be required to obtain more information on geotechnical properties of the soil including water content, unit weight, strength, compressibility, and permeability, prior to any build.

This current conditions analysis report for the Delaware site and New Jersey site port locations has been prepared by civil and environmental engineering students at the University of Delaware. This report utilizes historical records and tools from the U.S. Geological Survey (USGS), Delaware Geological Survey (DGS), ArcGIS, Delaware Department of Natural Resources and Environmental Control (DNREC), New Jersey Department of Environmental Protection (NJDEP), and the Federal Emergency Management Agency (FEMA).

This publically available data has been compiled in order to present an understanding of the current conditions and engineering challenges at the two potential port locations. What follows is a comprehensive analysis on flood risk, present wetlands, elevations, tidal flows, watershed characteristics, saturated soils, and soil boring logs. This report offers a comprehensive overview of the currently available data on the hydrological and geological aspects of the site. We anticipate that the conclusions from this study will then be able to be used in comparing different port design options.

Any questions about the content of the information in this report should be referred to Willett Kempton at willett@udel.edu.

Site Specifications

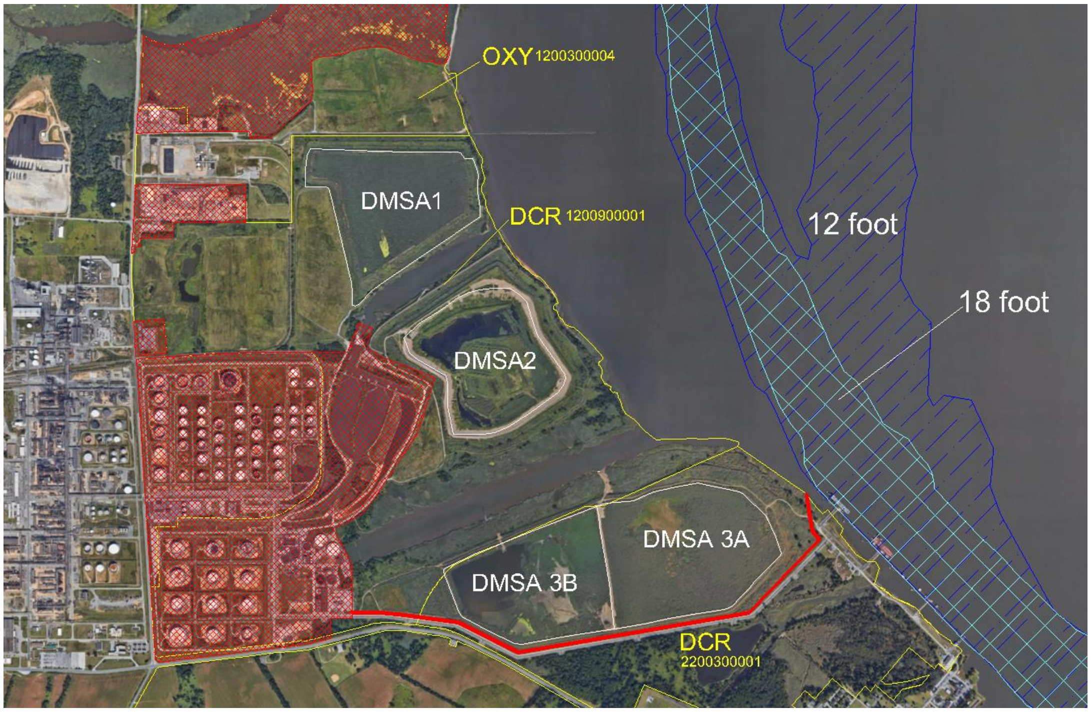

Figure 1: Property map for the Delaware site, located in New Castle County, DE, just north of Delaware City. Yellow lines are parcel lines indicating ownership[57], white lines represent dredge spoil areas, red hatched areas are unavailable for use, and royal and teal blue hatched lines indicate the area where there is a 12 and 18 foot deep contour in the Delaware River, respectively[58]. Areas will henceforth be referred to as Oxychem and DMSA1-3 as displayed[59].

Table 1: Area of Parcel Properties of Delaware site. The total Delaware site area is calculated by adding all land areas East of the exclusions shown in red hatching. DMSA areas are measured from the white lines outlined in Figure 1.

Parcel	Area (acre)	Area (hectares)
Oxychem	106.7	43.1
DMSA1	80.1	32.4
DMSA2	79.7	28.6
DMSA3A / 3B	92.9 / 74.6	37.6 / 30.2
Total Delaware site	831	336.2

57 Delaware City Property Map obtained from New Castle County records
58 https://nauticalcharts.noaa.gov/
59 Google Earth Image

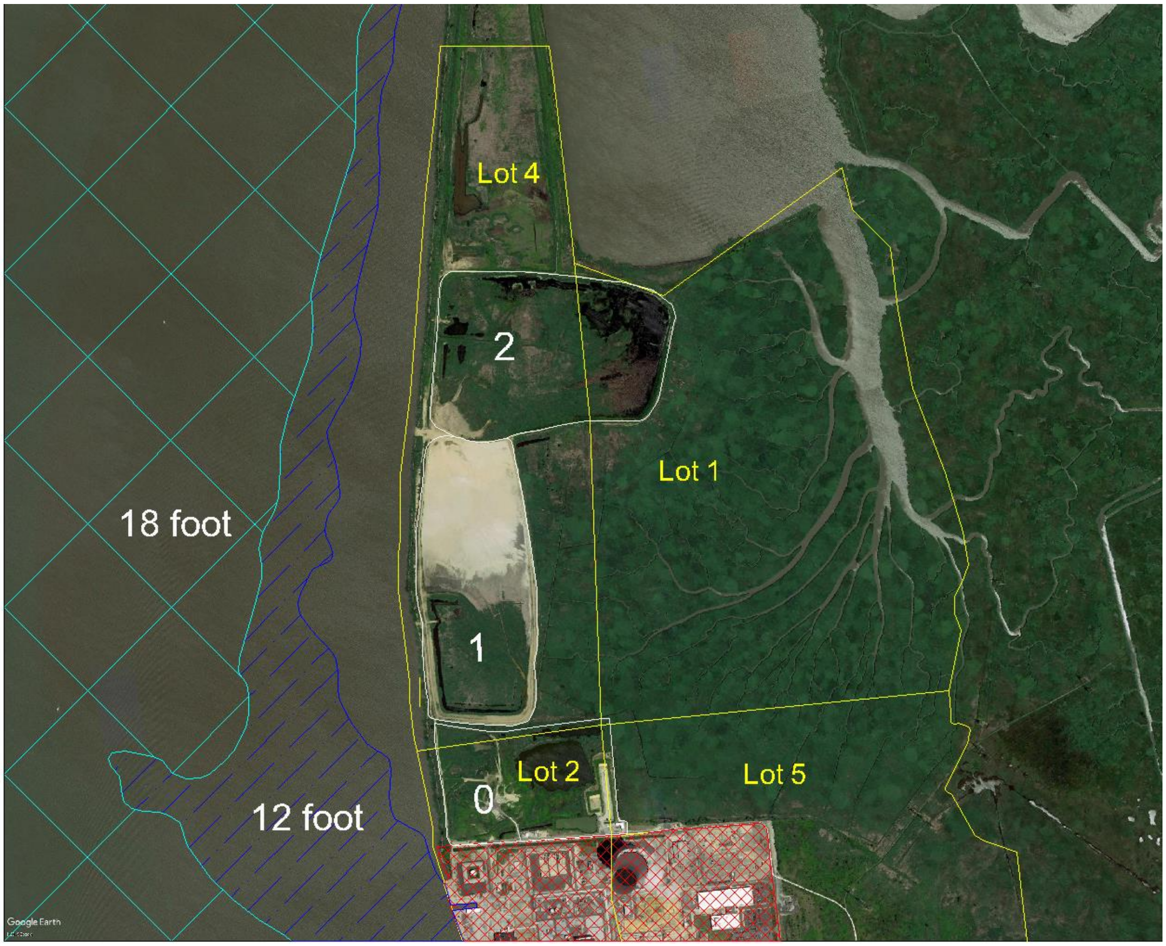

Figure 2: Property map for the New Jersey site, located in Lower Alloway Creek township in Salem County, NJ. Yellow lines are parcel lines indicating ownership[60], white lines represent dredge spoil areas, red hatched areas are unavailable for use, and royal and teal blue hatched lines indicate the area where there is a 12 and 18 foot deep contour in the Delaware River, respectively[57]. Areas will henceforth be referred to as Area 0, 1, 2, and the PSE&G reactor site[58].

Table 2: Area of Parcel Properties of New Jersey site. The total New Jersey site area is calculated by adding all the land Areas 0, 1, and 2. Site areas are measured from the white lines outlined in Figure 2.

Parcel	Area (acre)	Area (hectares)
Area 0	61.7	25
Area 1	95.7	38.7
Area 2	108	43.6
Total New Jersey site	265	107.3

[60] https://www.njmap2.com/parcels/all

II. Hydrological Conditions

A. Site Hydrologic Information

Watersheds are areas of land that drain into a river, stream, or lake network that later converge to an outlet such as the Delaware Bay. Having a basic understanding of the watersheds, hydrology, and precipitation drainage of the site will help determine which areas of the sites are prone to flooding.

Flooding in the areas along the Delaware Bay is usually related to hurricane-induced high tides (fluvial floods being rare in this region.) Tidal flooding that is experienced in this region is often due to a combination of astronomical forces, winds, and offshore storms[61].

There are several types of tidal tidal floods that affect the Delaware Bay. The first type occurs when wind surge occurring perpendicular to the shore causes tidal flooding along the coastline. Winds from the southeast are associated with hurricanes that can drive water into the bay. Northeast winds can also cause water to flow into the bay due to a temporary increase in ocean tide stage adjacent to the bay entrance. Storm surge, a component of storm tide, is the combination of wind and low pressure at the center of the storm that pulls up water and carries it inland. Tidal flooding results in the infrequent flooding of low-lying areas near the coast that must be accounted for in any engineering specifications.

The Delaware Bay is most vulnerable to tidal floods, and inundation maps produced by the Federal Emergency Management Agency (FEMA)[62] predict the flooding in the area. The General Comprehensive Development Plan[63] designates most of the areas adjacent to the Delaware River and the Delaware Canal for use as agricultural land, open space, or reference area (FIS). This means that the sites are expected to be exposed to frequent tidal flooding. A comprehensive development plan to respond to flooding should be included in any final build designs of the port.

The anticipated tidal flooding determines the flood stage of the site, which is the level at which the overflow of water from natural banks begins to cause damage in the local area of potential development from inundation. Remediation efforts in areas around the site include levees that provide the community some protection against flooding[64]. However, it is noted that levees somewhat protect the land from the 1-percent-annual-chance flood, more commonly known as the 100-year flood[65].

Both the Delaware and New Jersey sites of interest are influenced by similar forces such as flood patterns and tidal inundation from the Delaware River, and climate change. They are both on the Delaware River, the New Jersey site location being on the eastern coast approximately 6 miles downstream of the Delaware site location. Because of their close proximity, the weather and climate of the New Jersey site is similar to the Delaware site. The main differences in their specific hydrological conditions of the two sites are determined by the characteristics of the watersheds.

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61 https://www.nhc.noaa.gov/surge/
62 https://www.fema.gov/flood-mapping-products
63 https://stateplanning.delaware.gov/lup/comprehensive-plan.shtml
64https://riskfinder.climatecentral.org/place/delaware-city.de.us?comparisonType=place&forecastType=NOAA2017_int_p50&level=4&unit=ft
65 https://evogov.s3.amazonaws.com/media/126/media/48965.pdf

Delaware Site:

The hydrology for the Delaware site is determined by the watersheds of Red Lion Creek, Cedar Creek, Dragon Creek, and a number of smaller tributaries which drain to the Delaware River. The climate of New Castle County has average summer temperatures of 83º F, and winters where average winter temperatures are 44º F, and the annual precipitation of the area averages 42-48 inches[66]. This amount of precipitation is generally distributed evenly throughout the year however it increases around late spring and summer.

New Jersey Site:

The hydrology for the New Jersey site is influenced by the watersheds of Alloway and Hope creeks, as well as a wetland stream network which separates an artificial island from mainland New Jersey. The climate of Salem County consists of warm summers with average temperatures of 83º F, and cool winters where average winter temperatures are 44º F, and the mean annual precipitation is 28 - 59 inches[67].

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[66] https://www.nrcs.usda.gov/wps/portal/nrcs/detail/de/home/?cid=nrcs144p2_024936
[67] https://www.nrcs.usda.gov/wps/portal/nrcs/site/nj/home/

B. Existing Wetlands

Wetlands are vital for ecosystem function in a watershed, especially in vulnerable coastal areas. They protect water quality, provide habitats for fish and wildlife, and store floodwaters to prevent further flooding in surrounding areas[68]. Accommodating for existing wetlands is vital to the design of this port and quay so that existing environmental protections concerning wetlands are followed and effects on the environment are minimized. Important information on the classification of existing wetlands on the two sites of interest, provided by US Fish and Wildlife Service National Wetland Inventory (NWI), is listed in Appendix B and summarized below.

The following maps outline wetlands as classified by the NWI[69]. Wetland types are defined by characteristics such as differing flooding frequencies, landscape position, soil saturation and vegetation cover. Classification is done using codes, with each part of the code referring to distinct wetland characteristics being defined under one of the following options: system, subsystem, class, subclass, water regime, and special modifiers[70]. The major wetland types, or systems, are further defined as marine, tidal, lacustrine, palustrine, or riverine. Common NWI classification codes of existing wetlands on the two sites of interest are listed below, and their areas can be seen in Figures 3 and 4.

- E2EM1P - Estuarine deepwater tidal system, intertidal subsystem, emergent and persistent perennial vegetation, persistent subclass, irregularly flooded (less often than daily).
- E2EM1Pd - Estuarine deepwater tidal system, intertidal subsystem, emergent and persistent perennial vegetation, irregularly flooded (less often than daily), partially drained/ditched.
- E2EM1N - Estuarine deepwater tidal system, intertidal subsystem, emergent and persistent perennial vegetation, regularly flooded (at least once daily).
- PUBVx - Palustrine nontidal system, unconsolidated bottom, permanently flooded-tidal, excavated.
- PUBHx - Palustrine nontidal system, unconsolidated bottom, permanently flooded, excavated.
- PFO1R - Palustrine nontidal system, deciduous forested vegetation, seasonally flooded-tidal,
- PEM1Fs - Palustrine nontidal system, emergent and persistent perennial vegetation, semi-permanently flooded, spoil site.
- PEM1Ch - Palustrine nontidal system, emergent and persistent perennial vegetation, seasonally flooded, diked/impounded.
- E1UBL - Estuarine deep-water tidal system, subtidal subsystem, unconsolidated bottom, subtidal permanent flooding,
- PEM5Rh - Palustrine nontidal system, emergent perennial vegetation with phragmites present, seasonally flooded-tidal, diked/impounded.
- L2UBK - Lacustrine systems with low salinity, littoral subsystem, unconsolidated bottom, artificially flooded.

[68] https://www.epa.gov/wetlands/why-are-wetlands-important
[69] https://www.fws.gov/wetlands/data/mapper.html
[70] https://www.fws.gov/wetlands/data/wetland-codes.html

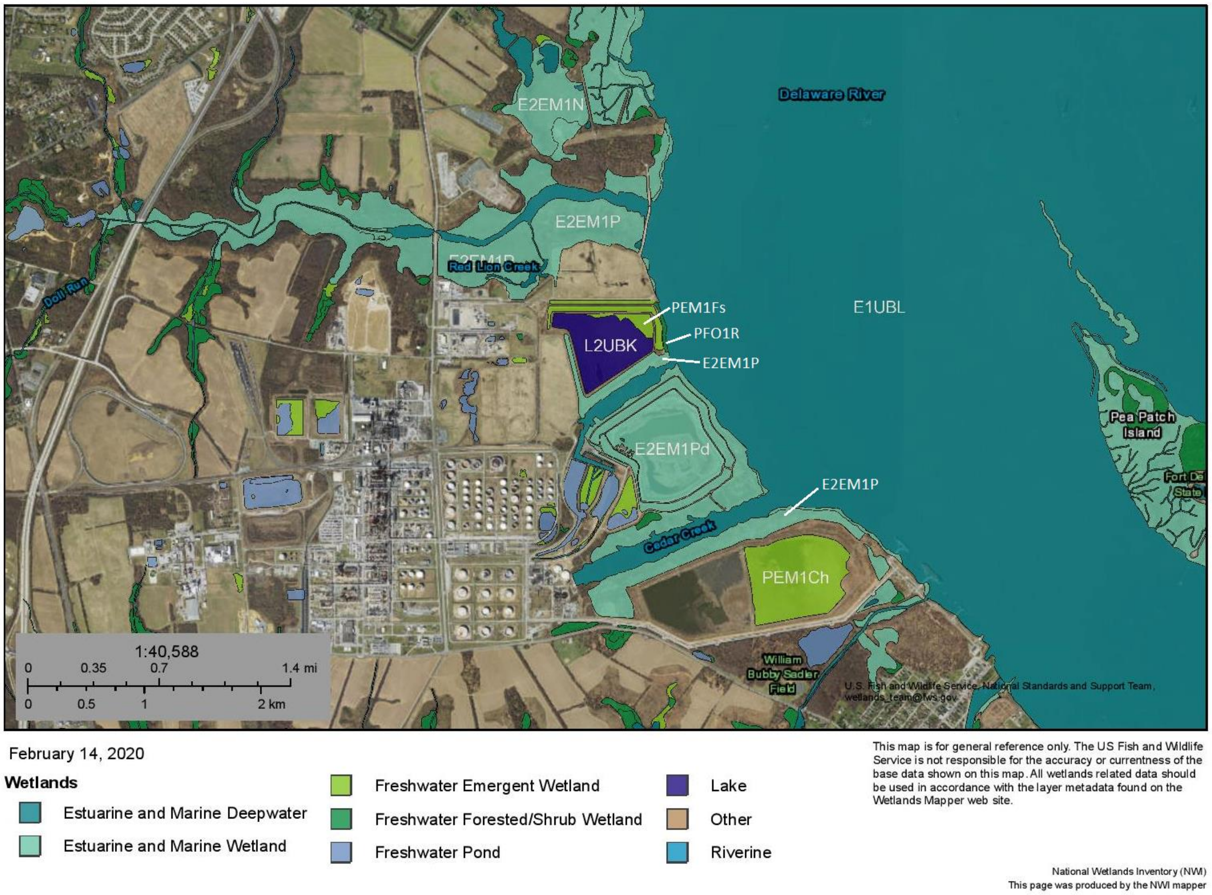

Figure 3: Wetlands present on the Delaware site with wetlands identified and classified by hydrological characteristics and wetland definitions. Information on the characteristics of each of these codes may be found in Appendix B (National Wetlands Inventory)[69].

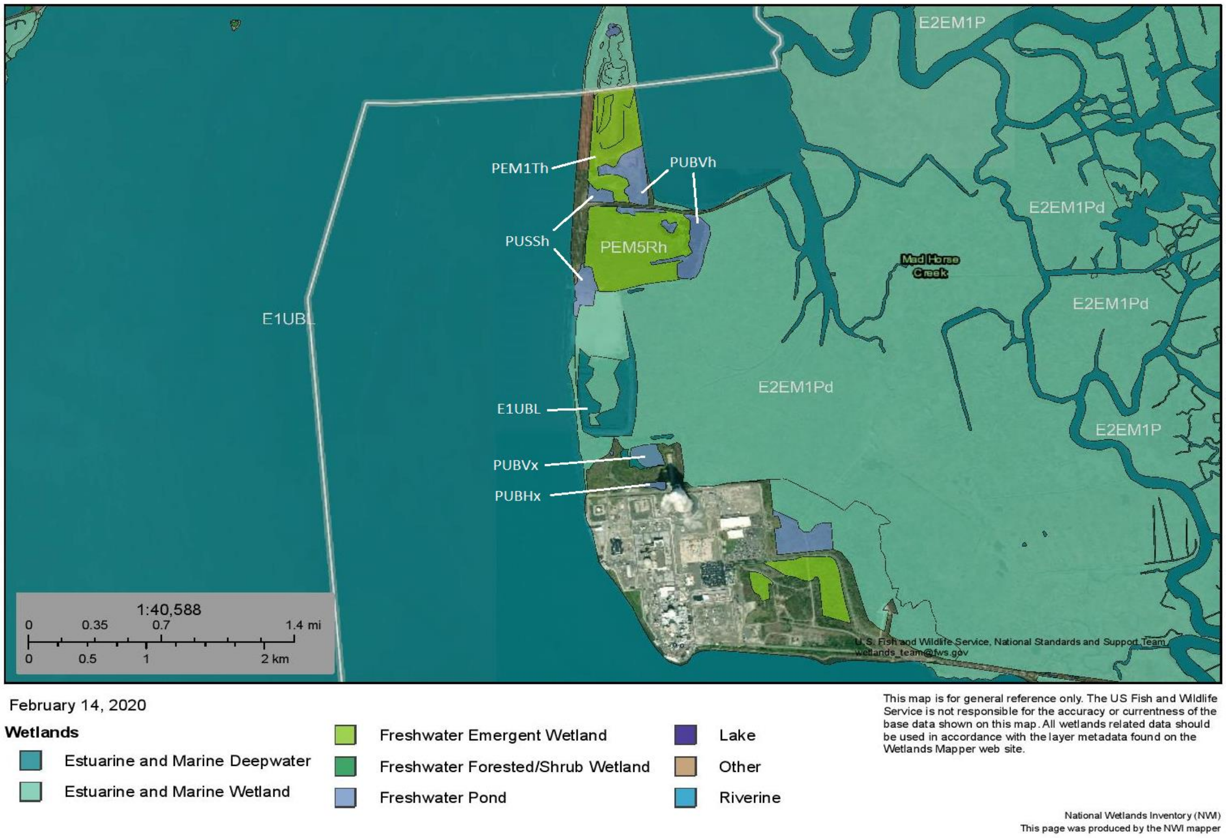

Figure 4: Wetlands present on the New Jersey site with wetlands identified and classified by hydrological characteristics and wetland definitions. Information describing the characteristics of each of these codes can be found in Appendix B (National Wetlands Inventory)[69].

C. Flood Risk Analysis

FEMA defines base flood as the 1-percent-annual-chance flood (or 100-year storm) for floodplain management purposes. Engineering designs generally follow these base floods to add a factor of safety and consider the risk of a natural disaster. Our sites of interest are within the Coastal Flood Zone as defined by FEMA so a basic understanding of the zone designation is needed in considerations for the development of the sites.

Introduction to Coastal Flood Zones:

FEMA has defined a number of coastal flood zones to help manage risk associated with these areas. They have conducted field visits after storms and performed laboratory testing to determine coastal flood hazard areas, concluding that wave heights from as low as 1.5 feet can create significant damage to structures that have not been designed to withstand coastal hazards.

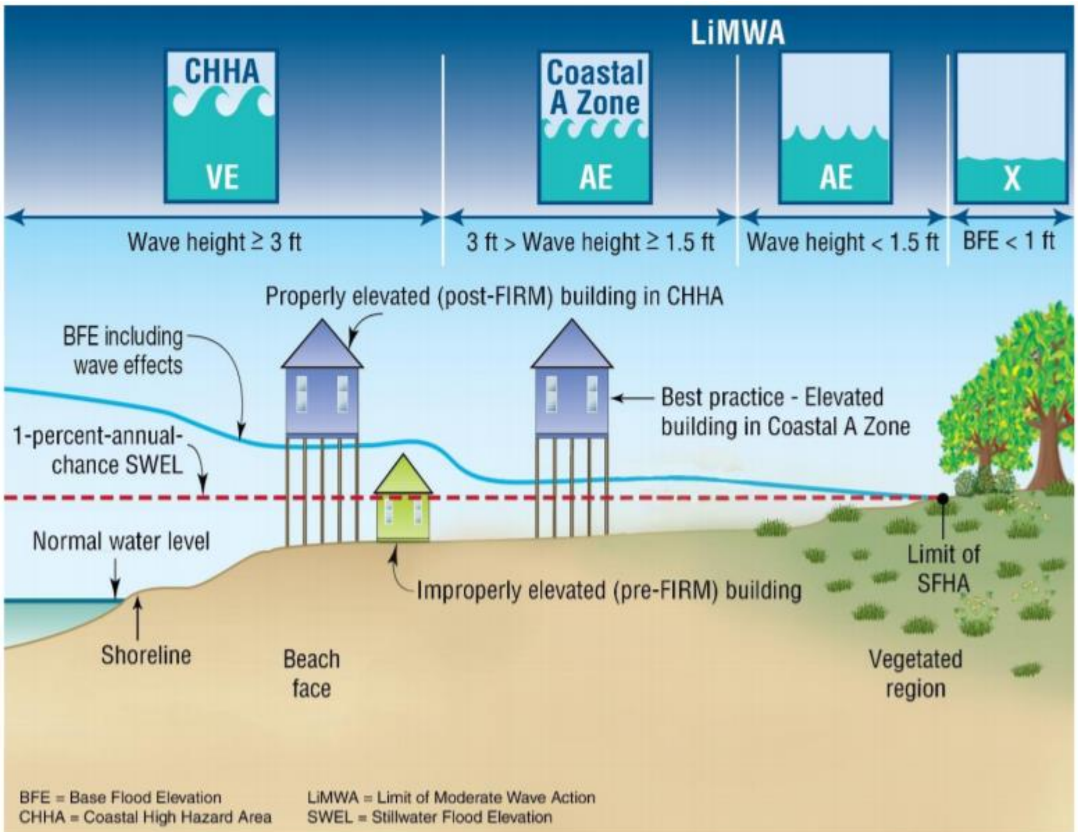

Figure 5: Flooding and wave conditions, intended for safe coastal development practices, Coastal Zone Areas classified by wave height for each zone (FEMA)[71].

Table 3: Flood terms as classified by FEMA for the zones present on the sites of interest, seen in the graphic in Figure 5, and delineated for the two sites in Figures 6 and 7 (FEMA)[72].

[71] https://www.fema.gov/pdf/rebuild/mat/coastal_a_zones.pdf

[72] https://www.fema.gov/national-flood-insurance-program/definitions

Term	Definition
Limit of Moderate Wave Action (LiMWA)	Low-lying coastal lands within the LiMWA boundary are vulnerable to damage from erosion, waves, and storm surge. There is a greater risk of damage on the seaward side of LiMWA, so these areas must either be avoided or built up to standard heights during port construction to avoid damage during storm events.
Special Flood Hazard Areas (SFHA)	An area having special flood, mudflow or flood-related erosion hazards and shown on any Flood Insurance Rate Map (FIRM) Zone.
Base flood	The flood having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the 1-percent-annual chance flood. The base flood is the national standard used by federal agencies for flood insurance and regulating new development.
Base Flood Elevations (BFE)	The elevation of surface water resulting from a flood that has a 1-percent-annual chance of equaling or exceeding that level in any given year. The BFE is shown on the FIRM for all zones
Coastal A Zone	The seaward portion of Zone AE, between Zone VE and LiMWA. This area is subject to flood hazards like floating debris and high-velocity flow that can erode building foundations and cause foundation failure. Base with wave heights less than 3 feet and greater than 1.5 feet.
Zone X	Moderate to Low Risk Area, usually the area between the limits of the 100- year and 500-year floods.
Zone AE	High Risk Areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. BFEs are shown, and wave heights less than 3 feet.
Zone VE	High Risk Coastal Areas subject to inundation by the 1-percent-annual-chance flood event with additional hazards due to storm-induced velocity wave action. BFEs derived from detailed hydraulic analyses are shown. Wave height is greater than 3 feet.

Based on the designation of the SFHAs, the FEMA report advises that structural fill should not be used in the Coastal A zone. Communities that adopt Zone VE building standards, such as Zone VE Building Standards for Coastal Communities, in Coastal A Zones can receive Community Rating System (CRS) credits which will lower flood insurance premiums[73]. As discussed in the table, Zone AE is divided into a seaward Coastal A Zone where construction would be regulated like a VE zone, and a more landward AE Zone where current construction standards would be maintained[74].

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[73]https://www.fema.gov/media-library-data/1517893153030-da3a700b0d220794eda4d6da801798a8/LIMWA_and_Higher_Construction_Standards_fact_sheet_12_18_17_reviewed.2_CLEAN.pdf

[74] https://www.fema.gov/media-library-data/20130726-1541-20490-5411/frm_p1zones.pdf

A major aspect of the FEMA construction standards advises that buildings must be elevated on pile, post, pier, or column foundations. Another standard that must be followed within the Zone VE is that the bottom of the lowest horizontal structural member must be above the BFE or the structure built with flood resistant materials. Specific requirements of building design are referred to in Title 44 Section 60.3 of the Code of Federal Regulations[75].

FIRM Maps

FEMA developed floodplain boundary data for most US coastal areas based on the 1-percent-annual chance flood to determine the BFEs and floodways, with data represented as a FIRM.

The maps are organized as a grid of numerous panels, with each panel having an equivalent area. There are three panels for the Delaware site and two panels for the New Jersey site. To study the 1-percent-annual flood, we analyzed each panel relevant to the sites of interest. Each panel has a map number to easily identify areas and to place map orders. The FIRM panels for the Delaware site were published in 1996 and accessed via on the FEMA website[76]. The panels for the New Jersey site were published in 2016. More information on how to find FIRM is available in the Data Disclaimers: Appendix A section of this report.

FEMA also has spatial data available with the flood hazard areas which was used in this report to create personalized flood risk maps for the sites of interest found in Figures 6 and 7 respectively.

Inundation of the Delaware Site

Some areas of this Delaware site are vulnerable to flooding of the 1-percent-annual chance flood or the SFHA. A large wetland area around the borders of Red Lion Creek experiences frequent inundation as shown Figure 6, due to low topographic elevations and hydric soil type. Zone AE is present here as well as along the canals. Future port developers must be cautious of the potential for flooding and retain enough undeveloped land to preserve the natural functions of the floodway. This will require the inclusion of development-free areas on the site in any construction designs.

The inundation does not affect the current engineering recommendations to a high degree, because most of the area around Red Lion Creek that experiences inundation is wetlands. Wetland areas in Zone AE have been determined to be not suitable for construction, as elevations are low and the soil is extremely saturated. They have thus been deemed areas not usable for use in Figure 1. Based on our analysis of the FIRMs, we have concluded that it is better to develop areas further south, away from the wetlands. The lower half of Oxychem, and the Delaware City Refinery's DMSA 1, 2, and 3 (Figure 1) may be usable and relatively clear from the Special Flood Hazard Zones.

Inundation of the New Jersey Site:

The FIRM for the New Jersey site shows some areas of this site are subject to flooding of the 1-percent-annual chance flood or the SFHA (Figure 7). The designated Areas 0, 1, and 2, (Figure 2), show varying amounts of inundation due to flooding. Area 0 has an area that is designated to be half Zone X and half Zone AE. Area 1 shows that approximately three quarters of the site is designated Zone AE. All of Area 2 is designated as Zone X. The entire coastline of the New Jersey site has a small portion of land classified as Zone VE. Zones characterized as VE and AE pose a definite concern for designers of the

[75] https://www.govregs.com/regulations/expand/title44_chapterI_part60_subpartA_section60.3

[76] https://msc.fema.gov/portal/home

potential port. The quay and laydown area must be built above the BFE or otherwise constructed in the northern area of the site that is less threatened by inundation.

It is assumed that the reactor site was built based on the 100-year flood analysis because there is minimal inundation from the 100-year storm as shown in Figure 7. It is likely that before construction, the area where the reaction site is was significantly inundated and a majority of the land would have been a SFHA. It is noted that the reaction site has experienced minimum inundation because it has been appropriately designed based on this type of storm event. This shows us that it is possible to construct a port next to the coast in this specific area by designing based on the FIRM's 100-year storm predictions.

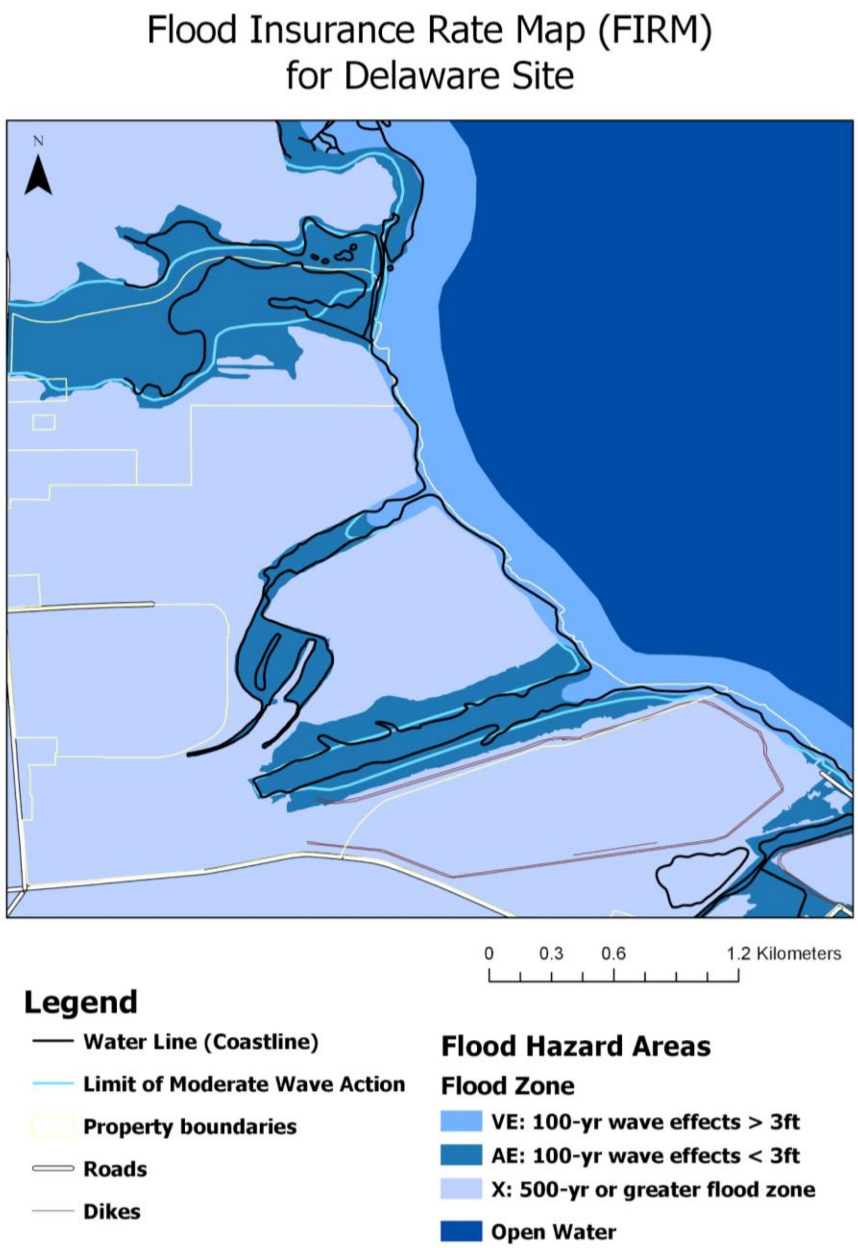
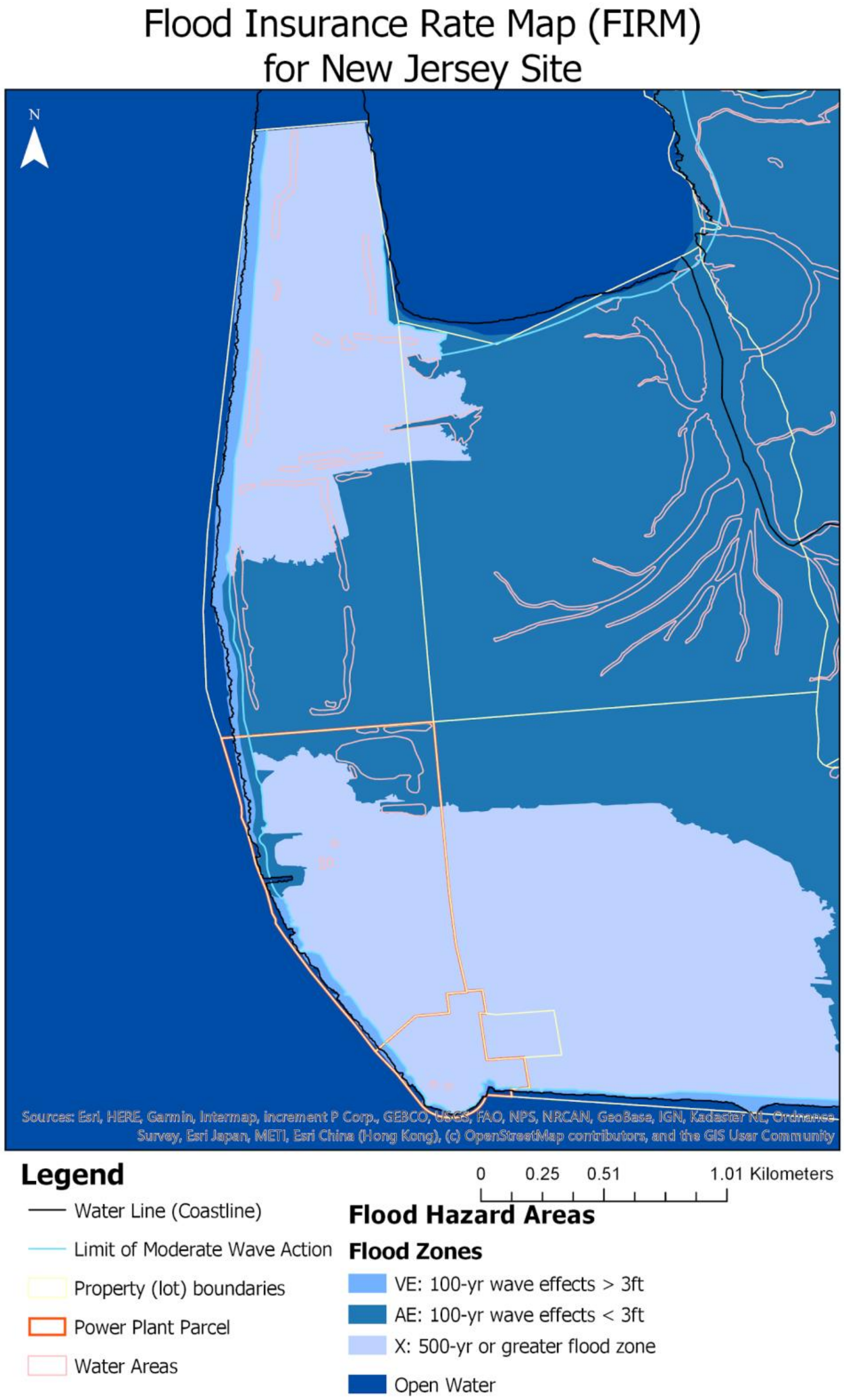


Figure 6: Mapped out 100-year flood event on the Delaware site. Flood Hazard Areas are depicted in blue-scale and their inundation over the coast can be considered according to the shoreline in black (FEMA National Flood Hazard Layer)[77].



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77 https://www.fema.gov/national-flood-hazard-layer-nfhl

Figure 7: Mapped out 100-year flood event on the New Jersey site. Flood Hazard Areas are depicted in blue-scale and their inundation over the coast can be considered according to the shoreline in black (FEMA National Flood Hazard Layer)[77].

D. Tidal Analysis

In order to accurately evaluate the tidal effects on the sites of interest, mean and peak tide height data from meteorological and water level stations in the area were referenced. The Delaware City gauge located in the Delaware River, station number 8551762, was used to evaluate the Delaware site[78]. The Delaware City gauge is located at latitude 39.58°N and longitude 75.58°W. The Reedy Point gauge located in the Chesapeake and Delaware canal, station number 8551910, was used to evaluate the New Jersey site[79]. The Reedy Point gauge is located below the Fort Dupont State Park and is at the location with latitude: 39.55° N and longitude: 75.57° W (Figure 8). For these sources, the horizontal datum spatial reference is NAD83/WGS84. The water level of Reedy Point station is 4.33 feet and Delaware City is 4.71 feet.

However, uncertainty arises when referencing these gauges due to their distance from the sites. For the Reedy Point reference, its location on the Chesapeake & Delaware canal rather than the Delaware River must be accounted for. As a result, the Reedy Point station may experience different water levels than the New Jersey site itself, but it is the closest estimate readily available at this time. Therefore, the application of the conclusions from this section for the New Jersey site should be taken as an assumption.

Figure 8: Location of the Delaware City and Reedy Point meteorological and water level stations for the analysis of the Delaware and New Jersey sites, respectively (NOAA Tides and Currents)[78].

The common definition is the stage at which overflow of the natural banks of a stream begins to cause damage in the local area from inundation (flooding)[80]. There are four different flood stages that are measured in stream gauges and can represent varying degrees of inundation along the banks (Figure 9). The four stages are major, moderate, normal, and low. The values for each for the Reedy Point gauge are as follows; the major flood stage is 9.2 feet, the moderate flood stage is 8.2 feet, the minor flood stage is

[78] https://tidesandcurrents.noaa.gov/stationhome.html?id=8551910
[79] https://tidesandcurrents.noaa.gov/stationhome.html?id=8551762
[80] https://water.usgs.gov/wsc/glossary.html#Floodstage

7.2 feet, and the low flood stage is -2 feet[81]. The moderate flood stage is the point where the inundation of buildings can occur, as water can overtop the natural dune and minor flooding is expected at this level and few buildings are expected to be inundated.

The different tide levels constitute the datum from which observed tide information is referred. Mean Lower Low Water (MLLW) is “the average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch” is where widespread flooding occurs and may become a danger[82]. At this height roadways near the bay, river, and tidal tributaries in New Castle County will begin to flood. For the Reedy Point gage, the MLLW was last reached on April 16, 2011, with a height 9.24 feet These values in Figure 11 below are the historic crests of the ten highest wave peaks for the Reedy Point gauge. Historic crests are the tallest waves during a flood/storm event, so they should be used in the design of a future port along with flood stages.

For the Delaware City gauge, the major flood stage is 9.5 feet with a record of 9.7 feet, the moderate flood stage is 8.5 feet, the minor flood stage is 7.5 feet, and the low flood stage is -2 feet[83]. Again, the moderate flood stage of 8.5 feet is where water may be inundated over the natural dune and cause flooding. The record flood height MLLW of 9.73 feet was reached on October 30, 2012 when Hurricane Sandy hit the US east coast. This height should be taken into account when designing the quay height and resilience plan for this project, as large storms are expected to cause similar wave crests and flood heights increasingly into the future[84].

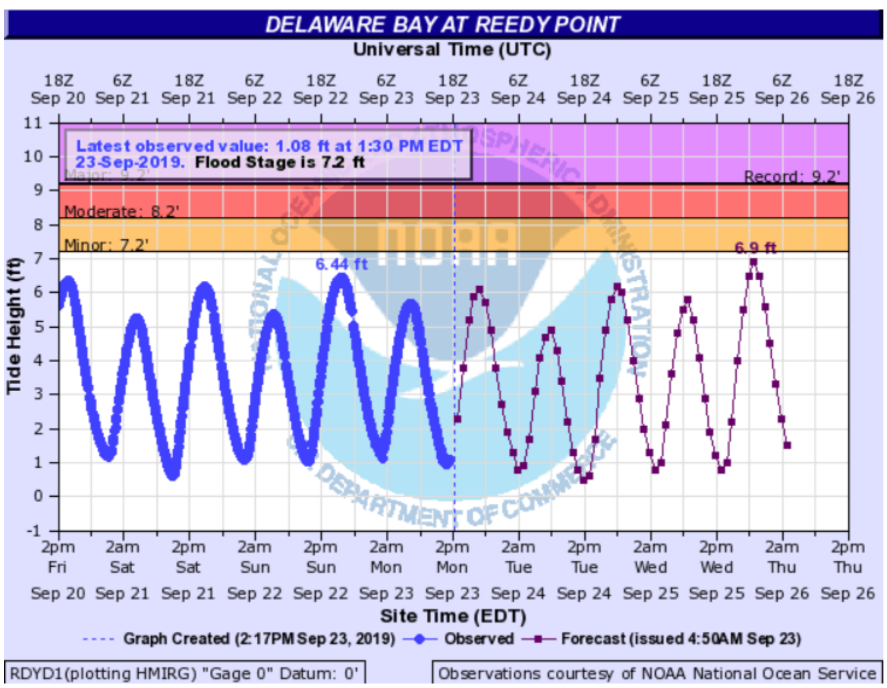


Figure 9: Recent Tide Height graph for the Reedy Point tidal gauge for September 20- 26, 2019 (National Weather Service)[81].

[81] https://water.weather.gov/ahps2/hydrograph.php?wfo=phi&gage=rdyd1
[82] https://tidesandcurrents.noaa.gov/datum_options.html
[83] https://water.weather.gov/ahps2/hydrograph.php?wfo=phi&gage=deld1
[84] https://climateactiontool.org/content/storms-and-floods

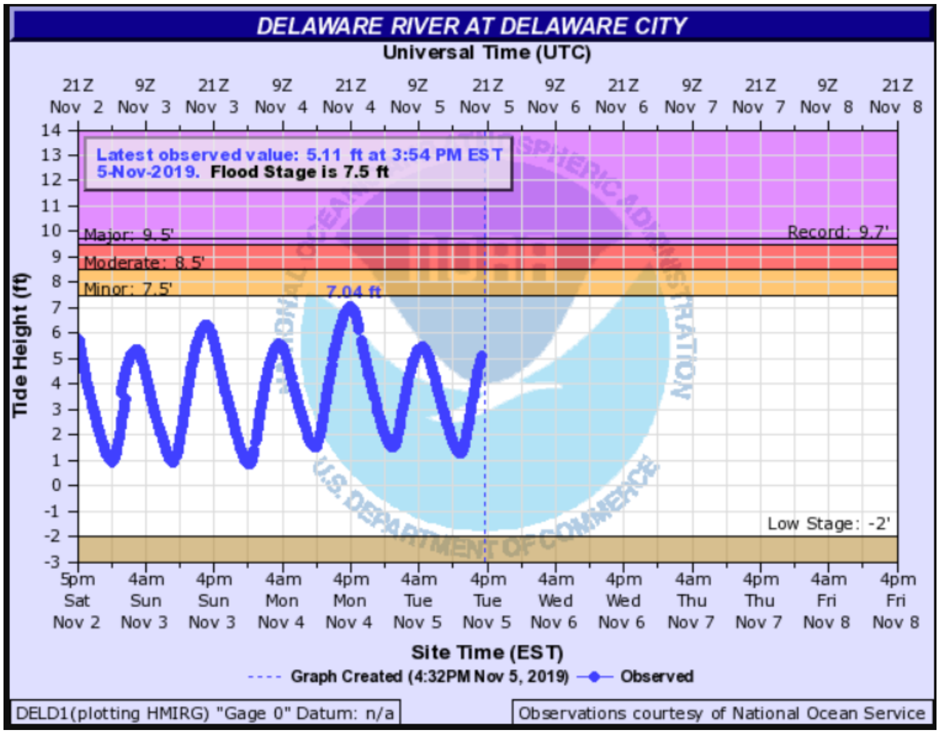


Figure 10: Recent Tide Height graph for the Delaware City tidal gauge for November 2-5, 2019 (National Weather Service)[83].

Historic Crests - Reedy Point		
Rank	Height (ft)	Date
1	9.24	4/16/2011
2	9.19	12/21/2012
3	9.1	10/30/2012
4	8.88	10/25/1980
5	8.66	9/19/2003
6	8.62	9/10/2018
7	8.33	5/12/2008
8	8.33	12/11/1992
9	8.28	11/28/1993
10	8.25	5/1/2014

Figure 11: List of historic crests observed with the Reedy Point gauge, corresponding to the tidal height graph in Figure 10 (National Weather Service 2019)[81].

Historic Crests - Delaware City		
Rank	Height (ft)	Date
1	9.73	10/30/2012
2	9.47	12/21/2012
3	9.38	4/16/2011
4	9.13	5/12/2008
5	9.09	9/10/2018
6	8.83	8/27/2011
7	8.72	1/23/2016
8	8.71	9/19/2003
9	8.46	5/1/2014

Figure 12: List of historic crests observed with the Delaware City gauge, corresponding to the tidal height graph in Figure 11 (National Weather Service 2019)[83].

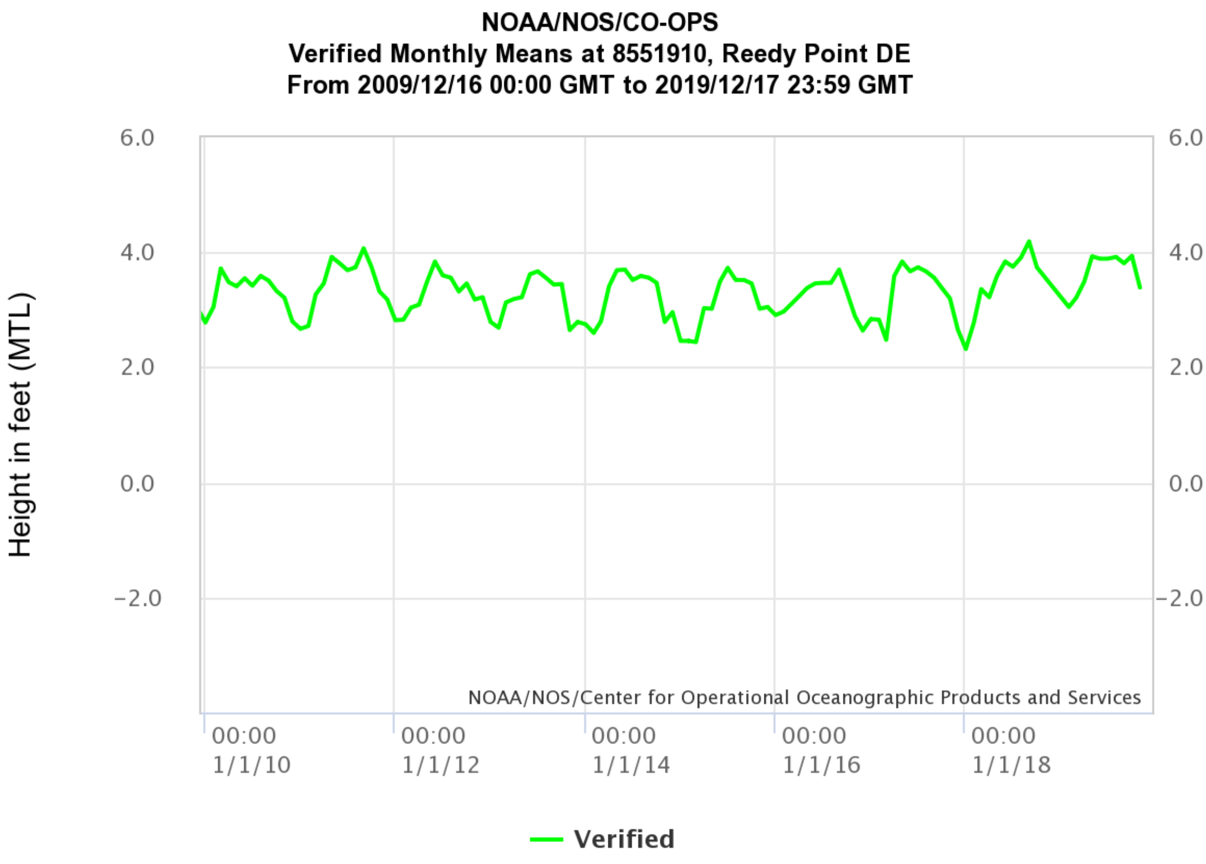


Figure 13: Tide height graph showing the daily tide changes for the Reedy Point gauge with a datum of MTL and the data graphed is the MHHW (NOAA Tides and Currents)[85].

[85] https://tidesandcurrents.noaa.gov/waterlevels.html?id=8551910

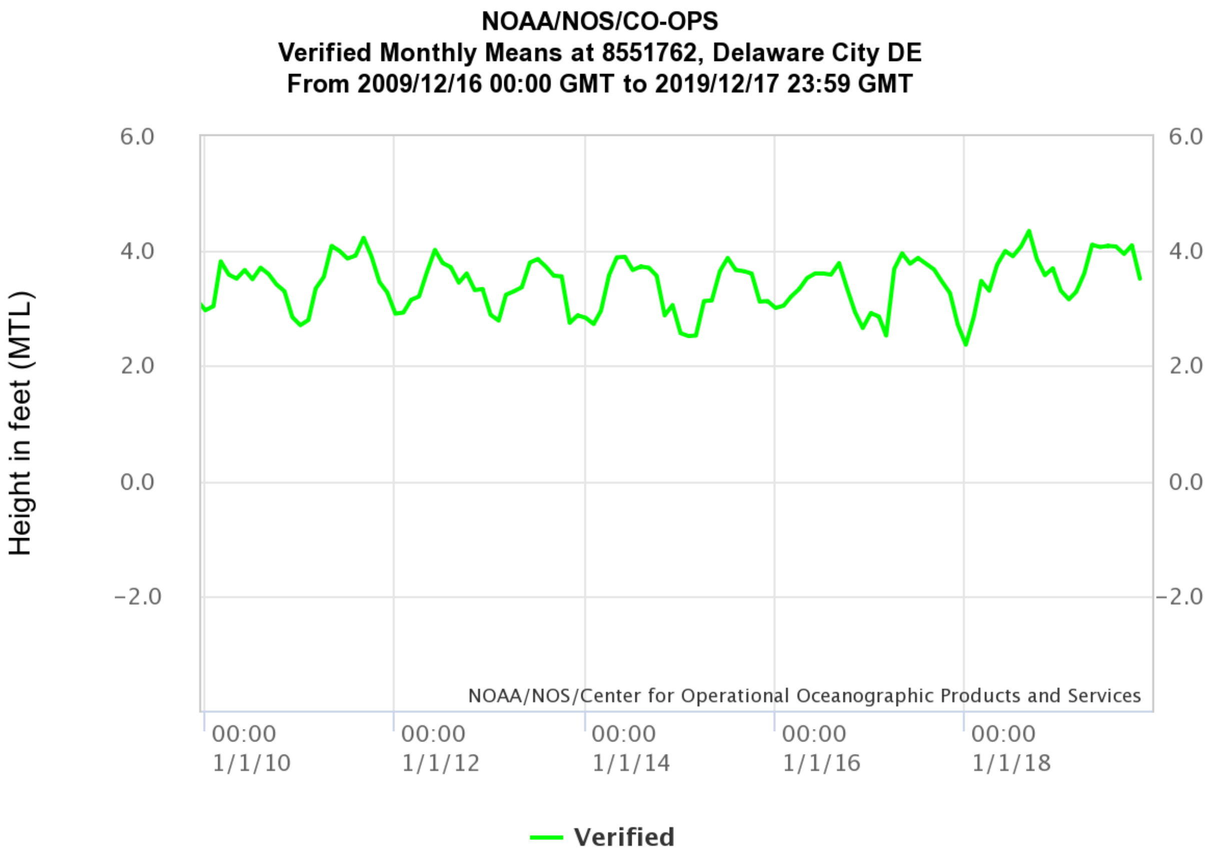


Figure 14: Tide height graph showing the daily tide changes for the Delaware City gauge with a datum of MTL and the data graphed is the MHHW (NOAA Tides and Currents)[86]*.*

[86] https://tidesandcurrents.noaa.gov/waterlevels.html?id=8551762

E. Climate Change Analysis

Not only do daily tides and historic data need to be considered in the analysis of the hydrologic conditions of the sites on the Delaware River, long-term sea level rise and future tide predictions should also be incorporated. Since Delaware and areas of New Jersey are low lying coastal zones, consideration of sea-level rise trends is essential to a sustainable port that is designed for future environmental changes to the land area. NOAA has abundant data on sea level data and has analyses on sea-level trend predictions, as shown for the Reedy Point gauge. As shown in Figure 15, the relative sea-level trend is an increase of 3.6 millimeters per year.

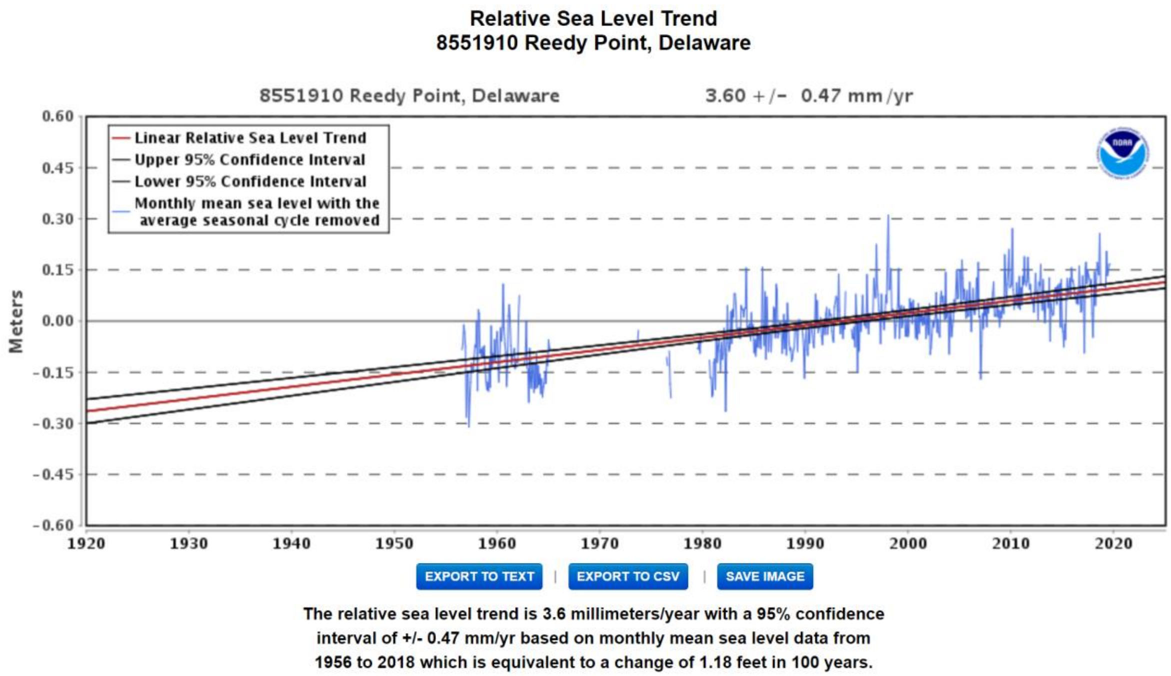


Figure 15: Reedy Point gauge linear relative Sea Level Trend shows a rise of 3.6 mm/yr using historical tide observation data (NOAA)[87].

Another source, Climate Central, uses spatial analysis to visually demonstrate this rate of sea level rise value in the form of inundation of the water line expected by 2050. Their coastal risk screening tool[88] uses a model with a P50 estimate, of which 50% of estimates exceed and 50% of estimates fall below. This P50 estimate shows the land area at risk of being below Mean High High Water (MHHW) tide line, or the "average of the higher high water height of each day observed over the National Tidal Datum Epoch" by the year 2050 due to sea level rise (Figures 16 and 17).[89] Land areas indicated as "at risk" by the tool are determined to be unfit to build on in their current condition because of the evident risks in the near future. These maps are different from the FEMA maps because instead of representing a design storm's potential strength in today's climate, they indicate a trend of increasing storm intensity

[87] https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8551910
[88]https://coastal.climatecentral.org/map/12/-73.9605/40.7101/?theme=sea_level_rise&map_type=year&contiguous=true&elevation_model=best_available&forecast_year=2050&pathway=rcp45&percentile=p50&return_level=return_level_1&slr_model=kopp_2014
[89] https://tidesandcurrents.noaa.gov/datum_options.html

through 2050. Due to scientifically validated climate change predictions, the same 100-year storm accounted for in FEMA maps will have a greater impact in the year 2050.

Analysis of the P50 estimates have shown that the Delaware site location is predicted to experience moderate inundation at the Cedar Creek canal and minimal inundation along the southern coast of the Delaware City Refinery property and DMSA2 (Figure 16). The northern section of the parcels including the Oxychem property are not expected to be as affected by sea-level rise due to their higher elevation at the coast.

The New Jersey site faces a more serious threat from sea-level rise. The rise in the water level of the Delaware River will have direct influence on the large Alloway and Hope Creeks which determine the hydrologic conditions east of the New Jersey site. Climate Central delineates the desired port location parcels as moderately at risk along the coast with extreme inundation to the east and in the stream network (Figure 17).

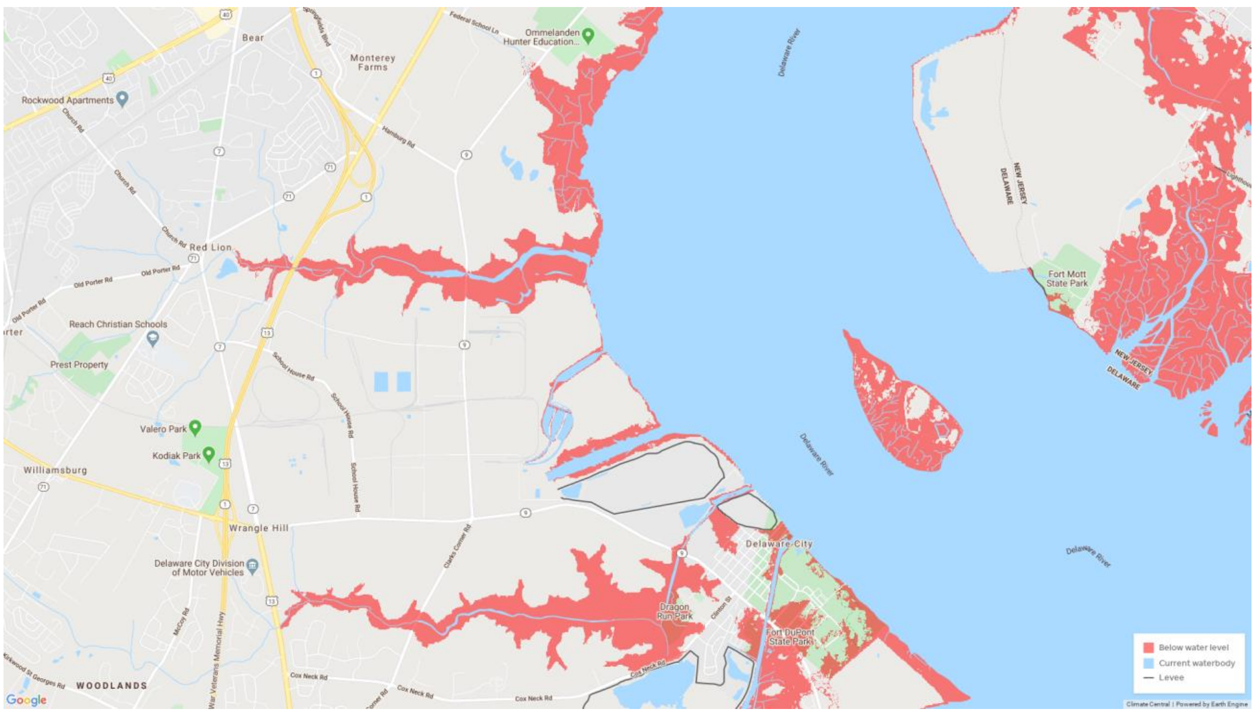


Figure 16: Impact of land area due to sea level rise by 2050 for the Delaware port option, estimated using the coastal risk screening tool (Climate Central, 2014)[88]. The red color is the inundation of land at risk of sea level rise.

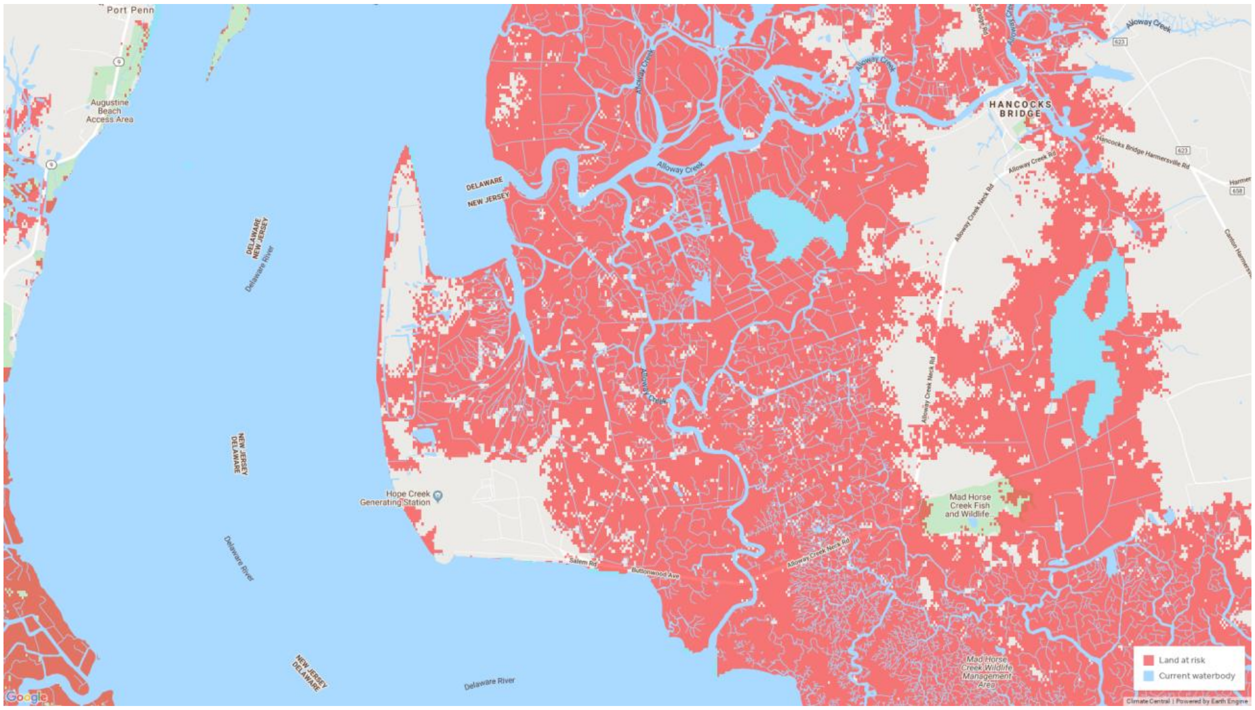


Figure 17: Impact of land area due to sea level rise by 2050 for the New Jersey port option, estimated using the coastal risk screening tool (Climate Central)[88]. The red color is the inundation of land at risk of sea level rise.

II. Topography

A. Topographic Map

The topographic maps taken from the USGS Quadrangle map[90] indicate the elevations for the area of each site (Figures 18 and 19). The thin brown lines indicate contour lines, the blue symbols indicate a significantly wet area, and the inward tick-marks indicate lower elevation contour lines. The 25 foot contour lines are indicated in the maps shown below, but more precise contour lines and elevation information may be found by examining the source as shown in the point elevations section.

Since elevation is an important factor for building on coastal sites, these maps offer valuable information for site design and practical application of a deployment port on these properties. Quay and laydown area placement must be determined with consideration given to elevation at the coastline, surface slope, and the existence of wetlands.

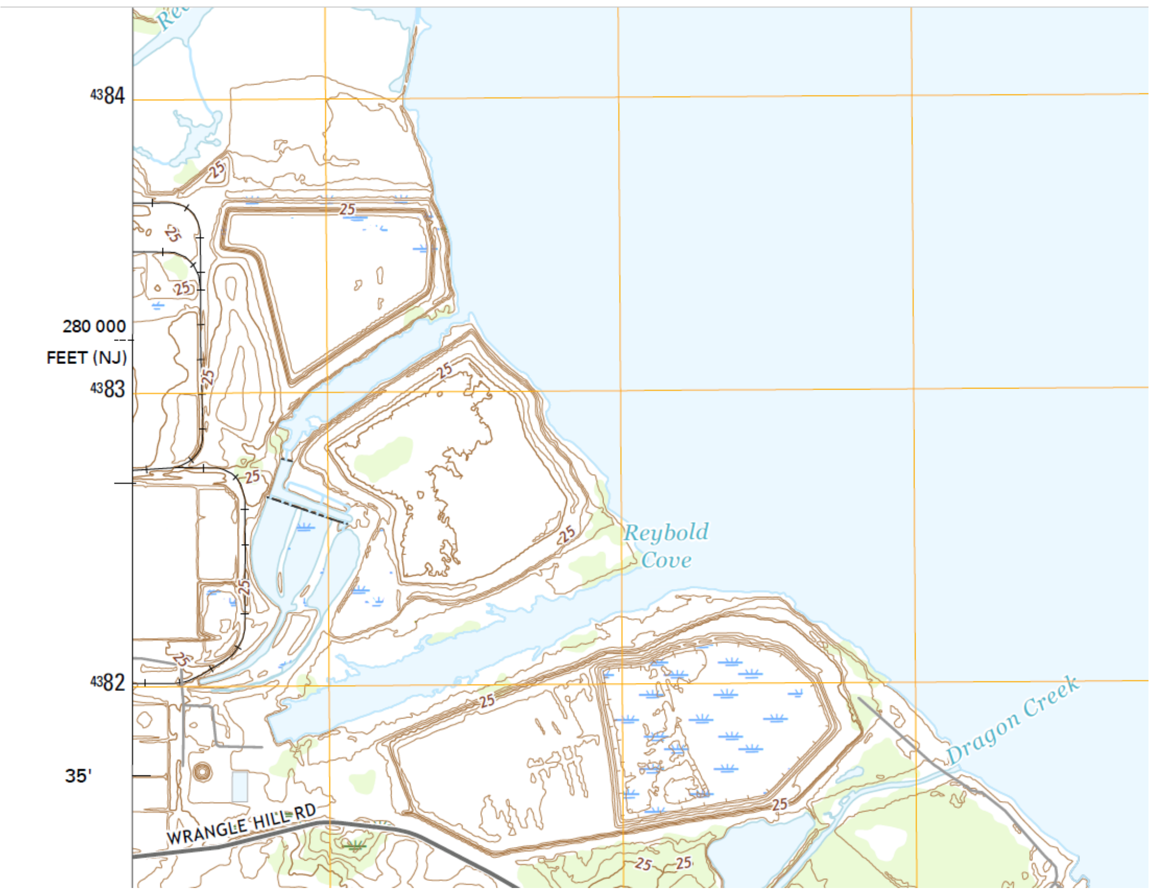


Figure 18: The quadrangle topographic map of the Delaware site, with contour lines indicating elevation and other land and water features (USGS National Map)[90].

[90] https://www.usgs.gov/core-science-systems/national-geospatial-program/topographic-maps

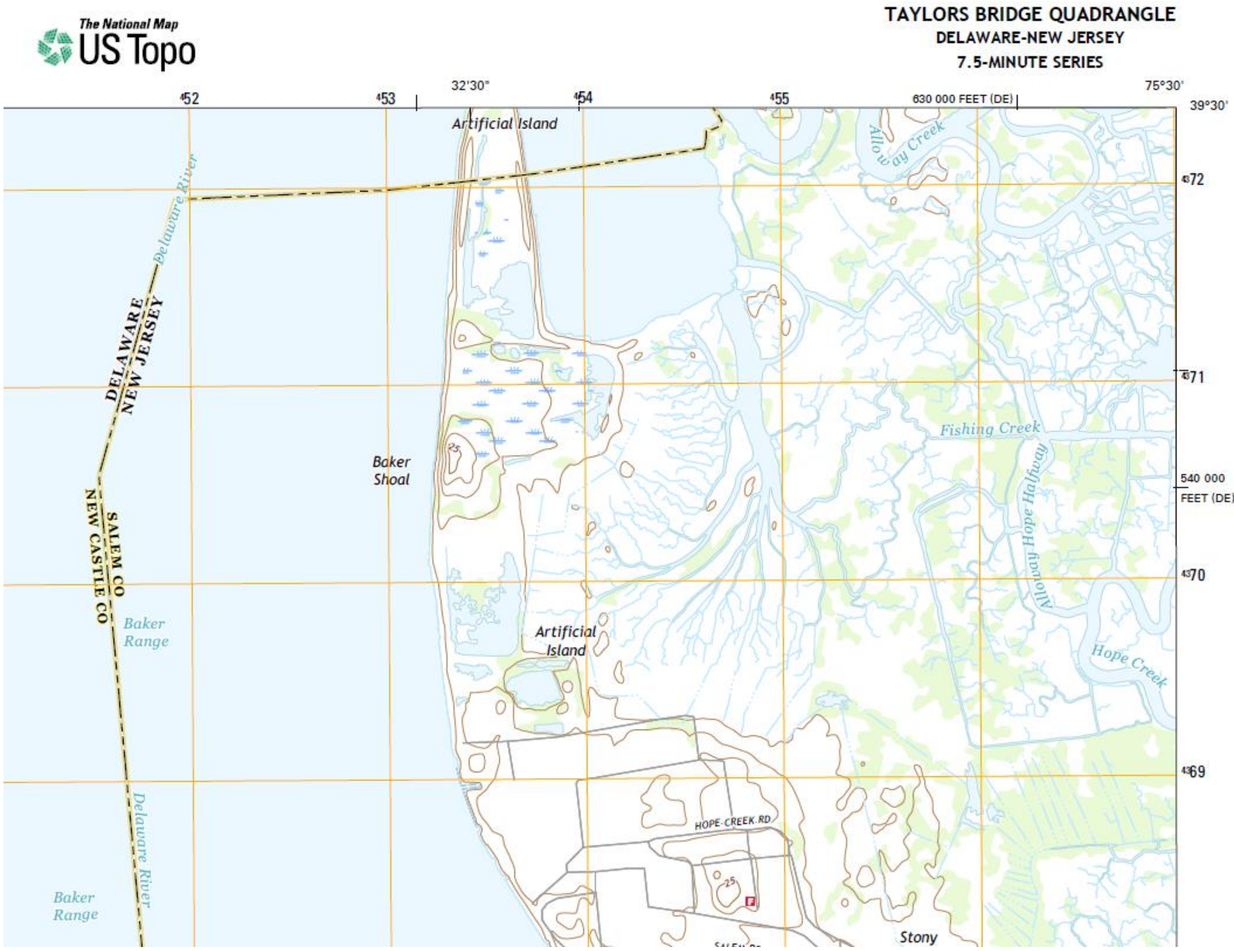


Figure 19: The quadrangle topographic map, "Taylors Bridge Quadrangle" of the New Jersey site, with contour lines indicating elevation and other land and water features (USGS National Map)[90].

B. Point Elevations

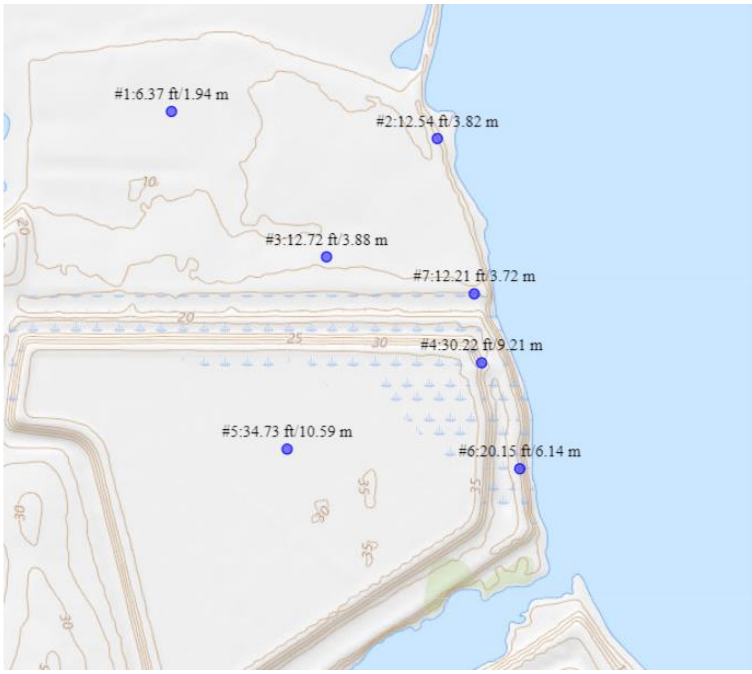
Spot elevations are measured using the USGS National Map Viewer Spot Elevation tool[91] based on an interactive topographic map tool. The three-dimensional software is from the National Geospatial Program. The Elevation Point Query Service returns the elevation in feet or meters for any latitude, longitude coordinate pair according to the North American Datum (NAD1983). The service interpolates the elevation from the highest resolution DEM data set that is a ⅓ arc- second layer.

We chose varying points throughout the sites to analyze to determine the elevation along the coasts, further inland, and special areas of interest like ponds or dikes. This will give useful preliminary information on current sites' topographic conditions. Contractors will use topographic information to design a port with laydown and quay areas above sea level and compliant with coastal building standards. Figures 20-25 show specific spot elevations that are critical to the area that will potentially be developed into a marshalling port.

Delaware Site:

Due to the man-made spoils distributed along the sections of the Delaware site, the topographic elevations and the slopes are higher in some places than where it would be naturally. The topographic elevations of the Oxychem property ranges from 6 to 12 feet as demonstrated by points 1, 2, 3, and 7 in Figure 20, DMSA1 has elevations between 20 to 30 feet as shown by points 4, 5, and 6 in Figure 20. The topographic elevations of the DMSA2 range from 4 to 28 feet as shown by points 1 through 7 in Figure 21. Along the bayside, the elevations begin at 5 feet and increase inland to between 12 to 28 feet. DMSA3A has elevations ranging from 7 to 39 feet as shown by points 1 through 7, 11 and 12 in Figure 22. The shaded wetlands symbol does not affect the elevation of the site as there is no significant difference in elevation between the marked wetlands and the non-wetlands area. DMSA3B has elevations ranging from 27 to 30 feet as shown by points 8, 9, 10 in Figure 23.

[91] https://viewer.nationalmap.gov/advanced-viewer/



Click 'Activate' button and click on the map to retrieve elevation.

Deactivate

Pause Point Query

Point Query Status: Active

#	Lat	Lon	Elev (ft)	Elev (m)
1	39.60374	-75.61863	6.37	1.94
2	39.60337	-75.61399	12.54	3.82
3	39.60179	-75.61592	12.72	3.88
4	39.60037	-75.61322	30.22	9.21
5	39.59921	-75.61661	34.73	10.59
6	39.59894	-75.61256	20.15	6.14
7	39.60129	-75.61335	12.21	3.72

Figure 20: Point elevations for the Delaware site option: Oxychem and DMSA1. Points referred to in the analysis with their coordinates and elevations above sea level are shown to the right of the map image (USGS National Map Viewer Spot Elevation tool)[90].

Click 'Activate' button and click on the map to retrieve elevation.

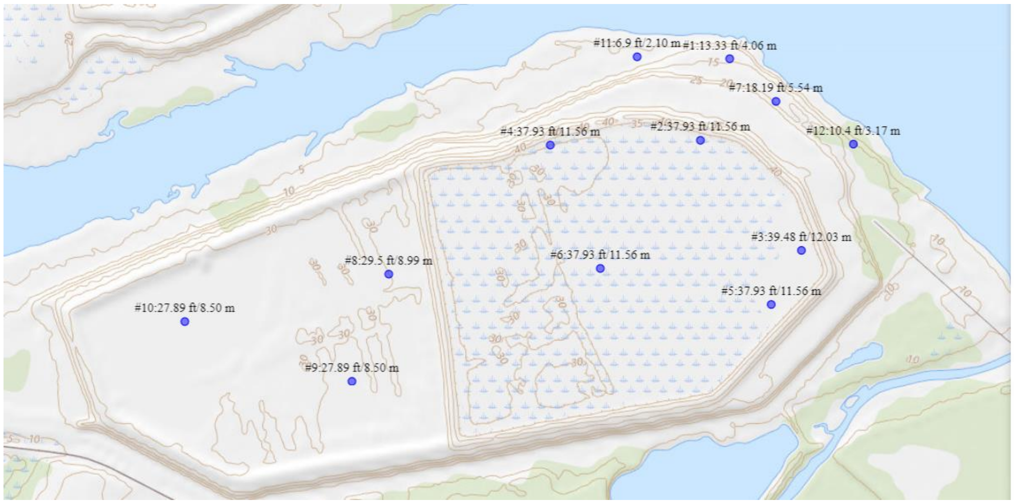
Deactivate

Pause Point Query

Point Query Status: Active

#	Lat	Lon	Elev (ft)	Elev (m)
1	39.59641	-75.61118	21.99	6.70
2	39.59474	-75.61339	19.56	5.96
3	39.59369	-75.60968	27.75	8.46
4	39.59367	-75.61206	14.38	4.38
5	39.59311	-75.60732	4.66	1.42
6	39.59159	-75.61073	25.88	7.89
7	39.59314	-75.61526	11.54	3.52

Figure 21: Point elevations for the Delaware site option: DMSA2. Points referred to in the analysis with their coordinates and elevations above sea level are shown to the right of the map image (USGS National Map Viewer Spot Elevation tool)[90].



Deactivate

Pause Point Query

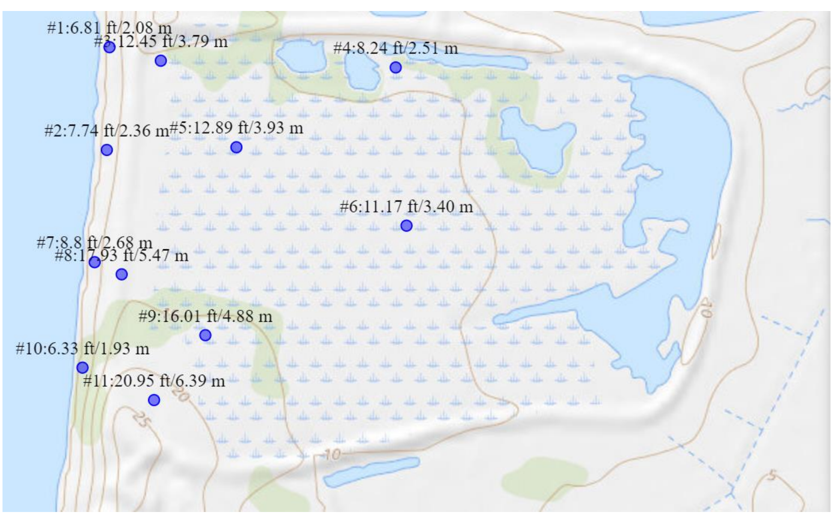
Point Query Status: Active

#	Lat	Lon	Elev (ft)	Elev (m)
1	39.58854	-75.59944	13.33	4.06
2	39.58712	-75.60011	37.93	11.56
3	39.58520	-75.59781	39.48	12.03
4	39.58704	-75.60352	37.93	11.56
5	39.58426	-75.59850	37.93	11.56
6	39.58489	-75.60238	37.93	11.56
7	39.58780	-75.59839	18.19	5.54
8	39.58479	-75.60719	29.5	8.99
9	39.58292	-75.60803	27.89	8.50
10	39.58396	-75.61183	27.89	8.50
11	39.58858	-75.60155	6.9	2.10
12	39.58706	-75.59663	10.4	3.17

Figure 22: Point elevations for the Delaware site option: DMSA3A and DMSA3B. Points referred to in the analysis with their coordinates and elevations above sea level are shown to the right of the map image (USGS National Map Viewer Spot Elevation tool)[90].

New Jersey Site:

The topographic elevations for the New Jersey site are represented in Figures 24-26. As shown in Figure 24, Area 2 at the northern part of the site has elevations ranging from 2 to 21 feet, demonstrated by points 1 through 10. Point 6 has been ignored because it is negative so this indicates it is below sea level in the water. This section of the site has a substantial amount of water within its craters, yielding lower elevations. For the second section of the site shown in Figure 25, designated Area 1, the elevations range from 6 to 21 feet as shown by points 1-11. For the third section of the site, shown in Figure 26 and designated Area 0, elevations range from 0 to 7 feet.



Pause Point Query

Point Query Status: Active

#	Lat	Lon	Elev (ft)	Elev (m)
1	39.48906	-75.54304	6.81	2.08
2	39.48780	-75.54308	7.74	2.36
3	39.48890	-75.54222	12.45	3.79
4	39.48881	-75.53849	8.24	2.51
5	39.48784	-75.54102	12.89	3.93
6	39.48688	-75.53832	11.17	3.40
7	39.48643	-75.54327	8.8	2.68
8	39.48628	-75.54284	17.93	5.47
9	39.48554	-75.54152	16.01	4.88
10	39.48515	-75.54347	6.33	1.93
11	39.48475	-75.54233	20.95	6.39

Figure 23: Point elevations for the New Jersey site option: Area 2. Points referred to in the analysis with their coordinates and elevations above sea level are shown to the right of the map image (USGS National Map Viewer Spot Elevation tool)[90].

Deactivate

Pause Point Query

Point Query Status: Active

Error-Service unavailable.

#	Lat	Lon	Elev (ft)	Elev (m)
1	39.48374	-75.54366	8.08	2.46
2	39.48258	-75.54386	3.3	1.01
3	39.48190	-75.54345	7.16	2.18
4	39.48327	-75.54263	23.25	7.09
5	39.48260	-75.54197	16.21	4.94
6	39.48061	-75.54396	3.57	1.09
7	39.47996	-75.54369	7.24	2.21
8	39.47693	-75.54345	2.01	0.61
9	39.47971	-75.54132	7.28	2.22
10	39.48177	-75.54160	13.87	4.23

Figure 24: Point elevations for the New Jersey site option: Area 1. Points referred to in the analysis with their coordinates and elevations above sea level are shown to the right of the map image (USGS National Map Viewer Spot Elevation tool)[90].

Deactivate

Pause Point Query

Point Query Status: Active

#	Lat	Lon	Elev (ft)	Elev (m)
1	39.47592	-75.54336	0.65	0.20
2	39.47471	-75.54293	7.35	2.24
3	39.47357	-75.54276	5.42	1.65
4	39.47269	-75.54293	1.34	0.41
5	39.47125	-75.54270	2.07	0.63
6	39.47108	-75.54092	11.5	3.51
7	39.47216	-75.54173	11.34	3.46
8	39.47367	-75.54075	8.11	2.47
9	39.47267	-75.53993	14.07	4.29
10	39.47436	-75.53886	5.3	1.62

Figure 25: Point elevations for the New Jersey Site Area 0. Points referred to in the analysis with their coordinates and elevations above sea level are shown to the right of the map image (USGS National Map Viewer Spot Elevation tool)[90].

C. Watersheds

The area of the watershed is traditionally calculated from the drainage divide outlined on a topographic map based on elevation contour lines. There is a line of higher elevation ridgeline that distinguishes the border of each watershed. The purpose of the delineation of a watershed is to determine where water flows within the site. This information is crucial to making decisions for the site's stormwater design and ensuring the protection of the health of the watershed.

Impervious cover, or surfaces in the urban landscape that cannot effectively infiltrate rainfall[92], affects the natural surface and subsurface drainage pattern of a watershed. Flowing water is destructive once its velocity and volume increases. Hydrologic elements must provide adequate drainage for road design. For development to be effective throughout its design life, the drainage system has two criteria, minimum disturbance of the natural drainage pattern and the protection of developed areas. This may be done by directing the flow of stormwater away from roads and impervious cover and following the original flow patterns of the watershed.[93]

The identification number or hydrologic unit code for the majority of the Delaware area is HUC-020402050703, for the Red Lion Creek - Delaware River watershed. Hydrologic Unit Codes (HUC) are used to identify watersheds as separate entities as well as describe their interconnectedness and nesting structures. For the New Jersey site area, no true watershed is able to be delineated due to its location in a flat tidal area (See Data Disclaimers Appendix A), but area characteristics are still able to be calculated by the Digital Soil Map of the World (DSMW)[94]. For both of the potential sites, the drainage class is poor and the available water storage capacity is relatively high. The watersheds contain soils similar to those of marshes and/or wetlands.

USGS StreamStats Watershed Delineation Reports:

The watershed basins include important streams and tributaries on and near the sites, which affect the stormwater flow and therefore management strategies for any future development on the site. Through the USGS Streamstats application[95], we delineated the watersheds present on the sites as shown in yellow and the blue marker indicates the point where the water drains to. For example, the Red Lion Creek basin (Figure 26) located on the northern part of the Oxychem site, shows the direction from which water that falls on the area shown in yellow will drain into the Red Lion Creek and eventually the Delaware River.

The StreamStats application produces reports of basins and their associated characteristics[96]. One important characteristic is the percentage of impervious area, which tells how much of the watershed is covered in concrete/asphalt, a material which impedes the movement of water more than soils. Since after development of the quay and laydown area, the site will include impervious cover, it is important to understand how this will affect the drainage of the watershed which might cause flooding in important

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92 https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1280#
93 http://www.fao.org/3/t0099e/t0099e04.htm
94 http://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1026564/
95 https://streamstats.usgs.gov/ss/
96 https://streamstatsags.cr.usgs.gov/ss_defs/basin_char_defs.aspx

areas of the site design. The following section (Stormwater Runoff, Section IID) goes in further detail about the drainage of the watersheds.

Delaware Site Basin Characteristics

The Delaware site is influenced by 8 different watersheds that drain to the Delaware River. Drainage areas of the basins range from 0.08 to 10 square miles, with the largest being Red Lion Creek basin. This basin contains wetlands and significant impervious areas, and has influence on the drainage characteristics of the Northern Oxychem area of the site. DMSA1 drains in two directions to the Delaware River. As the point elevation section indicates, the elevations are higher further inland of the site and lowest along the coastline of the Delaware River. DMSA2 also drains in two directions to each of the surrounding canals. One of the basins (Figure 29) contains the Refinery so over half of the area is impervious. The basin of DMSA3B drains into Cedar Creek and its area also contains parts of the impervious Refinery property, while the basin of DMSA3A is generally contained within its borders, with some of the area flowing towards Dragon Creek. Overall, the Delaware site in its current condition has a minimum impervious area with natural drainage flow to the Delaware River.

Table 4: Basin Characteristics that are important for design for the following watersheds present in the Delaware port option area (USGS Streamstats)[94].

Figures	Drainage area (sq-mi)	Percent of Impervious area (%)	Mean Basin Slope (%)
26	10	11.5803	2.3
27	0.12	0.2105	1.67
28	0.0817	24	3.09
29*	0.61	66.1515	2.17
30	0.16	3.97	1.4
31	0.7	8.8317	2.09
32	0.21	0.8036	1.19
33	8.77	5.7074	2.56

*Northern Canal Basin is the only basin with significant impervious area attributed to the Refinery

The Basin Characteristics of the following watersheds are outlined in Table 4. The drainage area is the area of the watershed shown in yellow on Figures 26-32, and the percent impervious area is found from National Land Cover Dataset (NLCD) 2001 Impervious Dataset.

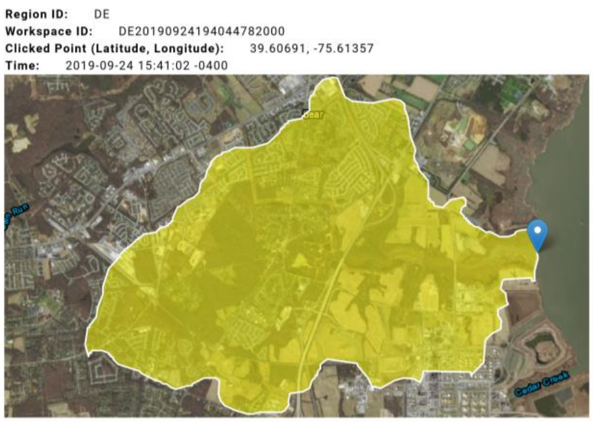


Figure 26: Red Lion Creek basin basin

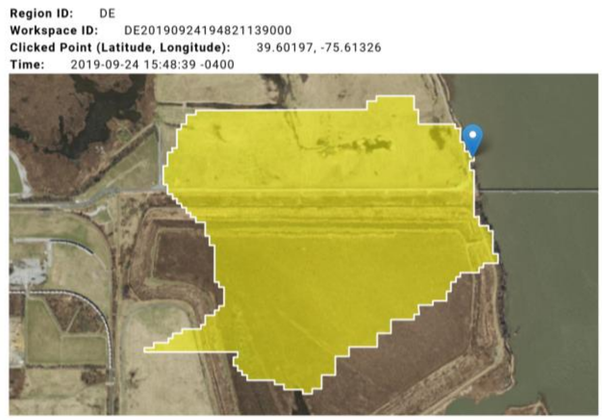


Figure 27: South Oxychem and North DMSA1

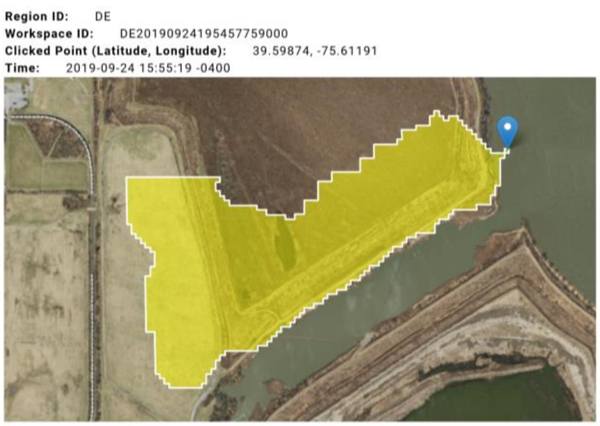


Figure 28: DMSA1 basin

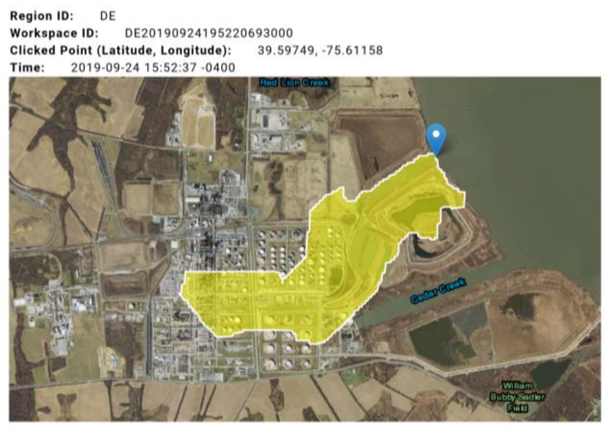
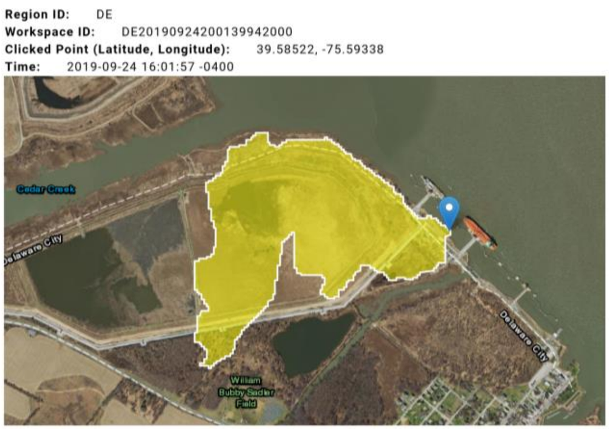


Figure 29: Northern Canal basin

Figure 30: DMSA2 basin

Figure 31: Cedar Creek Canal basin, DMSA3B



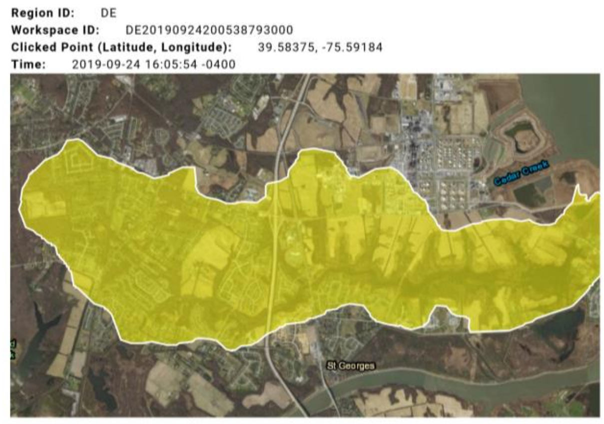


Figure 32: DMSA3A basin

Figure 33: Dragon Creek basin

New Jersey Site Basin Characteristics

The New Jersey site is influenced by 2 watersheds that drain to the Delaware River and Alloway Creek, but the delineation by Streamstats only indicates the drainage to the creek. Drainage areas of the basins are around 0.8 square miles. The basin with influence on Area 0 (Figure 35) contains significant impervious area because of the laydown of the Reactor site also present in the basin. This contrasts with the basin with influence on Areas 1 and 2 as it has negligible impervious area as the sites are undeveloped. Both basins with Areas 0, 1, and 2 have stormwater flows that drain to Alloways Creek, because site elevations are higher along the coast of the Delaware River. There is also significant ponding in Area 0 as elevations decrease and undulate inland. To mitigate this for the construction of a port, the area can be leveled with the addition of fill materials, and drainage pathways can be created with outlets to prevent ponding.

Table 5: Basin Characteristics that are important for design for the following watersheds in the New Jersey port option area (USGS Streamstats).

Figures	Drainage area (sq-mi)	Percent Impervious area (%)	Mean Basin Slope (ft/mi)
34	0.83	0.0021	2.14
35	0.77	48.7	4.3

*The Area 0 and Reactor Basin is the only basin with significant impervious area attributed to the Reactor

The areas and characteristics compiled in the table above are for each of the basins with influence on the New Jersey site. There are a few differences that can be identified between the StreamStats outputs for the New Jersey site and the Delaware site. In the case for the New Jersey site, slope is measured by change in elevation in feet per mile of length. The percent storage between the two basins evaluated (in Figures 34 and 35) is widely different due to the percent of impervious area on the power plant site.

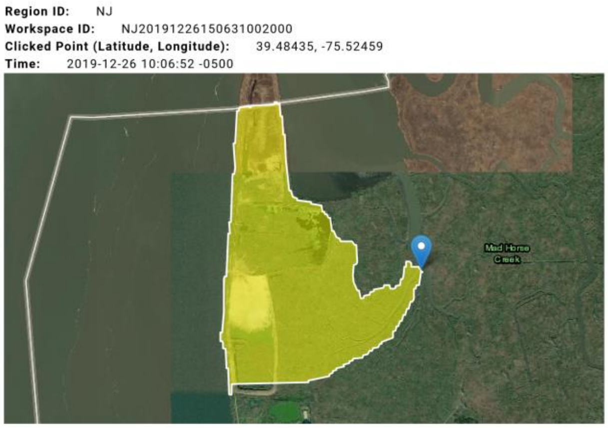


Figure 34: Area 1 and 2 basin

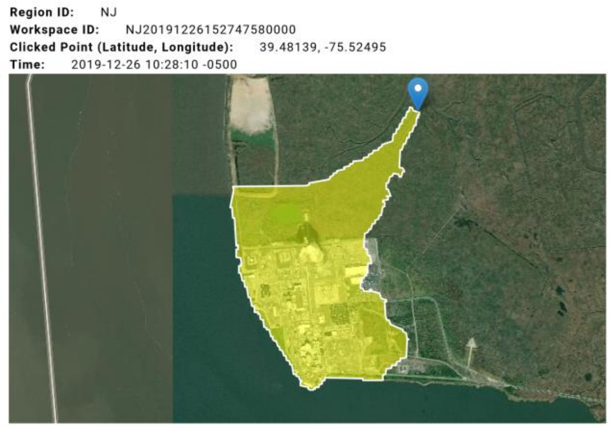


Figure 35: Area 0 and Reactor basin

D. Stormwater Runoff

As mentioned previously, defining watershed boundaries is crucial in understanding the flow of water during a storm event. Increases in stormwater runoff occur with the addition of impervious surfaces such as concrete and roads. In order to effectively manage the quantity and quality of stormwater runoff after construction and development, certain regulations will be followed by water quality standards.

To demonstrate the increase in stormwater runoff, we modeled certain conditions using the EPA's National Stormwater Calculator[97] for a 12-acre area on each of the sites in this analysis. Conditions that were selected are:

- Design storm of 5 inches
- Wilmington, DE rain gauge information (42.6 in annual rainfall and 0.18 Evapotranspiration rate)
- Climate change scenario: median change, near term (2020-2049)

Model input and output conditions for stormwater runoff for each of the sites are replicated in the following tables and figures.

Table 6: Input and output conditions for the Delaware and New Jersey sites for a 12 acre of developed vs. undeveloped area and the resulting runoff (EPA National Stormwater Calculator)[96]. Ro stands for Runoff.

Conditions	Soil Type /Ro potential	Soil Drainage (in/hr)	Topography	Ro - Current conditions (inches annual)	Ro - Developed conditions (inches annual)
Delaware Site	Clay loam / mod. high	0.01 to 0.1	Flat	9.37	39
New Jersey Site	Clay loam / mod. high	0.1 to 1.0	Mod. flat	4.61	38

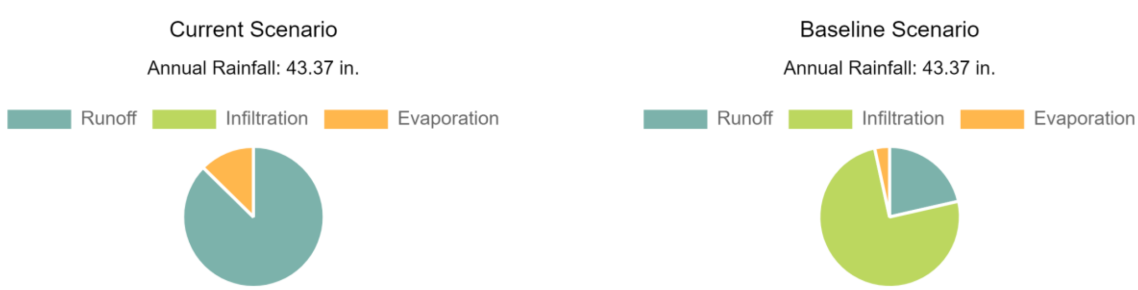


Figure 36: Pie graph of end results for rainfall that occurs on the Delaware site pre- (right) and post- (left) development of 12 acres. Numerical runoff results may be found in Table 6 (EPA National Stormwater Calculator)[96].

[97] https://swcweb.epa.gov/stormwatercalculator/

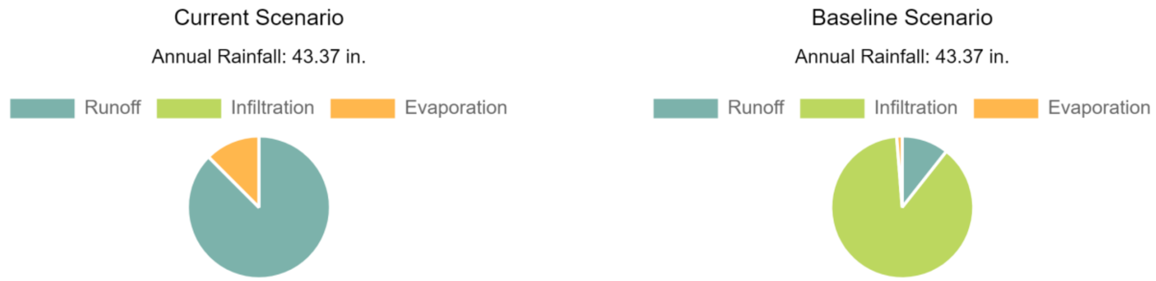


Figure 37: Pie graph of end results for rainfall that occurs on the New Jersey site pre- (right) and post- (left) development of 12 acres. Numerical runoff results may be found in Table 6 (EPA National Stormwater Calculator)[96].

It is evident that under the selected conditions, conversion of a 12-acre site that consists of near-fully pervious surfaces to one that is fully impervious will have a significant effect on the stormwater runoff from the area. As shown in the figures outlining the basins above, water on these sites will drain to the Delaware River and the surrounding smaller rivers and creeks. Water that flows over a site where heavy machinery is being used, such as the proposed port, may be contaminated by pollution from construction and everyday port activities. In order to protect the ecosystems present in the watersheds, wetlands, and vulnerable streams surrounding the sites, stormwater controls should be implemented by developers in the form of a National Pollutant Discharge Elimination System (NPDES) permit. Please refer to the accompanying regulatory analysis of this document.

Low Impact Development (LID) controls are often used in the development of large sensitive areas. These may include disconnection of impervious areas, the addition of rain gardens, rain harvesting, infiltration basins, green roofs, or use of permeable pavement. Not all of these may be able to be implemented for this specific project but methods employed to decrease the runoff volume via increasing infiltration and evapotranspiration should be considered.

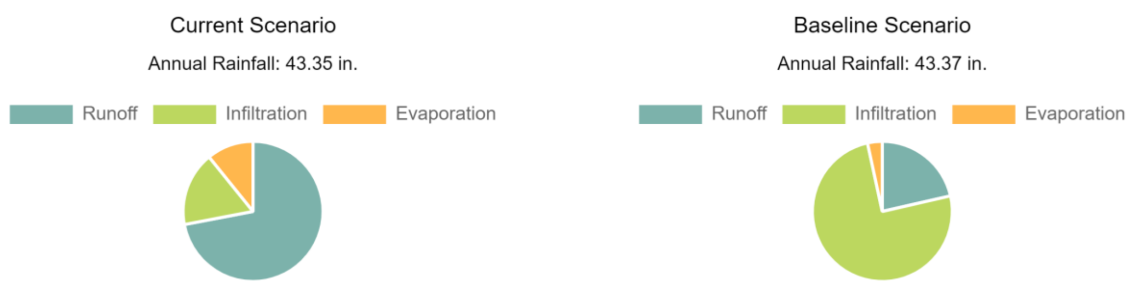


Figure 38: Pie graph of end results for rainfall that occurs on the 12-acre site pre- (right) and post- (left) development with LID controls on the Delaware site, with New Jersey producing consistent results. Runoff was decreased from 39 inches to 34 inches with 10% disconnection and 5% rain gardens by area (EPA National Stormwater Calculator)[96].

III. Geological Conditions

A. Site Geologic Information

We are interpreting field data so that we can obtain design properties for the soil such as classes, types, depths, water saturation, and hydraulic conductivity. An understanding of these geological conditions give an understanding about the strength of the soil and give a better sense of what geotechnical engineering methods should be used to support the laydown of the port.

Subsurface Investigative Techniques:

To gain a better understanding of the subsurface material, it is important to do subsurface investigative techniques such as drilling and evaluating laboratory data from the subsurface samples collected. One important test that should be conducted is a cone penetration test (CPT), in which an instrumented cone determines the bearing capacity of a soil sample. Another important test to consider in future evaluations is the shear vane test, in which stress is applied to determine if there is sliding failure along the plane that is parallel to the force that is applied. The purpose of this test is to determine shear strength of the material. A third test to consider is a standard penetration test (SPT), which is used to determine the strength of cohesive soils. This test estimates the compressive strength of a soil sample.

Based on previously performed site investigations by the Natural Resources Conservation Service (NRCS), the Delaware Geological Survey (DGS), and the New Jersey Geological and Water Survey (NJGWS), soil types have been determined on the surface and in the subsurface. The following is a description of soil types most present on the sites and how they affect engineering properties.

Load Bearing Capacity:

A knowledge of the load bearing capacity of various soils is essential to determining how the site may be constructed to support the high load bearing demand. Bearing capacity of soil can be determined based on a soil's pressure. For the requirements of a major OEM port, the ground bearing pressure of the laydown area is required to be 1,200 psf (6 tons/m²)[98]. The ground bearing pressure of the quay or lift area with crane loads should be 6,000 psf (30 tons/m²)[98].

Based on the 2014 Florida Building Code Section 1806 Presumptive Load Bearing Values for Soil[99], for most sandy gravel or gravel soils, the vertical foundation pressure without additional geotechnical modification is 3,000 psf and the lateral bearing pressure is 200 psf. Sand, silty sand, clayey sand, silty gravel, and clayey gravel all have a vertical pressure of around 2,000 psf and lateral bearing pressure of about 150 psf. Clay, sandy clay, silty clay, sandy silt, and clayey silt have a vertical foundation pressure of about 1,500 psf and an average lateral pressure of 100 psf. Although there is minimum geological information available, it is understood that both sites contain fine grained soils with an overall high water content. Based on presumptive load bearing values for soil, it is our interpretation that the load bearing capacities of the Delaware and the New Jersey sites that we investigated are within the range of 1,000 to 2,000 psf, although these estimates are first-order and will need to be determined

[98] Conversations with a industry experts
[99] https://up.codes/s/presumptive-load-bearing-values

based on directly sampling and subsequent laboratory measurements of the physical properties of the soils. If required, geotechnical methods may be employed to increase bearing capacity by compacting the soil. Our preliminary analyses suggest that geotechnical modification may be necessary at the sites that we have examined.

The settlement of marine sediments takes several years. The most cost-effective solution to accelerate settlement and increase strength is using wick drains. This technique is implemented throughout the compressible soil layer a certain distance from the coast. Wick drains are made with porous synthetic fibers which collect the water by a pump system to remove the contaminated fluids and the remediation process will occur. Another technique to increase the bearing capacity of the soil is to place sheet piles and bulkheads down to a more solid layer in the subsurface. This method may not be feasible for such deep soft sediments as are present on the sites analyzed here so further geotechnical analysis is strongly advised.

B. Surficial Geologic Materials

The USDA NRCS conducts a national soil survey in collaboration with federal, regional, state, and local agencies. The National Soil Survey is known as the single authoritative source for soil information in the US[100]. NRCS maintains a website where information collected in these soil surveys is published. A summary of common surficial materials found within our sites of interest is presented below, and more detailed information may be found in Appendix C, NRCS Soil Type Classifications. Also, information on general soil types may be found in Appendix D, Soil Mechanics Terms.

Although the following information is very helpful in the preliminary understanding of the geology of the site, further on-site analysis must be conducted for more accurate engineering applications.

Delaware site:

The majority of the soil within the site is classified as Endoaquepts and Sulfaquept (ESA) (Figure 39). Endoaquepts are tidal marshes with a broad range of moderately low to moderately high capacity to transmit water through pore spaces of the soil (K_{sat} = 0.06 to 0.57 inch/hour), and Sulfaquepts are tidal marsh with poorly drained silt loam material (Ksat = 0.06 to 1.28 in/hr)[100].

A portion of the site around the southern canal and Red Lion creek, is Broadkill (Br) tidal marsh material which is very frequently flooded, very poorly drained, and contains loamy marine sediments. This material is mostly silty clay loam and has a moderately high to high capacity to transmit water (K_{sat} = 0.2 to 2.0 inch/hour). These areas are shaded as "All hydric" soils in the NRCS maps in Section III.E.

New Jersey Site:

The majority of the site is classified as Udorthent material, which is loamy, dredged fine material (Figure 40). The capacity of the soil to transmit water ranges from moderately low to moderately high (Ksat is 0.06 to 0.20 in/hr)[100]. Udorthents are classified by the American Association of State and Highway and Transportation Officials (AASHTO) as being low strength due to their high clay content[101].

There are also small areas within the site that are classified as water due to the saturation and ponding tendencies of the coastal soil.

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[100] https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
[101] https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/new_jersey/NJ033/0/NJSalem06_08.pdf

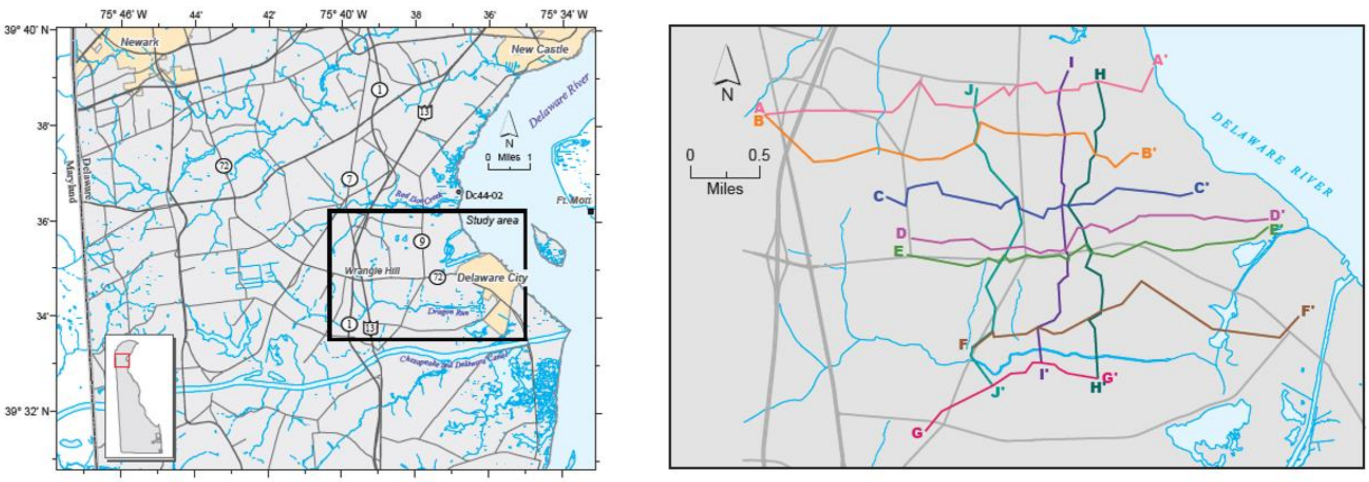
Figure 39: NRCS Soil Survey for the Delaware site of interest[100]. More information about the common soil types identified on this site may be found in Appendix C.

Figure 40: NRCS Soil Survey for the New Jersey site of interest[100]*. More information about the common soil types identified on this site may be found in Appendix C.*

C. Subsurface Geologic Materials for DE Site

Boring logs are records of information on sections of soil that have been removed by drilling. For the Delaware site, the engineering team analyzed the logs collected by the Delaware Geological Survey (DGS)[102]. The boring logs in this site have been recorded sporadically since the 1950's to present day by various engineering firms. Analyzing samples of the soil is necessary for understanding the soil characteristics above the bedrock.

DGS has developed qualitative analyses of the area, titled DGS Report Investigation No. 78: "Sub-surface Geology of the area between Wrangle Hill and Delaware City, Delaware." The map and locations of the boreholes is in the document, "R178 Plate 1: Data Location Map[103]" shown in Figure 41. Soil layers are also depicted within the document "R178 Plate 2: Structural Cross sections[104]." The cross sections range from west to east, and we have analyzed the most eastern section of the cross section along the coast. What follows consists of a short summary of the data that is detailed further in the Appendix E: Subsurface Geological Information.



Location map

Locations of cross sections

Figure 41: Structural Cross Sections, A-A', B-B', C-C', D-D', and E-E', of Wrangle Hill and Delaware City Area[103].

102 Boring log records collected from Kelvin Ramsey from DGS

103 R178 Plate 1: Data Location Map Report by DGS

104 R178 Plate 2: Structural Cross Sections Report by DGS

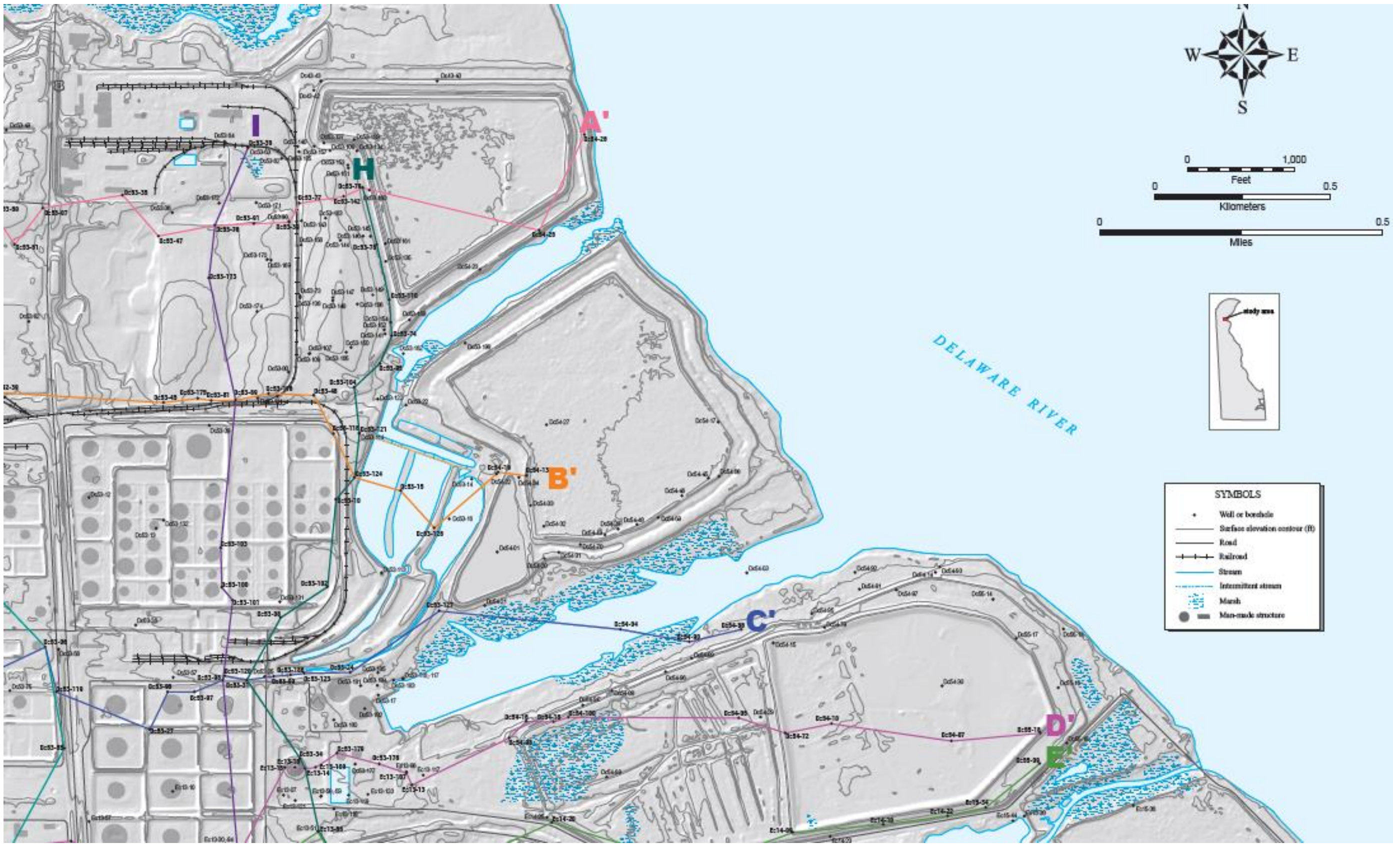


Figure 42: A detailed map of the locations of cross sections[104]. The Delaware potential port location property is located between cross sections A through E. For this application, it is useful to analyze everything east of cross section H to H'.

DMSA1 Site:

The pink cross section through A' shown in Figure 42 and Figure 43 runs through the DMSA1 site. Two boring logs that we analyzed are 54-25 and 54-26 (Appendix E). These boring logs sample soil from beside the coast and canal so appear more saturated compared to the soil that is sampled further inland. The primary characteristics of the soil in each log on the DMSA1 site are silty clay with traces of peat.

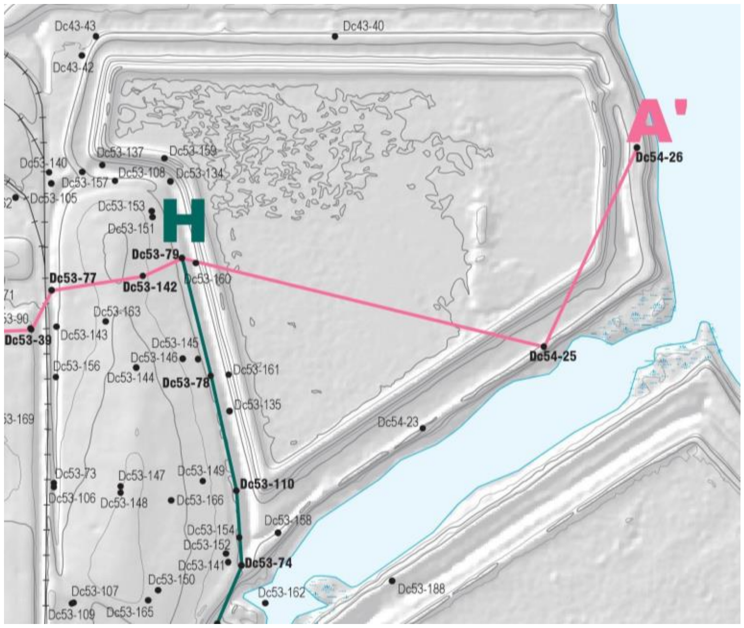


Figure 43: Zoomed in image of the boring log samples of cross section A to A'[104]. The boring logs analyzed are Dc54-25, Dc54-26.

DMSA2:

The orange cross section to B' in Figure 42 and Figure 44 runs through a small section of DMSA2. Four boring logs shown in Figure 4 that we analyzed further in the Subsurface Geology Appendix E are Dc54-17, Dc54-46, Dc54-68, Dc54-69. These boring logs are next to the coast and canal so they are more saturated compared to the soil that is inland. The primary characteristics of the soil in logs on the DMSA2 site are silty clay and clayey silt with traces of peat and silty sand.

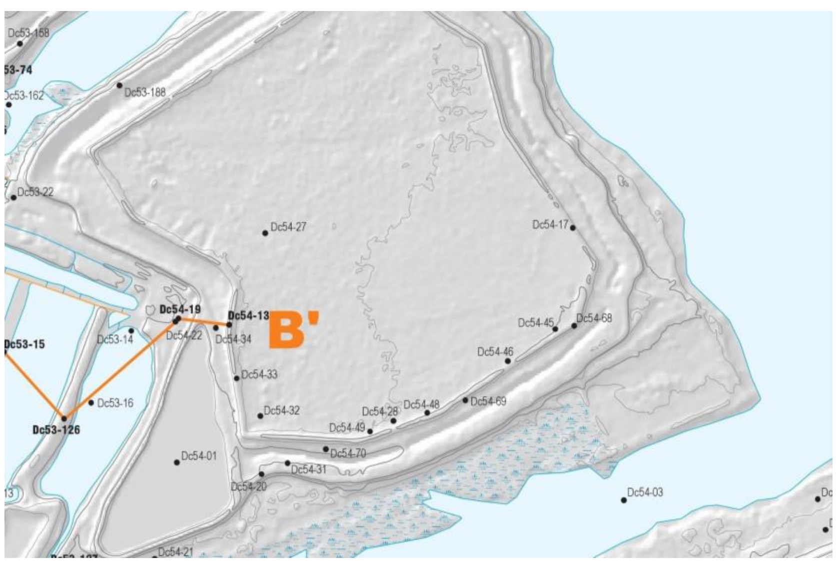


Figure 44: Zoomed in image of the boring log samples of cross section B to B' which only extends to part of DMSA2[104]. The boring logs analyzed from this image are Dc54-25, Dc54-26.

DMSA3:

The blue cross section to C,’ purple cross section to D’, and green cross section to E’ in Figure 42 and Figure 45 runs through the northern, middle, and southern edge of DMSA3 respectively. Four boring logs that we analyzed further in the Subsurface Geology Appendix E are Dc54-03, Dc55-13, Dc55-14, and Dc55-15. These boring logs are next to the coast and canal so they are more saturated compared to the soil that is inland. The borehole Dc54-03 was taken in the Southern Canal where the soil is mostly silty clay loam. The primary characteristic of the soil inland in DMSA3 is silty clay loam with traces of peat.

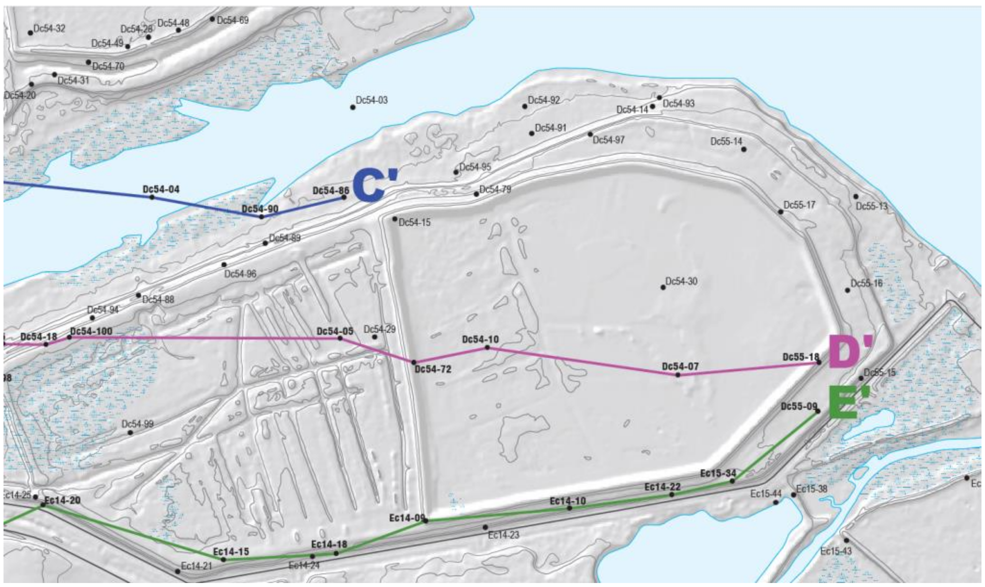


Figure 45: Closer image of DMSA 3[104]*, analyzed borehole Dc54-03, Dc55-13, Dc55-14, and Dc55-15.*

D. Subsurface Geologic Materials for NJ Site

Information on the subsurface geology for New Jersey is provided by the New Jersey Geological and Water Survey (NJGS) in cooperation with the USGS National Geologic Mapping Program[105]. Information is available on the NJDEP website including detailed subsurface maps that were used to analyze soil characteristics of this site. From the source, the area of interest for the New Jersey port location does not have any soil boring information, but the PSE&G reactor site does have soil boring information, as well as a constructed geologic cross section. It is assumed in this analysis that the subsurface geologic composition at the area of interest for a potential offshore wind deployment port is very similar to that of the area directly south of it, at the reactor site, which does have information available.

The entire surface area of the New Jersey site is shown to be made of saltmarsh and estuarine deposits (Qm, in Figure 46) which consists of peat, clay, silt, fine sand, minor medium sand, and pebble gravel. Organic matter is abundant, as this geological material is found in tidal wetlands, salt marshes, tidal flats, and tidal channels. There is a notable amount of dredge spoils (afd, in Figure 46) which is described as fine sand, silt, clay, minor medium to coarse sand and gravel; this layer is 40 feet thick[105].

The subsurface information provided by the NJGS is structured differently from that available for the Delaware site, the descriptions given in the legend are far more general and give a wide range of soil types. Another difference is the boring logs available for the analysis of the Delaware site are much deeper into the subsurface, as much as 945 feet (Log 34-1031). This means that there is more adequate information to determine the depth to which pilings or other soil stabilizing infrastructure must be installed. Also available at the Delaware site is information indicating the elevation of the base of surficial deposits, around 75 feet below the surface at the site of interest (Figure 46).

The permeable sediments in the New Jersey site are at least 500 feet deep as determined by the analysis of the cross-sections of the site (Appendix E). For depths of 0 to 200 feet, the sediments consist of miscellaneous fine soil types such as clay, silt, fine sand, and peat. Below the depth of 200 feet, sediments consist primarily of sand deposits which can be extended to be more than 1000 feet in thickness.

Further more detailed investigation is recommended for the specific area of interest and purposes of this project. This is in order to determine critical subsurface information that is needed for the design of an offshore wind deployment port.

[105] https://www.state.nj.us/dep/njgs/pricelst/ofmap/ofm92.pdf

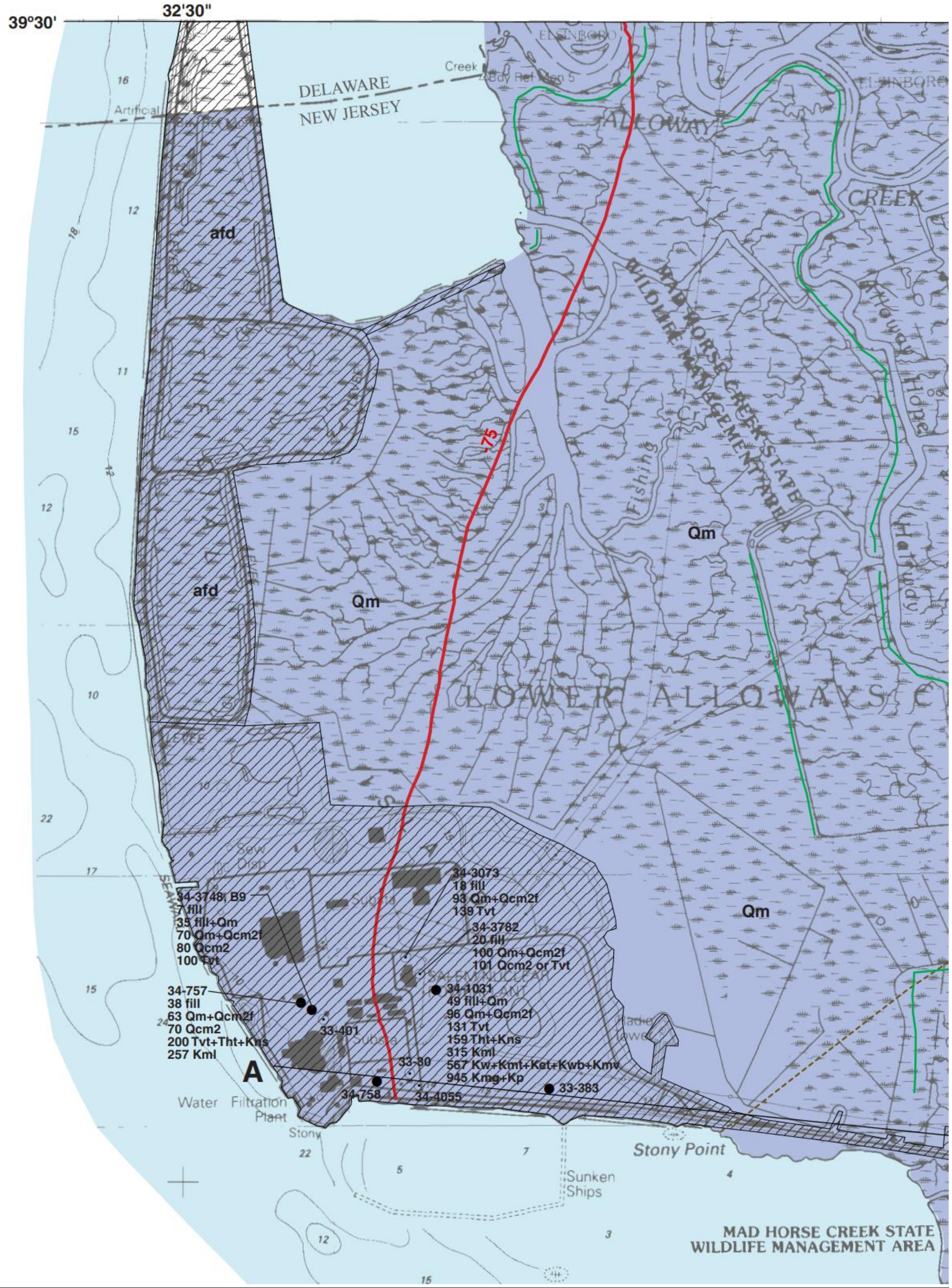


Figure 46: Geologic map for the New Jersey site[105]. Information on the cross section A and boring holes, seen at the southern end of the artificial island, may be found in Appendix E.

E. NRCS Soil Class Information

Figures 47 - 50 were created in GIS using NRCS soil data interpreted in service of this report[106]. Each map layer identifies different classes of soil with different hydrological characteristics that factor into the structural integrity of each soil type. These are important to consider when designing a potential port for: quay and laydown area location decisions, soil stabilization techniques, and planning decisions.

Soils Hydric Class Map:

Soil hydric layers depict wet soils that are saturated for periods long enough to create wetland-like conditions (Figures 47 and 48). Different shades of blue represent the hydric class of the soil or percentage of saturation that develop anaerobic conditions in the upper part of the soil. These are very poorly drained and are an indicator of present wetland areas.

The dark blue sections, classified as "all hydric," means that there is frequent flooding of the land. Frequent flooding over the years has caused this area to become marsh-like. For the Delaware site, the areas surrounding Cedar Creek and Red Lion Creek are vulnerable to flooding and not suitable for construction due to the highly saturated soil (Figure 47). The lighter blue sections, classified as "partially hydric," are more preferred for quay and laydown area operations because their soil characteristics lead to a greater load-bearing capacity than those classified as "all hydric." This will lead to the opportunity for a more stable design and less risk of flooding.

Although there is a lack of data on the saturation of the soils for the New Jersey site, we suspect that the majority of this area is "partially hydric." This is based on maps published by NRCS that designates a large area of soils on the site as Group C, defined as having a slow rate of infiltration[107] (Figure 50). Remaining areas are suspected to be "all hydric" areas, labeled as Group A/D or B/D defined as having a very slow rate of infiltration due to a high water table. These areas will have a high rate of infiltration if they are drained.

Soils Hydrologic Group Map:

Hydrologic groups are assigned to soils based on the measured rainfall, runoff, and infiltrometer data (Figures 49 and 50). The soil's associated runoff curve number is used to determine amounts of direct runoff. This runoff curve number is calculated using factors of land use, management practices, and hydrologic groups.

Most of the sites being considered for a potential deployment port are made up of soils in hydrologic group C. They have a moderately high runoff potential when fully saturated and the saturated hydraulic conductivity of the least transmissive layer is between 0.14 and 1.42 inches/hour (1 to 10 micrometer per second)[106]. Group C soils have restricted water transmission and typically have between 20 percent and 40 percent clay and less than 50 percent sand[107]. The depth to the water table is greater than 24 inches (60 centimeters). Soil texture plays a role in soil strength and load bearing capacity as well, as Group C soil usually has a minimum of cohesion and clay content is usually low. This type of soil is the least stable and most prone to collapse[108]. Therefore, development in areas with Group C soils

[106] https://www.usgs.gov/core-science-systems/national-cooperative-geologic-mapping-program
[107] https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba
[108] https://tools.niehs.nih.gov/wetp/public/Course_download2.cfm?tranid=4432

requires the highest degree of protective measures such as ground improvement methods like compression and settlement to drain the water out and increase the bearing capacity of the soil. After ground improvements methods have been conducted, the soil can support the required bearing capacity of an offshore wind port.

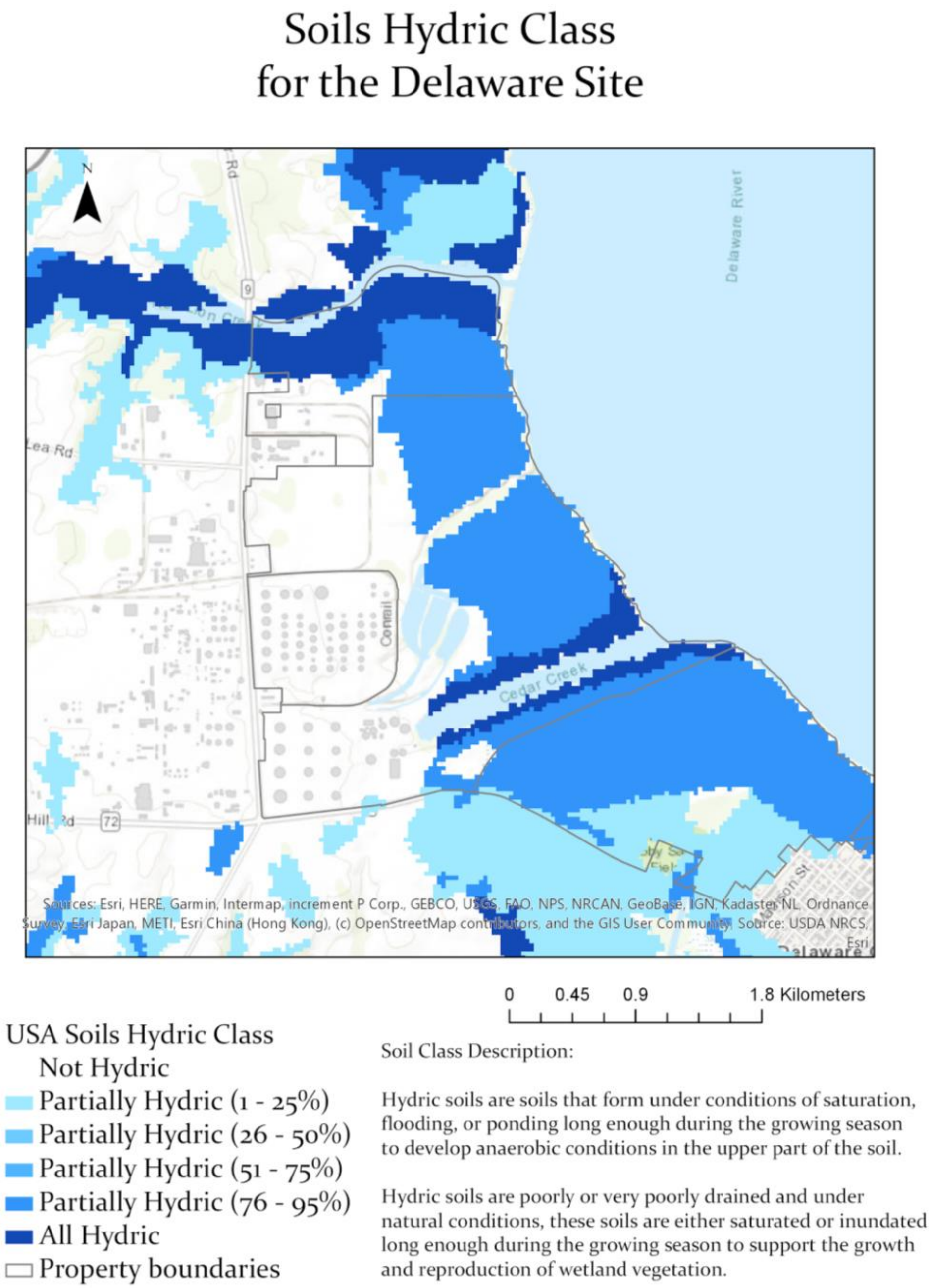


Figure 47: Soils Hydric Class map showing the soils and their associated hydric class percentages present at the Delaware site[105].

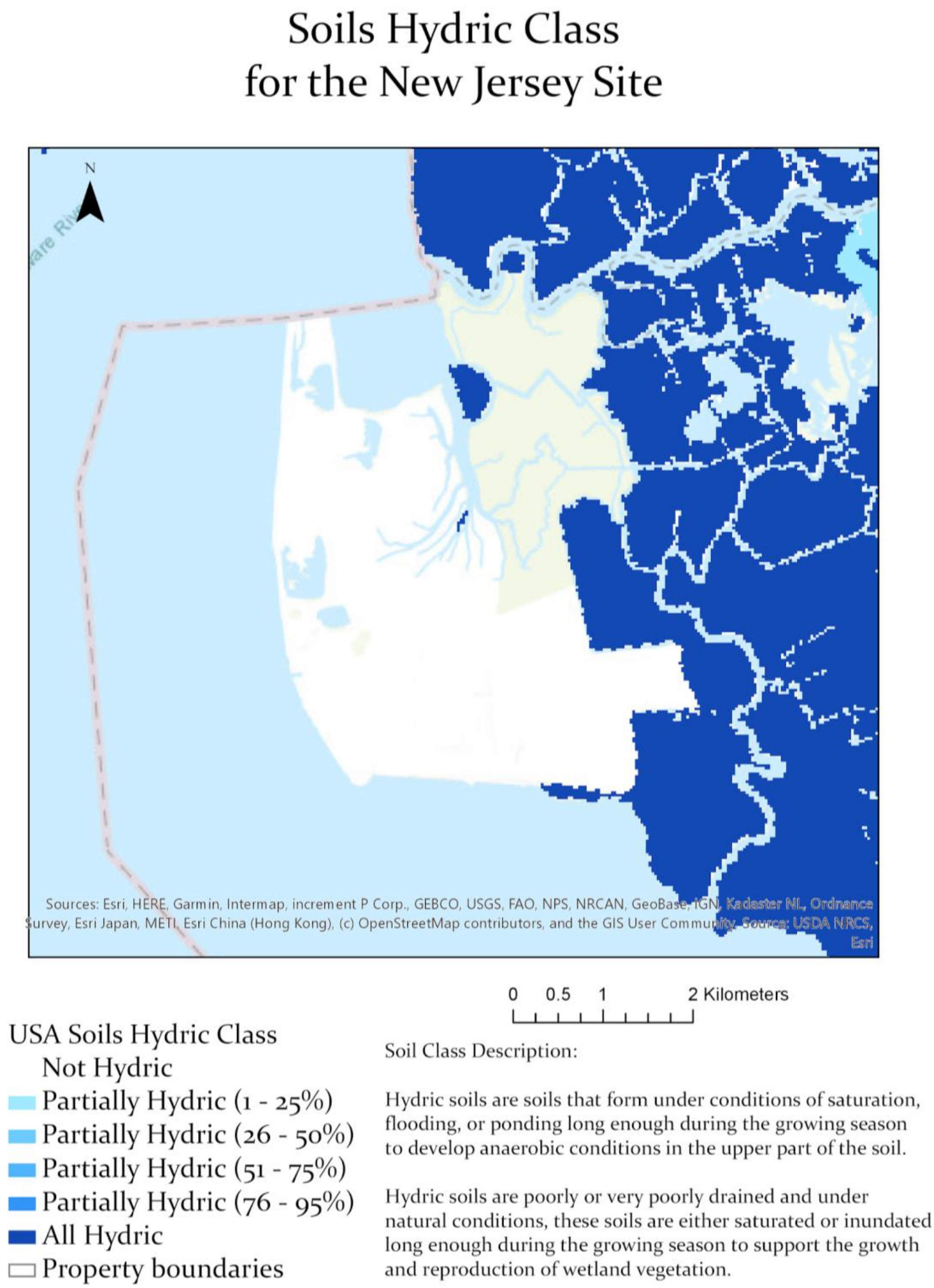


Figure 48: Soils Hydric Class map showing the soils and their associated hydric class percentages present at the New Jersey site[105].

Figure 49: Soils Hydrologic Group map showing the soils and their associated hydrologic group present at the Delaware site[105].

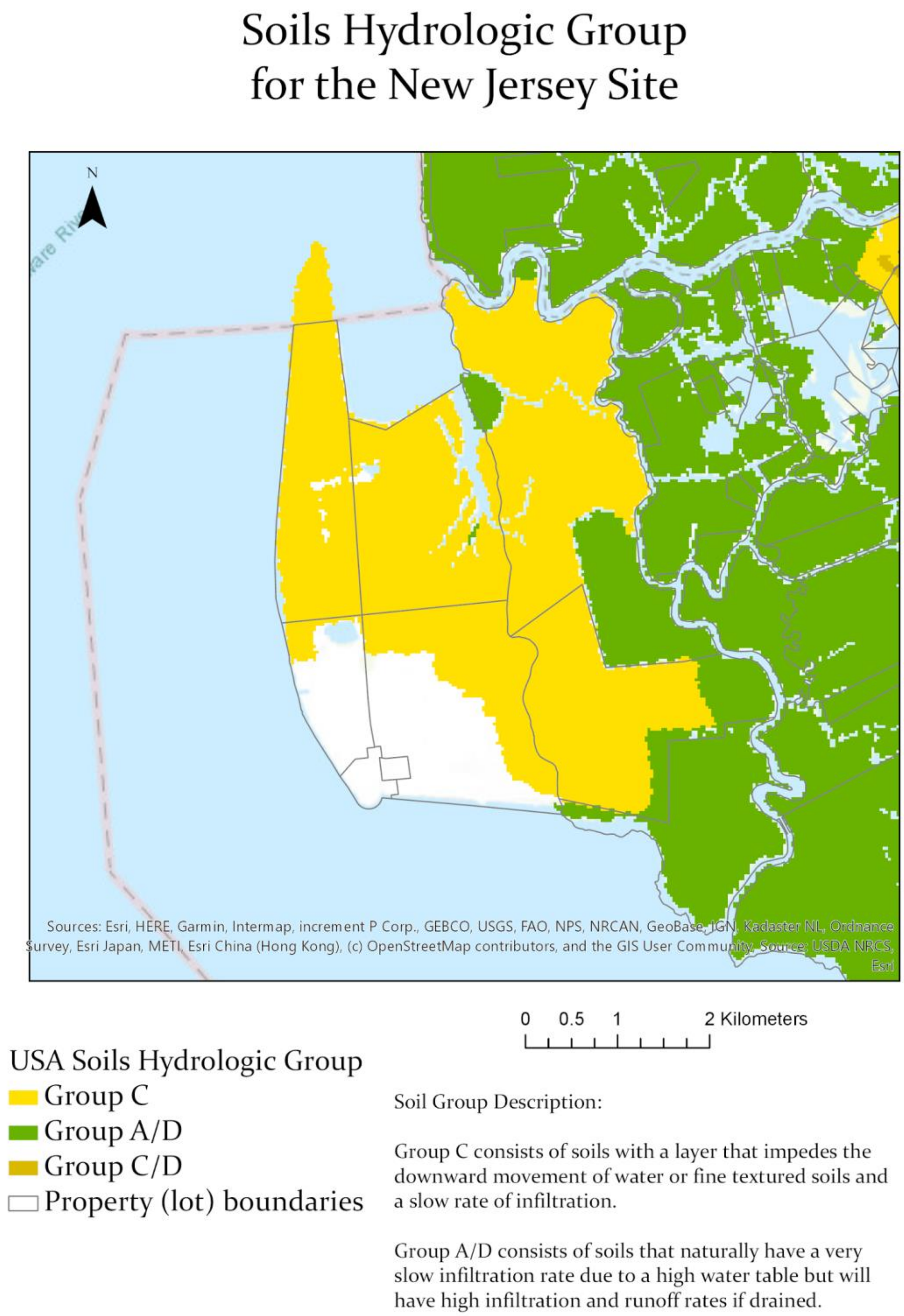


Figure 50: Soils Hydrologic Group map showing the soils and their associated hydrologic group present at the New Jersey site[105]*.*

Conclusions

Based on preliminary analysis of the sites of interest, a current state of hydrologic and geologic conditions has been determined. For the sake of concise conclusions, a short summary of each report section is listed below.

Section I: Hydrological Conditions

A. **Site hydrologic information -** Surrounded by creeks and wetlands, along the coastline of the Delaware River, both site locations are influenced by tidal flood inundation, so the land is considerably prone to flooding. The New Jersey site is highly influenced by tidal flood inundation on both the east and west from the Alloway Creek network and the Delaware River.

B. **Existing wetlands -** Although the National Wetland Inventory has classified the majority of the site areas as wetlands, most of them are not a concern for future development. The most common wetland types present on the Delaware site are estuarine, marine, and freshwater emergent wetlands. Conversations with DNREC have determined that no wetlands south of the Red Lion Creek at the Delaware site are vulnerable or will hinder any development. It should be noted that the wetlands existing on the New Jersey site are extremely similar to the DE site, and that they therefore may have the same characteristics.

C. **Flood risk analysis -** Special Flood Hazard Areas represented in the FIRM maps gives an estimate of how much of the site is in the 100-year flood plain.

   For the Delaware Site, the inundation does not affect the current engineering recommendations to a high degree because most of the area around Red Lion Creek that experiences inundation is wetlands. These high risk areas subject to inundation by the 1-percent-annual-chance flood event have been determined to be not suitable for construction in their current condition. Based on our analysis of the FIRMs, we have concluded that it is better to develop areas further south, away from the wetlands. The lower half of Oxychem, and the Delaware City Refinery's DMSA 1, 2, and 3 may be usable and relatively clear from the Special Flood Hazard Zones. Zone AE is the most common flood zone inland, and Zone VE is the most common to affect the coastline.

   For the New Jersey site, the middle of Area 1 has the most flood risk as it is vulnerable to the 1-percent-annual chance flood which would cause inundation from Alloway Creek, and north and south of this site, Areas 2 and 0 and the lower half of Area 1 has less inundation and flood risk. The coastline along the Delaware River is High Risk Coastal Areas subject to inundation by the 1-percent-annual-chance flood event with wave heights greater than 3 feet. Due to the built-up area and impervious cover placed on the nuclear reactor, it may be assumed that the area used to be more inundated, but was designed for the 1% chance of flooding.

   It is necessary to account for flooding effects and quay vulnerability to wave heights greater than 3 feet. To flood proof the site, FEMA recommends within the Zone VE, the construction of the laydown and piers must be elevated above the Base Flood Elevation with pile, post, pier, or column foundations or the structure built with flood resistant materials. Specific requirements of building design are referred to in Title 44 Section 60.3 of the Code of Federal Regulations for Zone VE building standards.

D. **Tidal flood analysis** - The flood stage, or the stage at which overflow of the natural banks of a stream begins to cause damage in the local area from inundation due to flooding. There are four different flood stages that are measured in stream gauges and can represent varying degrees of inundation along the banks.

For both the New Jersey and the Delaware site, the major flood stage is 9.5 feet, determined as the historic maximum gauge height of two tidal gauges in close proximity. Construction of the quay and laydown must be built to be above this height to prevent damage to the coastline and to build for resilience. Large storms are expected to cause wave crests reaching similar and increasing flood heights in the future.

E. **Climate change analysis** - As the sites are located on the coast of a major US coastal river, sea level rise as caused by global climate change was found to have a substantial impact. Sea level rise is expected to encroach significantly into portions of both sites. Areas along the canals and wetlands are especially vulnerable, as seen in the FEMA maps. Also, frequency and intensity of storms are expected to increase. It is important to realize the 1-percent-annual chance flood (or base flood) is likely to be exceeded more often than once per 100 years. This is due to changes in climate and sea-level rise as weather patterns and climate variability become more extreme. These factors need to be taken into consideration when planning for resilience and sustainable development on such coastal sites.

The New Jersey site is predicted to undergo much more significant inundation than the Delaware Site due to more present water bodies, such as the Alloway Creek wetland system, that will be affected by sea-level rise. Not only is much of the coastline predicted to be below the water level, making it less possible for a quay to be easily built there, but the marshy area surrounding Alloway Creek is predicted to be submerged, preventing accessible road and railway access.

Section II: Topography

A. **Topographic map** - The coastal location of these sites makes elevation an important consideration due to the threat of inundation and tidal floods. The lower elevations of the sites is where water collects. Information on where water accumulates in pools on the site will factor into successful stormwater management and the design of the port. Engineers will need to add fill to the cavities and the lower elevation coastline in order to prevent damaging tidal inundation to the port.

B. **Point Elevations** - For the Delaware site, Oxychem and DMSA2 contain the lowest average elevations. Overall, the average of the coastline of the Delaware site is 12 feet which is higher than the major stage. For this site, the average topographic elevation inland of this site is 22 feet. Due to the man-made spoils distributed along the sections of the Delaware site, the topographic elevations and the slopes are higher in some places than where it would be naturally. The New Jersey site has more natural elevation contours. The average for the New Jersey site is 5 feet along the coastline; this is at or below sea level during flood conditions for some areas in the New Jersey site. Further inland of the New Jersey site, the elevations undulate and decrease towards Alloway Creek and it averages around 13 feet.

C. **Watersheds -** The two site areas influenced by their surrounding water bodies: Red Lion Creek and the Delaware River for the Delaware site, and Alloway Creek and the Delaware River for the New Jersey site. Fluctuations of the water level driven by precipitation and tidal changes affects the flooding on the sites. Watershed areas as outlined in the Section II.C report define where rainfall on the site will be drained to. The total drainage area, percent impervious area, and other factors of the existing watersheds such as slope and existing wetlands, will play a major part in the effective design of stormwater management controls necessary to the development of the sites.

D. **Stormwater Runoff -** A stormwater analysis was run for each site using pre- and post-development conditions for a 12-acre area using the EPA National Stormwater Calculator tool. Taking into account factors of climate, soil and drainage types, and existing and proposed pervious and impervious areas, the calculator determined stormwater runoff volumes from any storm event was to increase by 76% at the Delaware site and 88% at the New Jersey site after port construction. Stormwater controls such as infiltration basins, permeable materials, and disconnection of impervious areas are imperative and standard practice for the future development of sites such as these. NPDES regulates stormwater discharges to surface water to protect water quality in the Delaware River. Also, mitigated stormwater runoff prevents the degradation of the port and turbine components to ensure the longevity of the port.

Section III: Geological Conditions

A. **Site Geologic Information -** Sampling and subsequent laboratory measurements of the physical properties of soils are recommended for both sites to gain a better understanding of the site subsurface. These include a cone penetration test to determine the bearing capacity, a shear vane test to determine the shear strength of the material, and the standard penetration test to determine compressive strength of any area considered for development. The most cost effective solution to accelerate settlement and increase strength is using wick drains and further geotechnical analysis is strongly advised.

B. **Surficial Geologic Materials -** The NRCS conducted surveys that show the majority of the Delaware site to be tidal marshes which are frequently flooded, poorly drained and contain loamy marine sediments unsuitable for high load bearing capacities. The most common material on the Delaware site is silty clay loam which has a high capacity to transmit water. The material of the New Jersey site is loamy, fine material that has been dredged from the Delaware River. This material has been classified as being low strength due to their high clay content.

C. **Subsurface Geological Materials for DE Site -** The major soil type below the surface of the Delaware site is silty clay and silty clay loam. Silty clay has a support capacity of around 1,500 pounds per square foot (7.3 tons/m^2). Several clays and silts have bearing capacities that are higher than 1,500 psf, however a soil test is needed to determine the true bearing strength. Additionally, based on the New Castle County Geologic Map, the majority of the site contains fill from dredge materials of the Delaware River, composed of a thick layer of very soft materials, including organic soils that are excessively compressible. Certain areas of the fill material are stiff, but the marsh or swamp area below is soft and has a high water content. This high saturated soils can be drained with wick drain.

For the requirements of a major OEM port, the ground bearing pressure of the laydown area is required to be 1,200 psf (6 tons/m²). The ground bearing pressure of the quay or lift area with crane loads should be 6,000 psf (30 tons/m²). Based on presumptive load bearing values for soil, it is our interpretation that the load bearing capacities of the site soil materials are within the range of 1,000 to 2,000 psf (4.9 to 9.8 tons/m²), although these estimates are first-order and will need to be further tested.

D. **Subsurface Geological Materials for NJ Site -** The New Jersey site has more general information available on its subsurface geology. Information from boring logs and wells venture deeper into the surface, with the permeable sediments in this area determined to be at least 500 feet deep based on the cross-sections of the site. From depths of 0 to 200 feet, the sediments consist of miscellaneous fine soil types such as clay, silt, fine sand, and peat with an approximate support capacity of 1,500 psf (7.3 tons/m²). Below the depth of 200 feet, sediments are primarily sand deposits and this layer of sand which can be a thickness greater than 1000 feet. Sand is a suitable geologic material for piling, as it has an approximate support capacity of 2,000 psf (9.8 tons/m²).

E. **NRCS Soil Class Information -** The hydrologic group map produced by the Natural Resources Conservation Service provides information on the soil saturation and infiltration characteristics of the analyzed sites. Both New Jersey and Delaware sites consist of very saturated soils. To make the area buildable, there needs to be geotechnical techniques employed to drain the water and strengthen the soil.

Section 4:

Preliminary Engineering Design for the Delaware and New Jersey Offshore Wind Port Locations

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June 2020

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Willett Kempton and Sara Parkison

Table of Contents

Introduction

The purpose of this report is to provide a preliminary design of two potential port locations in the Delaware Bay for the deployment of offshore wind turbines in the US Mid-Atlantic region. Designs of these ports consider the sites' current conditions, present industry standards, future growth projections, and recommendations from federal regulators. This report is intended to help investors visualize potential designs of a marshaling port for offshore wind on the Delaware and New Jersey sites.

Each design focuses on the quay that is built from a pier structure out to the deeper part of the channel, with a minimum depth of 12 feet. Quay design requirements are based on requirements from a major turbine original equipment manufacturer (OEM). A crane will need to be installed on the outer edge of the quay to load turbine components on and off the installation vessels. Our design options feature a quay that is an extension off of different areas of the Delaware and New Jersey sites' coasts. Factors that were considered in the quay design process were access for heavy machinery and cranes for operation, laydown space, and available land area. These designs are informed by analysis of the hydrologic and geologic conditions of the sites. Harmful flooding, inundation due to tides, soil types and saturation were factors that played a role in the placement of the quay designs.

The Delaware and New Jersey sites were selected based on their central location on the Mid-Atlantic coast, allowing these ports to support installation vessels for offshore wind projects from Virginia to Massachusetts. These locations also are proximate to the open ocean and importantly lack any overhead obstructions between the site and the open ocean. Although policy and financial considerations represent significant determining factors for port location, design based on sound engineering principles is an essential component of site selection. Most importantly, these sites contain areas with enough laydown space to support deployment port operations, with room for future industry growth.

Any questions about the content of the information in this report should be referred to Willett Kempton at willett@udel.edu.

Site Specifications

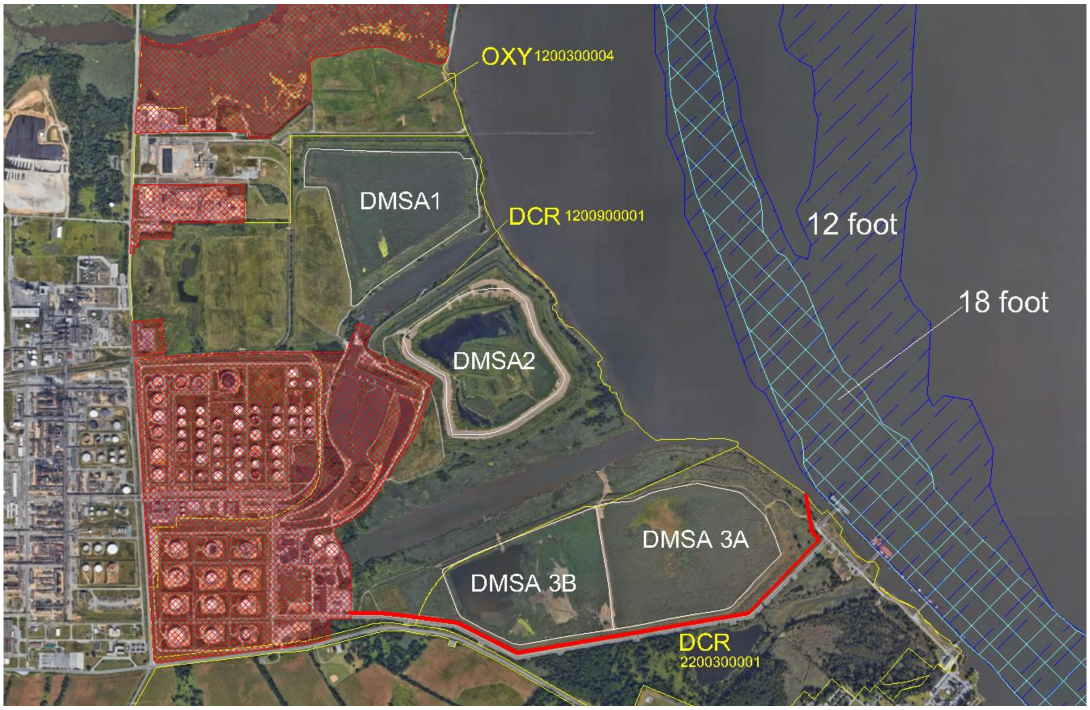

Figure 1: Property map for the Delaware site, located in New Castle County, DE, just north of Delaware City. Yellow lines are parcel lines indicating ownership[109], white lines represent dredge spoil areas, red hatched areas are unavailable for use, royal blue hatched lines indicate the area where there is a 12 foot deep contour in the Delaware River[110], and teal blue hatched boxes indicate the area where there is a 18 foot deep contour in the Delaware River. Areas will henceforth be referred to as Oxychem and DMSA1-3 as displayed [111].

Table 1: Area of Parcel Properties of Delaware site. The total Delaware site area is calculated by adding all land areas East of the exclusions shown in red hatching. DMSA areas are measured from the white lines outlined in Figure 1.

Parcel	Area (acre)	Area (hectares)
Oxychem	106.7	43.1
DMSA1	80.1	32.4
DMSA2	79.7	28.6
DMSA3A /3B	92.9 / 74.6	37.6 / 30.2
Total Delaware site	831	336.2

109 Delaware City Property Map obtained from New Castle County records
110 https://nauticalcharts.noaa.gov/
111 Google Earth Image

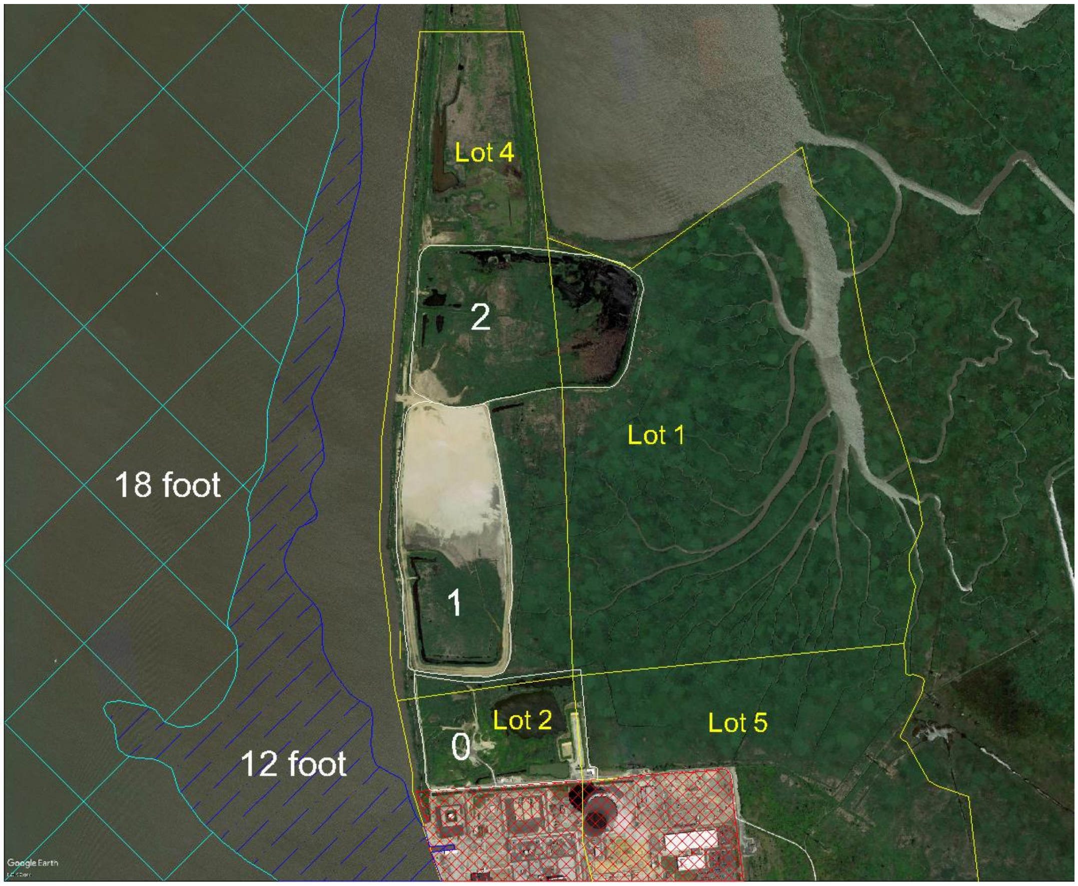

Figure 2: Property map for the New Jersey site, located in Lower Alloway Creek township in Salem County, NJ. Yellow lines are parcel lines indicating ownership[112], white lines represent dredge spoil areas, red hatched areas are unavailable for use, royal blue hatched lines indicate the area where there is a 12' deep contour in the Delaware River, and teal blue hatched boxes indicate the area where there is a 18' deep contour in the Delaware River[110]. Areas will henceforth be referred to as Area 0, 1, 2, and the PSE&G reactor site[111].

Table 2: Area of Parcel Properties of New Jersey site. The total New Jersey site area is calculated by adding all the land Areas 0, 1, and 2. Site areas are measured from the white lines outlined in Figure 2.

Parcel	Area (acre)	Area (hectares)
Area 0	61.7	25
Area 1	95.7	38.7
Area 2	108	43.6
Total New Jersey site	265	107.3

I. Design Considerations

[112] https://www.njmap2.com/parcels/all

A. Factors Affecting Port Design

Construction of the quay and laydown area must consider the major flood stage, as described in the Current Conditions Analysis, to prevent damage to the coastline and to plan for resilience. For both the New Jersey and the Delaware site, the major flood stage is about 9.5 feet. In the future, large storms are expected to cause wave crests reaching similar and increasing flood heights.

The sites of interest are located in coastal zone areas defined by the Federal Emergency Management Agency (FEMA), so certain development standards apply. Pursuant to FEMA regulation, it is necessary to account for flooding effects and quay vulnerability to wave heights greater than 3 feet in Zone VE. This zone is classified as high-risk coastal areas subject to inundation by the 1-percent-annual-chance flood event, or Base Flood Event (BFE), with additional hazards due to storm-induced velocity wave action. To flood-proof the site, FEMA mandates that within Zone VE, construction of the laydown and piers must be elevated above the BFE with pile, post, pier, or column foundations or the structure must be built with flood resistant materials. Specific requirements of building design are referred to in Title 44 Section 60.3 of the Code of Federal Regulations for Zone VE building standards[113].

Prior to construction of either site of interest, geotechnical techniques must be employed to drain the water and strengthen the soil. Quay loading and unloading areas need to meet the minimum industry requirements for high load-bearing capacities, which are approximately 20-30 tons/m² for varying zones. The built quay and pier must meet or exceed this load-bearing pressure to account for safety and sustainability of the port.

The most significant component to pier design is the depth of the channel to which it is built out to. The depth the channel must be dredged to and maintained is determined by the draft of various installation vessel types (Table 3). Important information on channel depths found in the National Oceanic and Atmospheric Administration (NOAA) Navigational Charts were referenced in this report.

B. Installation Vessels

The current generation of installation vessels provide metrics and insight for designing an effective marshaling port. For vessel loading and unloading, the first requirement for the quay is that it must be suitable for the loading and unloading of Turbine Installation Vessels (TIV). This includes that the port is accessible to both supply ships and TIVs, in draft and length, and in load bearing capability of the quay.

The draft of a vessel is the vertical distance between a ship's waterline and the lowest point of the keel or bottom of the boat. Developers of a pier must dredge at sufficient depths to clear enough space for the draft. Navigational depths of the Delaware River are referenced in the NOAA Navigational Charts (Figures 3 and 4). Additional dredging beyond the natural depth where piers are built out may be required according to the drafts of selected installation vessels (Table 3).

The horizontal length of the supply and TIV vessels is a factor that determines the pier or quay length, as vessels will need to be accommodated in the appropriate loading/unloading zones as outlined in Section D, Port Zones. The vessels in Table 3 summarize dimensions of recent TIVs, majorly from a

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[113]https://www.fema.gov/media-library-data/1517893153030-da3a700b0d220794eda4d6da801798a8/LIMWA_and_Higher_Construction_Standards_fact_sheet_12_18_17_reviewed.2_CLEAN.pdf

report in 2014[114]. These figures are in flux. There is general industry expectation that vessels will increase in size and capacity into the future, to transport larger turbines. On the other hand, some Gulf of Mexico lift vessels (like the L/B Paul in Table 3) have shallower draft, also, future industrialized deployment with more assembly in port may allow simpler and smaller vessels.[115]

Table 3: Common TIV and their horizontal clearance and draft requirements.

Owner	**Vessel Name (year)**	**Length (meters/feet)**	**Width (meters/feet)**	**Draft (meters/feet)**
Gaoh Offshore[115]	Deepwater Installer (concept)	140 / 460	40 / 131	6.5 / 21.3
A2SEA[115]	Sea Installer (2012)	132 / 433	39 / 128	5.3 / 17.4
Seajacks[115]	Seajacks Zaratan (2012)	81 / 266	41 / 135	5.3 / 17.4
Inwind[115]	INWIND Installer (concept)	101 / 331	68 / 223	4.5 / 14.8
Workfox[115]	Seafox 5 (2012)	151 / 495	50 / 164	10.9 / 35.8
SAL[116]	MV Lone (2011)	160.5 / 527	27.5 / 90	13.8 / 45.3
Seacor Marine[117]	L/B Paul	42 / 138	26 / 86	3.6 / 11.7

C. Channel Depths

Channel depth is a significant factor to consider in port design and vessel access to the ocean. NOAA provides Electronic Navigational Charts (ENC), which we used for the two sites of interest in Figures 4 and 5. The white areas have depths of 18 feet and greater. The straight dashed lines are the areas that the Army Corps of Engineers have dredged out and continually provide maintenance dredging to preserve 26-55 feet, depending on the location. In the Main Channel Deepening Project, completed in Summer 2019, the Army Corps and the Port Authority aimed to deepen the shipping channel to 45 feet[118].

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[114] https://www.energy.gov/sites/prod/files/2013/12/f5/assessment_vessel_requirements_US_offshore_wind_report.pdf

[115] Kempton, W. et al, 2017 “Industrializing Offshore Wind Power with Serial Assembly and Lower-cost Deployment”, Final Report to DOE (99 pages), 11 Dec 2017. https://cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/5/8632/files/2020/02/Industrializing-Offshore-Wind-Power-Final-2017.pdf

[116] https://sal-heavylift.com/uploads/tx_salext/download/SAL_Company_Brochure.pdf

[117] https://seacormarine.com/vessel/l-b-paul/

[118] http://www.philaport.com/channel-deepening/

The maximum drafts of vessels that can enter the Delaware River through the Chesapeake and Delaware Canal is 33 feet[119]. When passing through the Chesapeake and Delaware Canal, ship navigators must also be cautious of side clearance. The maximum combined beam of two vessels through the canal at the same time is 190 feet. The Bulkhead Shoal Channel is privately maintained and extends from north, depths of 28 feet to 38 feet were reported with deck height of 15 feet[118].

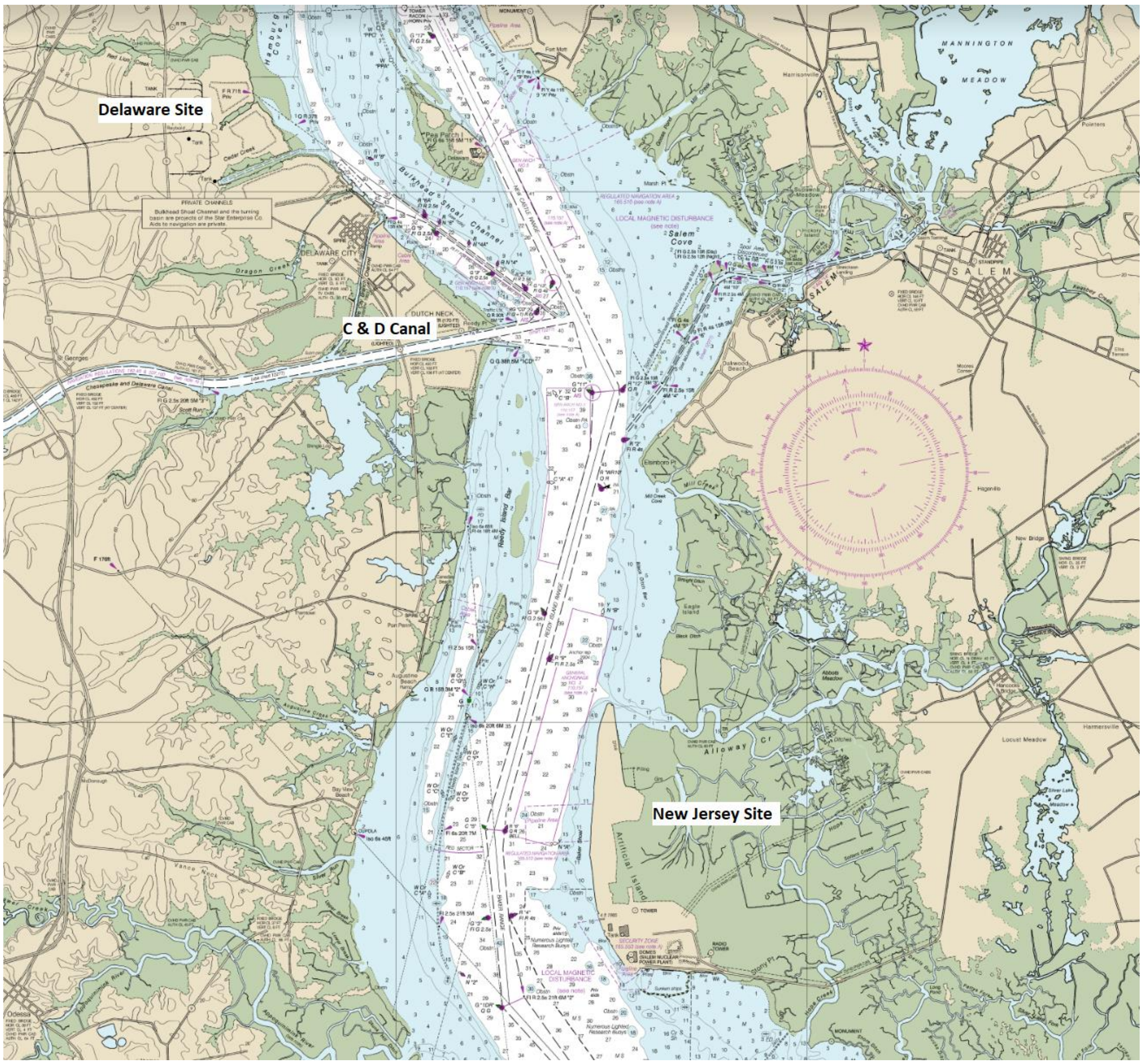

Figure 3: NOAA Navigational Chart with both areas of interest and the C&D Canal labeled, showing their proximity to highlight the potential for canal use[120].

[119] https://nauticalcharts.noaa.gov/publications/coast-pilot/files/cp3/CPB3_WEB.pdf
[120] https://nauticalcharts.noaa.gov/

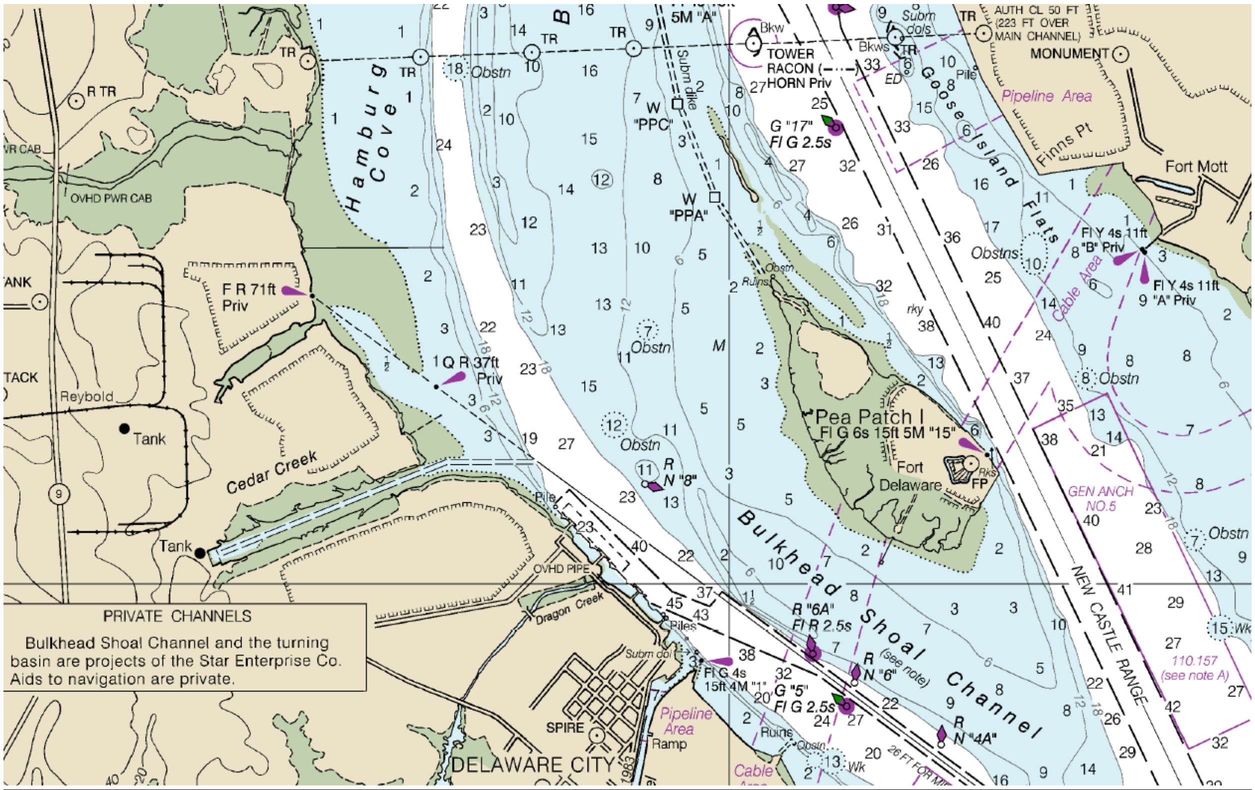

Figure 4: NOAA Navigational Chart for the channel by the Delaware Site. The 18-foot depth contour is shown as the border of the white area; this is the pathway for installation vessels to travel. The distance to the 12 foot and 18-foot contour is shown in Tables 3 and 4. Hamburg Cove surrounds the Delaware Site, and the New Castle Range is one of the deepest parts of the river in close proximity to this site[120].

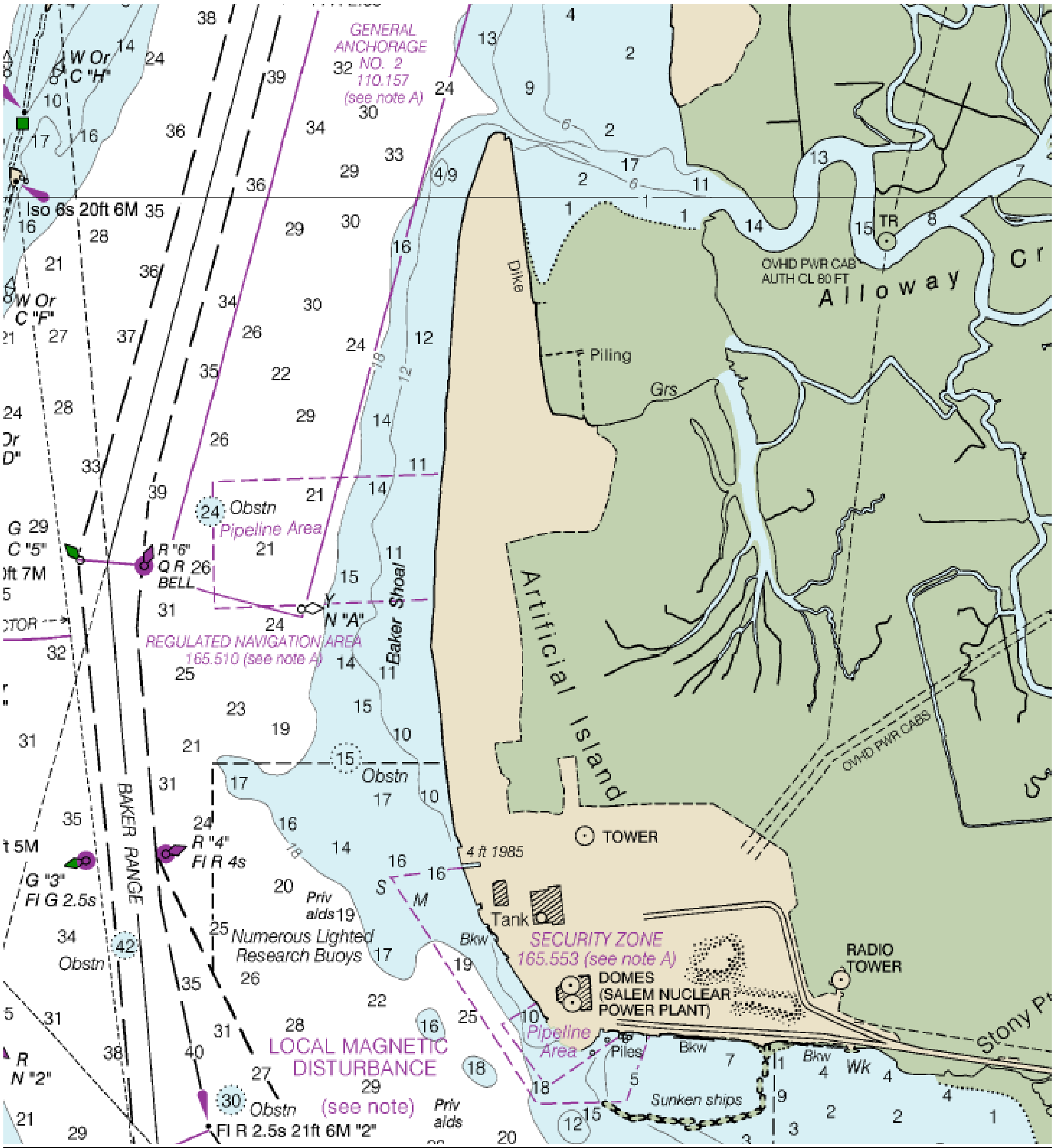

Figure 5: NOAA Navigational Chart for the channel by the New Jersey Site. The 18-foot depth contour is shown as the border of the white area; this is the pathway for installation vessels to travel. The distance to the 12 foot and 18 foot contour are shown in Table 3 and 4. The Baker Shoal surrounds the New Jersey site, and Baker Range is the deepest part of the river in close proximity to this site[120].

The extent of dredging will be dependent on the required minimum draft depth of the selected installation vessels used for the port. To analyze this extent we recommend looking at the drafts of typical heavy loading vessels (Table 3). Deepening of the channel to extend the pier and quay area beyond the 18-foot depth may be necessary for vessels to reach the deep channel by some TIV specifications. This comparison also illustrates the advantage of shallow-draft crane barge vessels like the L/B Paul, at least as an initial solution.

D. Port Zones

There need to be several zone areas in an offshore wind marshalling port: storage, pre-assembly, and loading/unloading. The storage zone is dedicated for three tower components, nacelles, blades, and empty transport frames. Subsea foundation would also be needed in some cases, but here we are expecting monopile foundations to come from elsewhere in the area and are thus not in our example design. Blades can be stacked or unstacked depending on the size of this zone. The layout of this zone should have an area of approximately 3600 m^2 (0.9 acres). The load bearing capacity is 23 tons/m^2.

A second required zone is required for pre-assembly of the tower components so that they may be loaded as complete structures onto the TIV. This zone must be in close proximity to the quay for load out, and operation of the vessel and access to onshore cranes for assembly of the components. The required area of this zone differs by project based on the following variables: the size of TIV used, number of components needed to be assembled, and the expected duration. The load bearing capacity is 30 tons/m^2.

Another zone should be for loading and unloading components to and from the transport vessels, components will be transferred to this area from the storage area and pre-assembly area and assembled turbines will be transported to this loading area to be deployed on the TIV. Transportation of these components will be with SPMTs, vessel cranes, and onshore cranes. Explicit specifications from the major OEM turbine manufacturer for the quay/loading area are 320 meters (1050 feet) long by 50 meters (164 feet) wide. The ground bearing pressure of the quay or lift area with crane loads should be 6,000 psf (30 tons/m^2). The load carrying capacity of the component offloaded on the SPMT is 10 tons/m^2.

E. Comparable Port Designs: The Port of New Bedford

To gain insights into design potential for the Delaware and New Jersey site options, we have examined two existing US ports: the Port of New Bedford and the Port of New London. The Port of New Bedford is currently used for cargo transport. Currently the port of New Bedford is the only operating offshore wind deployment port in the region that meets the necessary requirements for turbine deployment. This makes this the first facility in the United States to support offshore wind projects as a marshalling port. It is an ideal location to support the industry because of the close proximity (a minimum of 35 nautical miles) to current Wind Energy Areas, the absence of overhead restrictions, good highway connections, and sufficient deep water access for vessels common to most break bulk projects[121]. It is also the most protected port in the U.S., with the US Army Corps Hurricane Barrier guarding against storms up to Category 3 hurricanes[122].

New Bedford Marine Commerce Terminal (NBMCT) is a 26 acre facility located in the Port of New Bedford that is designed for US offshore wind deployment (Figure 6). The quay is 1,200 feet long where 1,000 feet provides sufficient bearing capacity for cranes and heavy loading, with a bulkhead design supported by a system of cofferdams and piles. The laydown area has a geotechnical aggregate to allow for heavy loads, both uniform and concentrated. Over 21 acres of this facility can support uniform loads of 4,100 pounds per square foot (20 tons/m^2) and concentrated loads of 20,485 pounds per square foot (100 tons/m^2)[123].

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[121] http://www.nbedc.org/wp/wp-content/uploads/2014/02/MA-Port-Study-Final-Report_4-20-10.pdf
[122] https://www.masscec.com/facilities/new-bedford-marine-commerce-terminal
[123] http://newbedfordwindenergycenter.org/a-full-service-port/new-bedford-marine-commerce-terminal/

To allow for heavy loading vessels to navigate to the NBMCT, dredging of the adjacent water body, the Acushnet River, was required. The area east of the Terminal is dredged from a depth between 1 and 6 feet deep to between 14 and 32 feet for the access of the vessels. Over 300 feet of this water body was dredged to provide a wide enough navigational channel for vessels to turn around. The channel by the Terminal bulkhead is dredged to 30 feet deep to provide enough vertical clearance for vessel drafts[124].

Figure 6: New Bedford Marine Commerce Terminal facility with wind turbine components[122].

F. Comparable Port Designs: The Port of New London

The Port of New London is currently used to ship general cargo, but is slated to be used for offshore wind development projects in the future. Connecticut's first 200 MW procurement from Revolution Wind, estimated to begin construction in 2022, has a stipulation to utilize the port of New London. A preliminary design by an artist at the Connecticut Port Authority outlines the potential for the expansion of this marshalling port (Figure 8). The Connecticut Governor announced in 2019 that State Pier will be revitalized to support the offshore wind industry by serving as a marshalling port[125].

The current state pier facility is 35 acres which has three operational areas including two main piers, near dock shoreline areas, and upland storage areas. The current design of New London (Figure 7) has two piers that expand outward, the CVVR to the left and the right State Pier. CVRR pier's length is 1080 feet with 150-200 feet width and the right State Pier's length is 1000 feet with 200 feet width. For the support of general cargo vessels, the dredge depth along the piers is 37 feet deep along the east face and 22 feet deep along the west face and south end[126]. The shoreline edge is built with sheet piling, pile-supported docks, and stone block walls and the materials of the pier are constructed with a granite block retaining wall. There are plans to expand in between the two piers to allow for more laydown and quay

[124] https://semspub.epa.gov/work/01/529000.pdf

[125]https://portal.ct.gov/Office-of-the-Governor/News/Press-Releases/2019/05-2019/Governor-Lamont-Announces-Development-Plan-That-Will-Establish-New-London-as-a-Hub-of-Offshore-Wind

[126] http://ctportauthority.com/wp-content/uploads/2017/05/state_pier_preliminary_design_report_april_2015.pdf

area for both bulk cargo and wind turbine components. The development of the State Pier is expected to provide sufficient area and loading capacities to support the deployment of offshore wind.

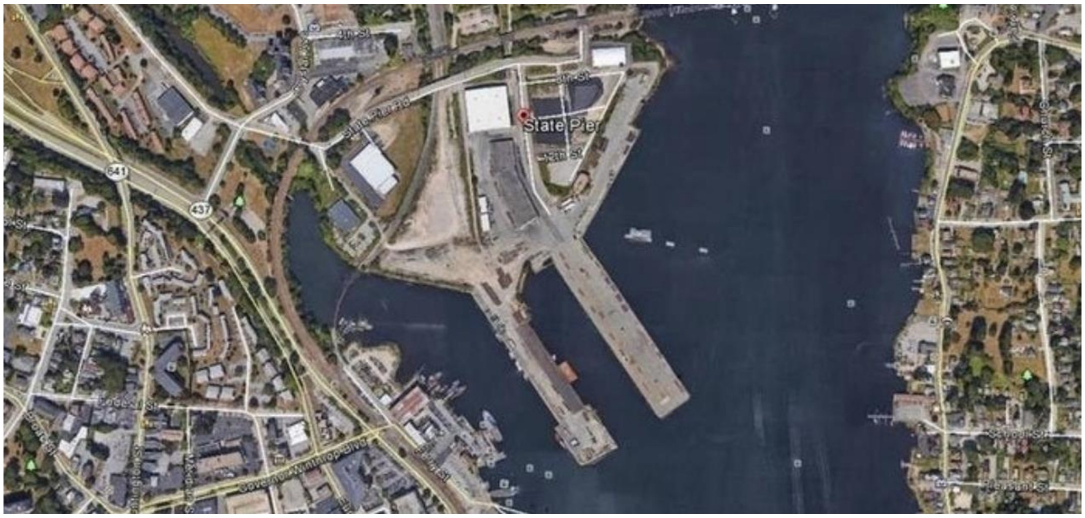


Figure 7: Current State Pier in New London, CT[127].

Figure 8: Artist rendering of buildout of the existing State Pier in New London for use by the offshore wind industry, expected to be completed in March 2022[128].

II. Pier Designs for the Delaware and New Jersey Port Locations

A. Designs

[127] https://patch.com/connecticut/newlondon/new-london-state-pier-lands-wind-energy-contract

[128] https://www.theday.com/article/20200211/NWS01/200219882

Based on our analysis of site conditions (laid out in the Current Conditions Analysis), industry standards, existing and proposed US port designs, and numerous discussions with regional, port, and offshore wind industry experts, our team hereby proposes several port designs for both port site options.

The design for the Delaware and New Jersey offshore wind deployment port options include the buildout of three and two pier options, respectively. The piers are designed to extend outwards toward the deeper area of the channel (12-foot depth contour) in the Delaware River. An extended pier design with the shape of an "L" was chosen over the bulkhead design as used in the New Bedford Terminal because through building out to the deeper part of the channel, there is less cost for dredging and a reduced impact on the environment.

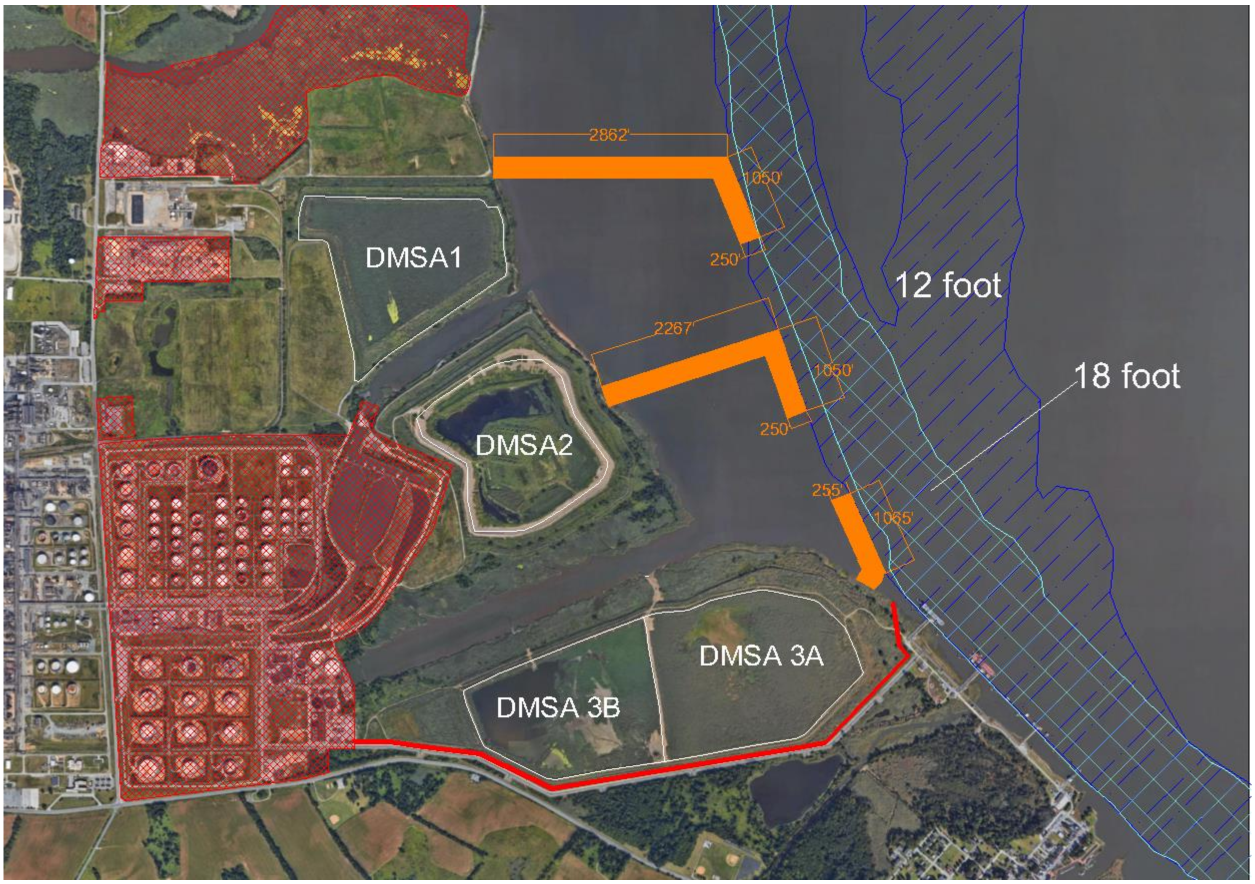


Figure 9: Pier and quay designs for the Delaware site. Shown in orange are three design options based off of the Current Conditions report of three potential sections of the property, referred to from North to South as Oxychem, DMSA2, and DMSA3A as identified in the drawing.

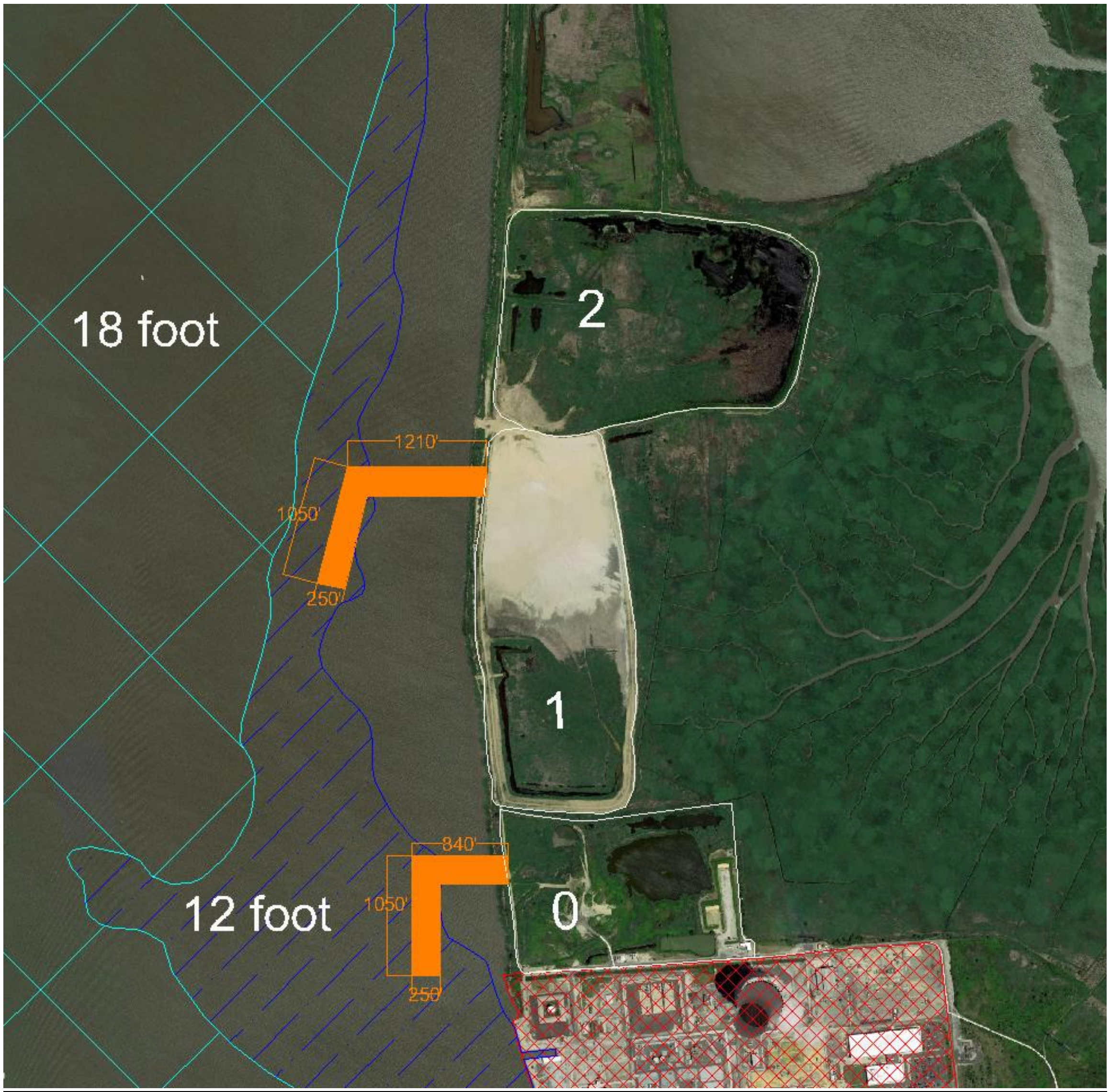


Figure 10: Pier and quay designs for the New Jersey site. Shown in orange are two design options based off of the current conditions analysis of three potential sections of the property, referred to from North to South as Area 1 and Area 0 as identified in the drawing.

Table 3: Depicts the distance to the deeper parts of the channel from the designed pier locations at the shore of the Delaware and New Jersey sites (12 foot and 18-foot contour lines) as shown in the NOAA navigational chart Figures 9 and 10.

Pier Options for the Delaware site		
Area	**Distance to the 12 foot depth channel contour (ft)**	**Distance to the 18 foot depth channel contour (ft)**
Oxychem	2862	2989
DMSA2	2267	2448
DMSA3A	355	684
Pier Options for the New Jersey site		
Area 1	878	1520
Area 0	500	2962

Using the industry standard area specifications for the loading/unloading zone, we designed options for a quay that extends off of the coast of the Delaware and New Jersey sites, with extra space for pre-assembly and room for transportation of the turbine components. The final design is 320 meters (1050 feet) by 76 meters (250 feet). More than sufficient storage area, according to industry standard requirements, is available on the site land area and the pier.

Each pier is 1050 feet long at the quay and 250 feet wide, in accordance with design requirements from a major turbine OEM. This is with the exception of the pier off of DMSA3A as it has a length of 1065 feet and 255 feet width to add additional area to the quay to account for the short buildout. Additionally, we ensured enough space between the Delaware City Refinery's vessels and the pier off of DMSA3A based on measurements of their loading dock.

B. Army Corps Recommendations

A meeting with the Army Corps of Engineers concerning the Delaware site educated certain design decisions. Specifically, the deep channel outlined in the Delaware River appropriate for installation vessels was identified by the Army Corps to be a self-scouring channel. River sedimentation is reduced in a self-scouring channel. This is favorable because maintenance dredging will not be required so there will be a cost reduction. Despite costs expanding outwards, there might be a federal offshore wind bill that will support the investment for building out a pier (this is elaborated upon within the Permitting Report).

We did not solicit any input from the Army Corps of Engineers concerning the New Jersey site, thus no site specific design choices on this site were informed by the Corps. However, some of the same conclusions may potentially be drawn as both sites share the same channel and similar pre-developed conditions.

C. Port Comparison

As can be seen in Figure 11, we drew current and planned marshalling ports used for offshore wind development and included the Delaware and New Jersey sites of interest to compare the available areas. Table 4 outlines the areas of the current, planned and proposed US ports. In the United States, New Bedford currently exists as a marshalling port, New London is expected to be redeveloped into a marshalling port in 2022, and Arthur Kill is a proposed marshalling port. Also shown in Figure 11, are the Esbjerg port located in Denmark and the Hull port located in the United Kingdom, which both share the North Sea. The international offshore wind industry is more developed than the US industry which is one of the reasons why there is a major size difference in the existing or planned ports between the countries. A major factor that restrains the expansion of the current and proposed US marshalling ports is that they have limited areas due to the dense abutting infrastructure and population, the presence of cities and roads, and the subsequent scarce available land along the eastern coast. Meanwhile, the New Jersey and Delaware sites have plenty of area available for thoughtful design specifically for offshore wind and expansion beyond any initial construction.

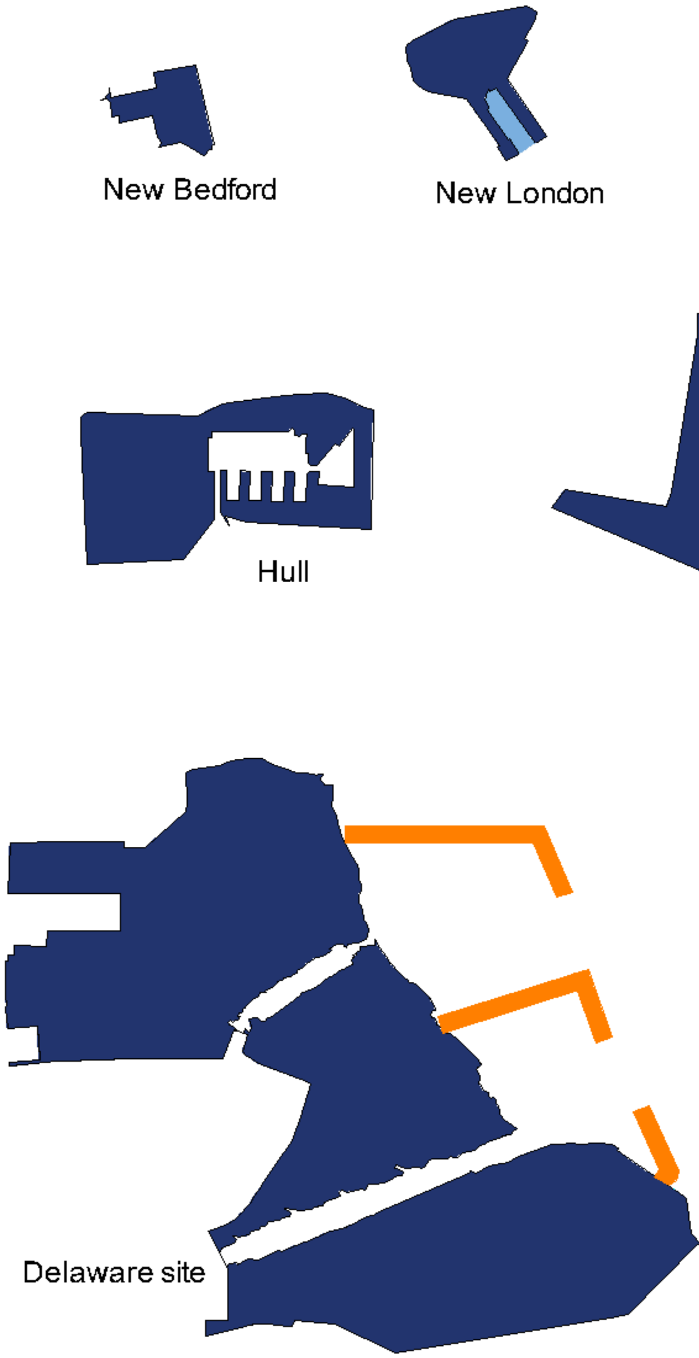


Figure 11: Proposed or current marshalling ports for offshore wind deployment.

Table 4: Acreage and Capacities of Regional Ports

Marshalling Port	Site Acreage*	Annual MW capacity**
New Bedford	29	268
New London (planned)	35	324
Arthur Kill (proposed)	35	324
Delaware Site (conceptual)*	831	500 +
New Jersey Site (conceptual)*	265	500 +

* acreage represents total land area available for development, not any added pier area.
+ Annual 500 MW capacity is based on example 54 acre development, not total site.
** see section 1: Market Analysis

D. Design Recommendations

Informed by the analysis detailed in this section and the current conditions of the sites of interest, we have developed the following design recommendations for port construction.

- We recommend that the pier is constructed on piling structures for the protection of the environment, sturgeon habitat, and the natural flow of the Delaware River.

- When comparing the lengths of the buildout options to the deep channel, the designs for the pier off of DMSA3A on the Delaware site and the piers off of Area1 and Area 0 on the New Jersey site are the closest to the channel, thus will be the least expensive to construct.

- On the Delaware site, we recommend building the pier off of the DMSA3A site because it is closest to the deep channel and thus would require a very short buildout. On the New Jersey side, we recommend building the pier off of Area 0 if further analysis determines the quay be built to the 12 foot contour, but we recommend building off of Area 1 if the choice is to build the pier out to the 18 foot contour line. This is due to the distance to each deeper part of the channel from the shore.

- Although these are our recommendations and designs based on the current site conditions, industry needs for port capabilities, and US examples, alternative options are possible for either site. It will be necessary to conduct further examination of the site's geotechnical conditions and financial feasibility of the port options to yield final, detailed designs.

- For both the New Jersey and Delaware sites, there is great potential for future expansion as the US offshore wind industry grows. The land area, outlined in Table 1 and 2, is larger than any other land area of marshalling ports now available, as shown in Figure 11, so laydown area for storage and operations of a larger marshalling port is feasible.

Appendix A: Data Disclaimers

USGS Data Disclaimer: Unless otherwise stated, All data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

Notes to Users about Point Elevation Maps: The datasets are being continuously updated with new elevation sources and the national coverage can be derived from topographic map contours that can be a couple of decades old[91].

Notes to User about FIRM Maps: The floodplain boundaries shown in the FEMA FIRMs were computed at cross sections and interpolated between them using county topographic maps[77].

On the FIRM maps, the BFEs are intended only for flood insurance rating purposes and should not be used as the only source for flood elevation information. The flood elevation data presented in the Flood Insurance Study (FIS) should be utilized for construction and floodplain management. The coordinate system used for the production of the FIRM was Universal Transverse Mercator (UTM). Flood elevations on the map are referenced to the North American Vertical Datum of 1988. The projection used in the FIRM map was the NAD83.

The sources of authority for the Flood Insurance Study are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. For the FIS report of Delaware City, the hydrologic and hydraulic analysis performed by Dewberry & Davis in August 1976 prepared by the Delaware River Basin Commision for FEMA under contract No. H-3747. The hydrologic and hydraulic analysis for the FIS report in May 1991 were performed by the U.S. Army Corps of Engineers for FEMA for the unincorporated areas of New Castle County.

Notes to User about USGS StreamStats application: There is also a disclaimer and associated assumption made by the USGS StreamStats application: that since the delineation points are within a tidal area, estimated values for percent storage are extrapolated with unknown error[95]. Since the site of interest is in a tidal zone, it is stated that this delineation is possible but not advised. This warning was given for the analysis of the NJ site only.

Appendix B: NWI Wetland Classifications

The following definitions are for the NWI Wetland Classification Codes[69], presented in section I.B. for wetlands present on the Delaware and New Jersey sites of interest. Each code generally contains information on the wetland system, subsystem, class, subclass, water regime, and any special modifiers. This identifies the wetland present and gives important information about the physical characteristics of the areas such as vegetation, soil types, and flooding tendencies.

System:

- **Estuarine (E)** : The Estuarine System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The salinity may be periodically increased above that of the open ocean by evaporation. Along some low-energy coastlines, there is appreciable dilution of seawater. Offshore areas with typical estuarine plants and animals, such as red mangroves (Rhizophora mangle) and eastern oysters (Crassostrea virginica), are also included in the Estuarine System.
- **Palustrine (P)** : The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) area less than 8 ha (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2.5 m (8.2 ft) at low water; and (4) salinity due to ocean-derived salts less than 0.5 ppt.
- **Lacustrine (L)** : The Lacustrine System includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, and emergent mosses or lichens with 30 percent or greater areal coverage; and (3) total area of at least 8 hectares (ha) (20 acres). Similar wetlands and deepwater habitats totaling less than 8 ha are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin equals or exceeds 2.5 m (8.2 ft) at low water. Lacustrine waters may be tidal or nontidal, but ocean-derived salinity is always less than 0.5 ppt.

Subsystem:

- **Subtidal (1)** : The substrate in these habitats is continuously covered with tidal water (i.e., located below extreme low water).
- **Intertidal (2)** : The substrate in these habitats is flooded and exposed by tides; including the associated splash zone.
- **Littoral (2)** : This Subsystem includes all wetland habitats in the Lacustrine System. It extends from the shoreward boundary of the System to a depth of 2.5 m (8.2 ft) below low water, or to the maximum extent of nonpersistent emergents if these grow at depths greater than 2.5 m.

Class:

- **Emergent (EM)** : Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.
- **Unconsolidated Bottom (UB)** : Includes all wetlands and deepwater habitats with at least 25% cover of particles smaller than stones (less than 6-7 cm), and a vegetative cover less than 30%.
- **Forested (FO)** : Characterized by woody vegetation that is 6 m tall or taller.

Subclass:

- **Persistent (1)** : Dominated by species that normally remain standing at least until the beginning of the next growing season. This subclass is found only in the Estuarine and Palustrine systems.
- **Broad-Leaved Deciduous (1)** : Woody angiosperms (trees or shrubs) with relatively wide, flat leaves that are shed during the cold or dry season; e.g., black ash (Fraxinus nigra).
- **Phragmites australis (5)** : Large perennial grass found in wetlands throughout temperate and tropical regions of the world. It is characterized by its towering height of up to four meters (about 14 feet) and its stiff wide leaves and hollow stem. Its feathery and drooping inflorescences (clusters of tiny flowers) are purplish when flowering and turn whitish, grayish or brownish in fruit.

Water Regime:

- **Irregularly Flooded (P)** : Tides flood the substrate less often than daily.
- **Regularly Flooded (N)** : Tides alternately flood and expose the substrate at least once daily.
- **Permanently Flooded-Tidal (V)** : Tidal fresh water covers the substrate throughout the year in all years. This Modifier is used for Riverine, Lacustrine, and Palustrine habitats.
- **Permanently Flooded (H)** : Water covers the substrate throughout the year in all years.
- **Semipermanently Flooded (F)** : Surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land surface.
- **Seasonally Flooded-Tidal (R)** : Tidal fresh surface water is present for extended periods (generally for more than a month) during the growing season, but is absent by the end of the season in most years. When surface water is absent, the depth to substrate saturation may vary considerably among sites and among years. This Modifier is used for Palustrine habitats only.
- **Seasonally Flooded (C)** : Surface water is present for extended periods especially early in the growing season, but is absent by the end of the growing season in most years. The water table after flooding ceases is variable, extending from saturated to the surface to a water table well below the ground surface.
- **Subtidal (L)** : Tidal salt water continuously covers the substrate.
- **Semipermanently Flooded-Tidal (T)** : Tidal fresh surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land surface. This Modifier is used for Riverine, Lacustrine, and Palustrine habitats.
- **Artificially Flooded (K)** : The amount and duration of flooding are controlled by means of pumps or siphons in combination with dikes, berms, or dams. The vegetation growing in these areas cannot be considered a reliable indicator of Water Regime. Examples of Artificially Flooded wetlands are some agricultural lands managed under a rice-soybean rotation, and wildlife management areas where forests, crops, or pioneer plants may be flooded or dewatered to attract wetland wildlife. Neither wetlands within nor resulting from leakage from man-made

impoundments, nor irrigated pasturelands supplied by diversion ditches or artesian wells, are included under this Modifier. The Artificially Flooded Water Regime Modifier should not be used in the Riverine system or for impoundments or excavated wetlands unless both water inputs and outputs are controlled to achieve a specific depth and duration of flooding.

Special Modifiers:

- **Excavated (x)** : This Modifier is used to identify wetland basins or channels that were excavated by humans.
- **Partially Drained/Ditched (d)** : A partly drained wetland has been altered hydrologically, but soil moisture is still sufficient to support hydrophytes. Drained areas that can no longer support hydrophytes are not considered wetland. This Modifier is also used to identify wetlands containing, or connected to, ditches. The Partly Drained/Ditched Modifier can be applied even if the ditches are too small to delineate. The Excavated Modifier should be used to identify ditches that are large enough to delineate as separate features; however, the Partly Drained/Ditched Modifier also should be applied to the wetland area affected by the ditching.
- **Spoil (s)** : The Spoil Modifier is used to describe wetlands where deposition of spoil material forms the primary substrate type. By definition, spoil is material that has been excavated and emplaced by humans. Ancillary data may be needed to identify spoil in areas such as reclaimed strip mines that have become vegetated.
- **Diked/Impounded (h)** : These wetlands have been created or modified by a man-made barrier or dam that obstructs the inflow or outflow of water.

Appendix C: NRCS Soil Type Classifications

Physical characteristics for the classifications of the most common surficial materials found on the Delaware and New Jersey sites for potential port locations. These are codes Br, ESA, HkB, UzC, and UddfB. The classification for further types may be found on the NRCS Web Soil Survey website[106].

Br—Broadkill mucky peat, very frequently flooded, tidal

Map Unit Setting

- *National map unit symbol:* 2p7dc
- *Mean annual precipitation:* 42 to 48 inches
- *Mean annual air temperature:* 52 to 58 degrees F
- *Frost-free period:* 180 to 220 days
- *Farmland classification:* Not prime farmland

Map Unit Composition

- *Broadkill, very frequently flooded, tidal, and similar soils:* 70 percent
- *Minor components:* 30 percent
- *Estimates are based on observations, descriptions, and transects of the mapunit.*

Description of Broadkill, Very Frequently Flooded, Tidal

Setting

- *Landform:* Tidal marshes
- *Landform position (three-dimensional):* Talf
- *Down-slope shape:* Linear
- *Across-slope shape:* Linear
- *Parent material:* Loamy marine sediments, high in silt

Typical profile

- *Oe - 0 to 6 inches:* mucky peat
- *Ag - 6 to 13 inches:* silty clay loam
- *Cg1 - 13 to 38 inches:* silty clay loam
- *Cg2 - 38 to 72 inches:* silty clay loam

Properties and qualities

- *Slope:* 0 to 1 percent
- *Depth to restrictive feature:* More than 80 inches
- *Natural drainage class:* Very poorly drained
- *Runoff class:* Low
- *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.20 to 2.00 in/hr)
- *Depth to water table:* About 0 inches
- *Frequency of flooding:* Very frequent
- *Frequency of ponding:* Frequent

- *Salinity, maximum in profile:* Strongly saline (16.0 to 35.0 mmhos/cm)
- *Sodium adsorption ratio, maximum in profile:* 90.0
- *Available water storage in profile:* Very high (about 18.1 inches)

Interpretive groups

- *Land capability classification (irrigated):* None specified
- *Land capability classification (nonirrigated):* 8w
- *Hydrologic Soil Group:* B/D
- *Hydric soil rating:* Yes

ESA—Endoaquepts and Sulfaquepts, 0 to 5 percent slopes

Map Unit Setting

- *National map unit symbol:* 2p7h6
- *Elevation:* 0 to 20 feet
- *Mean annual precipitation:* 42 to 48 inches
- *Mean annual air temperature:* 52 to 58 degrees F
- *Frost-free period:* 180 to 220 days
- *Farmland classification:* Not prime farmland

Map Unit Composition

- *Endoaquepts, drained, and similar soils:* 50 percent
- *Sulfaquepts, drained, and similar soils:* 40 percent
- *Minor components:* 10 percent
- *Estimates are based on observations, descriptions, and transects of the mapunit.*

Description of Endoaquepts, Drained

Setting

- *Landform:* Tidal marshes
- *Landform position (three-dimensional):* Talf
- *Down-slope shape:* Linear
- *Across-slope shape:* Linear

Typical profile

- *Bw - 0 to 36 inches:* silty clay loam
- *Bwj - 36 to 43 inches:* clay
- *Cg - 43 to 79 inches:* silt loam

Properties and qualities

- *Slope:* 0 to 5 percent
- *Depth to restrictive feature:* More than 80 inches
- *Natural drainage class:* Poorly drained

- *Runoff class:* Medium
- *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.57 in/hr)
- *Depth to water table:* More than 80 inches
- *Frequency of flooding:* None
- *Frequency of ponding:* Rare
- *Salinity, maximum in profile:* Nonsaline to moderately saline (0.0 to 8.0 mmhos/cm)
- *Available water storage in profile:* Moderate (about 8.6 inches)

Interpretive groups

- *Land capability classification (irrigated):* None specified
- *Land capability classification (nonirrigated):* 5s
- *Hydrologic Soil Group:* C
- *Hydric soil rating:* Yes

Description of Sulfaquepts, Drained

Setting

- *Landform:* Tidal marshes
- *Landform position (three-dimensional):* Talf
- *Down-slope shape:* Linear
- *Across-slope shape:* Linear

Typical profile

- *Bw - 0 to 12 inches:* silt loam
- *Bwj - 12 to 45 inches:* silt loam
- *Cg - 45 to 79 inches:* silt loam

Properties and qualities

- *Slope:* 0 to 5 percent
- *Depth to restrictive feature:* 0 to 24 inches to sulfuric
- *Natural drainage class:* Poorly drained
- *Runoff class:* Medium
- *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 1.28 in/hr)
- *Depth to water table:* More than 80 inches
- *Frequency of flooding:* None
- *Frequency of ponding:* Rare
- *Salinity, maximum in profile:* Nonsaline to moderately saline (0.0 to 8.0 mmhos/cm)
- *Available water storage in profile:* Very low (about 1.8 inches)

Interpretive groups

- *Land capability classification (irrigated):* None specified

- *Land capability classification (nonirrigated):* 5s
- *Hydrologic Soil Group:* C
- *Hydric soil rating:* Yes

HkB—Hambrook-Urban land complex, 0 to 5 percent slopes

Map Unit Setting

- *National map unit symbol:* 2p7fj
- *Elevation:* 0 to 260 feet
- *Mean annual precipitation:* 40 to 48 inches
- *Mean annual air temperature:* 52 to 58 degrees F
- *Frost-free period:* 180 to 250 days
- *Farmland classification:* Not prime farmland

Map Unit Composition

- *Hambrook and similar soils:* 45 percent
- *Urban land:* 35 percent
- *Minor components:* 20 percent
- *Estimates are based on observations, descriptions, and transects of the mapunit.*

Description of Hambrook

Setting

- *Landform:* Depressions, flats, fluviomarine terraces, knolls
- *Landform position (three-dimensional):* Rise
- *Down-slope shape:* Concave, linear, convex
- *Across-slope shape:* Concave, linear, convex

Typical profile

- *Ap - 0 to 10 inches:* sandy loam
- *BE - 10 to 14 inches:* loam
- *Bt - 14 to 28 inches:* sandy clay loam
- *BC - 28 to 65 inches:* loamy sand
- *2Cg - 65 to 80 inches:* silt loam

Properties and qualities

- *Slope:* 0 to 5 percent
- *Depth to restrictive feature:* More than 80 inches
- *Natural drainage class:* Well drained
- *Runoff class:* Very low
- *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.20 to 1.98 in/hr)
- *Depth to water table:* About 40 to 72 inches
- *Frequency of flooding:* None

- *Frequency of ponding:* None
- *Available water storage in profile:* Moderate (about 7.9 inches)

Interpretive groups

- *Land capability classification (irrigated):* 2e
- *Land capability classification (nonirrigated):* 2e
- *Hydrologic Soil Group:* B
- *Hydric soil rating:* No

Description of Urban Land

Setting

- *Landform:* Flats
- *Down-slope shape:* Linear
- *Across-slope shape:* Linear

UzC—Udorthents, 0 to 10 percent slopes

Map Unit Setting

- *National map unit symbol:* 2p7dw
- *Elevation:* 10 to 200 feet
- *Mean annual precipitation:* 42 to 48 inches
- *Mean annual air temperature:* 52 to 58 degrees F
- *Frost-free period:* 180 to 220 days
- *Farmland classification:* Not prime farmland

Map Unit Composition

- *Udorthents, loamy, and similar soils:* 90 percent
- *Minor components:* 10 percent
- *Estimates are based on observations, descriptions, and transects of the mapunit.*

Description of Udorthents, Loamy

Setting

- *Landform:* Flats, knolls
- *Down-slope shape:* Linear, convex
- *Across-slope shape:* Linear, convex
- *Parent material:* Fluviomarine sediments

Typical profile

- *C1 - 0 to 4 inches:* sandy loam
- *C2 - 4 to 80 inches:* sandy loam

Properties and qualities

- *Slope:* 0 to 10 percent
- *Depth to restrictive feature:* More than 80 inches
- *Natural drainage class:* Well drained
- *Runoff class:* Medium
- *Capacity of the most limiting layer to transmit water (Ksat):* High (1.98 to 5.95 in/hr)
- *Depth to water table:* About 40 to 72 inches
- *Frequency of flooding:* None
- *Frequency of ponding:* None
- *Available water storage in profile:* Moderate (about 6.1 inches)

Interpretive groups

- *Land capability classification (irrigated):* None specified
- *Land capability classification (nonirrigated):* 3e
- *Hydrologic Soil Group:* A
- *Hydric soil rating:* No

UddfB—Udorthents, dredged fine material, 0 to 8 percent slopes

Map Unit Setting

- *National map unit symbol:* 4k49
- *Elevation:* 0 to 170 feet
- *Mean annual precipitation:* 28 to 59 inches
- *Mean annual air temperature:* 46 to 79 degrees F
- *Frost-free period:* 161 to 231 days
- *Farmland classification:* Not prime farmland

Map Unit Composition

- *Udorthents, dredged fine materials, and similar soils:* 90 percent
- *Minor components:* 10 percent
- *Estimates are based on observations, descriptions, and transects of the map unit.*

Description of Udorthents, Dredged Fine Materials

Setting

- *Landform:* Depressions
- *Landform position (two-dimensional):* Toeslope
- *Landform position (three-dimensional):* Base slope
- *Down-slope shape:* Concave
- *Across-slope shape:* Concave
- *Parent material:* Loamy material transported by human activity; fine-loamy dredge spoils

Typical profile

- *A - 0 to 12 inches:* loam
- *C - 12 to 80 inches:* clay

Properties and qualities

- *Slope:* 0 to 8 percent
- *Depth to restrictive feature:* More than 80 inches
- *Natural drainage class:* Well-drained
- *Runoff class:* Medium
- *The capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr)
- *Depth to water table:* More than 80 inches
- *Frequency of flooding:* None
- *Frequency of ponding:* None
- *Available water storage in profile:* High (about 11.3 inches)

Interpretive groups

- *Land capability classification (irrigated):* None specified
- *Land capability classification (nonirrigated):* 3w
- *Hydrologic Soil Group:* C
- *Hydric soil rating:* No

Appendix D: Soil Mechanics Terms

_______In the following table there are definitions for geologic terms that are commonly used in Section III of this Current Conditions Analysis as well as in many geotechnical references. Various types of soil as described below are often present in the surface or subsurface and have different characteristics and subsequent implications to a potential port design.

Type of Soil	Description
Peat	Dark brown or black soil that can store a lot of water. Compressible, so it is not ideal for support because foundations are most stable on soil that is not prone to shift or change structure.[129]
Clay	Composed of tiny particles, so stores water well. When moist, it will expand greatly. When dry, it will shrink significantly because it has a tight grasp of water. Not ideal for foundations because foundations exert a lot of pressure on the soil. When pressure is applied clay moves up and down easily, and can crack. Clay particles have a flakey shape that results from chemical or physical weathering. Clay is fine soil, with extremely small particle sizes (less than 0.004 mm). When clay particles are wet, clay is sticky. When clay is dry, it is hard.[130]
Silt	Composed of small particles that retain water and drain poorly. When retaining moisture, the silty soil pushes against the foundation and will weaken it.[130]
Sand/Gravel	Large openings between particles, so water drains easily. If compacted, the soils will be good to support a foundation because it does not retain water. Moist particles lose their friction and can be washed away (leaving gaps beneath foundation). Sands are broken particles formed from weathering or breaking down rocks (particle sizes are 0.06 to 2 mm).[130]
Loam	Composed of a combination of sand, silt, clay. Perfect combination of loam is 40% silt, 40% sand, and 20% clay. It is great for supporting foundations because it has evenly balanced properties.[130]

[129] https://www.ramjack.com/blog/2015/august/different-soils-how-they-affect-foundations/

Rock	This category of soil has high bearing capacity and is suitable for supporting foundations due to its stability and depth. Types of bedrock include, limestone, sandstone, shale and hard chalk.[130]
Fill	Man made deposits of natural earth material, most commonly silt, clay or mud. Can contain small amounts of sand. Dredge spoil, one type of fill, is used to extend shore land.[130]
Cohesion	The capacity of a soil to resist shearing stress, exclusive of functional resistance[130]. Hydrologic Group C soils have minimum cohesion.

[130] https://tools.niehs.nih.gov/wetp/public/Course_download2.cfm?tranid=4432

Appendix E: Subsurface Geological Information

Delaware Site: DMSA1

Soil Profile (Figure E.1):

The soil profile of cross-section A to A' represents different soil types in this cross section that goes through DMSA1. Fill (gray) ranges about 0 to 35 feet above elevation. Swamp or marsh (yellow) land ranges about 0 to -10 feet above elevation. Merchantville formation (light green) is below the swamp material and it is about -10 to -40 feet above elevation. Below is Potomac Formation (forest green) ranging from -40 feet to -150 feet above the datum.

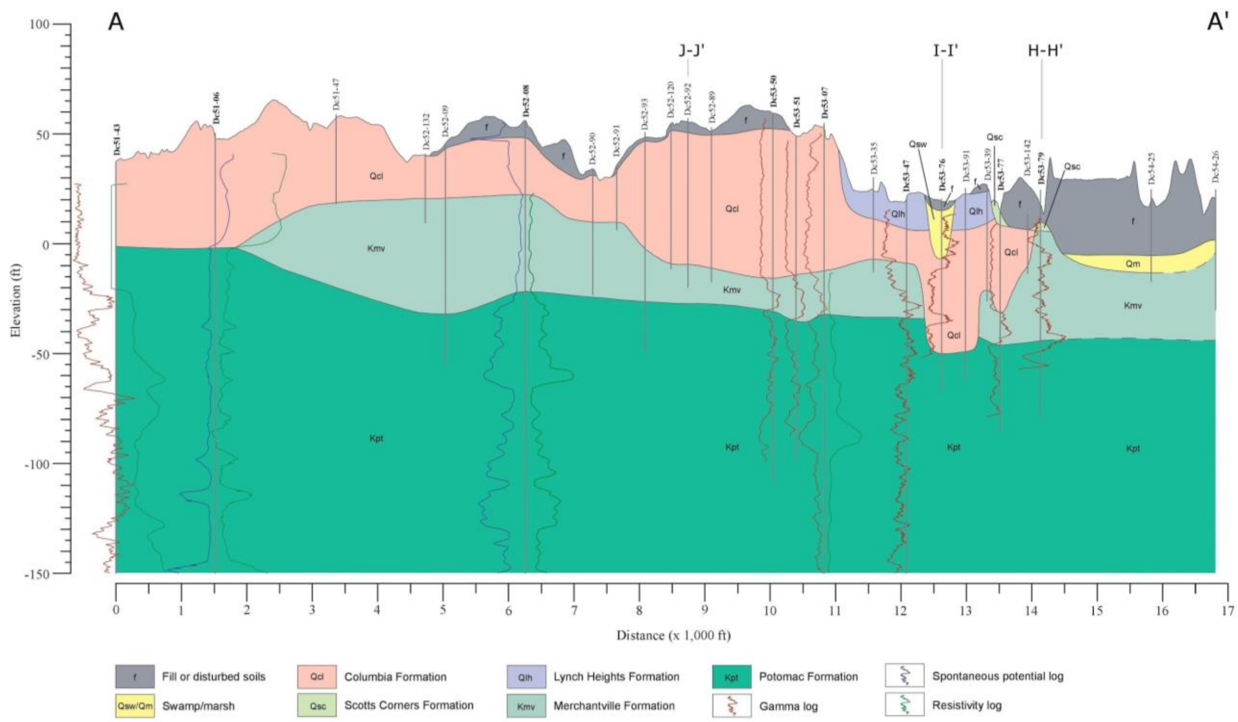


Figure E.1: Cross Section A through A'[104].

Boring Logs: (Figure E.2)

Borehole 54-25

- The surface elevations are 24.5 feet above sea level.
- From 0 to 25' it is brown to gray silty clay
- The depths 25 to 30' consist of yellow-brownish medium to fine sand with some silty clay
- Between 30 to 42' depth are organic silty clay and black to dark brown peat

Borehole 54-26

- Surface elevations are 24.5 feet above sea level
- From 0 to 25' it is brown to gray silty clay

- The depths 25 to 30’ consist of black to brown peat
- Depths 30 to 40’ consists of organic silty clay

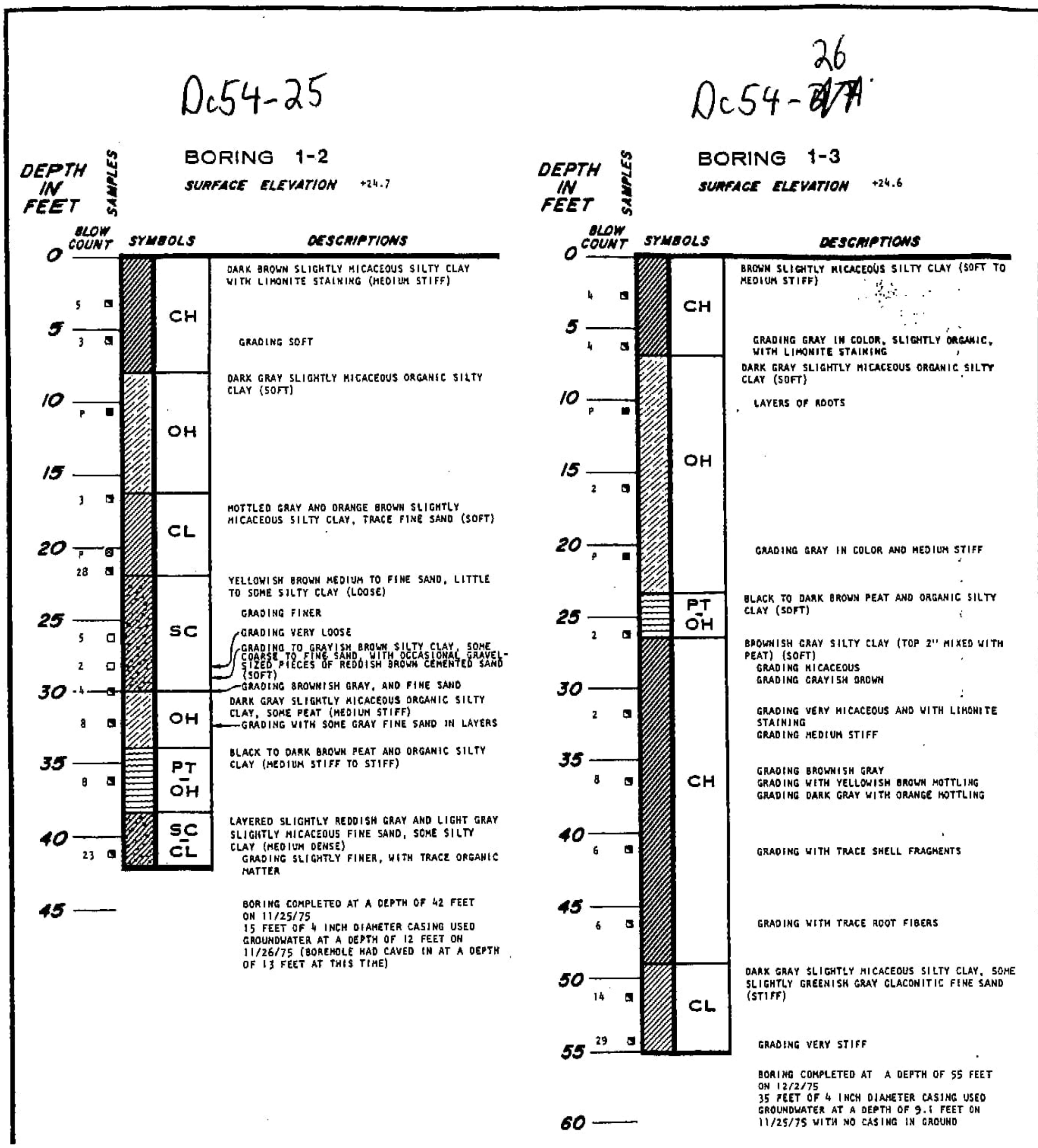


Figure E.2: Boring logs Dc54-25 and Dc54-26 showing the surface elevation and the descriptions for each depth[102].

Delaware Site: DMSA 2:

Soil Profile (Figure E.3):

Since this cross-section of B to B’ only extends to a small section of the DMSA 2, we can analyze the last hundred feet of the soil profile from Dc54-19 to Dc54-13 depicted in Figure E.4. The soil profile of cross-section B to B' is in Figure E.3, fill (gray) ranges from about -5 to 23 feet above sea level. Swamp or marsh (yellow) land ranges about -5 to -32 feet above elevation. Merchantville formation (light green) is below the swamp material and it is about -30 to -70 feet above elevation. Below is Potomac Formation (forest green) ranging from -70 feet to -150 feet above elevation.

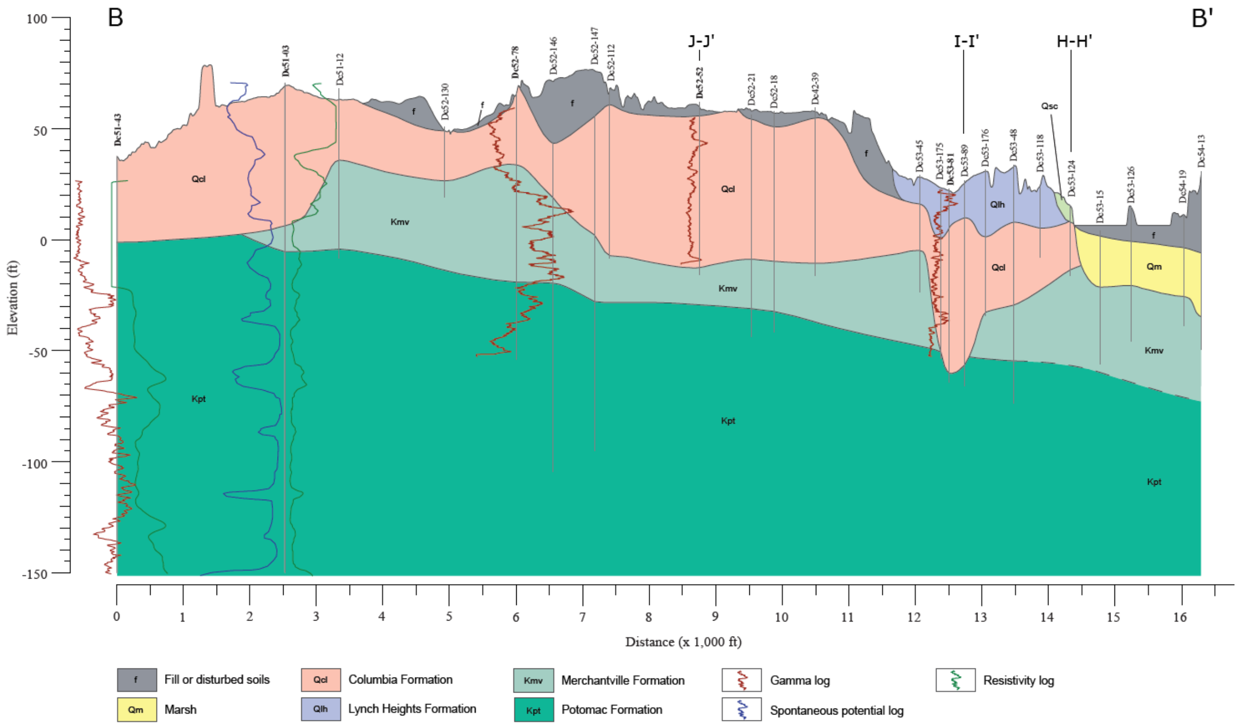


Figure E.3: Cross Section B to B'[104]. We analyzed from 54-19 to Dc54-13.

Boring Logs (Figures E.4 - E-12):

Borehole 54-17:

- Surface elevation is 31 feet
- Gray silty clay
- Ranges from 0 to 72 feet
- Water content increases 23 to 81%
- Stiffness varies

Borehole 54-46:

- Surface Elevation is 31.5 feet
- Water content ranges from 22% to 191%
- Depth 0-4 feet: silty fine sand, trace gravel with water content averaging 22%
- Depth 4-9 feet: sandy silty clay with water content averaging 29%
- Depth 9-50 feet: Stiff silty clay with water content averaging 49% (ranges 36-71%)
- Depth 50-52 feet: Dark brown fibrous peat with a water content of 191.5%

- Depth 52-60 feet: Soft gray silty clay with water content ranging from 55.8% to 105%

Borehole 54-68:

- Surface elevation is 22 feet
- Depth 0-7 feet: Medium dense brown silty sand
- Depth of 7-17 feet: Soft dark gray silty clay with occasional organics (roots)

Borehole 54-69:

- Surface Elevation is 21 feet
- Depth of 0-8 feet: Silty fine sand with water content: 31.6%
- Depth of 8 to 23 feet: Soft organic silt with water content: 59%
- Depth of 23 - 25 feet: Loose silty sand with fine sandy clayey silt with water content: 38%
- Depth of 25 - 33 feet: Soft organic silt, trace fine sand with a water content of 66%
- Depth 33- 36 feet: Dark gray fibrous peat
- Depth 36-47 feet: Soft organic clayey silt with water content averaging 92% ranging 63.5 to 120%, Liquid limit: 52% and Plastic Limit: 39 %
- Depth 47 - 50 feet: Stiff to hard gray fine sandy silty clay with Liquid limit: 26% and plastic limit: 19%

Dc54-17

LOG of BORING NO. B-8

Sheet 1 of 3

DATE: February 26, 1998 SURFACE ELEVATION: 31.0 LOCATION: See Plan

DEPTH, ft	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER (tsf)	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0	11	SS	Stiff to very stiff brown micaceous sandy clayey silt/silty clay			16.0			
	16	SS				20.9			
5	28	SS				21.0			
	35	SS				22.6			
	29	SS	Fill			31.0			
10				20.6		23.6			
	25	SS	Stiff dark gray micaceous silty clay, trace organics		1.4	33.1			
15	16	SS				23.9			
	9	SS	-- becoming medium stiff		0.75	23.9			
20									
25	5	SS	Qm		1.1	59.0			
30	2	SS			0.7	48.5			
		ST				42.6			X
	2	SS	-- becoming soft		0.3	50.2			
35									

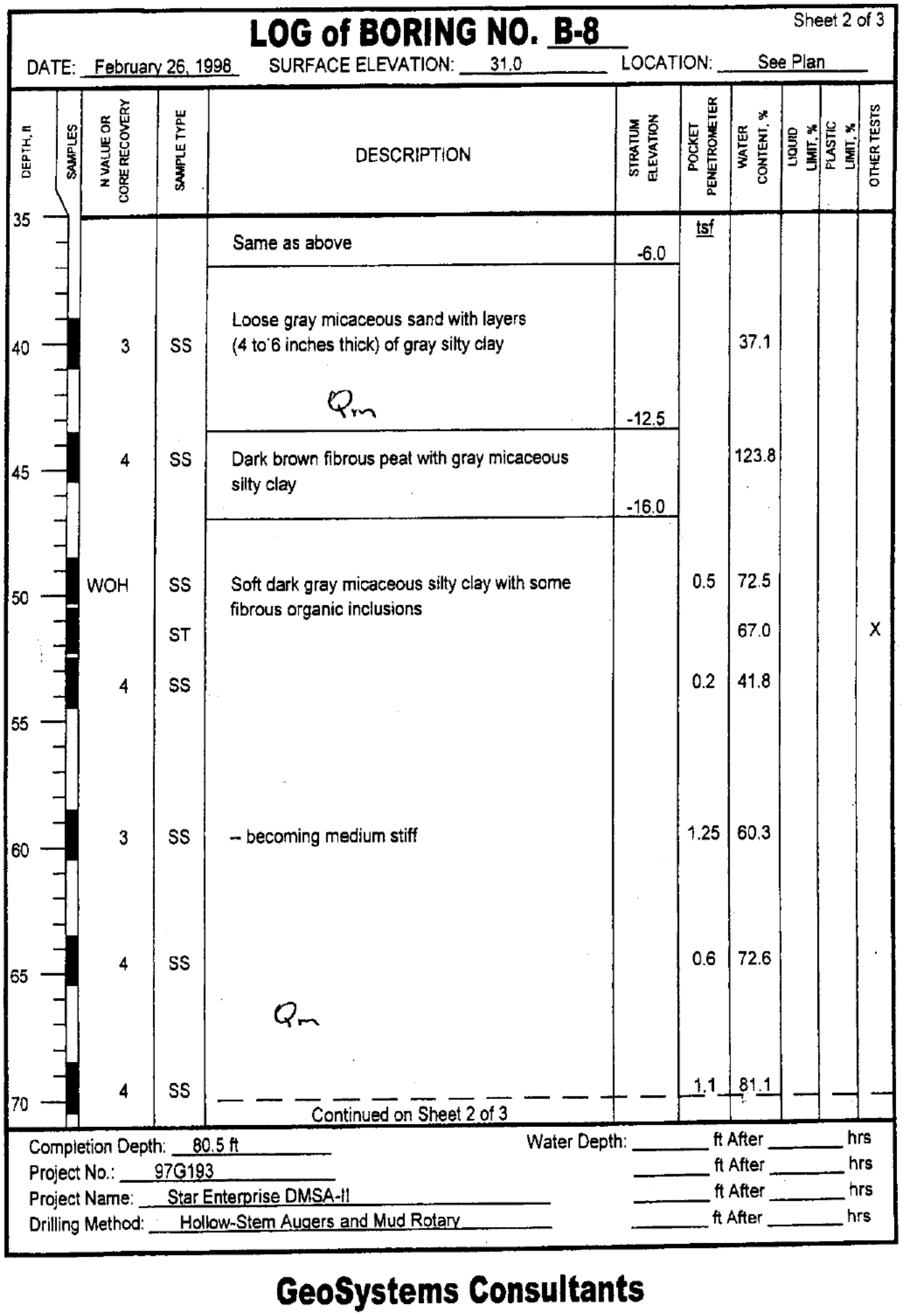
Continued on Sheet 2 of 3

Completion Depth: 80.5 ft
Project No.: 97G193
Project Name: Star Enterprise DMSA-II
Drilling Method: Hollow-Stem Augers and Mud Rotary

Water Depth: ____ ft After ____ hrs
____ ft After ____ hrs
____ ft After ____ hrs
____ ft After ____ hrs

GeoSystems Consultants

Figure E.4: Dc54-17 part A[102].



LOG of BORING NO. B-8 — Sheet 2 of 3

DATE: February 26, 1998 SURFACE ELEVATION: 31.0 LOCATION: See Plan

DEPTH, ft	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER (tsf)	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
35			Same as above	-6.0					
40	3	SS	Loose gray micaceous sand with layers (4 to 6 inches thick) of gray silty clay Qm	-12.5		37.1			
45	4	SS	Dark brown fibrous peat with gray micaceous silty clay	-16.0		123.8			
50	WOH	SS	Soft dark gray micaceous silty clay with some fibrous organic inclusions		0.5	72.5			
		ST				67.0			X
	4	SS			0.2	41.8			
55									
60	3	SS	-- becoming medium stiff		1.25	60.3			
65	4	SS	Qm		0.6	72.6			
70	4	SS			1.1	81.1			

Continued on Sheet 2 of 3

Completion Depth: 80.5 ft Water Depth: ____ ft After ____ hrs

Project No.: 97G193 ____ ft After ____ hrs

Project Name: Star Enterprise DMSA-II ____ ft After ____ hrs

Drilling Method: Hollow-Stem Augers and Mud Rotary ____ ft After ____ hrs

GeoSystems Consultants

Figure E.5: Dc54-17 Part B[102].

Sheet 3 of 3

LOG of BORING NO. B-8

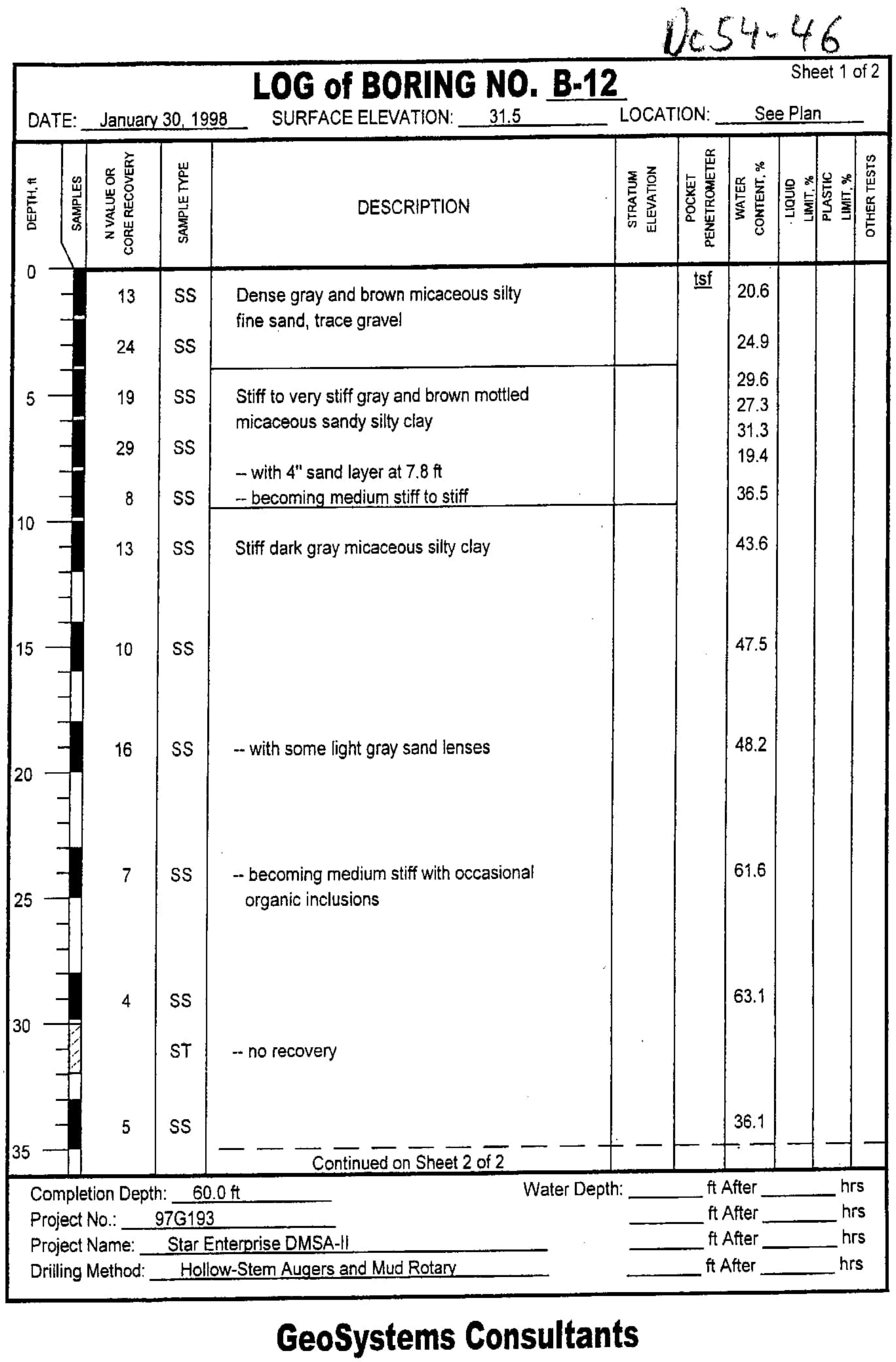
DATE: February 26, 1998 SURFACE ELEVATION: 31.0 LOCATION: See Plan

DEPTH, ft	SAMPLES	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
70				Same as Above	-41.0					
75		9	SS	Stiff gray and brown sandy silty clay	-46.0		16.5			
80		21	SS	Medium dense light gray silty medium to fine sand	-49.5		23.7			
		Qcl ?								
85										
90										
95										

Completion Depth: 80.5 ft Water Depth: ____ ft After ____ hrs
Project No.: 97G193 ____ ft After ____ hrs
Project Name: Star Enterprise DMSA-II ____ ft After ____ hrs
Drilling Method: Hollow-Stem Augers and Mud Rotary ____ ft After ____ hrs

GeoSystems Consultants

Figure E.6: Dc54-17 part C[102].



Dc54-46

LOG of BORING NO. B-12

Sheet 1 of 2

DATE: January 30, 1998 SURFACE ELEVATION: 31.5 LOCATION: See Plan

DEPTH, ft	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER (tsf)	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0	13	SS	Dense gray and brown micaceous silty fine sand, trace gravel			20.6			
	24	SS				24.9			
5	19	SS	Stiff to very stiff gray and brown mottled micaceous sandy silty clay			29.6 27.3			
	29	SS				31.3 19.4			
	8	SS	-- with 4" sand layer at 7.8 ft -- becoming medium stiff to stiff			36.5			
10	13	SS	Stiff dark gray micaceous silty clay			43.6			
15	10	SS				47.5			
20	16	SS	-- with some light gray sand lenses			48.2			
25	7	SS	-- becoming medium stiff with occasional organic inclusions			61.6			
30	4	SS				63.1			
		ST	-- no recovery						
35	5	SS				36.1			

Continued on Sheet 2 of 2

Completion Depth: 60.0 ft
Project No.: 97G193
Project Name: Star Enterprise DMSA-II
Drilling Method: Hollow-Stem Augers and Mud Rotary

Water Depth: ____ ft After ____ hrs
____ ft After ____ hrs
____ ft After ____ hrs
____ ft After ____ hrs

GeoSystems Consultants

Figure E.7: Dc54-46 Part A[102].

Sheet 2 of 2

LOG of BORING NO. B-12

DATE: January 30, 1998 SURFACE ELEVATION: 31.5 LOCATION: See Plan

DEPTH, ft	SAMPLES	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER tsf	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
35				Medium stiff dark gray micaceous silty clay						
		5	SS				35.3			
40										
		5	SS				40.9 45.5			
45										
		7	SS		-18.1		71.1			
50				Dark brown fibrous peat	-20.0		191.5			
		2	SS	Soft gray micaceous silty clay, trace organics			105.3			
55										
		WOH	SS		-28.5		55.8			
60										
65										
70										

Completion Depth: 60.0 ft
Project No.: 97G193
Project Name: Star Enterprise DMSA-II
Drilling Method: Hollow-Stem Augers and Mud Rotary

Water Depth: ____ ft After ____ hrs
____ ft After ____ hrs
____ ft After ____ hrs
____ ft After ____ hrs

GeoSystems Consultants

Figure E.8: Dc54-46 Part B[102].

Dc54-68

LOG of BORING NO. B-36

Sheet 1 of 2

DATE: May 15, 1998 SURFACE ELEVATION: 22.1 LOCATION: See Plan

DEPTH, ft	SAMPLES	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0						tsf				
		6	SS	Medium dense brown micaceous silty sand with seams (1/8 to 1/2 inch) of gray silty clay						
		6	SS							
5		4	SS							
		2	SS	-- becoming loose and gray	14.9					
		1	SS	Soft dark gray micaceous silty clay with occasional organic inclusions (roots)		0.5				
10										
		2	SS	-- becoming medium stiff, trace organic inclusions		0.75				
15					3.8					
		5	SS	Loose gray and dark gray micaceous fine sand						
20										
		2	SS	-- with occasional 1-inch-thick layers of gray silty clay						
25					-6.9					
		1	SS	Soft dark gray silty clay and brown fibrous peat		0.5				
30			ST		-10.9					
		2	SS	See below						
35										

Continued on Sheet 2 of 2

Completion Depth: 55.0 ft
Project No.: 97G193
Project Name: Star Enterprise DMSA-II
Drilling Method: Hollow-Stem Augers

Water Depth: 3.0 ft After 72 hrs
3.5 ft After 96 hrs
ft After hrs
ft After hrs

GeoSystems Consultants

Figure E.9: Dc54-68 Part A[102].

LOG of BORING NO. B-36

Sheet 2 of 2

DATE: May 15, 1998 SURFACE ELEVATION: 22.1 LOCATION: See Plan

DEPTH, ft	SAMPLES	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
35						tsf				
40	■	2	SS	Medium stiff dark gray micaceous silty clay with occasional fine sand lenses and fibrous organic inclusions	-19.9	0.6-1.0				
45	■	woh	SS	Very loose gray medium to fine sand	-24.4					
50	■	8	SS	Medium stiff brown and gray mottled silty clay		0.75				
55	■	9	SS	-- becoming stiff gray micaceous silty clay	-32.9	1.25				
60										
65										
70										

Completion Depth: 55.0 ft
Project No.: 97G193
Project Name: Star Enterprise DMSA-II
Drilling Method: Hollow-Stem Augers

Water Depth: 3.0 ft After 72 hrs
3.5 ft After 96 hrs
ft After hrs
ft After hrs

GeoSystems Consultants

Figure E.10: Dc54-68 Part B[102].

Dc54-69

LOG of BORING NO. B-37

DATE: May 18, 1998 SURFACE ELEVATION: 21.1 LOCATION: See Plan

DEPTH, ft	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER (tsf)	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0	6	SS	Medium dense brown and gray silty fine sand with layers (1/2 to 1 inch) of gray silty clay			26.6			
	5	SS				39.2			
5	5	SS				28.9			
	3	SS		13.4					
	2	SS	Soft to very soft dark gray micaceous organic silt		0.3-0.25	46.9	NP	NP	
10									
	1	SS	-- with fibrous organic inclusions		0.1	59.8			
15		ST							
	woh	SS	-- with lenses of gray silty fine sand		0.25-0.5	70.5			
20				-1.9					
	wor	SS	Very loose gray silty sand with lenses of fine sandy clayey silt	-3.9		37.8			
25									
	2	SS	Soft dark gray micaceous organic silt, trace lenses of fine sand		0.5	65.7			
30				-11.9					
	3	SS	Dark gray fibrous peat						
35									

Continued on Sheet 2 of 2

Completion Depth: 50.0 ft Water Depth: 5.5 ft After 24 hrs
Project No.: 97G193 ft After hrs
Project Name: Star Enterprise DMSA-II ft After hrs
Drilling Method: Hollow-Stem Augers ft After hrs

GeoSystems Consultants

Figure E.11: Dc54-69 Part A[102].

LOG of BORING NO. B-37

Sheet 2 of 2

DATE: May 18, 1998 SURFACE ELEVATION: 21.1 LOCATION: See Plan

DEPTH, ft	SAMPLES	N VALUE OR CORE RECOVERY	SAMPLE TYPE	DESCRIPTION	STRATUM ELEVATION	POCKET PENETROMETER	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
35				Dark brown fibrous peat	-14.9	tsf				
	■	woh	SS	Soft gray micaceous organic clayey silt		0.3	63.5	52	39	
40										
	■	8	SS	-- becoming medium stiff with dark brown fibrous peat inclusions		0.75	119.7			
45					-25.9					
	■	25	SS	Very stiff to hard greenish gray fine sandy silty clay	-28.9	4.5+	20.7	26	19	
50										
55										
60										
65										
70										

Completion Depth: 50.0 ft
Project No.: 97G193
Project Name: Star Enterprise DMSA-II
Drilling Method: Hollow-Stem Augers

Water Depth: 5.5 ft After 24 hrs
ft After hrs
ft After hrs
ft After hrs

GeoSystems Consultants

Figure E.12: Dc54-69 Part B[102].

Delaware Site: DMSA3

Soil Profile (Figure E.13 - E.15):

The soil profile for DMSA3 is cross-section C to C,' D to D,' and 'E to E'. Each color represents a different soil. Fill (gray) ranges about 0 to 35 feet above elevation. Swamp or marsh (yellow) land ranges about 0 to -10 feet above elevation. Merchantville formation (light green) is below the swamp material and it is about -10 to -40 feet above elevation. Below is Potomac Formation (forest green) ranging from -40 feet to -150 feet above the datum.

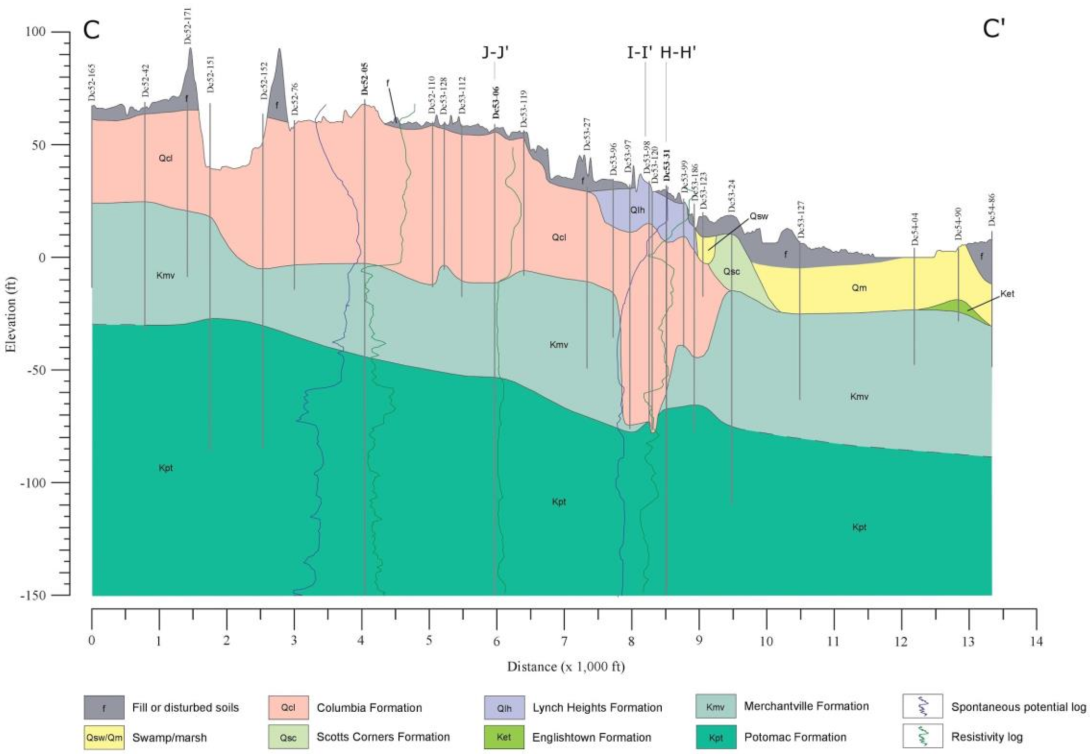


Figure E.13: Cross Section of C to C' analyzed[104].

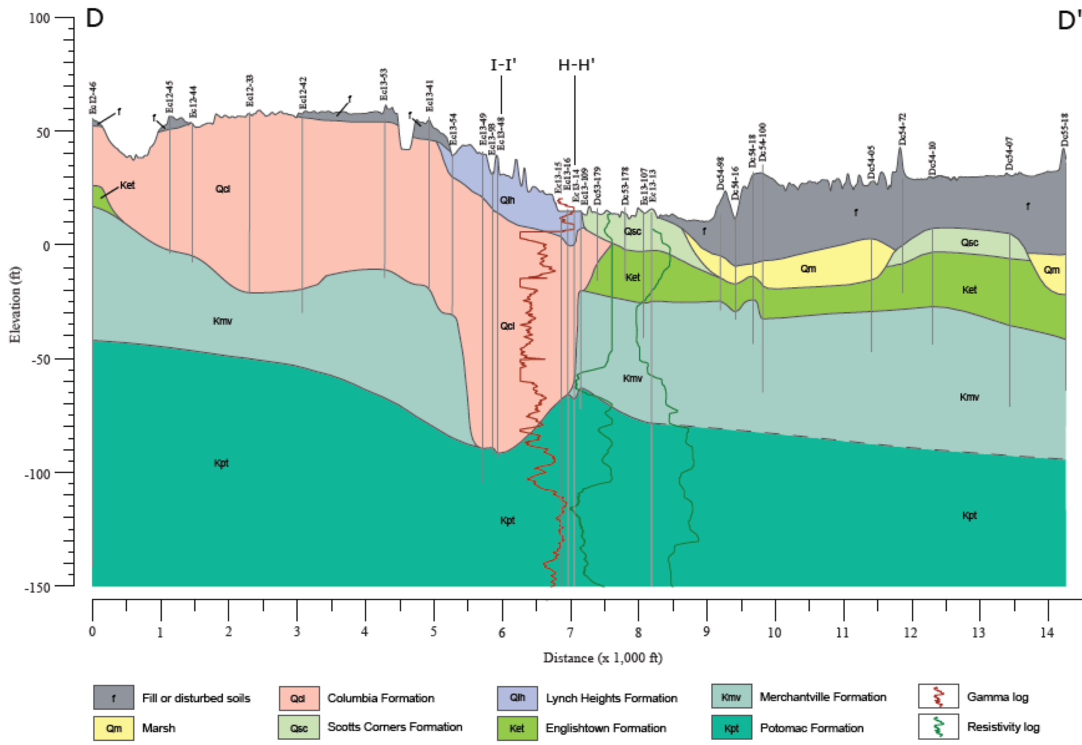


Figure E.14: Cross Section D to D' analyzed[104].

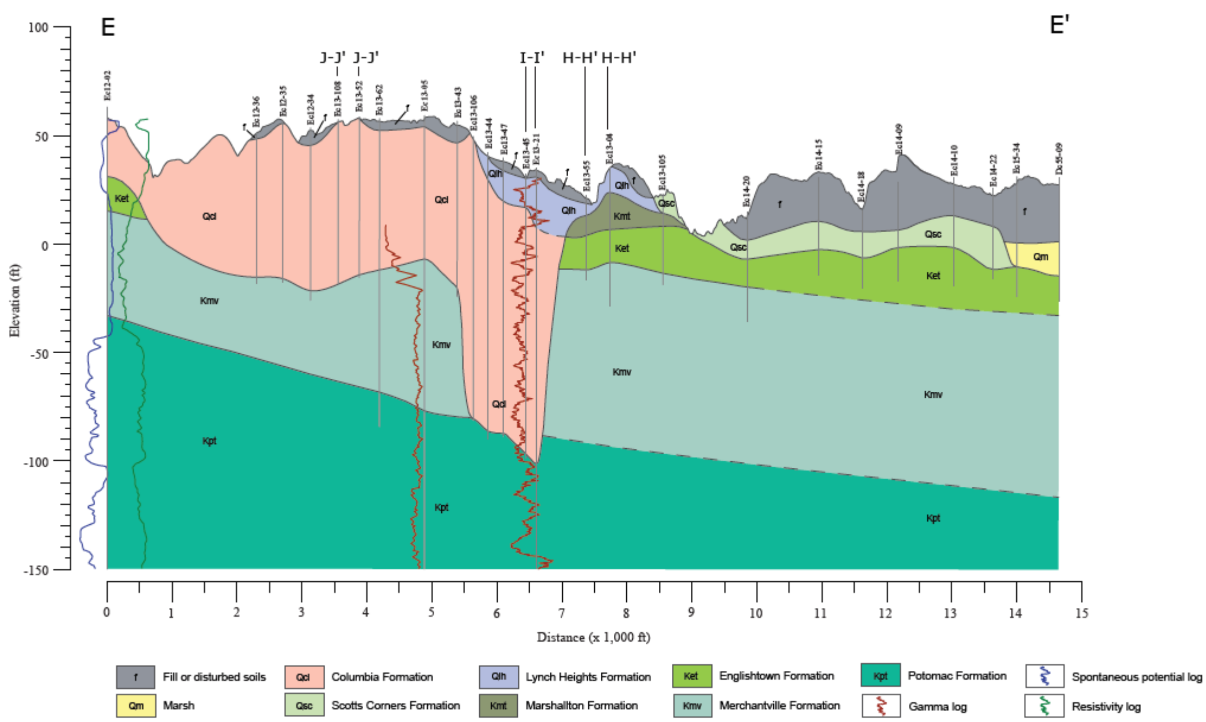


Figure E.15: Cross Section E to E' analyzed[104].

Boring Logs (Figures E.16 - E.18):

Borehole Dc55-03: Taken in 1956, surface elevation

- Depth 0-3' soft silty clay
- Depth 3-7' silty loam and sandy loam
- Depth 7-15' fine to medium sand with gravel
- Depth 15-43': Dark gray silty clay loam
- Depth: 43-60': Clay loam

Borehole Dc55-13: Taken in 1975, surface elevation 10.8 feet

- Depth 0-22': Gray micaceous fine sand and silt
- Depth 22-42': Organic clay with trace amounts of gray fine sand

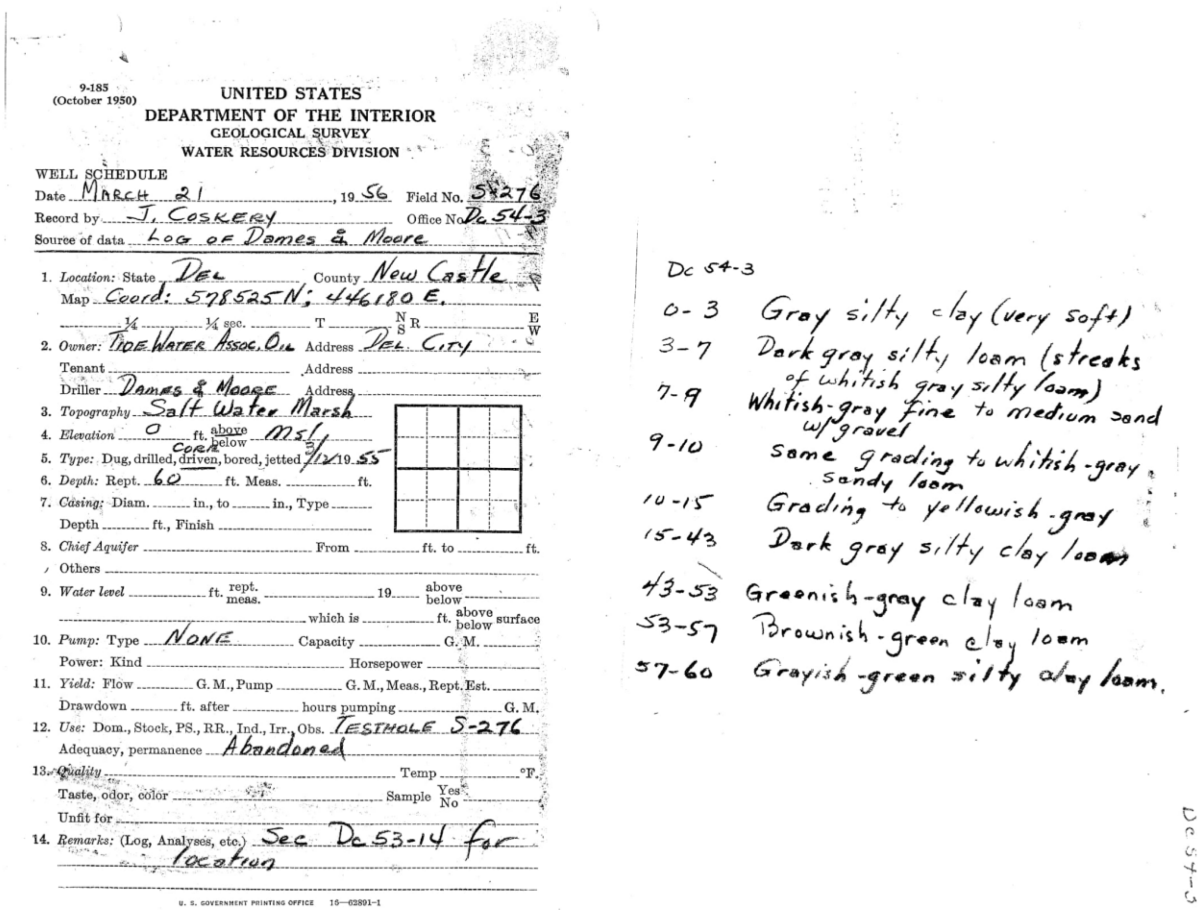
Borehole Dc55-14: taken in 1973, surface elevation 25.9 feet

- Depth 0-15: is brown sandy silt with trace roots
- Depth 15-23: is gray silty clay
- Depth 23-32: gray micaceous silty fine sand
- Depth 32-45: Gray micaceous silty clay

Borehole 55-15: taken in 1973, surface elevation 23.1 feet

- Depth 0-8': Brown Micaceous silty fine sand
- Depth 8-21': Brown silty clay
- Depth 21-27': gray silty fine sand
- Depth 27-33': peat with organic clay
- Depth 33-42': silty clay

.



9-185
(October 1950)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

WELL SCHEDULE

Date MARCH 21, 19 56 Field No. S-276
Record by J. COSKERY Office No. Dc 54-3
Source of data LOG OF Dames & Moore

1. Location: State DEL County New Castle
Map Coord: 578525 N; 446180 E.
¼ ¼ sec. T N/S R E/W
2. Owner: TIDE WATER ASSOC. OIL Address DEL. CITY
Tenant Address
Driller DAMES & MOORE Address
3. Topography Salt Water Marsh
4. Elevation 0 ft. above/below MSL
5. Type: Dug, drilled, driven (CORE), bored, jetted 7/12/19 55
6. Depth: Rept. 60 ft. Meas. ft.
7. Casing: Diam. in., to in., Type
Depth ft., Finish
8. Chief Aquifer From ft. to ft.
Others
9. Water level ft. rept./meas. 19 above/below
which is ft. above/below surface
10. Pump: Type NONE Capacity G. M.
Power: Kind Horsepower
11. Yield: Flow G. M., Pump G. M., Meas., Rept. Est.
Drawdown ft. after hours pumping G. M.
12. Use: Dom., Stock, PS., RR., Ind., Irr., Obs. TESTHOLE S-276
Adequacy, permanence Abandoned
13. Quality Temp °F.
Taste, odor, color Sample Yes/No
Unfit for
14. Remarks: (Log, Analyses, etc.) See Dc 53-14 for location

U. S. GOVERNMENT PRINTING OFFICE 16—62891-1

Dc 54-3

0- 3	Gray silty clay (very soft)
3-7	Dark gray silty loam (streaks of whitish gray silty loam)
7-9	Whitish-gray fine to medium sand w/gravel
9-10	Same grading to whitish-gray sandy loam
10-15	Grading to yellowish-gray
15-43	Dark gray silty clay loam
43-53	Greenish-gray clay loam
53-57	Brownish-green clay loam
57-60	Grayish-green silty clay loam.

Dc 54-3

Figure E.16: Boring log Dc54-3 is located in the Southern canal and this boring was recorded in 1956[102].

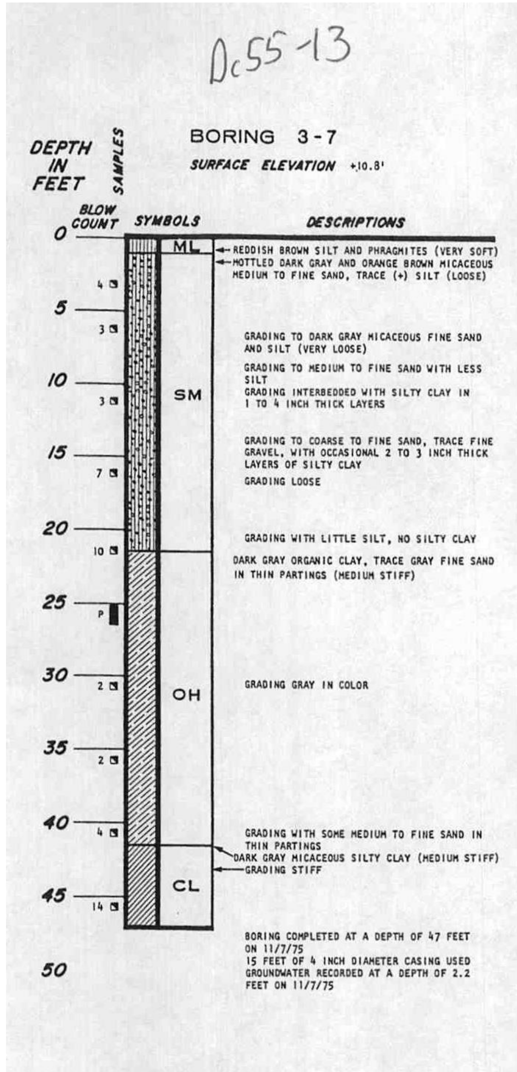


Figure E.17: Dc55-13[102].

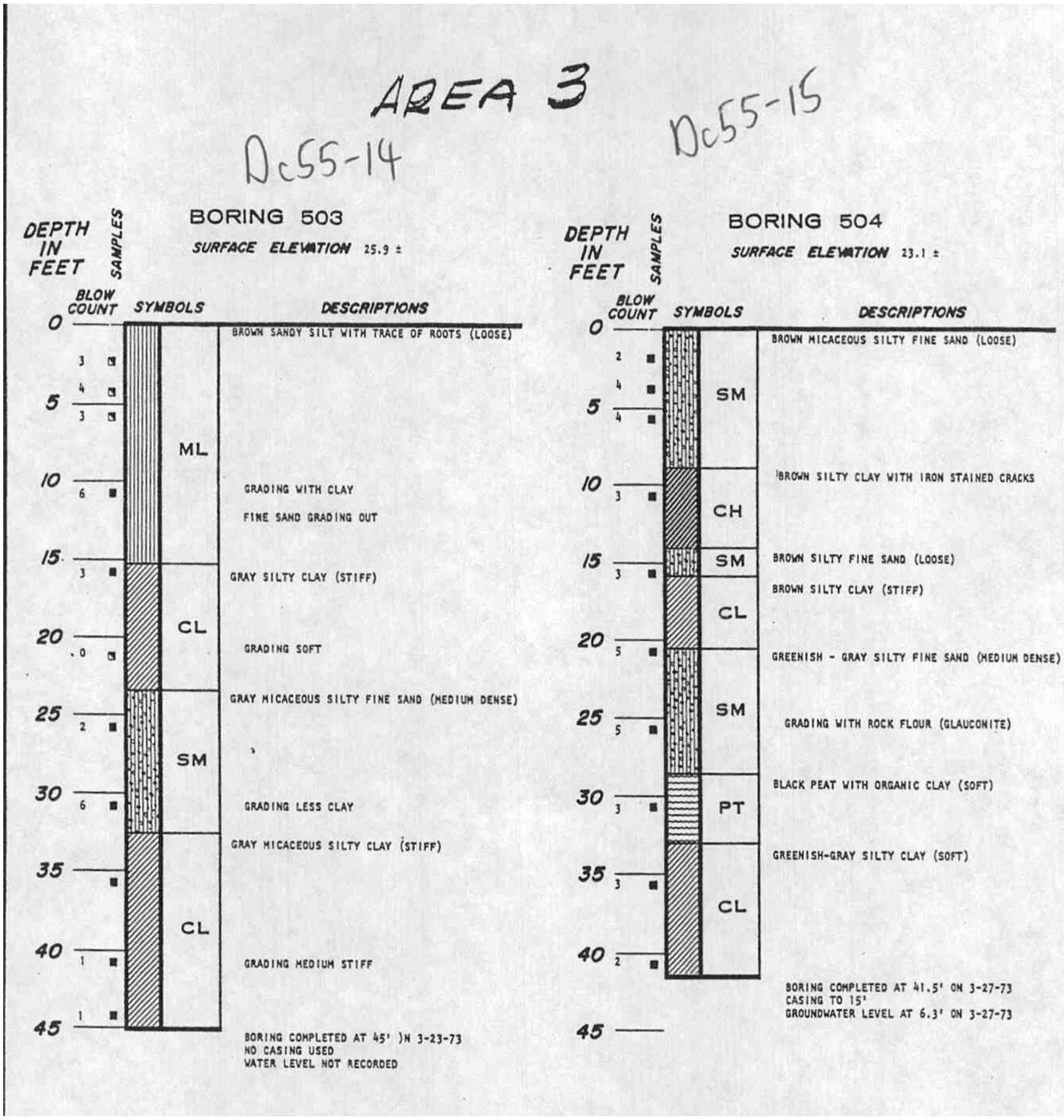


Figure E.18: Dc55-14 and Dc55-15[102].

New Jersey Site

Soil Profile (Figure E.19):

The artificial island, where both the reactor site is located, was analyzed in a cross-section of A through the Salem reactor site. The base of the quaternary or surficial sediments through the reactor site is 75 feet deep. The permeable sediments in this area are at least 500 feet deep based on the cross-sections of the site (Figure E.19). The top 200 feet consist of miscellaneous fine soil types such as clay, silt, fine sand, and peat. Below the 200 feet, sediments are primarily sand deposits and this layer of sand.

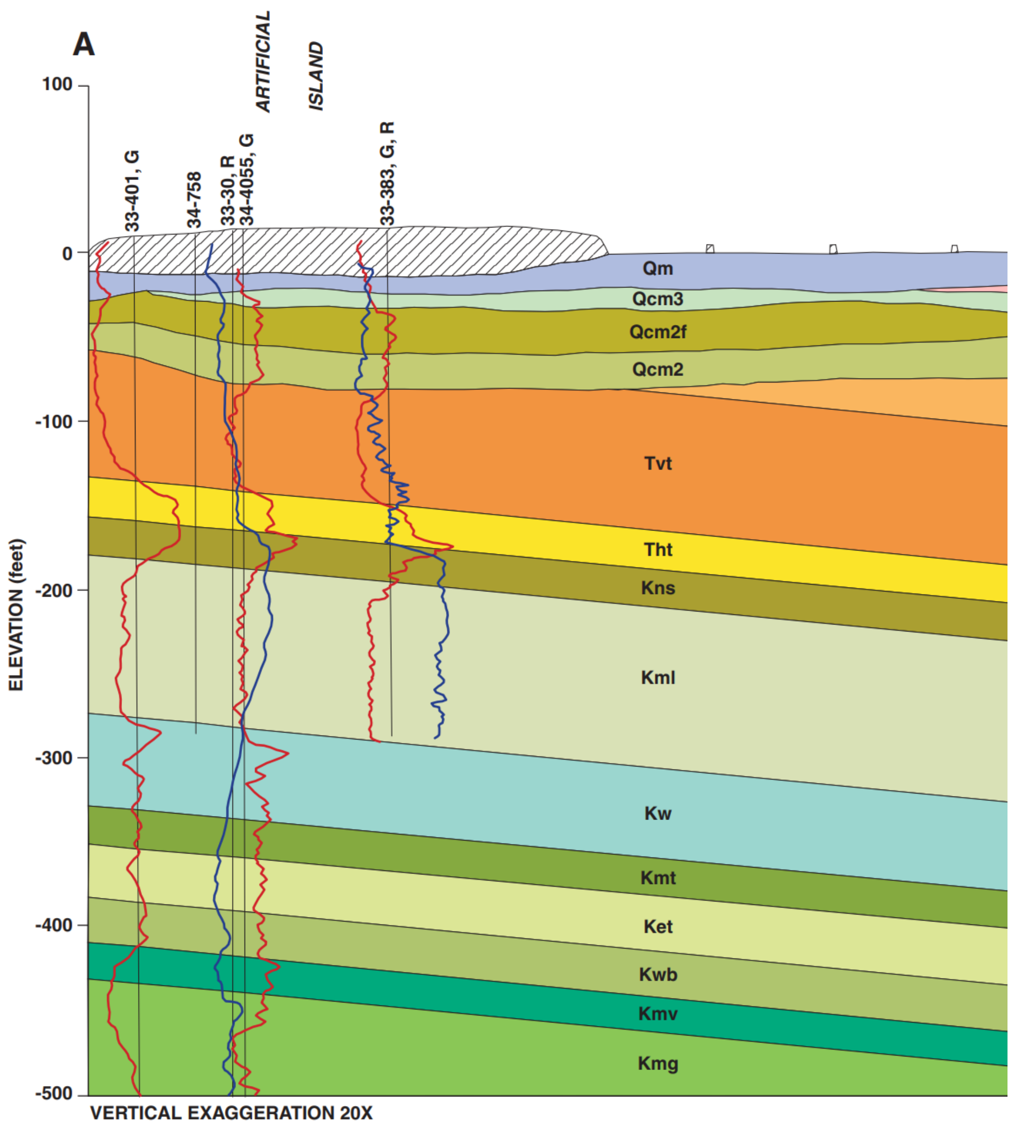


Figure E.19: East-most portion of the geologic cross-section for line A (shown in Figure E.20) for the Salem, NJ port location, the depths reach 500 feet. The first 200 feet deep are clay type soils and below the initial 200 feet is a majority sand[105]. Refer to Figure E.22 for the legend of soil descriptions.

Boring Logs (Figure E.20)

Borehole 34-757:

- 0’-38’: Miscellaneous fill such as sand, silt, gravel, and clay
- 38’-63’: Saltmarsh and Estuarine deposits which include peat, clay, silt, and fine sand (Qm) and Cape May Formation unit 2 is silty fine sand, fine-sandy silt, fine to medium sand, silty clay, and peat (Qcm2f)
- 63-70’: Cape May Formation unit 2 is silty fine sand, fine-sandy silt, fine to medium sand, silty clay, and peat (Qcm2)
- 70-200’: Vincentown formation is clayey sand, medium-grained, and silty clay (Tvt)
- 200-257’: Wenonah formation which is quartz fine-grained sand (Kml)

Borehole 34-1031:

- 0 - 49’: Miscellaneous fill such as sand, silt, gravel, and clay and Saltmarsh and Estuarine deposits which include peat, clay, silt, and fine sand (Qm)
- 49 - 96’: Saltmarsh and Estuarine deposits which include peat, clay, silt, and fine sand (Qm) and Cape May Formation unit 2 is silty fine sand, fine-sandy silt, fine to medium sand, silty clay, and peat (Qcm2f)
- 96 -131’: Vincentown formation is clayey sand, medium-grained, and silty clay (Tvt)
- 131 -159’: Hornerstown formation which is clay (Tht)
- 159 - 315’: Wenonah formation which is quartz fine-grained sand (Kml)
- 315 - 567’: Kst: is Wenonah formation which is quartz fine-grained sand (Kw); Kwb is Woodbury Foundation which is clay with thin beds of sand (Kwb); Merchantville Foundation which is fine sandy silty clay to clayey silt (Kmv); Marshalltown formation is clayey sand, fine to medium-grained sand (Kmt)
- 567 - 945’: Magothy formation is quartz sand and coarse-grained sand (Kmg)

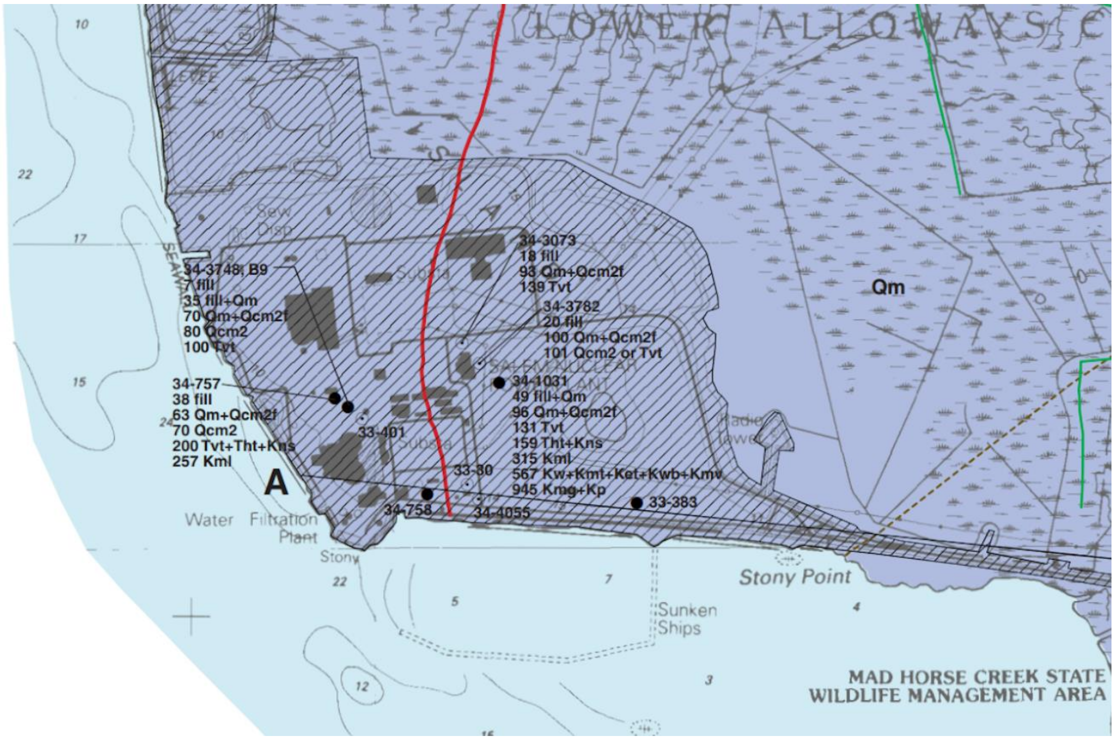


Figure E.20: Snip of the map where the Salem Reactor site is and where two boring logs were analyzed[105]. The red line cutting through the reactor site is the base of surficial or quaternary sediments. The permeable sediments in this area are at least 500 feet deep. Refer to Figure E.21 for the legend description.

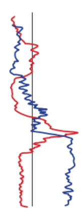
Elevation of base of surficial deposits—Contour interval 25 feet. Approximately located, based on well and boring data. Shown only where thickness of surficial deposits exceeds 20 feet. Shows topography of composite Quaternary erosional surface at top of Coastal Plain bedrock formations.

● 34-3784
28 Qcm1
35 Tkw

Well or boring, location accurate to within 200 feet—Number followed by map-unit symbol is depth, in feet below land surface, of base of unit as inferred from driller's log. Final number is total depth of well rather than base of unit. Depths may deviate from those on map and sections owing to variations in drillers' descriptions. Units joined with a "+" cannot be separately identified in the driller's description. Map units are not listed for wells shown on sections. Identifiers of the form 33-xxx are U. S. Geological Survey Ground Water Site Inventory numbers. Identifiers of the form 34-xxxx are N. J. Department of Environmental Protection well permit numbers. Identifiers of the form CANx are auger borings drilled by D. S. Powars and J. P. Owens of the U. S. Geological Survey. Logs for borings B36 and CAN3 are from Newell and others (1995). Auger borings Canton 1, Canton 2, and Canton 3 were drilled for this study. Logs for these borings are provided in table 1.

⊙ 34-1103
11 Qcm1
85 Tkw
138 Tkw+Tsr

Well or boring, location accurate to within 500 feet—Identifiers and symbols as above.



Geophysical well log—On sections. Gamma-ray log shown by red line, intensity increases to right. Resistivity log shown by blue line, resistance increases to right. For well 33-33, blue lines show resistivity on right-hand curve and spontaneous potential on left-hand curve, with voltage increasing to the right.

Figure E.21: Legend description for the map in Figure E.20 with descriptions of the symbology shown: boring holes indicating observed depths of sediment material types and the red line indicating the base of quaternary sediment deposits[105].

Qcm3 CAPE MAY FORMATION, UNIT 3—Silty very-fine-to-fine sand, fine-sandy silt, fine-to-medium sand, minor coarse sand, silty clay, and peat; yellow, brownish-yellow, pale brown, very pale brown, light gray; and minor pebble gravel, rare fine cobbles. Weakly stratified to laminated, sand is cross-bedded in places. Sand consists chiefly of quartz with a trace of glauconite, mica, feldspar, and chert. Feldspar and chert grains may be partially or completely weathered. Pebbles are chiefly white, gray, and yellow quartz and quartzite, with minor gray chert. Cobbles are white to gray subangular quartzite and quartz-pebble conglomerate, derived from silcrete-cemented zones in the Cohansey and Bridgeton formations on the upland east of the Cape May terraces. As much as 40 feet thick. Forms a terrace with a maximum surface elevation of about 15 feet.

Qcm2

Qcm2f

CAPE MAY FORMATION, UNIT 2—Silty fine sand, fine-sandy silt, fine-to-medium sand, minor coarse sand, silty clay, and peat; yellow, brownish-yellow, very pale brown, light gray; and minor pebble gravel, rare cobbles. Weakly stratified to laminated, sand is cross-bedded in places (fig. 5). Sand and gravel composition as in unit 3. As much as 35 feet thick. Forms a terrace with a maximum surface elevation of about 35 feet. In the subsurface in the paleovalley at and east of Artificial Island, wells and borings, and the foundation excavation for the Salem power plant (Owens and Minard, 1979), penetrated gray to dark gray silt, clayey silt, and sandy silt, with some peat and wood, as much as 30 feet thick, beneath sandier deposits of unit 3. These fine-grained sediments are mapped separately as unit Qmc2f on section AA', and also fill the Illinoian paleovalley to the north and south of the section line, beneath Holocene marsh deposits and unit 3 sands.

Qcm1 CAPE MAY FORMATION, UNIT 1—Fine-to-medium sand, some silty fine sand, minor clayey silt; very pale brown, yellow, locally reddish-yellow and reddish-brown; and minor pebble gravel. Weakly stratified. Sand consists chiefly of quartz with a trace of glauconite and mica. Gravel consists chiefly of white and yellow quartz with minor gray chert. Locally, sand and gravel beds are hardened or cemented by iron, particularly near the base of the deposit. In places atop terrace remnants, fragments of reddish, silty-clayey paleosol material occur in the upper several feet of the deposit, reflecting the longer exposure to weathering of unit 1 compared to units 2 and 3. As much as 30 feet thick. In eroded remnants of a terrace with a maximum surface elevation of 65 feet.

Tvt VINCENTOWN FORMATION—Glauconitic clayey quartz sand, medium-grained, and, in the upper 20 to 30 feet of the formation, silty clay. Olive, light gray, brown, dark gray. Locally calcareous and fossiliferous, with coral, echinoid, and bryozoan remains. Glauconite occurs primarily in soft grains of medium sand size. The upper, clayey part of the Vincentown in this region is informally termed the "Ancora Member" by Sugarman and others (2005). As much as 90 feet thick. In subsurface only, covered by surficial deposits and younger Coastal Plain formations. Described by drillers as coral sand, limestone, lime rock, and marl sand. Late Paleocene in age, based on foraminifera (Olsson and Wise, 1987). Unconformably overlies the Hornerstown Formation. The unconformity is marked by a sharp positive gamma-ray response on geophysical well logs.

Tht HORNERSTOWN FORMATION—Glauconite clay. Olive, green, black. Glauconite occurs primarily in soft grains of fine-to-medium sand size. Quartz, mica, feldspar, and phosphatic material also occur as minor constituents. Between 20 and 25 feet thick. In subsurface only. Described by drillers as black or green marl. Early Paleocene in age based on foraminifera (Olsson and Wise, 1987). Unconformably overlies the Navesink Formation. The unconformity is marked by a positive gamma-ray response on geophysical well logs.

Kns NAVESINK FORMATION—Glauconite clay to sandy clay. Locally fossiliferous, with calcareous shell beds. Olive, green, black. Between 20 and 25 feet thick. In subsurface only. Described by drillers as gray or green marl, rock with shells, or crystal clay. Glauconite occurs primarily in soft grains of medium-to-coarse sand size. Quartz sand, medium-grained, is the principal accessory. Late Cretaceous (Maastrichtian) in age, based on foraminifera (Olsson, 1964). Strontium stable-isotope age estimates for the Navesink range between 69 and 67 Ma (Sugarman and others, 1995). Unconformably overlies the Mount Laurel Formation. The unconformity is marked by sharply decreased gamma-ray response in the Mount Laurel on geophysical well logs.

Kml MOUNT LAUREL FORMATION—Quartz sand, slightly glauconitic (5-10% by volume), medium-grained. Olive, gray, black. Between 90 and 100 feet thick. In subsurface only. Described by drillers as salt-and-pepper sand, pepper sand, and crystal sand. Late Cretaceous (late Campanian) in age based on nannoplankton (Sugarman and others, 1995). Grades downward into the Wenonah Formation. The contact is marked by a sharp positive gamma-ray response on geophysical well logs. The Mount Laurel is the principal aquifer for domestic water supplies in the map area.

Kw WENONAH FORMATION—Quartz sand, micaceous, slightly glauconitic, fine- to very fine-grained. Gray to pale-olive. Between 50 and 60 feet thick. Late Cretaceous (late Campanian) in age based on pollen (Wolfe, 1976) and ammonite fossils (Kennedy and Cobban, 1994). Grades downward into the Marshalltown Formation.

Kmt MARSHALLTOWN FORMATION—Glauconitic clayey quartz sand, fine- to medium-grained. Olive to dark gray. Between 20 and 25 feet thick. Late Cretaceous (middle Campanian) in age, based on nannoplankton (Sugarman and others, 1995). Unconformably overlies the Englishtown Formation.

Ket ENGLISHTOWN FORMATION—Quartz sand, fine- to medium-grained, with thin beds of clay and silt. Sand is white, light gray, and gray. Silt and clay are light gray, dark gray, and black. Between 20 and 30 feet thick. Sand contains some lignite and mica and minor amounts of glauconite; silt and clay contain some mica and lignite. Late Cretaceous (early Campanian) in age, based on pollen (Wolfe, 1976). Grades downward into the Woodbury Formation. Transition to Woodbury is marked by increased gamma-ray response on geophysical well logs.

Kwb WOODBURY FORMATION—Clay with minor thin beds of very fine quartz sand. Dark gray and black. Between 20 and 30 feet thick. Clay is micaceous, with some pyrite and lignite and traces of glauconite. Late Cretaceous (early Campanian) in age based on pollen (Wolfe, 1976). Grades downward into the Merchantville Formation. Transition to Merchantville is marked by increased gamma-ray response on geophysical well logs.

Kmv MERCHANTVILLE FORMATION—Glauconitic fine-sandy silty clay to clayey silt. Olive, dark gray, black. Between 20 and 30 feet thick. Glauconite occurs primarily as soft grains of fine-to-medium sand size. Late Cretaceous (early Campanian) in age based on nannoplankton (Sugarman and others, 2005). Unconformably overlies the Magothy Formation. The unconformity is marked by sharply decreased gamma-ray response in the Magothy on geophysical well logs. The lowermost 5 to 10 feet of the Merchantville may include the Cheesequake Formation, which is identified in core holes at Fort Mott and Millville (Sugarman and others, 2004, 2005) but, as a thin silty unit, cannot be distinguished from the Merchantville based on well data in the map area.

Kmg MAGOTHY FORMATION—Quartz sand, fine- to very coarse-grained, and clay and silt, thin-bedded. Sand is white, light gray, gray. Clay and silt are white, yellow, brown, rarely reddish-yellow where weathered, gray to black where unweathered. Gray colors are dominant. Sand includes some lignite, pyrite, and minor feldspar and mica. Silt and clay beds include abundant mica and lignite. Between 30 and 50 feet thick. Late Cretaceous (Turonian-Coniacian) in age based on pollen (Christopher, 1979, 1982). In the Fort Mott corehole (about 10 miles northwest of Canton), pollen from the Magothy Formation at a depth of 137 feet indicates a late Turonian age (Sugarman and others, 2004), as does pollen from the Magothy at a depth of 1249-1292 feet in the Millville core hole (about 20 miles east of Canton) (Sugarman and others, 2005). Unconformably overlies the Potomac Formation.

Figure E.22: Legend description for the cross section in Figure E.19 with descriptions of the symbology shown: characteristics of sediment material types present in the subsurface[105].