FINAL REPORT

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AB 525 PORT READINESS PLAN

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CALIFORNIA STATE LANDS COMMISSION

moffatt & nichol

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List of Acronyms and Abbreviations

Acronym	Meaning
AACE	Association of the Advancement of Cost Engineering
AB	Assembly Bill
ABS	American Bureau of Shipping
ACI	American Concrete Institute
AHTV	Anchor Handling Tug Vessel
AISC	American Institute for Steel Construction
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
AWS	American Welding Society
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
Cal Poly	California Polytechnic State University
CARB	California Air Resources Board
CBC	California Building Code
CDFW	California Department of Fish and Wildlife
CEC	California Energy Commission
CHC	Commercial Harbor Craft
CPUC	California Public Utilities Commission
CSLC	California State Lands Commission
CTV	Crew Transfer Vessel
DNV	Det Norske Veritas
DPF	Diesel particulate filter
e.g.	Exempli gratia, “for example”
EJ	Environmental Justice
El.	Elevation
etc.	Et cetera, “and others especially of the same kind”
Ft	Feet
GW	Gigawatt
HLV	Heavy Lift Vessel
i.e.	Id est, “that is”

Acronym	Meaning
IDIQ	Indefinite Delivery / Indefinite Quantity
LRFD	Load and Resistance Factor Design
M	Meter
MARAD	Maritime Administration
MEG	Mooring Equipment Guidelines
MF	Manufacturing / Fabrication
MW	Megawatt
NFPA	National Fire Protection Association
nm	nautical mile(s)
NMFS	National Marine Fisheries Service
No.	Number
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
OCIMF	Oil Companies International Marine Forum
OCS	Outer Continental Shelf
OEM	Original Equipment Manufacturer
OGV	Ocean Going Vessel
PIANC	Permanent International Association of Navigation Congresses
psf	Pounds per square foot
PPE	Personal Protective Equipment
RCW	Regulated California Waters
RD	Renewable diesel
RORO	Roll-on/Roll-off
ROV	Remote-operated vehicle
RWQCB	Regional Water Quality Control Board
S&I	Staging and Integration
SB	Senate Bill
SATV	Service Accommodation Transfer Vessels
Schatz	Schatz Energy Research Center
SLO	San Luis Obispo

Acronym	Meaning
SPMT	Self-propelled Modular Transporter
SOV	Service Operation Vessel
TO	Task Order
TOC	total organic carbon
UC	University of California
UFC	United Facilities Criteria
ULSD	Ultra low sulfur diesel
U.S.	United States
USACE	United States Army Corps of Engineers
USDOE	United States Department of Energy
USFWS	U.S. Fish and Wildlife Service
WEA	Wind Energy Area
WG	Working Group
WTG	Wind Turbine Generator
yr	year

Executive Summary

Background

Assembly Bill (AB) 525 (Chiu, Chapter 231, Statutes of 2021) was signed by the Governor in 2021 and requires the Californica Energy Commission (CEC), in coordination with the California Coastal Commission, Ocean Protection Council, State Lands Commission (CSLC), Office of Planning and Research, Department of Fish and Wildlife, Governor's Office of Business and Economic Development, Independent System Operator, and Public Utilities Commission (and other relevant federal, state, and local agencies as needed) to develop a strategic plan (AB 525 Strategic Plan) for offshore wind development in federal waters by June 30, 2023.

On August 1, 2022, the CEC established a planning goal of 2 to 5 GW of offshore wind energy by 2030 and 25 GW by 2045 (Flint 2022). To meet these goals, the AB 525 Strategic Plan shall include, at a minimum, the following five chapters:

1. Identification of sea space, including the findings and recommendations resulting from activities undertaken pursuant to Section 25991.2 of AB 525.
2. Waterfront facilities improvements plan, including facilities that could support construction and staging of foundations, manufacturing of components, final assembly, and long-term operations and maintenance, pursuant to Section 25991.3 of AB 525. Economic and workforce development and identification of port space and infrastructure, including the plan developed pursuant to Section 25991.3 of AB 525.
3. Transmission planning, including the findings resulting from activities undertaken pursuant to Section 25991.4 of AB 525.
4. Permitting, including the findings resulting from activities undertaken pursuant to Section 25991.5 of AB 525.
5. Potential impacts on coastal resources, fisheries, Native American and Indigenous peoples, and national defense, and strategies for addressing those potential impacts.

Per Section 25991.3 of AB 525, based on the sea spaces identified pursuant to Section 25991.2 of AB 525, the CEC, in coordination with relevant state and local agencies, must develop a plan to improve waterfront facilities that could support a range of floating offshore wind energy development activities, including construction and staging of foundations, manufacturing of components, final assembly, and long-term operations and maintenance facilities. The purpose of this ***AB 525 Port Readiness Plan*** is to perform a detailed assessment of the necessary investments in California ports to support offshore wind energy activities, including construction, assembly, and operations and maintenance. This report will inform the AB 525 Strategic Plan.

Report Outline

This report has twelve sections, below is a brief overview of each section.

- Section 1: Introduction and Background – Provides background on the California offshore wind initiatives to date and previous port assessments that help inform this study.
- Section 2: Identification of Sea Space – Provides assumed locations of sea space for offshore wind development to support the basis of the port evaluation.
- Section 3: Floating Offshore Wind Overview – Provides an overview floating offshore wind energy area construction and operation activities.
- Section 4: Offshore Wind Port Requirements – Provides an overview of offshore industry requirements for port use.
- Section 5: Offshore Wind Port Demands – Determines how many port sites are needed to meet the State's offshore wind planning goals.
- Section 6: Offshore Wind Port Availability – Identifies which ports or locations in the State have available sites that can be used for various offshore wind activities.
- Section 7: Environmental Considerations – Environmental evaluation and site ranking was completed using a comparative approach for the identified port sites.
- Section 8: Offshore Wind Port Improvements – Provides construction cost estimates and timelines for the needed port infrastructure improvements at the identified port sites.
- Section 9: Offshore Wind Port Lessons Learned – Provides lessons learned from the U.S. East Coast offshore wind ports and recommendations for the State's port development plan.
- Section 10: Recommended Port Development / Investment Plan – Provides a summary of the study and recommendations for the State's port development and investment plan.

Port Development / Investment Plan

Ports will play a key role in establishing the floating offshore wind industry in California. Though there are many fixed-bottom offshore wind turbines installed across the world, there are only a few floating offshore wind turbines in the water today for projects in Europe. This was achieved by utilizing waterfront facilities at ports to manufacture components and transport them to another port site for integration of the floating offshore wind turbine system. Once assembled, the fully integrated wind turbine generator (WTG) was towed out to the offshore installation site or wind energy area (WEA). The installed projects were for smaller systems ranging from 2 MW to 9.5 MW turbines. For projects in California, it is anticipated that the WTG capacity will be at least 15 MW. Components for a 15 MW turbine are so large, that the only feasible way to transfer them from one location to another is by waterborne transit; road and rail transit would not be possible.

This report assumes that California's floating offshore wind turbines will be constructed as they have to date in Europe; by manufacturing and assembling large components at ports prior to towing the fully assembled turbine systems to the WEAs. Although some innovative approaches may be developed that would allow for the assembly of the turbine system at sea, these approaches have not been proven yet, may not be ready in time to meet the State's deployment targets, and may limit the scale of projects the State is proposing. Additionally, outreach to the offshore wind industry has signaled that utilizing ports is the preferred methodology to execute these projects. Therefore, the State should plan for ports to have a significant role in developing offshore wind projects.

Funding offshore wind port development projects and obtaining timely environmental approvals are critical challenges to solve. In general, floating offshore wind port development projects are not commercially viable, solely within the traditional port business model. Therefore, the State's port development strategy must include a plan for funding these projects. Multiple funding sources (State, Federal, and potentially private investment) will need to be identified. In addition, the traditional timelines for obtaining permits and environmental approvals within California are time consuming. There is a need to accelerate review and approval timelines to ensure these port development projects are completed in time for industry use to meet State's wind planning goals.

Of the port site types that were studied: staging and integration (S&I), manufacturing / fabrication (MF), operations and maintenance (O&M), and mooring and cable laydown, the S&I sites are most critical sites that require urgent funding. These sites must be developed as soon as possible to provide the State with the best opportunity to achieve the offshore wind planning goals.

S&I Sites

S&I sites are most critical to identify and develop because only a few port sites within the State have the key characteristics required to support these activities. These sites play a critical role to execute the final step in the manufacturing process to assemble the full turbine system before being towed out to the final installation site. The State will require approximately three to five 80-acre S&I sites to meet the State's 2045 offshore wind planning goal of 25 GW. Within this study, six ports were assessed, three were within existing ports (Port of Humboldt, Port of Los Angeles, and Port of Long Beach) and three locations within Central California (Port San Luis, China Harbor, and Gato Canyon).

From a towing perspective, all sites are feasible to tow assembled offshore wind turbines to WEAs in the North or Central Coast. However, the Port of Humboldt, Port of Los Angeles, and Port of Long Beach appear to be better candidates because they are more cost effective since they do not require development of a new protected harbor and can be developed on a schedule that puts California in the best position to meet the State's offshore wind planning goals. Currently, both the Port of Humboldt and Port of Long Beach have announced projects to provide 180+ and 400-acre sites, respectively, to provide space for both S&I and MF activities. Between these two ports, the three to five S&I sites required to meet the State's 2045 offshore wind planning goals can be provided.

MF Sites

Having MF sites located within California is not necessarily required to complete these offshore wind projects. However, if manufacturing facilities were to be established within the State, it would maximize economic benefits and job creation. Based on developer and industry outreach, a strong project backlog is required for manufacturers to justify making a long-term investment and to establish a manufacturing facility in California. Therefore, it is important to provide the industry clarity on both the auctioning schedule for the wind energy areas and the process for offtake.

If all MF sites were to be located within California, the state would need two blade MF sites (100 acres each), one tower MF site (100 acres), one nacelle assembly site (25 acres), four foundation subcomponent MF sites (40 acres each), and four foundation assembly sites (40 acres each) to meet California's planning goal of 25 GW by 2045. These sites could be provided at the Port of Humboldt, Bay Area Ports, Port of Los Angeles, Port of Long Beach, and Port of San Diego.

O&M Sites

O&M sites also play a critical role in the offshore wind industry. The scale and functionality of these O&M sites will vary depending on wind energy area size, proximity, and strategy of the contractor executing the Service and Maintenance Agreement (SMA). The State is estimated to require approximately 9 to 16 berths to support the required O&M vessels to meet the State's offshore wind planning goals. In this report, locations that could serve as O&M sites are identified. It is anticipated that developers will mainly determine which locations will become O&M sites based on their operations plan.

Summary

Based on this study, there are several port sites within the State that can be used to help achieve the State's offshore wind planning goal of 25 GW by 2045. Obtaining adequate and timely funding and environmental approvals for these projects are critical challenges to resolve. As it stands today, achieving the 2 to 5 GW by 2030 offshore wind planning goal will be very challenging because of the extensive port upgrades and short timelines in which they must be completed.

To meet the State's offshore wind planning goals, a multi-port strategy is needed and an investment of approximately $11 to $12 billion (in 2023 US Dollars) would be required to upgrade existing port infrastructure. Note, there are several different port development scenarios that will allow the State to achieve its 2045 offshore wind planning goal. Table ES.1 presents one example, among many, of these port development scenarios. The purpose of Table ES.1 is to provide an approximate total investment required to meet the State's offshore wind planning goals.

Table ES.1. Potential port development summary

Site Type	Location	Assumed Ready Date	Cost * ($ in millions)
S&I	Port of Humboldt	2028	$700
S&I	Port of Humboldt	2031	$700
S&I	Port of Long Beach	2031	$1,100
S&I	Port of Long Beach	2035	$1,100
MF (Foundation Assembly)	Port of San Francisco	2030-2032	$520
MF (Foundation Assembly)	Port of Long Beach	2033	$1,100
MF (Foundation Assembly)	Port of Long Beach	2035	$1,100
MF (Foundation Assembly)	Port of Long Beach	2035	$1,100
MF (Foundation Subcomponents)	Port of San Diego	2030-2035	$275
MF (Foundation Subcomponents)	Bay Area Port	2030-2035	$375
MF (Foundation Subcomponents)	Bay Area Port	2030-2035	$350
MF (Foundation Subcomponents)	Bay Area Port	2030-2035	$350
MF (Blades)	Bay Area Port	2030-2035	$520
MF (Blades)	Bay Area Port	2030-2035	$520
MF (Tower)	Port of Humboldt, Bay Area Port, or Port of Los Angeles	2030-2035	$1,000
MF (Nacelle Assembly)	Bay Area Port	2030-2035	$350

O&M	Assume 10 sites at $50M each	2028-2045	$500
Mooring Line & Anchor Storage	Port of Humboldt & Bay Area Port	2030-2035	<$50
Electrical Laydown Sites	Port of Humboldt & Bay Area Port	2030-2035	<$50
Total			$11,760

* Cost is in 2023 dollars. Escalation is not included. Estimate accuracy is -30% / +50%.

The estimated port investment cost of $11 to $12 billion is to prepare the port sites to grade including on-site utilities and lighting. The cost of above-grade improvements such as warehouses, buildings, equipment, cranes, etc. is not included. Similarly, any improvements required outside the footprint of the offshore wind port site to provide adequate access or utility service to the site are not included. Navigation channel improvements such as widening or deepening, if required, are also excluded from this estimate.

Based on the NREL West Coast ports strategy study (NREL 2023b), it is estimated that a capital investment of $4 million is required for every 1 MW of installed floating offshore wind energy. Therefore, 25 GW of floating offshore wind requires a capital investment of approximately $100 billion. This number includes procurement and installation costs for all major components (turbines, platforms, cables, mooring, anchors, onshore substation, offshore substation) but does not include cost of port investments, transmission grid investments, cable landings, or vessel fleet construction. To put the required port investment into perspective, it is anticipated the capital investment into ports will represent approximately 10% to 15% of the cost of the wind energy area. If MF facilities are not provided in the State, the total capital investment in ports represents approximately 5% of the wind energy area project cost. When full project costs are considered (wind energy area, cable landing, transmission improvements, and vessel fleet construction) the port investment is a relatively small portion of the overall capital investment.

Some recommendations for next steps include:

- The State’s port development strategy should consider how ports will be subsidized for project development and construction costs. Funding sources will need to be identified. The funding strategy should include incentivizing and funding early-stage port development work (site readiness, conceptual design, engineering, permitting, etc.) as this will be important to prepare the port sites in time to meet the State’s goals.
- The State’s offshore wind procurement approach coupled with the availability and timing of port funding will drive the schedule for availability of port sites for the offshore wind industry.
- The State’s approach to incentivizing local content and job creation within the state will significantly impact manufacturing investments into ports.

- A clear commitment to support local content and job creation increases the need for a broader network of California ports, especially the demand for MF sites. MF sites can maximize economic benefit and job creation in the State.
- A strong focus on a lower levelized cost of energy (LCOE) may lead to less investment in California ports for manufacturing resulting in a missed opportunity for job creation and economic impact.
- Committing to a schedule for future offshore leases and providing insight into the power procurement process will signal to developers and OEMs a strong backlog of projects to justify local supply chain development and manufacturing investments into California.

Based on the work performed in this study, several items were identified that need to be further studied. The following topics are recommended for additional study:

- Evaluate the capacity of U.S. shipyards to construct the required fleet of vessels in time to support the offshore wind industry and to meet California's deployment targets. Many new and purpose-built vessels will need to be constructed to support the offshore wind industry and meet existing requirements such as the Jones Act and CARB regulations.
- Evaluate the port space required for the fleet of tugs and other construction support vessels that will need home port and re-supply services.
- Evaluate the space needed within ports to support offshore wind end of life decommissioning activities.
- Evaluate escalation costs and distribute the port investment costs over the deployment timeline to provide decision makers with a clear understanding of the actual investment costs and the likely years when the investments need to be made.
- In addition to the work performed in this study to evaluate S&I, Tier 1 MF, and O&M, evaluate the port space required for additional flexible laydown and Tier 2 and Tier 3 needs.
- Evaluate ideal locations to serve as cable landing sites.
- Evaluate port needs to support the construction and installation of offshore electrical substations required to support the wind energy areas.

1. Introduction and Background

Senate Bill (SB) 100 (De León, Chapter 312, Statutes of 2018), the 100 Percent Clean Energy Act of 2018, establishes a requirement that every retail seller of electricity procure 60% of its retail electricity sales from eligible renewable energy resources by 2030 and 100% by 2045. In 2021, the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and California Air Resources Board (CARB) issued an SB 100 Joint Agency Report showing that offshore wind could contribute at least 10 gigawatts (GW) of electricity toward California's 2045 clean energy policy.

Assembly Bill (AB) 525 (Chiu, Chapter 231, Statutes of 2021) was signed by the Governor in 2021 and requires the CEC, in coordination with the California Coastal Commission, Ocean Protection Council, State Lands Commission (CSLC), Office of Planning and Research, Department of Fish and Wildlife, Governor's Office of Business and Economic Development, Independent System Operator, and Public Utilities Commission (and other relevant federal, state, and local agencies as needed) to develop a strategic plan (AB 525 Strategic Plan) for offshore wind development in federal waters by June 30, 2023.

In a letter to CARB dated July 22, 2022, Governor Gavin Newsom urged the CEC to establish an offshore wind planning goal of at least 20 GW by 2045 (Newsom 2022). On August 1, 2022, the CEC established a planning goal of 2 to 5 GW of offshore wind energy by 2030 and 25 GW by 2045 (Flint 2022). To meet these goals, the AB 525 Strategic Plan shall include, at a minimum, the following five chapters:

1. Identification of sea space, including the findings and recommendations resulting from activities undertaken pursuant to Section 25991.2 of AB 525.
2. Waterfront facilities improvements plan, including facilities that could support construction and staging of foundations, manufacturing of components, final assembly, and long-term operations and maintenance, pursuant to Section 25991.3 of AB 525. Economic and workforce development and identification of port space and infrastructure, including the plan developed pursuant to Section 25991.3 of AB 525.
3. Transmission planning, including the findings resulting from activities undertaken pursuant to Section 25991.4 of AB 525.
4. Permitting, including the findings resulting from activities undertaken pursuant to Section 25991.5 of AB 525.
5. Potential impacts on coastal resources, fisheries, Native American and Indigenous peoples, and national defense, and strategies for addressing those potential impacts.

The strategic plan must emphasize and prioritize near-term actions, particularly those related to port retrofits and investments and the workforce, to accommodate the probable immediate need for jobs and economic development. In considering port retrofits, the strategic plan must strive for compatibility with other harbor tenants and ocean users to ensure that the local benefits related to offshore wind energy construction complement other local industries. The strategic plan must emphasize and prioritize actions that will improve port infrastructure to support land-based work for the local workforce. The development of the workforce development portion of the strategic plan must include consultation with representatives of key labor organizations and apprenticeship programs that would be involved in dispatching and training the construction workforce. There will be an opportunity for public review and comment on a draft strategic plan.

Seaport and Workforce Development Chapter

Per Section 25991.3 of AB 525, based on the sea spaces identified pursuant to Section 25991.2 of AB 525, the CEC, in coordination with relevant state and local agencies, must develop a plan to improve waterfront facilities that could support a range of floating offshore wind energy development activities, including construction and staging of foundations, manufacturing of components, final assembly, and long-term operations and maintenance facilities. The plan developed must include all the following:

1. A detailed assessment of the necessary investments in California seaports to support offshore wind energy activities, including construction, assembly, and operations and maintenance. The assessment shall consider the potential availability of land and water acreage at each seaport, including competing and current uses; infrastructure feasibility; access to deep water; bridge height restrictions; and potentially impacted natural and cultural resources, including coastal resources, fisheries, and Native American and Indigenous peoples.
2. An analysis of the workforce development needs of the California offshore wind energy industry, including occupational safety requirements, the need to require the use of a skilled and trained workforce to perform all work, and the need for the Division of Apprenticeship Standards to develop curriculum for in-person classroom and laboratory advanced safety training for workers.
3. Recommendations for workforce standards for offshore wind energy facilities and associated infrastructure, including, but not limited to, prevailing wage, skilled and trained workforce, apprenticeship, local hiring, and targeted hiring standards that ensure sustained and equitable economic development benefits.

On December 16, 2022, the CEC submitted to the Natural Resources Agency and the relevant fiscal and policy committees of the Legislature a preliminary assessment of the economic benefits of offshore wind as they relate to port investments and workforce development needs and standards (Deaver 2022). The purpose of this ***AB 525 Port Readiness Plan*** is to inform the detailed assessment of California ports to support offshore wind energy activities.

BOEM California 2022 Lease Sale

The key to a successful port development strategy requires coupling it with the future Bureau of Ocean Energy Management (BOEM) California offshore wind lease sales and target deployment goals. To date, BOEM has identified two offshore wind energy areas (WEA) off the coast of California, the Humboldt WEA and Morro Bay WEA. On December 6, 2022, BOEM held an offshore wind energy lease sale for five lease areas, two within the Humboldt WEA and three within the Morro Bay WEA (BOEM 2022). The size of each lease area ranges from 63,338 to 80,418 acres. According to BOEM, each lease areas has a potential installation capacity of 769 to 976 megawatts (MW) for a total capacity of 4.6 GW across the five lease areas.

On December 7, 2022, the lease sale ended, and five provisional winners were announced – RWE Offshore Wind Holdings, LLC; California North Floating LLC; Equinor Wind US LLC; Central California Offshore Wind LLC; and Invenergy California Offshore LLC. Note, the potential installation capacities provided by BOEM in Table 1.1 may be conservative, since the lessees are reporting higher potential installation capacities, which are displayed in Table 1.2. For example, RWE Offshore Wind Holdings, LLC is reporting a potential capacity of approximately 1.6 GW for lease area OCS-P0561, California North Floating LLC is reporting over 1.0 GW for lease area OCS-P0562, Equinor Wind US LLC is reporting approximately 2.0 GW for lease area OCS-P0563, Central California Offshore Wind LLC is reporting approximately 2.0 GW for lease area OCS-P0564, and Invenergy California Offshore LLC is reporting over 1.5 GW for OCS-P0565. In summary, this could bring the potential total capacity of the five lease areas to 8.1 GW, compared to the 4.6 GW provided by BOEM.

It is imperative that the port infrastructure and workforce are developed to support both current and future BOEM offshore wind lease sales and deployment scenarios. Refer to Table 1.1, Table 1.2, and Figure 1.1 for details on the five lease areas and results of the lease sales.

Table 1.1. Potential energy impact of the California lease areas (BOEM 2022)

Lease Number	Developable Acres	Installation Capacity * (MW)	Power Production (MWh/yr)	Homes Powered
OCS-P0561	63,338	769	2,694,436	269,136
OCS-P0562	69,031	838	2,936,632	293,328
OCS-P0563	80,062	972	3,405,888	340,200
OCS-P0564	80,418	976	3,421,025	341,712
OCS-P0565	80,418	976	3,421,025	341,712

Table 1.2. Provisional winners of the California lease areas (BOEM 2022)

Lease Number	Lease Area Provisional Winner	Installation Capacity (GW)	Winning Bid
OCS-P0561	RWE Offshore Wind Holdings, LLC	1.6	$157,700,000
OCS-P0562	California North Floating LLC	1.0	$173,800,000
OCS-P0563	Equinor Wind US LLC	2.0	$130,000,000
OCS-P0564	Central California Offshore Wind LLC	2.0	$150,300,000
OCS-P0565	Invenergy California Offshore LLC	1.5	$145,300,000

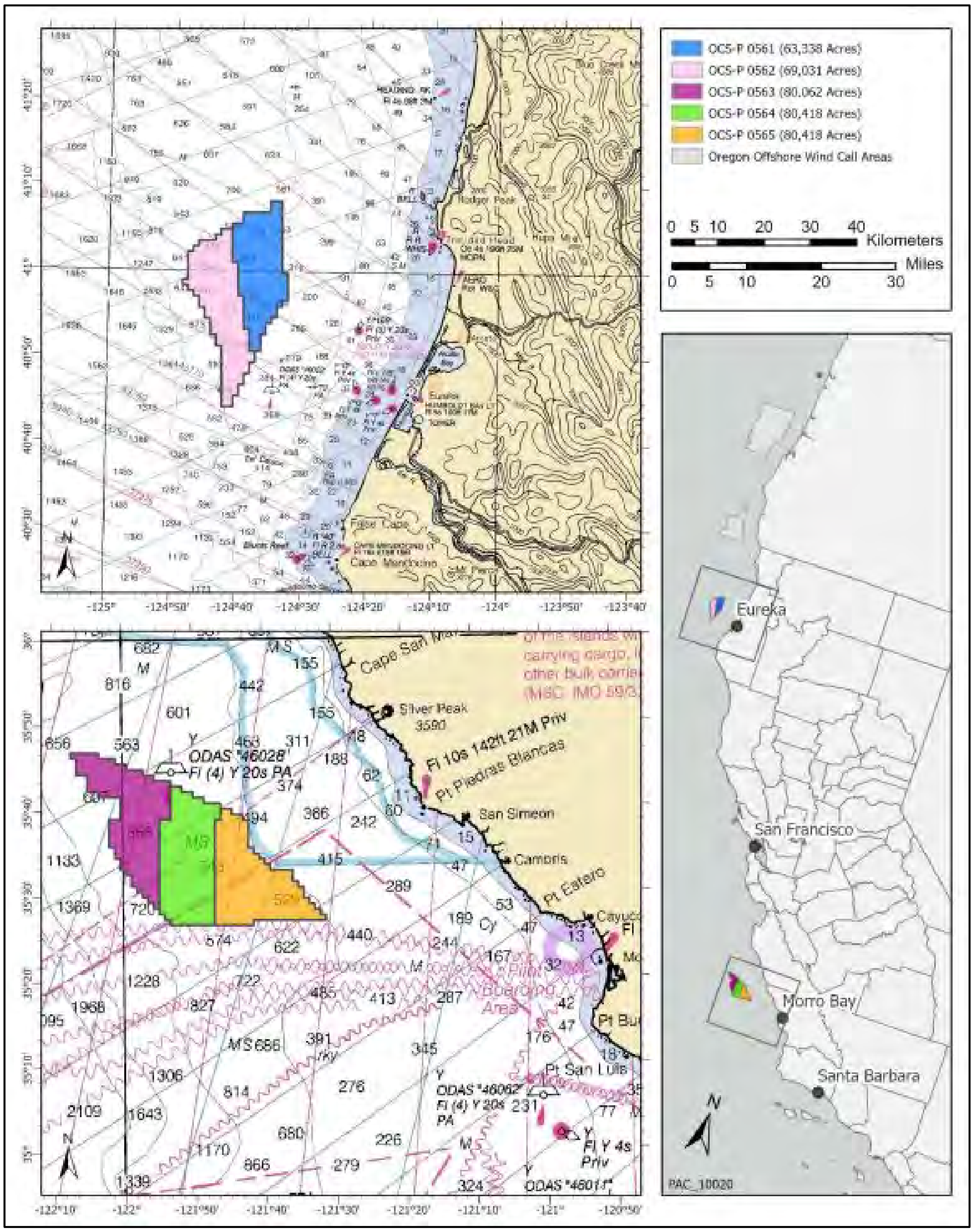

Figure 1.1. Locations of California offshore wind lease areas (BOEM 2022)

1.1. Background Studies

The Pacific Outer Continental Shelf (OCS) is characterized by rapidly increasing water depths that exceed the feasible limits of traditional fixed-bottom offshore wind turbines. Thus, floating offshore wind technology is more suitable for this region. To construct floating offshore wind turbines, the turbine components will need to be fabricated, assembled, and transported from an onshore port to the offshore wind site. Existing port infrastructure on the U.S. West Coast, including the California coast, is not adequate to support these activities and significant investment is required to develop offshore wind port facilities. For more information regarding offshore wind port requirements, refer to Section 4.

This *AB 525 Port Readiness Plan* is informed by the following four studies:

- BOEM Study, Port of Coos Bay Port Infrastructure Assessment for Offshore Wind Development (Moffatt & Nichol 2022)
  - Extensive offshore wind developer outreach was conducted within this Port of Coos Bay, Oregon, study to help inform the port facility requirements for offshore wind on the U.S. West Coast. These port requirements are summarized within Section 4.
- BOEM Study, California Floating Offshore Wind Regional Ports Assessment (Moffatt & Nichol 2023a)
  - Extensive California port outreach was conducted for the entire state within this study to assess how much capacity the existing California ports have available to support the offshore wind industry. This is summarized within Section 5.8.
- BOEM Study, California Floating Offshore Wind Regional Ports Feasibility Analysis (Moffatt & Nichol 2023b)
  - The feasibility of port upgrades and associated cost estimates and timelines was determined and assessed for the available sites within existing California ports. This is summarized within Section 8.
- CSLC Study, Alternative Port Assessment to Support Offshore Wind (Moffatt & Nichol 2023c)
  - A feasibility assessment was conducted for the region between San Francisco and Long Beach to determine the opportunities and limitations for creating new alternative port locations to support the offshore wind industry. This is summarized within Section 5.8.

1.2. Port Site Type Definitions

Large port facilities include multiple terminals, including industry-specific terminals, piers, wharves, yards, marinas, deepwater channels, and sheltered harbors. Port components include the following per the American Association of Port Authorities (AAPA, no date):

- Barge: A large, flat-bottomed boat used to carry cargo that is typically navigated and powered by a tug or towboat
- Berth: The space at a terminal at which a ship docks. A terminal may have multiple berths, depending on the length of incoming ships.
- Breakwater: a barrier built into a body of water to protect a coast or harbor from the ocean wave conditions
- Cargo: The freight (goods, products) carried by a ship, barge, train, truck, or plane.
- Dock: A dock is a structure built along, or at an angle from, a navigable waterway so that vessels may lie alongside to receive or discharge cargo.
- Harbor: A sheltered location where ships may anchor.
- Marina: A protected harbor for mooring of small craft vessels for fishing and recreational purposes.
- Port Terminal or Port Site: A single location within a port to transfer cargo to and from a vessel. Depending on the type of terminal, connections to land transportation such as road, rail, pipelines, etc. are provided.
- Terminal Equipment: Various vehicles and specialized equipment that is used to operate a terminal and move cargo around the terminal such as cranes, trucks, and other specialty vehicles or equipment.
- Pier: A type of marine structure, typically perpendicular to the shoreline, for mooring vessels and cargo handling.
- Port: This term is used both for the harbor area where ships are docked and for the agency (port authority), which administers use of public wharves and port properties.
- Tug: Strong and powerful boats used for maneuvering ships into and out of port safely.
- Vessel: A ship or large boat used to move cargo from one port to another.
- Wharf: A type of marine structure, typically parallel to the shoreline, where vessels moor to transfer cargo.
- Yard: An upland area adjacent to the berth where cargo is staged and/or stored either before vessel loading or after vessel unloading.

Defined below are terms commonly used when discussing floating offshore wind infrastructure. The floating offshore wind industry requires port sites to stage, assemble, and provide ongoing operations and maintenance of the wind turbines.

- Staging and Integration (S&I) Site: a site to receive, stage, and store offshore wind components and to assemble the floating turbine system for towing to the offshore wind area. In addition to turbine integration activities, this facility is likely to support the following services:
- Turbine Maintenance Site: a facility to perform major maintenance on a fully assembled turbine system that cannot otherwise be performed in the offshore wind area such as replacement of a nacelle or blade.
- End of Life Decommissioning Site: a site to decommission, disassemble, recycle, and dispose of turbine systems that are at end of life.
- Manufacturing/Fabrication (MF) Site: a port site located on a navigable waterway that receives raw materials via road, rail, or waterborne transport and creates larger components in the offshore wind supply chain. This site typically includes factory and/or warehouse buildings and space for storage of completed components.
- Operation and Maintenance (O&M) Site: a base of wind energy area operations with warehouses/offices, spare part storage, and a marine facility to support vessel provisioning and refueling/charging for the following O&M vessels during the operational period of the offshore wind energy area:
- Crew Transfer Vessel (CTV): transfers small crews to offshore wind turbine installations for day-trip O&M visits and inspections.
- Service Operating Vessel (SOV): vessels that loiter and operate as in-field accommodations for workers and platform assist for wind turbine servicing and repair work.
- Service Accommodation Transfer Vessel (SATV): intermediate between SOVs and CTVs, with ability to sleep onboard for multiday trips.
- Construction Support Facilities:
- Installation Support Site: a base of construction operations for the fleet of construction vessels necessary for construction and commissioning of the offshore wind energy area.
- Mooring Line, Anchor, and Electrical Cable Laydown Site: a site to receive and stage mooring lines, anchors, and electrical cables to support the installation of the offshore wind energy area.

There is an additional offshore wind site that may be located at or near a port. This site is excluded from this report but should be studied as part of the transmission work per Section 25991.4 of AB 525:

- Cable Landing Site: locations for the electrical cables to transition from the offshore (e.g., subsea cables) to a grid connection location. These sites may include electrical infrastructure onshore.

2. Identification of Sea Space

As outlined in Section 1, the state of California currently has two WEAs, Humboldt WEA and Morro Bay WEA. The two WEAs are comprised of five lease areas, two in Humboldt WEA and three in Morro Bay WEA. In total, these lease areas are projected to generate between 4.6 GW and 8.1 GW, according to BOEM and developer estimates. To meet the state's offshore wind planning goals of 25 GW by 2045, additional sea space must be identified in which additional WEAs can be sited.

The Humboldt and Morro Bay WEAs were developed from areas identified by BOEM in 2018 to explore interest in commercial wind energy leases. A third area off the central coast of California was also identified by BOEM in 2018, this area is identified as the Diablo Canyon Call Area. The Diablo Canyon Call Area has not yet been designated as a WEA at the time of this study.

Two additional areas off the northern coast of California — not yet designated by BOEM to move forward — were identified as possible offshore WEAs by the National Renewable Energy Laboratory (NREL) in the report titled *Potential Offshore Wind Energy Areas in California: An Assessment of Locations, Technology, and Costs* (Musial 2016a). These additional areas are referred to as the Cape Mendocino and Del Norte offshore wind resource zones. The boundaries and the resource potentials for the Cape Mendocino and Del Norte offshore wind resource zones were based on a combination of information from BOEM, NREL, and CEC studies. The locations and respective sizes for the five areas are shown in Figure 2.1.

While the initial WEAs were identified by BOEM, in accordance with AB 525, Section 25991.2 (Chiu 2021), it is the responsibility of the CEC, in coordination with other agencies, stakeholders, and the OSW energy industry to identify suitable sea space for future wind energy areas. In identifying suitable sea space, the CEC shall consider the following:

- Existing data and information on offshore wind resource potential and commercial viability.
- Existing and necessary transmission and port infrastructure.
- Protection of cultural and biological resources with the goal of prioritizing least-conflict ocean areas.

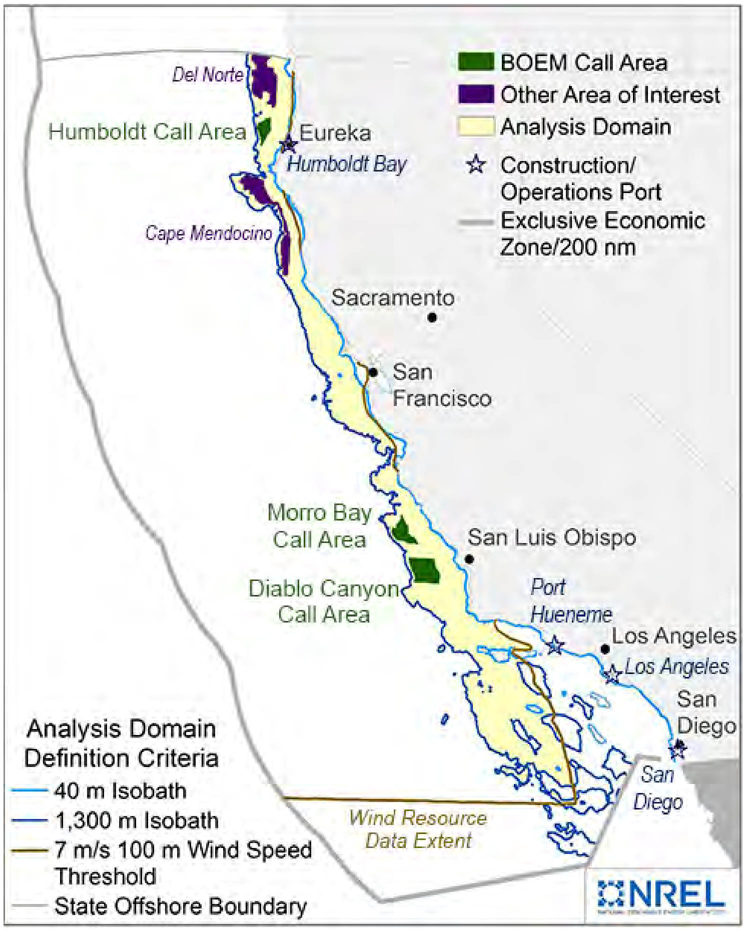

Figure 2.1. Five study areas within California (Beiter 2020)

AB 525 also requires the CEC, in coordination with relevant state and local agencies, to develop a plan to improve waterfront facilities based on the identified sea spaces. The purpose of this *AB 525 Port Readiness Plan* is to inform the CEC's "plan to improve waterfront facilities."

Given the relative location and sizes of the WEAs and existing areas of interest, the 25 GW is expected to come from sites located offshore in Northern California and Central California. The location of sea spaces will influence the port and workforce development strategies to achieve the State's offshore wind energy planning goals. Conversely, sea space locations must be cognizant of where port sites that can support offshore wind development are located. For example, proximity to the WEA is a crucial factor in determining the location of O&M sites, as transportation of crew across long distances is costly. Achieving a balance between sea spaces with ample capacity for wind energy production and ports that can support offshore wind is crucial.

Although AB 525 focuses on the offshore wind for California, support from neighboring states can help facilitate offshore wind development in California. In addition, ports in California can support offshore wind development in other states. This is further assessed as part of a West Coast ports strategy study by NREL (NREL 2023b).

3. Floating Offshore Wind Overview

This section provides an overview of offshore wind energy area construction and the types of vessels needed to support that construction and the continued maintenance.

3.1. Offshore Wind Energy Area Construction

The general marine operations required to construct a floating wind energy area are listed below. The processes shown below are not meant to be a prescriptive set of steps for constructing a wind energy area, as variations on the methods for the different steps may be possible and will be dependent on the individual construction projects. It is assumed that floating substations will likely be needed for wind energy areas off the California Coast, however these are not covered in detail in this report. This list is meant to encompass the marine operations for wind turbine generator (WTG) installation and does not include other marine activities such as survey, environmental monitoring, crew transfer, export cable landfall, etc. It should be noted some of these operations can be conducted in parallel.

Anchors and Mooring lines (may occur prior to installing WTG)

1. Anchor and mooring line components delivered to a laydown and staging site within a port
2. Anchor and mooring line components are loaded onto an anchor handling tug vessel (AHTV) from mooring component laydown site
3. Anchors are installed and mooring lines are pre-laid at wind energy area

Figure 3.1 depicts the above anchor and mooring line installation steps. It should be noted that the images below represent one possible method for these steps, and that the details of these operations may vary.

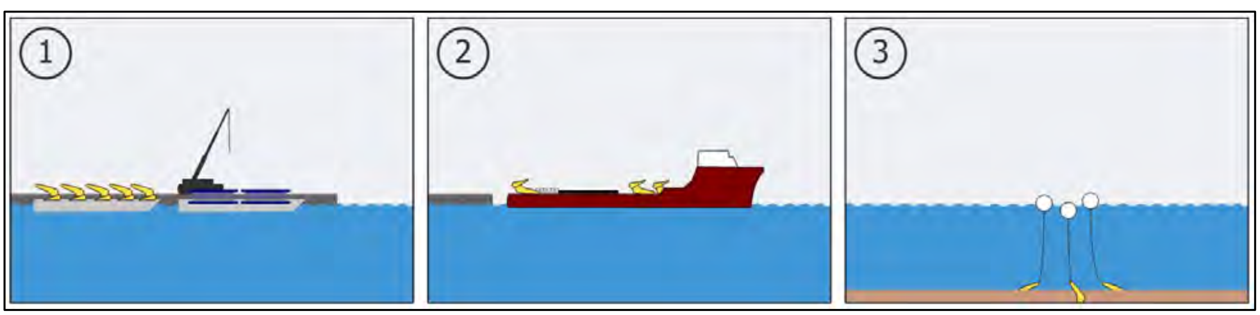

Figure 3.1. Anchor and mooring line installation steps

WTGs

1. WTG components (i.e., blades, nacelles, tower sections) and floating foundations are manufactured at a port site
2. WTG components (i.e., blades, nacelles, tower sections) are transported to S&I site by component delivery vessel
3. WTG floating foundations are fabricated at the S&I site or delivered to the S&I site by semi-submersible heavy lift vessel or towed by marine spread
4. WTG components and foundation are fully integrated at S&I site
5. Integrated WTG is towed out to wind energy area using a tow spread, likely consisting of an AHTV and ocean support tug(s)
6. Integrated WTG is hooked up to pre-laid mooring lines

Figure 3.2 depicts the above WTG construction and installation steps. It should be noted that the images below represent one possible method for these steps, and that the details of these operations may vary.

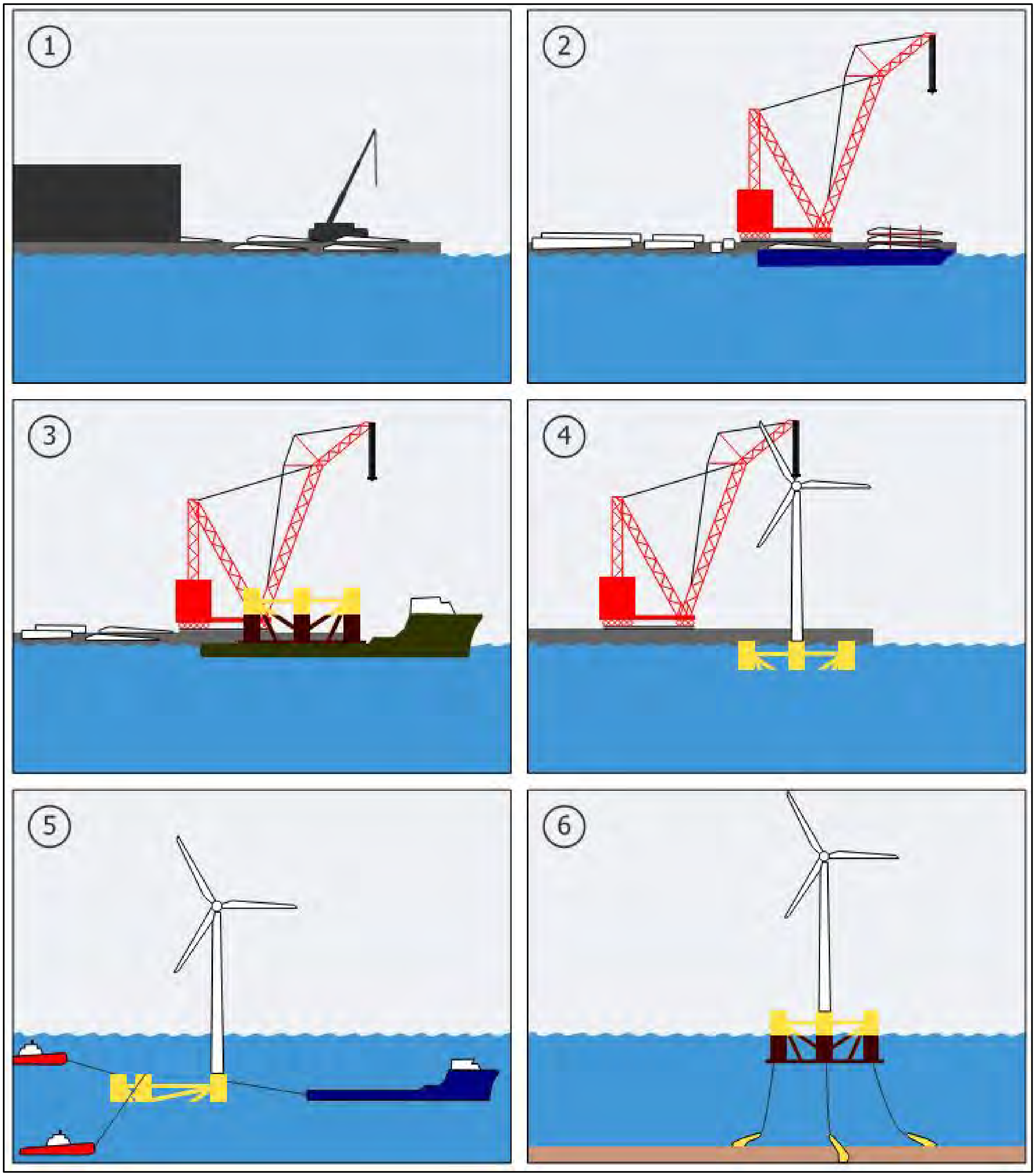

Figure 3.2. WTG construction and installation steps

Power Cables

1. Export cables are loaded onto a cable-lay vessel (CLV) from cable laydown area
2. Export cable is hooked up to substation using the CLV
3. Substation is tested and commissioned offshore
4. Inter-array cables are loaded onto a CLV or other construction support vessel from cable laydown area
5. Inter-array cables are hooked up to integrated WTGs using CLV or other construction support vessel
6. Inter-array cables are hooked up to integrated substation using CLV or other construction support vessel
7. WTG is tested and commissioned offshore

Figure 3.3 depicts the above power cable installation steps. It should be noted that the images below represent one possible method for these steps, and that the details of these operations may vary.

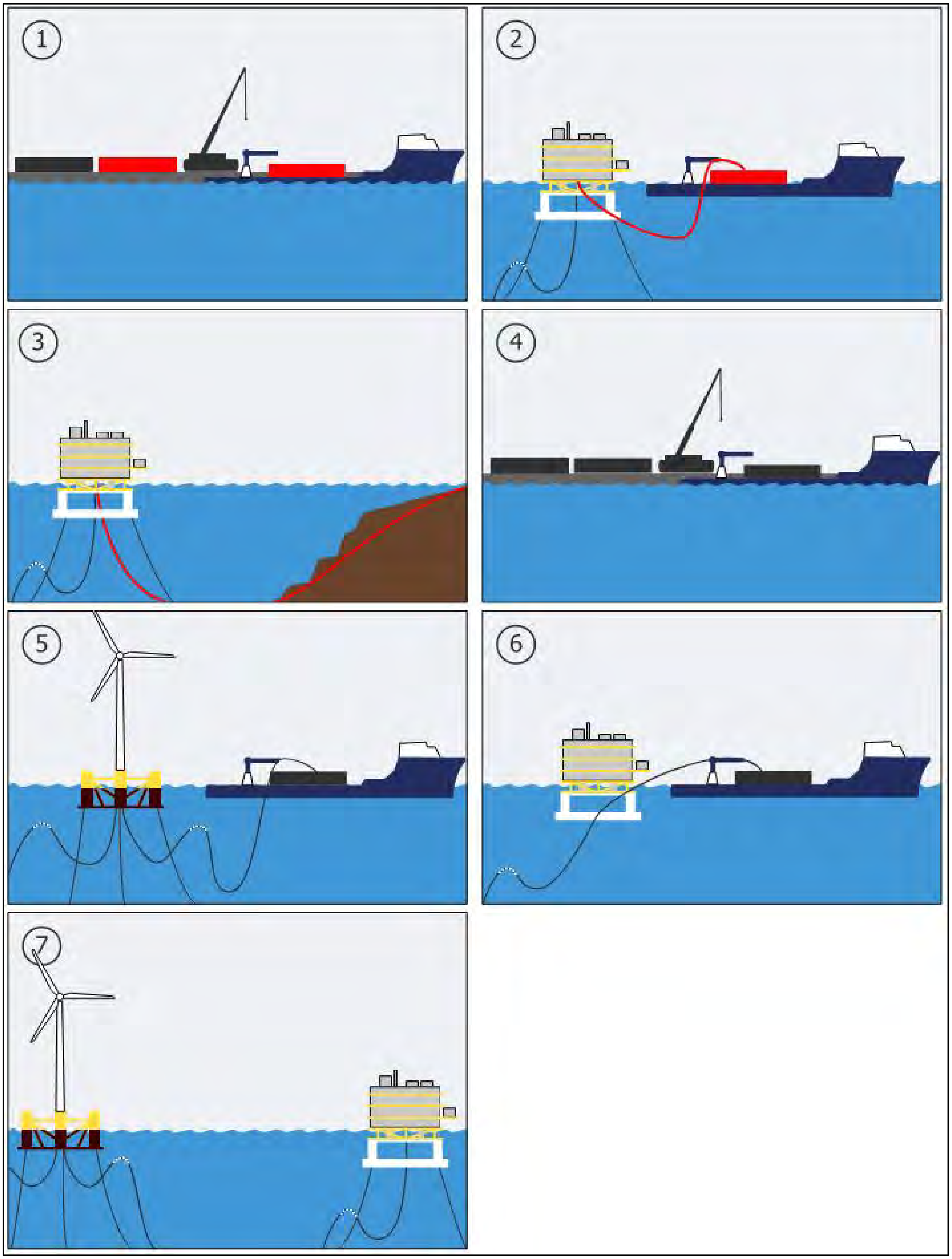

Figure 3.3. Power cable installation steps

3.2. Marine Operations

Based on the steps listed in Section 3.1, significant marine operations are required for floating offshore wind. This includes extensive harbor towage operations that must be coordinated either by chartered vessels or "just in time" day-chartered vessels depending on the location of the marine operations.

3.2.1. Fleet requirements

New vessels will need to be built. These will primarily be anchor handling tug vessels (AHTV), Azimuth Stern Drive (ASD) tugboats, construction support vessel (CSV), barges, crew transfer vessels (CTVs), cable-laying vessels, and service operation vessels (SOVs). These vessels will continuously operate in regulated California waters and will be required to meet California Air Resources Board (CARB) requirements. Refer to the CARB requirements in Section 3.2.3 for more detail.

Anchor Handling Tug Vessel: The primary purpose of this vessel, shown in Figure 3.4, tows the integrated WTG from port to WEA for installation. It also handles and installs the anchors that are used to secure the integrated WTG to the offshore installation location.

Figure 3.4. Anchor handling tug vessel (MMA Offshore)

Cable-laying vessel: A cable laying vessel, shown in Figure 3.5, is a sea-going vessel specially designed to lay underwater cables (telecommunications, electric power transmission, or other). The newest cable-laying design combines cable-laying and repair capabilities, so they can also retrieve broken or damaged sub-sea cables and repair them on board.

Depending on water depth and the risk of potential damage, sub-sea cables are buried in the sea floor by the cable layer using a special plow. A DP Class 2 (DP 2) system enables the vessel to remain in a precise position above the defined cable route.

Equipped with DP, such vessels can operate in extreme weather conditions while providing optimum protection for all cable-handling operations. In addition, it can be equipped to deploy a ROV.

Figure 3.5. Cable laying vessel (Marine Insight 2021)

Component Delivery Vessel: A component delivery vessel, shown in Figure 3.6, delivers WTG components from manufacturing facilities.

Figure 3.6. Component delivery vessel (DNV 2023)

Deck Barge: A deck barge, shown in Figure 3.7, is a barge with a flat deck that is used both for transportation of WTG components and construction support.

Figure 3.7. Deck barge (Port of Monroe 2022)

Semi-Submersible Barge: These specialized barges, shown in Figure 3.8, are equipped with pumping towers. This allows the barge to submerge below the water surface so floating foundations can be removed from the deck and placed in the water.

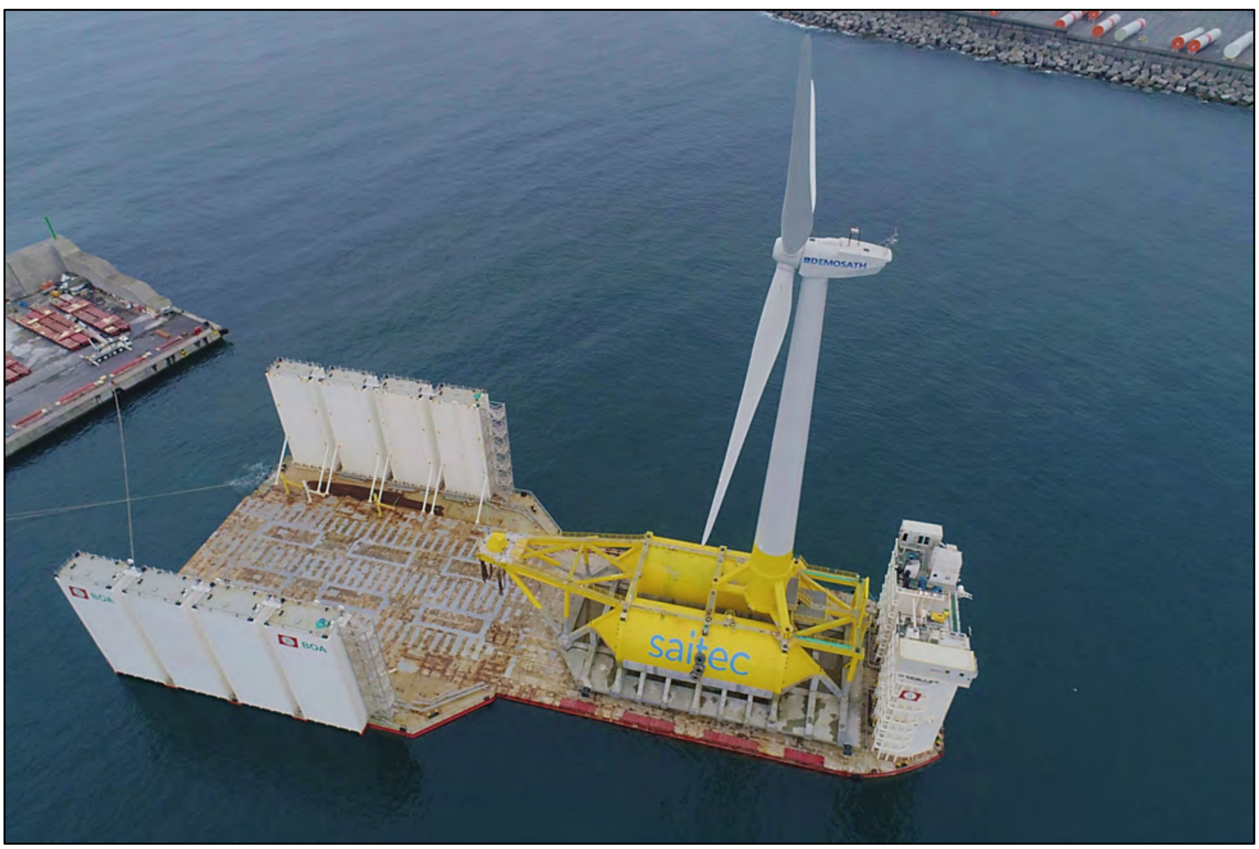

Figure 3.8. Semi-submersible barge (BOA 2022)

Semi-Submersible Heavy Lift Vessel: this vessel, shown in Figure 3.9, can transport large loads such as fully built floating foundations from manufacturing facilities to S&I sites.

Figure 3.9. Semi-Submersible heavy lift vessel (Boskalis 2020)

Azimuth Stern Drive Tugboat: An azimuth stern drive (ASD) tugboat, shown in Figure 3.10, is equipped with two stern engines capable of generating a 360 degree, all-directional propulsion force. ASD tugs normally have a towing winch forward, and when commercially required, a towing winch and/or towing hook aft.

Figure 3.10. Azimuth stern drive tugboat (Foss)

Conventional Tugboat: A tugboat, shown in Figure 3.11, is a marine vessel that maneuvers other vessels by pushing or pulling them with direct contact or a towline.

Figure 3.11. Conventional tugboat (Foss)

Crew Transfer Vessels: Crew transfer vessels (CTV), as shown in Figure 3.12, are used to transport wind energy area technicians and other personnel to and from the OSW energy area on a daily basis. Usually these trips are less than 50 kilometers (km). CTVs can also be used to take small amounts of cargo to the offshore wind energy area, such as components and equipment, for the installation and servicing of the WTG.

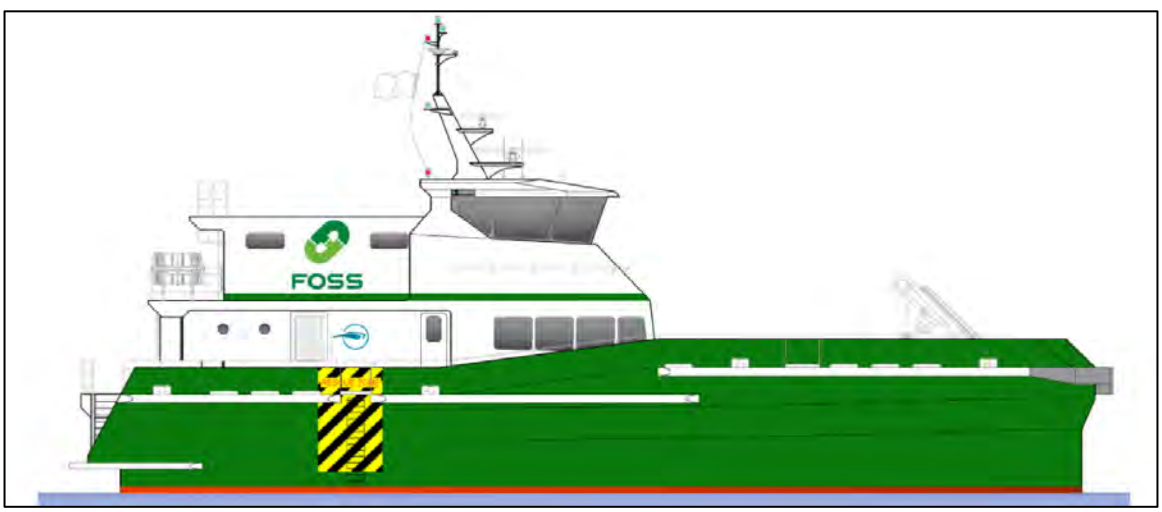

Figure 3.12. Crew transfer vessel (Foss)

Service Operation Vessel: Service operation vessels (SOV), shown in Figure 3.13, are fuel-efficient DP-enabled vessels that loiter and operate as in-field accommodations for workers and platform assistance for wind turbine servicing and repair work. An SOV can provide accommodation for approximately 40 personnel and is typically in-field for two weeks at a time.

Figure 3.13. Service operation vessel (Fincantieri Marine Group)

Metocean, Environmental, Geophysical, Geotechnical Survey Vessels: A survey vessel, shown in Figure 3.14, is a type of research vessel. It is a ship equipped with hydrographic survey tools to research specific data depending on its assigned task.

Figure 3.14. Survey vessel (WHOI 2019)

3.2.2. Jones Act

One potential challenge for the offshore wind industry is complying with the Jones Act, Section 27 of the Merchant Marine Act of 1920. The Jones Act generally requires that vessels carrying merchandise between any two points in the United States be owned and crewed by U.S. citizens, registered under the U.S. flag, and built in the United States.

Therefore, the Jones Act prevents foreign-flagged ships from carrying cargo between U.S. ports. For example, inbound foreign ships with cargo cannot stop at a U.S. port, offload its cargo, load additional cargo bound for another U.S. port, and continue to that U.S. port. Inbound foreign ships, however, can offload cargo and proceed to another U.S. port without picking up additional cargo meant to be delivered to another U.S. port.

The Jones Act requires all vessels that transport cargo between U.S. ports to be U.S.-built ships. Therefore, the vessels that will be transporting WTG components between various California ports must be built within the U.S.

Jones Act Challenges for California Floating Offshore Wind:

- A large gap between vessel demand and vessel supply
- A shortage of qualified U.S. mariners is rampant across the current Jones Act market and this will only worsen with projects in the future
- Shipyard availability to build Jones Act compliant vessels
- Vessel build costs are outpacing floating offshore wind day rates creating a high-risk low return investment climate for vessel operators
- The lack of long-term contracts additionally limits vessel operators' willingness to invest hundreds of millions of capital to build new vessels
- Without significant new vessel build programs, projects will come to a halt and a lack of investment will mean offshore wind planning goals will not be achieved

Jones Act Solutions to current and future challenges of California's Floating Offshore Wind Goals

- The Maritime Administration (MARAD) is offering financing specifically designed to stimulate the growth and modernization of the U.S. Merchant Marine and U.S. shipyards. This includes offering up to 87.5% financing, repayment periods up to 25 years, fixed or floating rates, and interest rates comparable to U.S. Treasury rate for comparable term securities.
- The offshore wind industry may need to take a new and more proactive approach to help the supply chain meet the challenges presented by larger turbines and foundations. Long-term contracts to support construction of new vessels and even direct investments in suppliers/shipyards will be critical if the supply chain is to match the ambitions of turbine producers and developers.
- Collaborative business models could unlock financing that otherwise would be unavailable for many suppliers by lowering the cost of capital, reducing equity needs, and providing confidence to investors.

- Green funding schemes could create more favorable finance terms to assist owners with lending by lowering the equity required in relation to the amount they need to borrow.
- Establishing partnerships between private and public entities to cultivate the essential competencies needed for the present and future workforce in California's Floating Offshore Wind sector.

3.2.3. California Air Resource Board (CARB) Regulations

CARB is charged with protecting the public from the harmful effects of air pollution and develops programs and actions to fight climate change. New and existing vessels operating in Regulated California Waters (RCW) must comply with CARB Regulations. The intent of these regulations is to reduce diesel particulate matter, oxides of sulfur, oxides of nitrogen, and greenhouse gas emissions from diesel propulsion and auxiliary engines on harbor craft in Regulated California Waters (CARB 2022).

The applicable Commercial Harbor Craft (CHC) Requirements include:

- A vessel is considered to operate in California if it is within Regulated California Waters (RCW)
- Tier 4 engines must be equipped with diesel particulate filters (DPF) beginning January 1, 2028
- Renewable diesel must be used by all CHC operating in California beginning January 1, 2023
- Towing vessels report to CARB within 30 days of operating in RCW

Why are CARB regulations a challenge for California Floating Offshore Wind?

- New-build vessel costs will be higher to meet CARB requirements
- Existing CARB-compliant vessels are not adequate to meet the needs of the floating offshore wind industry
- Diesel particulate filter (DPF) technology is not currently compatible with operational vessels in the California towage market

3.2.4. Energy/Fuel

The applicable energy or fuel requirements for vessels include:

- Renewable diesel (RD 100 or RD 99) is required by CARB for CHC.
- The California Ocean Going Vessel Fuel Regulation requires the use of distillate grade marine fuels (marine gas oil (DMA / DMX) or marine diesel oil (DMB)) with a maximum sulfur level of 0.1% while operating main engines, diesel-electric engines, auxiliary engines, and auxiliary boilers on Ocean Going Vessels (OGV)

within Regulated California Waters. (Cal. Code Regs., tit. 13, 2299.1(e).) CARB has primary enforcement authority for the California OGV Fuel Regulation.

- California Code of Regulations, Title 17, Division 3, Chapter 1, Subchapter 7.5, Sections 93130 to 93130.22, also known as the Control Measure for Ocean-Going Vessels At Berth, became effective on January 1, 2021. The Control Measure, enacted by CARB, extends an existing at-berth regulation for container, cruise, and refrigerated cargo vessels to tanker and roll-on/roll-off (RORO) vessels. The purpose of the Control Measure is to reduce emissions of oxides of nitrogen, reactive organic gases, particulate matter, diesel particulate matter, and greenhouse gas from ocean-going vessels while docked at berth in California ports. All parties necessary to achieving emission reductions from ocean-going vessels at berth have responsibilities and requirements under the Control Measure, including, but not limited to, vessel operators, terminal operators, ports, and operators of a CAECS (CARB Approved Emission Control Strategy). The control measure also includes a list of CAECS, definition of ocean-going vessels covered by the regulation, regulation exceptions, and regulation compliance start dates.

3.2.5. Homeport for Vessels

Vessel service requirements may vary depending on the vessel. However, at a minimum, services at a homeport should include:

- Gangway and/or crew accessways
- Crane availability (capacity varies)
- Truck access for pumping, fueling, etc.
- Maintenance and repair
- Shore power
- Utilities (electricity, potable water, etc.)

3.2.6. Workforce

The various vessel marine crew required for supporting floating offshore wind energy areas range from a minimum of 2 for a CTV to a crew of and mission staff of 100+ for a cable laying vessel. Hundreds of American mariners will be required to crew Jones Act vessels in California’s floating offshore wind market. These numbers are only for the vessel’s crew and do not include any special technicians that are required to operate systems such as cable laying, dynamic positioning, survey work, ROV work, etc.

Licensing requirements for crew members vary depending on the vessel's tonnage, duties, and area of operations. In general, all leadership positions onboard vessels, (Captain, Chief Engineer, Mate, Engineer, etc.) require years of specialized United States Coast Guard (USCG) approved training.

3.2.7. Floating Offshore Wind Challenges

Conducting maritime operations in any environment comes with certain inherent risks. Those risks are magnified when conducting an operation for the first time. The proposal of towing a 15 MW or larger fully integrated turbine from a port to an offshore wind energy area, regardless of distance, creates a unique set of challenges for the maritime industry. For context, an integrated offshore wind turbine structure will have 1,100 feet of air draft, see Figure 4.2. This is taller than the Golden Gate Bridge in San Francisco. Developing California's floating offshore wind projects will involve challenging maritime operations.

Specific challenges include:

- Severe weather and ocean conditions: Ensuring a common understanding among all stakeholders regarding operational weather conditions will be crucial.
- Transportation logistics: Comprehensive understanding by all parties of all necessary procedures, from the departure of the floating offshore wind turbine from port to its final installation and connection location, is imperative.
- Offshore worker safety: Ensuring the safety of offshore workers who operate and maintain floating offshore wind turbines and infrastructure in a potentially hazardous marine environment.
- Maintenance and repair: Accessing and repairing offshore wind turbines and infrastructure in the challenging marine environment, which can require specialized maintenance vessels and equipment (maintenance and repair operations will need to have strict weather parameters to mitigate operational risk). Some maintenance and repairs will require towing WTGs back to S&I sites, and the frequency and duration of these operations will affect turbine uptime and potential downtime at the S&I site.
- Mooring and integration: Developing standardized operating procedures for connecting a floating offshore wind turbine into its mooring spread is crucial, considering the involvement of various vessels in the mooring operations.
- Water depths: installation of mooring systems and cable systems in deep water (>1,000m) will pose significant challenges for the cable and mooring technology, as well as for the vessels used to perform the installations.

3.3. Terminal Operations

Terminal operations will be divided between various users which could include the OEM, the fabricator, assembler, and the terminal workforce. It is possible that components will be moved around the yard (or between yards) by road, rail, or waterway. For all three, a sophisticated Program Manager, as described below in Section 3.4, will need to provide coordination between users of the terminal and the overall wind energy area installation schedule. For port sites that are part of a larger commercial port like the Port of Long Beach or Port of Oakland, the Program Manager will have to manage competing interests between the ongoing commercial activities and the needs of the offshore wind terminal. For terminal operations solely devoted to offshore wind, activities with other developer projects using the same terminal may need to be coordinated.

3.4. Marine / Terminal Operations Interface

To ensure efficiency, a Program Manager could help coordinate the interface between marine and terminal operations, as well as between various terminal operation users. The Program Manager should work hand in hand with the developer to keep the project on schedule by managing the marine activity directly and overseeing the coordination of the various terminal operations. The Program Manager could segment the operations of the offshore wind terminal into various work packages including:

1. Pre-operations
2. OEM terminal operations (fabrication, assembly, transportation landside)
3. Marine coordination operations
4. Passenger transport
5. Tugs
6. Survey equipment
7. Offshore cable laying
8. Spill response
9. Personal protective equipment for workers

3.5. Offshore Wind Energy Area Operations and Maintenance

Given the nature of floating offshore wind, O&M work will occur both at sea and at a port site. O&M will be required throughout all four seasons of the year. In view of this, damage due to inclement weather may cause an increase in the number of semi-submersible structures needing to be towed for repair to an S&I site during the winter.

Operations, maintenance, and repair activities include:

- Maintenance crew transfer
- Device repair
- Inspection of cables
- Inspection of mooring lines

- Towing to and from S&I ports for major repairs.

Due to the significant distances (>50km) assumed between most potential O&M sites and offshore wind energy areas, the general O&M strategy is assumed to be SOV-based, with some support from CTVs if possible. Based on feedback from offshore wind developers, one SOV is expected to be able to support 100 turbines.

It is preferable to perform maintenance and repair activities offshore if possible, however some repairs cannot be made in-situ with current technology and require the turbine to be disconnected and towed back to an S&I site. The estimated frequency of repairs requiring tow-back is uncertain, however it is expected that S&I sites will need to reserve a portion of time each year to allow for these operations.

4. Offshore Wind Port Requirements

The floating offshore wind industry requires port sites to stage, assemble, and provide ongoing operations and maintenance to the wind turbines. This section summarizes the offshore wind port requirements and design criteria from the BOEM study titled *California Floating Offshore Wind Regional Ports Assessment* (Moffatt & Nichol 2023a).

Note, activities to support the construction and installation of offshore substations is not included in this report.

4.1. Floating Foundation Types

Currently, there are three types of floating foundations for floating offshore wind turbines, as shown in Figure 4.1. Per the BOEM study titled *Comparison of Environmental Effects from Different Offshore Wind Turbine Foundations*, the floating foundation types are defined as follows (ICF 2021):

- Spar: spars have a single ballasted cylinder that supports the tower and extends well below the waterline. The submerged ballast keeps the structure upright.
- Semi-submersible: semi-submersibles have multiple submerged columns or hulls attached together with connecting braces. The hulls have sufficient buoyancy to cause the structure to float and resist overturning.
- Tension Leg Platform (TLP): TLPs are buoyant multihull steel floating platforms vertically moored to the seafloor by a group of tendons to minimize vertical movement of the structure. TLPs add an additional downward and stabilizing force by tension forces developed in the tendons.

Figure 4.1. Illustration of floating foundation types (left to right: spar, semi-submersible, TLP) (NREL 2022)

Spar technology requires a deep draft due to the ballast needed for stability. This deep draft makes it an unlikely option on the U.S. West Coast, because it would require significant modifications to fit within California ports. TLPs require mooring-line tension for stability and can be unstable without them unless additional buoyancy is added. This can make WTG integration for TLPs difficult along the wharf, as well as towing to the offshore installation site. Semi-submersibles are the most common floating foundation type and with its shallow draft it can adapt to California ports (NREL 2023b).

By assuming that semi-submersible foundations will be utilized for offshore wind development on the West Coast, the port requirements developed in Table 4.2 are also suitable for TLP foundations—if utilized—as they are smaller and require less port infrastructure capacity.

A major challenge the industry identified is the transfer of the completed semi-submersible or TLP foundation from the assembly wharf into the water (i.e., launching). Several options are available to overcome this challenge and each developer may prefer a different option; however, a few common approaches were identified:

- Semi-Submersible Barge: The floating foundation is moved from the wharf onto the semi-submersible barge which is then moved to a 40 to 100-foot-deep sinking basin where the semi-submersible barge is partially submerged by taking on ballast and the foundation is floated off the barge.

- Ramp System: The floating foundation is moved onto a rail system and travels down a sloped ramp into the water. This methodology is similar to a marine railway ship launching system.
- Direct Transfer: Methods that include lifting the floating foundation directly from the wharf into the water (includes methods that involve placing pieces of the foundation into the water and finalizing the construction in the water).

4.2. Turbine Size

Currently, 15 MW offshore wind turbine systems are commercially available. However, the industry trend is that turbine sizes increase over time. In addition, each turbine design and floating foundation technology is uniquely designed for the WTG model and metocean conditions for its location. Dimensions and capacities will vary between projects. Thus, when planning for a major port terminal with a 50-year design life, designing for the largest anticipated size of offshore wind turbine through 2045 would keep the possibilities open for the maximum number of technologies and allow for flexibility for offshore wind port terminal operators. Since the dimensions for the largest anticipated turbine used in 2045 do not yet exist, they were estimated based on industry trends and information from developers, OEMs, and manufacturers. Table 4.1 summarizes the anticipated dimensions for a floating turbine system with a capacity of up to 25 MW. These dimensions were based on industry trends and information obtained from the industry outreach conducted in the BOEM Port of Coos Bay study (Moffatt & Nichol 2022). Figure 4.2 is a depiction of the turbine dimensions for a system up to 25 MW.

Table 4.1. Anticipated floating offshore wind turbine dimensions

Floating Offshore Wind Turbine	Approximate Dimension [ft]	Approximate Dimension [m]
Foundation Beam / Width	Up to 425 ft x 425 ft	Up to 130 m x 130 m
Draft (Before integration)	15 to 25 ft	4.5 to 7.5 m
Draft (After integration)	20 to 50 ft	6 to 15 m
Hub/Nacelle Height (from Water Level)	Up to 600 ft	Up to 183 m
Tip Height (from Water Level)	Up to 1,100 ft	Up to 335 m
Rotor Diameter	Up to 1,000 ft	Up to 305 m

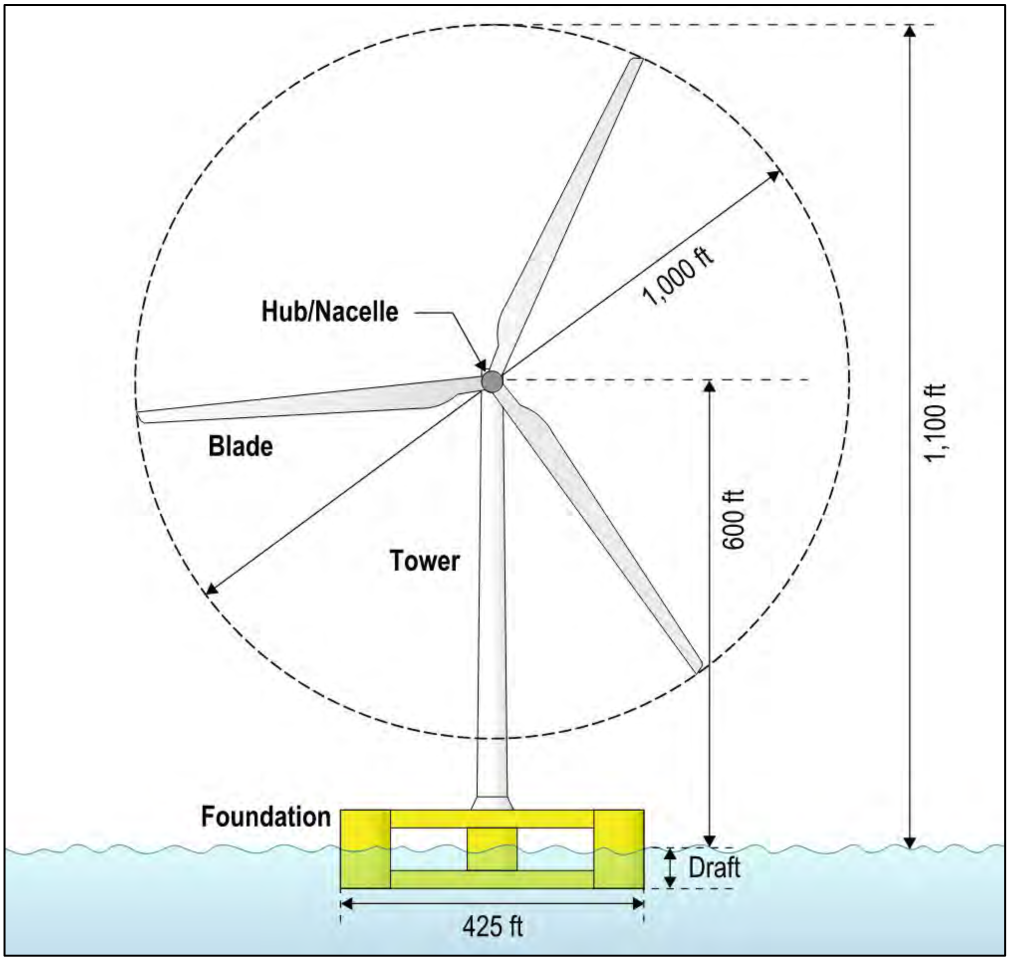

Figure 4.2. Anticipated floating offshore wind turbine dimensions (feet)

4.3. Port Requirements

The following parameters document the required port infrastructure to unload, store, pre-commission, and pre-assemble floating offshore wind components per the BOEM Port of Coos Bay study (Moffatt & Nichol 2022).

4.3.1. Air Draft Restrictions

S&I port sites shall have no air draft or air space restrictions, such as bridges, overhead power lines, or flight paths as the fully assembled turbines may require more than 1,100 ft of air draft to be towed from port to the lease areas. If there are air space conflicts, coordination with the airport and Federal Aviation Administration is required.

4.3.2. Port Wharf and Loading Requirements

Per discussions with industry, the S&I wharf shall accommodate the delivery of components and at least two turbine assemblies moored adjacent to one another, resulting in approximately 1,500 feet of wharf, as summarized in Table 4.2. For O&M

and component manufacturing facilities, the length of the wharf is dependent on the vessel type it serves. For example, O&M facilities will serve SOVs and CTVs, and component manufacturing facilities will serve delivery vessels and delivery barges.

In general, the uplands area for S&I and MF sites shall have a capacity of at least 2,000 to 3,000 pounds per square foot (psf) to support storage of offshore wind turbine generator (WTG) components. Additionally, the wharf loading at S&I and MF sites will be higher where the crane for turbine assembly and/or loading/unloading of delivery vessels and barges is located. Existing crawler cranes, such as the Liebherr 13000, are not large enough to assemble turbines greater than 15 MW. Thus, ring cranes or larger crawler or mobile cranes will likely be required to integrate components. Due to the significant size and weight of the WTG components, a wharf loading capacity of 6,000 psf is required for both S&I and MF sites. Loading at O&M facilities is expected to range from 100 to 500 psf.

The type of facility also informs the size of the site. For an O&M facility, the site shall be approximately 2 to 10 acres. For MF and S&I sites, a range of 30 to 100 acres is requested, depending on the developer and their use. During outreach, developers indicated that sites on the larger end of this scale are preferred, as it offers more flexibility to store components and not interrupt production. However, as has been seen on the U.S. East Coast, smaller sites could suffice, if necessary, but would limit production and increase the cost of operations.

Table 4.2. Port infrastructure requirements

Floating Offshore Wind Turbine	Approximate Criteria for S&I Sites	Approximate Criteria for MF Sites	Approximate Criteria for O&M, Mooring & Anchor Storage, & Construction Support Sites	Approximate Criteria for Electrical Cable Laydown Sites
Acreage	30 to 100 acres	30 to 100 acres	O&M: 2 to 10 acres Others: 10 to 30 acres	20 to 30 acres
Wharf Length, min.	1,500 ft	800 ft	300 ft	500 ft
Minimum Draft at Berth	38 ft	38 ft	20 to 30 ft	30 to 35 ft
Draft at Sinking Basin*	40 to 100 ft	N/A	N/A	N/A
Wharf Loading	> 6,000 psf	> 6,000 psf	O&M: 100 to 500 psf Others: 500 psf	1,000 psf
Uplands / Yard Loading	2,000 to 3,000 psf	2,000 to 3,000 psf	O&M: 100 to 500 psf Others: 500 psf	1,000 to 2,000 psf

*Options for transfer of floating foundation from land to water include use of semi-submersible barge and sinking basin, ramp system, or direct transfer methods (lifting portions or complete foundation units from land into water).

For planning purposes at an S&I site, 80 acres is a sufficient amount of upland space for an offshore wind developer to receive, stage, and store components for final turbine assembly at the wharf. A sample layout for an 80-acre S&I site with the necessary infrastructure is shown in Figure 4.3. Components such as blades, nacelles, and tower sections are delivered to the site and stored within the uplands area that is rated for 2,000 to 3,000 psf. A sinking basin is shown near the site that can be used to transfer a floating foundation substructure into the water. The heavy lift wharf is rated for 6,000 psf to withstand the heavy loads from components and equipment that load and unload cargo and assemble the wind turbine onto the floating foundation substructure.

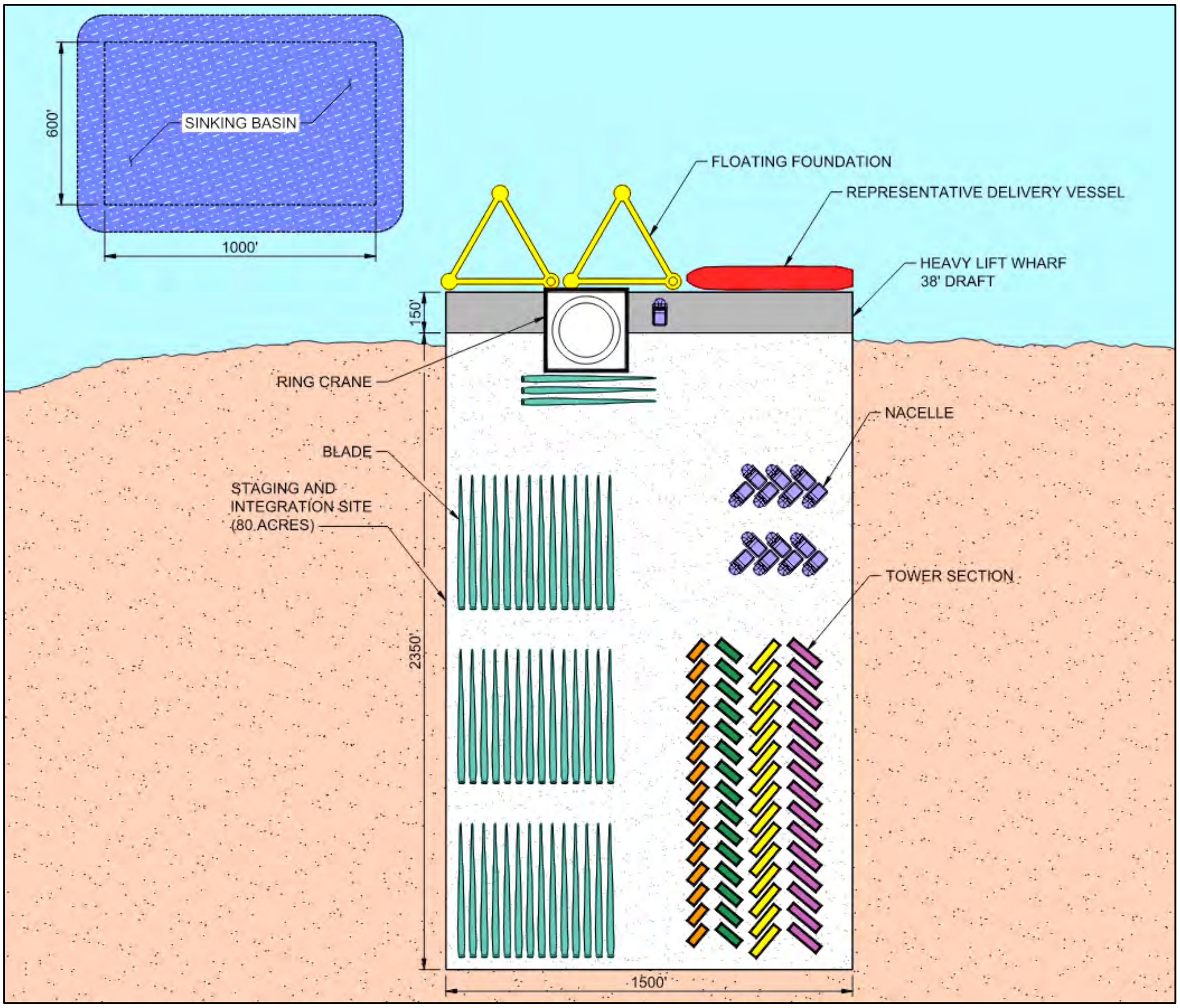

Figure 4.3. Sample 80-acre S&I site layout (Moffatt & Nichol 2023b)

A sample layout for a 40-acre nacelle assembly site and 800 feet heavy lift wharf is shown in Figure 4.4. In the figure, nacelles are assembled within the manufacturing building, stored on site, and then transferred via waterborne transport to an S&I site for turbine assembly.

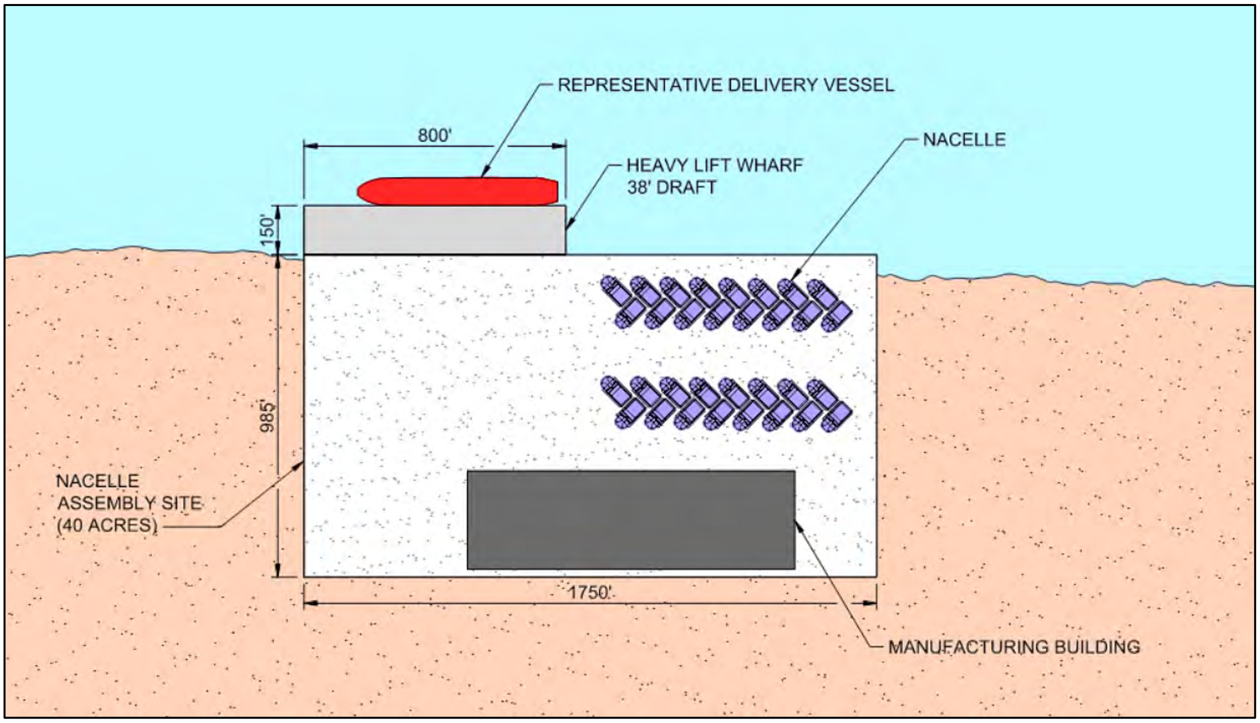

Figure 4.4. Sample 40-acre tower MF site layout (Moffatt & Nichol 2023b)

A sample layout for an O&M site with a 300 ft wharf and 10-acre nearshore area is shown in Figure 4.5. In the figure, an SOV and CTV are using the wharf for activities such as loading and unloading supplies and transferring crew to the offshore wind area.

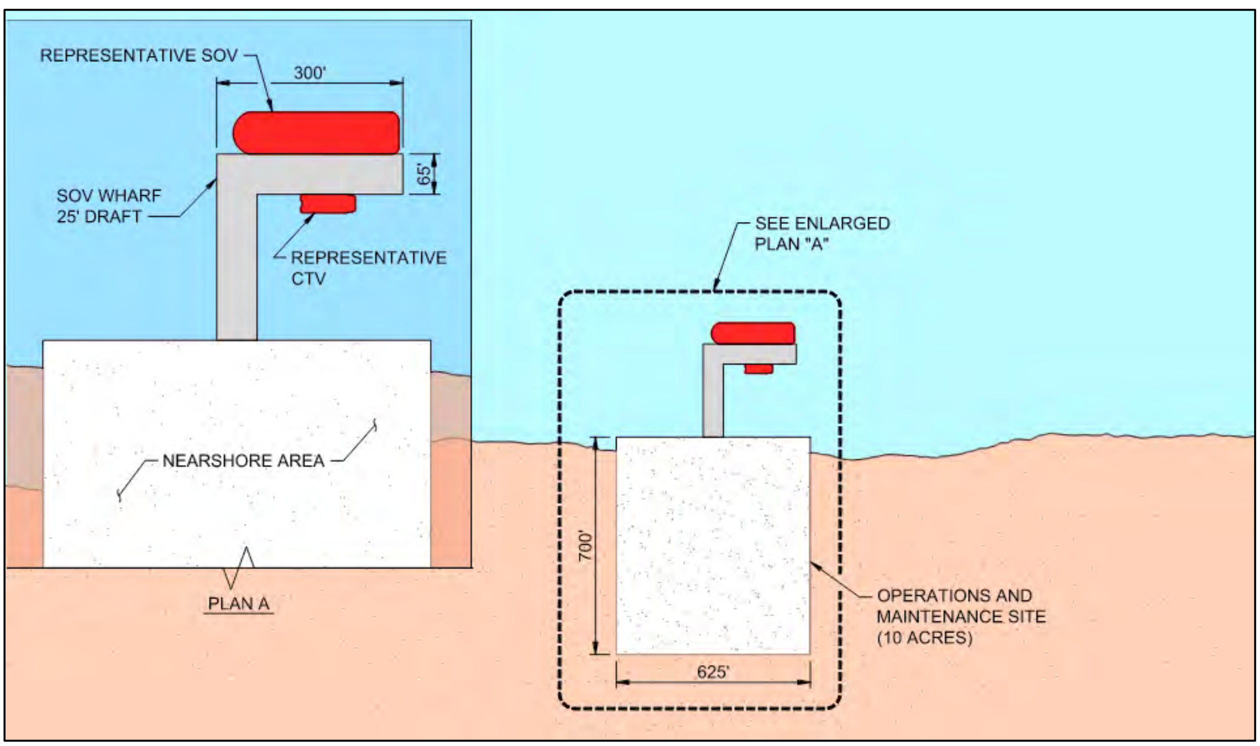

Figure 4.5. Sample O&M layout (Moffatt & Nichol 2023b)

4.3.3. Wet Storage Requirements

Wet storage space is required in addition to the water frontage and upland acreage. Ports must have locations where floating foundations or integrated turbines can be safely moored to mitigate the risk of weather downtime, vessel traffic, entrance channel congestion, and other transportation risks. This also allows the developers to store and complete diagnostic testing on the units. The size and depth of the required wet storage area is dependent on the developer's strategy, deployment schedule, downtime risk, and available port space.

4.3.4. Additional Port Requirements

Several additional port requirements include the following:

- Roll-on/Roll-off (RORO) Capabilities: port sites shall have RORO capability built into the wharf and yard to allow for a range of fabrication and assembly needs. Of particular importance would be to allow for inside port transfers between multiple facilities. This may require the construction of a sinking basin deeper than the proposed navigation channel depth.
- Green Port: new port terminals shall have infrastructure and equipment to support state and federal carbon reduction initiatives, including electrification of the terminal operations and the ability to accommodate vessel shore power. Considering greenhouse gas emission reduction initiatives and the desire to develop green ports, considerable load on the transmission grid may be needed. An assessment of power grid upgrades for the proposed development site will be needed to determine the range of power transmission upgrades needed to meet the vessel and terminal operational needs.
- Shoreside Vessel Services: port sites will require all standard ship services (e.g., potable water), shore power, and security requirements.
- Buildings: indoor storage/warehouses are required for some items (e.g., floating foundation mechanical equipment, painting, welding, etc.).

4.4. Design Life

All new marine structures at the port shall be designed for a 50-year service life. Design service life is generally considered to be the period of time during which a properly built and maintained structure is expected to operate as designed without requiring major replacement or rehabilitation. The port terminal designs must accommodate sea level rise when determining the elevation of the upland yard and the marine structures. If the developed marine infrastructure is no longer used for offshore wind after these projects, they can be used for other purposes. However, these facilities will likely be required for turbine end of life decommissioning and installation of replacement turbine systems.

4.5. Governing Codes, Standards, and References

The following codes, standards, and references govern the design of port infrastructure and offshore wind vessels.

American Bureau of Shipping (ABS):

- Guide for Building and Classing Floating Offshore Wind Turbine Installation, updated July 2014

American Concrete Institute (ACI):

- ACI 318-19, Building Code Requirements for Structural Concrete

American Institute for Steel Construction (AISC):

- AISC 303-16, Code of Standard Practice for Steel Buildings and Bridges
- AISC 341-16, Seismic Provisions for Structural Steel Buildings
- AISC 360-16, Specification for Structural Steel Buildings

American Petroleum Institute (API):

- API RP 2A-LRFD, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Load and Resistance Factor Design

American Society of Civil Engineers (ASCE):

- ASCE 7-16, Minimum Design Loads for Buildings and Other Structures
- ASCE 61-14, Seismic Design of Piers and Wharves

American Welding Society (AWS):

- AWS D1.1, Structural Welding Code, 2015

California Building Code (CBC):

- 2022 California Building Codes

National Fire Protection Association (NFPA):

- NFPA 307, Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves

Oil Companies International Marine Forum (OCIMF):

- Mooring Equipment Guidelines (MEG4), 4th Edition, 2018

Permanent International Association of Navigation Congresses (PIANC):

- PIANC MarCom WG 145, Berthing Velocity Analysis of Seagoing Vessels over 30,000 dwt, 2022

- PIANC WG 121, Harbour Approach Channels – Design Guidelines, 2014
- PIANC WG 33, Guidelines for the Design of Fenders Systems, 2002
- PIANC WG 34, Seismic Design Guidelines for Port Structures, 2001
- PIANC WG 153, Recommendations for the Design & Assessment of Marine Oil & Petrochemical Terminals, 2016

United States Army Corps of Engineers (USACE):

- USACE EM 1110-2-1100, Coastal Engineering Manual, 2002
- USACE EM 1110-2-1613, Hydraulic Design of Deep-Draft Navigation Projects, 2006
- USACE EM 1110-2-2502, Retaining and Flood Walls, 1989

Unified Facilities Criteria (UFC):

- UFC 4-152-01 Design: Piers and Wharves, 2017
- UFC 4-159-03 Design: Moorings, 2020

5. Offshore Wind Port Demands

To satisfy the AB 525 requirements of determining the necessary investments in California ports, a detailed assessment was performed to determine how many port sites are needed to meet the State's offshore wind planning goals. On August 1, 2022, the CEC established an offshore wind planning goal of 2 to 5 GW by 2030 and 25 GW by 2045 (Flint 2022). Using these goals as a baseline, the BOEM study titled *California Floating Offshore Wind Regional Ports Assessment* (Moffatt & Nichol 2023a) performed an assessment to determine how many port sites are needed to meet these goals.

Having all port sites located within California would bring the most economic benefit to the State. However, it is possible that some port sites, especially MF sites, may be located outside of California. This would mean components are imported, either internationally or from other states.

Per the requirements of AB 525, this report assumes California port sites are only contributing to offshore wind projects off the California coast. This study does not consider that California port sites may need to contribute to the Oregon and Washington offshore wind supply chains and, conversely, does not consider that Oregon and Washington port sites may contribute to the California offshore wind supply chain. For interstate collaboration, refer to the *West Coast Ports Strategy* (NREL 2023b).

5.1. Deployment Targets and Planning Goals

The BOEM *California Floating Offshore Wind Regional Ports Assessment* study looked at five different levels of offshore wind deployment or planning goals from 2030 through 2045, as shown in Table 5.1 (Moffatt & Nichol 2023a). Since AB 525 focuses on offshore wind planning goals of 2 to 5 GW by 2030 and 25 GW by 2045, these values are bolded and the main focus within this report.

Table 5.1. Offshore wind deployment scenarios (state targets highlighted)

Year	Low	Low–Medium	Medium	Medium–High	High
2030	1 GW	2 GW	3 GW	4 GW	5 GW
2035	3 GW	7 GW	10 GW	14 GW	17 GW
2038	5 GW	10 GW	15 GW	20 GW	25 GW
2045	8 GW	17 GW	25 GW	34 GW	42 GW

5.2. Towing and Installation Assessment

To support the evaluation of S&I port facility requirements, a conceptual towing and installation assessment was performed. This assessment was intended to outline tradeoffs between S&I sites with respect to annual towing and installation operations in the Northern and Central Coast regions of California and support the estimate of how many S&I port facilities are required to meet deployment goals. A summary of findings with respect to these objectives are provided in this section, with additional details found in Appendix B. The operations considered in this conceptual evaluation are the towing and hookup of integrated WTGs from an S&I site to a designated WEA and are shown in Figure 5.1.

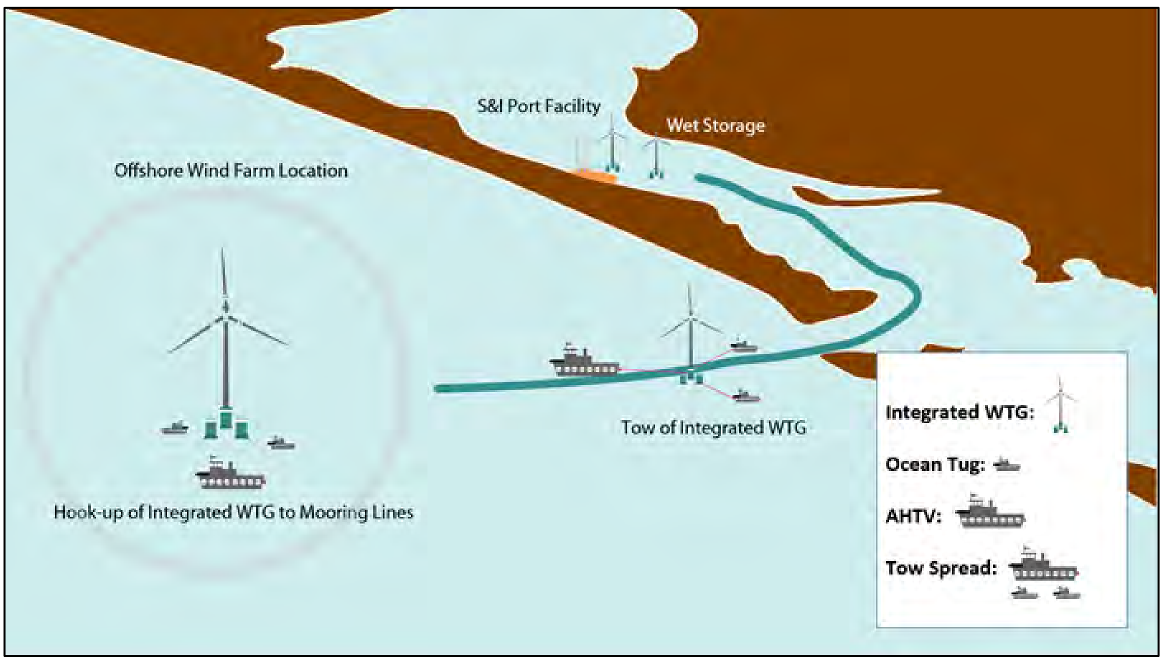

Figure 5.1. Operations and facilities considered in metocean conditions and towing assessment

The factors considered in this assessment included:

- Towing distance from S&I site to an offshore WEA.
- Metocean conditions (a combination of meteorological and oceanographic factors, such as wind, wave, and climate conditions) along the tow route of the integrated WTG and at the WEA.
- Towing logistics and limitations, such as how many tow spreads are available to tow the integrated WTG. A schematic of tow spreads is shown in Figure 5.2.
- S&I port logistics and limitations, such as how much wet storage is available and how quickly WTGs are integrated to the foundations.

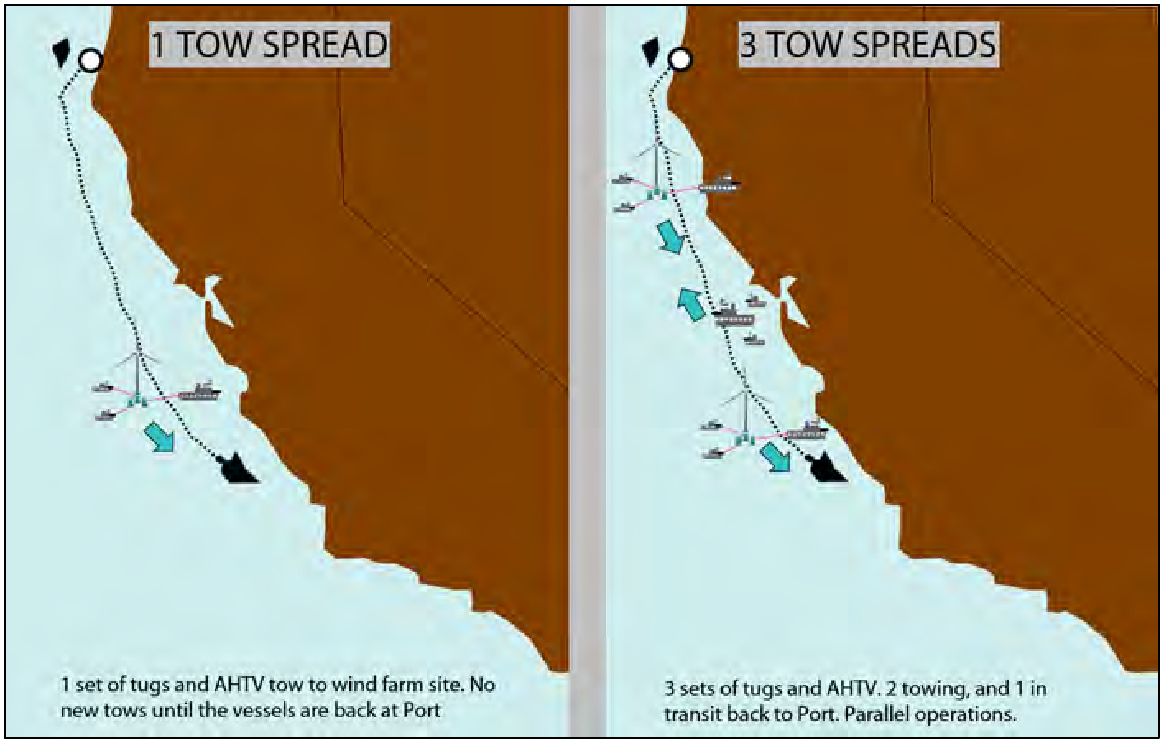

Figure 5.2. Schematic for number of tow spreads

This assessment focused on the comparison of routes between the potential S&I sites and WEAs in Northern and Central California. The potential S&I sites that are assessed in this study are within the Port of Humboldt, China Harbor, Port San Luis, Gato Canyon, Port of Los Angeles, and Port of Long Beach – refer to Section 6.1 for more details on locations. In general, these six locations can be generalized into three regions: Northern California, Central California, and Southern California. Tow routes from the Port of Humboldt (represents Northern California), Port San Luis (represents Central California), and Port of Long Beach (represents Southern California) to the WEAs are shown in Figure 5.3.

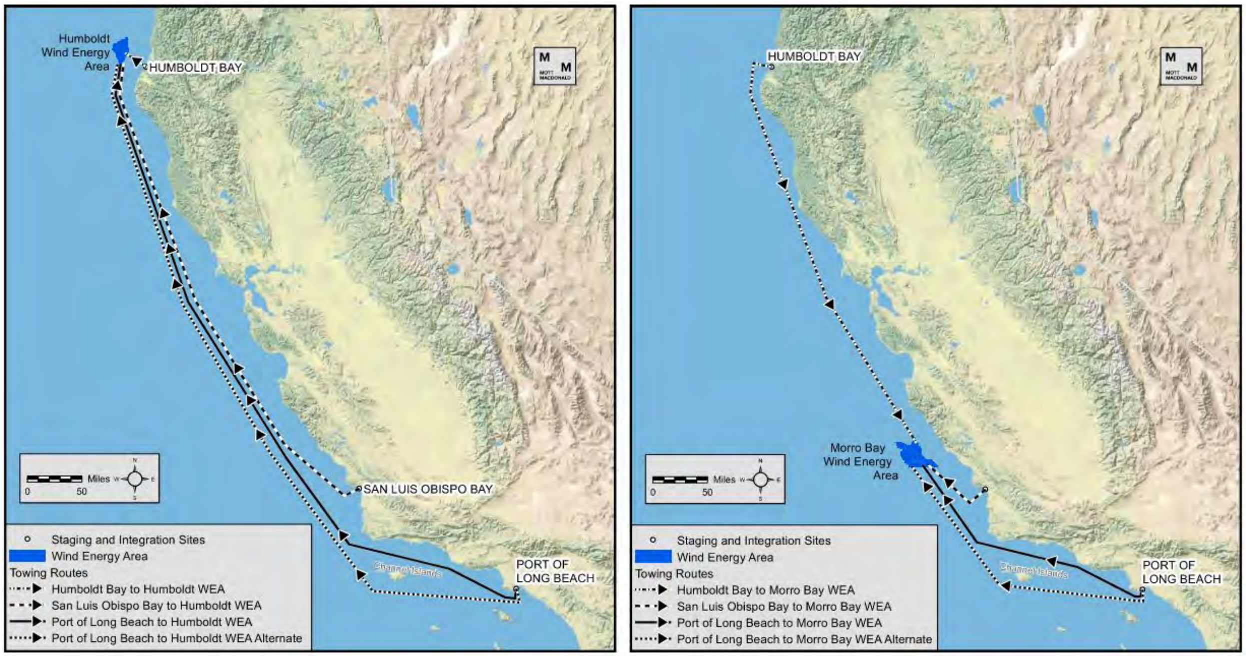

Figure 5.3. Tow routes to Humboldt Bay WEA (left) and Morro Bay WEA (right)

A conceptual desktop assessment for towing and installation was completed and included a comparison of a range of operational criteria to site-specific metocean conditions. The assessment included a time-based discrete event simulation analysis that is intended to provide relative assessments for average annual route-specific throughputs. It did not include analysis of a time-series through 2045. Therefore, this analysis did not include inefficiencies over a multi-year period such as transitions between developers utilizing the port, vessel maintenance, and other factors. Statewide throughput is expected to vary from year to year due to these factors. The assessment considered the following:

- Metocean conditions:
    - Metocean conditions are a critical element of the analysis, with seasonal variations in wave conditions as a major driver, refer to Figure 5.4.
    - Metocean conditions over multiple years are included in the assessment to address annual variability.
- Operational activities:
    - Activities include WTG and foundation integration at each S&I site, wet storage of the integrated WTG, towing to a WEA, hook-up of mooring lines to the floating foundation, and returning to the S&I site.
    - Baseline constant assumptions were used along with a series of variable parameters to test the sensitivity of annual WTG installation throughput to various factors. The constant and variable inputs assumed for this assessment are shown in Table 5.2 and Table 5.3, respectively.

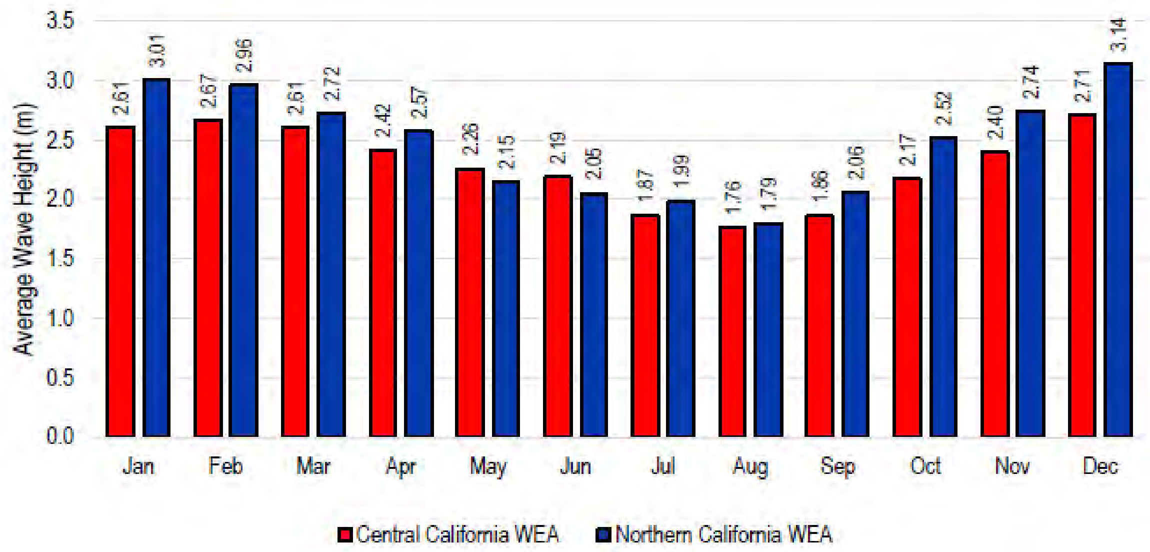

Figure 5.4. Monthly average wave height for each WEA region (See Appendix Table C.1. for source data)

Table 5.2. Constant inputs for tow spread assessment

Constant Inputs	Assumptions
Tow Speed/Duration	3 knots. 50% increase on towing times is assumed per DNV voyage planning guidance (DNVGL-ST-N001).
Hook-Up Criteria	35 hours, 2.5m Hs, 30-knot wind
Towing Metocean Criteria	3m Hs, 30-knot wind
Tow Spread Makeup	1 AHTV, 2 ocean tugs
Port Logistical Limitations	Humboldt: Maximum of 1 tow per day total for the port San Luis Obispo: Minimum 6 hours between tows, maximum of 2 tows per day Port of Long Beach: Minimum 6 hours between tows for each S&I site, maximum of 2 tows per day for each S&I site

Table 5.3. Variable inputs for Tow Spread Assessment

Variable Inputs	Assumptions
Number of Tow Spreads	1 – 6 Tow Spreads
Wet Storage	Humboldt Bay: 5 or 10 WTGs Port San Luis: 2 or 5 WTGs Port of Long Beach: 20 WTGs
WTG Integration Rates	5, 7, or 10 Days per WTG
Number of S&I Sites in One Port	Humboldt Bay: 1-2 S&I sites San Luis Obispo: 1 S&I site Port of Long Beach: 1-3 S&I sites

Below is a summarized list of the major takeaways from the towing and installation assessment:

- WEA distance from S&I Sites: S&I sites in both Northern and Central/Southern California are likely to be able to support WEAs in both Central and Northern areas. For example, the Port of Humboldt can likely support build-out of development on both the Northern and Central Coast WEAs and an S&I site within Central California or Southern California can likely support both the Central and Northern California WEAs.
- Central & Southern Coast S&I Sites: S&I sites in either Central California or Southern California can likely achieve similar annual throughputs, for projects in either Central California or Northern California WEAs. Central California S&I sites have some advantage at lower throughput rates due to shorter tow distances and the use of fewer vessels; however, the assumed possibility of significant wet storage available at Port of Long Beach can likely offset the installation disadvantages due to increased tow distance.
- Wet Storage and Vessel Availability: The availability of wet-storage and multiple tow spreads are likely to be major factors in maintaining annual throughput goals. This is due to reduced operational windows in the winter and the ability to take advantage of more favorable weather windows.
- Multiple Tow Spreads: To meet similar installation rates, longer tow routes (e.g., between Southern CA and Northern CA) and will likely require multiple tow spreads (multiple vessel groups to tow an integrated WTG). This is due to the longer route duration, and an increased risk of weather induced downtime. Shorter routes typically did not benefit from multiple tow spreads.
- Seasonality: Towing and installation in the winter may be possible, but there are significantly fewer installation windows. This assessment assumed installation could continue in the winter if windows were possible, however, it may not be efficient in practice (depending on the route). A pause in installations in the winter could be offset in part by wet storage of integrated units and multiple tow-spreads. However, a full pause in integration would result in a reduction of annual throughput.
- Vessels Needed: Similar to O&M, a significant number of specialized vessels will be needed to support integration and installation, which may exceed the number currently available on the US West Coast.
- Vessel Emissions: The varying distances and tow durations for each route will affect the vessel emissions for a given construction project. However, emissions for towing are only part of the total emissions for a single project, and representing emissions for just this activity may not provide a complete picture of emission scenarios, and therefore are not presented herein.

5.3. Staging and Integration

To determine the number of S&I sites needed to meet the various offshore wind deployment targets in Table 5.1, an evaluation was performed based on the year S&I sites are assumed to be available, the size of and rate WTGs can be assembled at an S&I site, and the results of the towing and installation assessment. With these inputs, the total offshore wind power generation can be determined per year through 2045, to back into the number of S&I sites needed to meet the offshore wind deployment targets in Table 5.1.

S&I Site Assumptions:

- Yard/Wharf Site Requirements: Sites in an existing California port are assumed to be upgraded to provide at least 1,500 feet of heavy lift wharf with greater than 6,000 psf capacity and a minimum of 80 acres of available land for developer use.
- Timing:
  - Sites 1 – 3 are assumed to be ready for developer use by 2028 and 2031.
  - Sites after this are assumed to be ready for developer use by 2035.
- Turbine Size: WTG sizes are assumed to be 15 MW up to 2035, then 20 MW after 2035.
- Turbine Assembly Rate: Assumes WTGs can be fully integrated with the floating foundation at a rate of 1.0 WTG/week depending on site location and wet storage capacity.
- Installation Inefficiencies / Delays: As mentioned in Section 5.2, there are additional factors that can affect how many turbines are assembled and installed, such as transitions between developers utilizing the port, vessel maintenance, and turbine maintenance. Table 5.4 summarizes some of the assumed inefficiencies that could affect turbine assembly and installation rate.

Table 5.4. Turbine assembly and installation inefficiencies at S&I Sites

Inefficiency Description	Inefficiency Factor	Notes
Distance to WEA	12%	Assume 10 GW is installed going from either a Northern California port to Central Coast WEA or Southern/Central California port to North Coast WEA and installs 30% less turbines than installations within the same region as the S&I port. Based on results from Section 5.2.
Tenant Changing	3%	Every 4 years, an S&I site gets a new tenant and there is 6 weeks of downtime
New Tenant Startup	5%	Every 4 years there is a tenant changeover that takes 10 weeks to get up to peak production.
Vessel Traffic	0%	Assume no delays.
Tug Availability	0%	Assume adequate tug availability.
Component Supply Chain	0%	Assume port sites are large enough to have adequate laydown area for contingency component supply.
Mechanical Downtime	5%	Assume port equipment or vessel fleet will have a mechanical breakdown that will cause a delay.
Contribution to Other States	0%	Assumes California ports are only supporting California offshore wind projects.
Turbine Major Maintenance	15%	Assume each turbine has to be towed back every 10 years. Each turbine stays at the berth for 1 day.
End of Life Decommissioning	0%	Not included, does not affect 2045 goals. This needs to be further studied.
Total	40%	

With these potential inefficiencies and delays for turbine assembly and installation, the number of required S&I sites shown in Table 5.5 are represented as a range. Not applicable (N/A) is assigned when it is not feasible to meet the deployment target for that year because not enough S&I sites are ready for industry use. An S&I site might not be ready for industry use because it takes a number of years to get through planning, engineering, permitting and regulatory approvals, and construction.

Table 5.5. Required number of S&I sites to meet OSW deployment scenarios

Year	Low	Low–Medium	Medium	Medium–High	High
2030	1 to 2	N/A	N/A	N/A	N/A
2035	1 to 2	N/A	N/A	N/A	N/A
2038	1 to 2	2 to 4	4 to 6	5 to 7	N/A
2045	1 to 2	2 to 3	3 to 5	4 to 6	5 to 7

Note: Number of S&I sites for each target and year have been rounded up to the nearest whole number.

Thus, as shown in Table 5.5, it may not be possible to meet the State's 2030 offshore wind planning goal of 2 to 5 GW, if the initial S&I sites aren't available for industry use till the late 2020s to early 2030s. To meet the State's 2045 planning goal of 25 GW, California may require three to five S&I port sites that are approximately 80 acres each. Three sites are required if none of the inefficiencies presented in Table 5.4 exist, while five sites are required if all the inefficiencies in Table 5.4 exist. This report assumes that the inefficiencies in Table 5.4 exist, however they may not be mutually exclusive, therefore this report assumes four S&I port sites at 80 acres each is required to meet the State's planning goal of 25 GW by 2045.

5.4. Manufacturing / Fabrication

Five different MF sites were considered:

- Blade MF Sites: a port site that receives raw materials and manufactures blades
- Tower MF Sites: a port site that receives raw materials and manufactures tower sections
- Nacelle Assembly Sites: a port site that receives furnished parts of the nacelle and assembles the completed nacelle
- Foundation Subcomponent MF Sites: a port site that receives raw materials and manufactures subcomponents of the floating foundation systems (tubes, columns, etc.)
- Foundation Assembly Sites: a port site that receives furnished subcomponents of the floating foundation and assembles the full foundation system

Similar to the evaluation for S&I sites, an evaluation was done to determine the number of MF sites needed to meet the various offshore wind deployment targets in Table 5.1, if all MF sites were to be located within California. As previously mentioned, if the supply chain is not developed within the state, WTG components can be imported from other locations to meet the offshore wind industry needs. For the first offshore wind projects it is likely that WTG components will be imported since the industry has signaled that the supply chain will take longer to be developed and will be initiated when future offshore wind projects are announced for the state.

The number of MF sites needed to meet the offshore wind deployment targets in Table 5.1 were determined based on the following assumptions:

- Yard/Wharf Site Requirements: Sites in an existing California port are assumed to be upgraded to provide a heavy lift wharf with 6,000 psf capacity and the following:
  - Blade and tower MF sites provide 800 feet of heavy lift wharf and a minimum of 100 acres of available land for manufacturer use.
  - Nacelle assembly sites provide 800 feet of heavy lift wharf and a minimum of 25 acres of available land for manufacturer use.
  - Foundation subcomponent MF sites provide 800 feet of heavy lift wharf and a minimum of 40 acres of available land for manufacturer use.
  - Foundation assembly sites provide 1,200 feet of heavy lift wharf and a minimum of 80 acres of available land for manufacturer use.
- Timing: Sites are assumed to be ready for use by 2030, 2032, and 2035.
- Production Rate:
  - Blade MF sites are assumed to have a production rate of 200 blades per year. Three blades are required for each turbine system.
  - Tower MF sites are assumed to have a production rate of 500 sections per year. Four tower sections are required for each turbine system.
  - Nacelle assembly sites receive prefabricated components and assemble the nacelles at a rate of 275 nacelles per year. One nacelle is required for each turbine system.
  - Foundation subcomponent MF sites are assumed to produce 350 subcomponents per year. Six subcomponents are assumed for each foundation.
  - Foundation assembly sites receive components and assemble the foundations at the same rate of turbine integration, but no faster than 52 per year. One foundation is required for each turbine system.
- Turbine Size: Turbine sizes are assumed to be 15 MW prior to 2035, then 20 MW after 2035.

The results of this evaluation are shown in Table 5.6 through Table 5.10. Not applicable (N/A) is assigned when it is not feasible to meet the deployment target for that year because not enough MF sites are ready for industry use.

Table 5.6. Required number of blade MF sites to meet deployment scenarios

Year	Low	Low–Medium	Medium	Medium–High	High
2030	N/A	N/A	N/A	N/A	N/A
2035	1	2	N/A	N/A	N/A
2038	1	2	2	N/A	N/A
2045	1	2	2	2	3

Note: Number of MF sites for each target and year have been rounded up to the nearest whole number.

Table 5.7. Required number of tower MF sites to meet deployment scenarios

Year	Low	Low–Medium	Medium	Medium–High	High
2030	N/A	N/A	N/A	N/A	N/A
2035	1	1	2	2	N/A
2038	1	1	1	2	2
2045	1	1	1	1	2

Note: Number of MF sites for each target and year have been rounded up to the nearest whole number.

Table 5.8. Required number of nacelle assembly sites to meet deployment scenarios

Year	Low	Low–Medium	Medium	Medium–High	High
2030	N/A	N/A	N/A	N/A	N/A
2035	1	1	1	1	N/A
2038	1	1	1	1	1
2045	1	1	1	1	1

Note: Number of nacelle assembly sites for each target and year have been rounded up to the nearest whole number.

Table 5.9. Required number of foundation subcomponent MF sites to meet deployment scenarios

Year	Low	Low–Medium	Medium	Medium–High	High
2030	N/A	N/A	N/A	N/A	N/A
2035	1	N/A	N/A	N/A	N/A
2038	1	3	5	6	N/A
2045	1	3	4	5	6

Note: Number of foundation assembly sites for each target and year have been rounded up to the nearest whole number.

Table 5.10. Required number of foundation assembly sites to meet deployment scenarios

Year	Low	Low–Medium	Medium	Medium–High	High
2030	N/A	N/A	N/A	N/A	N/A
2035	1	N/A	N/A	N/A	N/A
2038	1	3	5	6	N/A
2045	1	3	4	5	6

Note: Number of foundation assembly sites for each target and year have been rounded up to the nearest whole number.

If all MF sites were to be located within California, the state would need two blade MF sites, one tower MF site, one nacelle assembly site, four foundation subcomponent MF sites, and four foundation assembly sites to meet 25 GW by 2045.

The manufacturing / fabrication of anchors, mooring lines, and electrical cables are not considered in this report as this could be located at existing port sites without needing major infrastructure upgrades. If mooring line and electrical cable manufacturing is to occur within California ports, this could increase the demand on port sites.

5.5. Operations and Maintenance

To operate and maintain the State's 2045 offshore wind planning goal of 25 GW, multiple O&M sites will need to be developed. O&M facilities support minor maintenance and repair for offshore wind turbines by providing crew transfer to the turbines in-situ. Major repairs and maintenance are assumed to be performed at S&I facilities. O&M terminals will host SOVs, CTVs, and an operations base consisting of offices, warehouses, and a storage yard. The scale and functionality of these O&M facilities will vary depending on wind energy area size, distance, and the strategy of the contractor executing the Service and Maintenance Agreement (SMA). Each of these facilities would have the ability to support one or more offshore wind lease areas, and the extent of support capabilities will vary with the amount of SOVs and CTVs hosted at the terminal, as well as support the capabilities of each SOV. In general, SOVs are assumed to be the main O&M support system for wind lease areas, with CTVs providing additional flexibility and fast response when needed.

To estimate the number of O&M sites or berths required to support the State's 2045 offshore wind planning goal of 25 GW, the number of required SOVs was first determined. In this assessment, Northern California and Central California were considered as separate regions, and it was assumed each region was supported independently from the other. The following assumptions were made in the calculation of the required SOV support:

- A single SOV could support up to 100 turbines on its own.
- A developer could leverage an SOV to support more than one offshore wind project in the same region.
- There will be 5 to 10 total developers across the state for 25 GW of deployment.
- WTGs will produce an average of 17 to 18 MW each, using the assumption that 15 MW turbines and 20 MW turbines will be used.

Using the assumptions above, the estimated quantity of SOVs required to support offshore wind projects within California is shown in Table 5.11. The upper end of the SOV requirement range was generated using the assumptions above. The lower end of the SOV requirement range was calculated using an optimized approach where SOVs were distributed evenly amongst the offshore wind projects to support 100 turbines each within the two regions – Northern and Central.

The number of SOVs presented in Table 5.11 are the number of SOVs required to support the GW deployment scenarios provided in Table 5.1. For example, if 2 to 5 GW were to be installed by 2030, it may require 2 to 6 SOVs to provide O&M support to them. In addition, if 25 GW were to be installed by 2045 it may require 14 to 24 SOVs to provide O&M support.

Table 5.11. SOV demand for California to meet deployment scenarios

Year	Low	Low–Medium	Medium	Medium–High	High
2030	2 to 5	2 to 5	2 to 5	3 to 5	3 to 6
2035	3 to 5	5 to 8	6 to 12	8 to 15	9 to 19
2038	3 to 6	6 to 11	8 to 16	11 to 21	14 to 24
2045	5 to 10	9 to 18	14 to 24	18 to 29	23 to 34

Based on the identified number of SOVs, the number of berths is determined. SOVs can remain in the field for over two weeks at a time, so there may be opportunities for more than one SOV to share a berth. This will reduce the need for berth space, and therefore, construction costs. For the purposes of this assessment, it was assumed that each SOV berth would support one to two vessels. The number of berths required to support SOVs for the full build-out of 25 GW by 2045 is shown in Table 5.12.

The required quantity of SOVs and berths is provided since the number of O&M sites depends on the number of developers that are active in each region. A developer may choose to use one O&M site to host multiple SOV berths.

Table 5.12. Berth requirements for SOVs in California

Year	Low (0.5 GW/yr)	Low–Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium–High (2 GW/yr)	High (2.5 GW/yr)
2030	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4
2035	2 to 4	3 to 6	4 to 8	5 to 10	6 to 13
2038	2 to 4	4 to 8	5 to 11	7 to 14	9 to 16
2045	3 to 7	6 to 12	9 to 16	12 to 20	15 to 23

Though the O&M strategy for offshore wind projects within California is assumed to be primarily SOV-based, some O&M sites may also utilize CTVs. It should be noted that this assessment assumes the practical range for a CTV day trip is approximately 31 miles (50km). This range will limit the O&M sites that can support CTVs for certain wind lease areas. To account for this, O&M ports located closer to active wind lease areas may need to accommodate more CTVs. As CTVs return to port daily, each CTV will require its own berth. CTV moorage depends on the proximity of a given O&M site to the wind energy area that it is supporting and the operations strategy of the developer.

5.6. Mooring Line and Anchor Laydown

Mooring line and anchor laydown storage areas will be required to support ongoing WTG installation in Northern California and Central California. These areas will stage and maintain the different mooring components required to install a floating WTG, as well as the marine infrastructure to berth an anchor handling tug vessel (AHTV) to load and unload the components. These storage areas could be standalone facilities or could be a part of a larger facility with infrastructure that can support the berthing of an AHTV.

The mooring lines considered in this assessment are semi-taut mooring systems, using a synthetic rope or wire in between two lengths of chain. It should be noted that other mooring systems, such as catenary chain systems and tension leg systems, may be considered for offshore wind projects in California; however, semi-taut systems are likely to be the preferred system due to the large water depths off the California coast.

The mooring components required to be stored at a mooring laydown area are mooring chain, synthetic rope or steel wire, and anchors. Each wind turbine foundation is assumed to have three mooring lines. Each mooring line is assumed to consist of 2,000 ft of chain, 3,300 ft of either synthetic rope or steel wire, and one anchor. Mooring line component and quantity assumptions were based on NREL supply chain studies for the United States (NREL 2023a).

The laydown area required for mooring components is assumed to be dependent on the number of ongoing offshore wind installation projects at any time. An S&I site is assumed to only provide throughput, or turbine production, for one project at a time, and thus the storage area demands will depend on the number of S&I sites in operation at any given time, as shown in Table 5.17. For this assessment, it is assumed that any mooring component storage area will need to store components for 10 to 12 WTGs at any given time. The geographic location of the mooring and anchor laydown sites will likely depend on the location of the final installation and not the S&I sites, as AHTVs will transit between the wind energy area and the laydown area often.

Table 5.13 shows the approximate mooring line and anchor storage requirements to maintain an inventory of mooring equipment for 10 to 12 WTGs for each active installation project. These values show approximate requirements to support development in the two regions, however the total acreage is not required to be at one facility and would likely be split to allow for laydown areas close to the WEAs. It should be noted that these numbers are conservatively assumed ranges and specific storage requirements will vary with technology, supply chain, and individual project demands.

Table 5.13. Mooring line and anchor laydown area requirements

No. of Active S&I Sites	Chain	Rope/Wire Reels	Anchors	Storage Area
1	50,000 to 100,000 ft	30 to 40	30 to 40	5 to 15 acres
2	125,000 to 175,000 ft	60 to 80	60 to 80	10 to 25 acres
3	190,000 to 240,000 ft	90 to 120	90 to 120	20 to 40 acres
4	260,000 to 310,000 ft	120 to 160	120 to 160	25 to 50 acres
5	340,000 to 390,000 ft	150 to 200	150 to 200	30 to 65 acres
6	400,000 to 460,000 ft	200 to 250	200 to 250	40 to 75 acres
7	470,000 to 530,000 ft	230 to 280	230 to 280	45 to 90 acres

Each mooring line and anchor storage area will require access to a wharf that can accept an AHTV. The wharf will need to be at least 300 ft long and have a bearing capacity of at least 500 psf. This wharf could be shared with an O&M port or a construction support port, if the wharf size and strength requirements are met and if operational conflicts between O&M SOVs and AHTVs are mitigated.

5.7. Electrical Cable Laydown

Yard space and marine terminal facilities will be required to store and deploy export and array electrical cables to support offshore wind energy area development. These laydown areas will store carousels of electrical cable and have the ability to transfer these cables to a cable laying vessel (CLV). The storage area requirements can be divided into two functions: storage for active installation projects and storage for spare cable to be kept throughout the life of the wind energy area.

Carousels on CLVs and those stored in yards can hold 7,000 to 12,000 tons of cable, and can weigh 10,000 to 16,000 tons each when fully loaded. The amount of storage area required for electrical cable is assumed to be dependent on the number of ongoing installation projects at any time. An S&I site is assumed to only perform throughput for one project at a time, and thus the storage area demands will depend on the number of S&I sites in operation at any given time, as shown in Table 5.17. Using assumed weights per length of 60.5 and 28.6 lb/ft for export cable and array cable, respectively, each cable carousel can hold 45 to 75 miles of export cable and 90 to 160 miles of array cable (NREL 2023a).

The configuration of export cables for wind energy areas to be installed off the California Coast is still unknown, as challenges with interconnection as well as the progress of cable capacity technology are not yet fully defined. As such, this assessment has considered scenarios of projects using both high-voltage alternating current (HVAC) and high-voltage direct current (HVDC) export cable options. The two cable systems require many different considerations in design and installation: however, the most pertinent difference in terms of cable storage is the total distance required for export cables. HVDC cables are estimated to need to travel much longer distances to a point of interconnection, whereas HVAC cables will likely be able to make landfall close to the location of the wind energy area. Table 5.14 shows estimated distances and numbers of cables required for each wind energy area.

Table 5.14. Assumed potential export cable configurations

Wind Energy Region	Cable System	Number of Cables	Distance to Point of Interconnection
Northern California	HVAC	3	20 to 30 miles
Northern California	HVDC	1	300 to 400 miles
Central California	HVAC	3	40 to 60 miles
Central California	HVDC	1	100 to 200 miles

It is estimated that an electrical cable laydown area will need to hold one to two array cable carousels and two to six export cable carousels for each project the laydown area is supporting. The range of the estimated number of export cables required is a result of the wide range of export cable distances expected for projects due to differing designs. Table 5.15 shows the approximate storage area requirements to support active installation projects. The exact amount of cable will depend on the number of turbines in a single wind energy area, the spacing of those turbines, the distance from the wind energy area to the cable landfall location, and the design of the export cable system.

Table 5.15. Export and array cable storage requirements

No. of Active S&I Sites	Array Cable Carousels	Export Cable Carousels	Storage Area
1	1 to 2	2 to 6	3 to 7 acres
2	2 to 4	4 to 12	6 to 15 acres
3	3 to 6	6 to 18	9 to 20 acres
4	4 to 8	8 to 24	12 to 27 acres
5	5 to 10	10 to 30	15 to 35 acres
6	6 to 12	12 to 36	18 to 42 acres
7	7 to 17	14 to 42	21 to 49 acres

These cable storage areas for installation are likely to be a part of a cable OEM facility; however, offsite temporary storage of cables is also an option. To support cable carousels, a storage yard would likely need to have a 1,000 to 2,000 psf capacity.

Each electrical cable storage area will require access to a wharf that can accept a CLV. The wharf will need to be at least 500 ft long, have a bearing capacity of 1,000 psf, and a minimum berth depth of approximately 30 to 35 ft.

Operational offshore wind projects will need to store and maintain spare cable during the life of the offshore wind project. This spare cable is used to make repairs or replacements of cable connections when needed. It is estimated that approximately 5% of the total installed length of both export and array cables will be maintained as spare cable in a storage area throughout an offshore wind project's operational phase. Therefore, a single carousel for each type of cable was assumed to be stored, though the diameter of the export cable carousel is expected to be larger.

The storage areas for each year and deployment scenario shown in Table 5.16 are the estimated areas required for spare array and export cables to support the total GW deployment targets given in Table 5.1. For this assessment, carousels were sized such that one carousel could store the assumed spare export cable and one could store the assumed spare array cable.

Table 5.16. Spare cable storage requirements

Year	Low (0.5 GW/yr)	Low–Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium–High (2 GW/yr)	High (2.5 GW/yr)
2030	1 to 2 acres	1 to 2 acres	1 to 3 acres	1 to 4 acres	2 to 5 acres
2035	1 to 4 acres	3 to 6 acres	5 to 9 acres	6 to 12 acres	8 to 15 acres
2038	2 to 5 acres	4 to 9 acres	7 to 13 acres	9 to 17 acres	12 to 21 acres
2045	4 to 8 acres	8 to 14 acres	12 to 22 acres	16 to 28 acres	21 to 36 acres

Storage areas for spare cable will not need to be a single area. The spare cable can be stored in any location that a CLV is able to access; however, it is unlikely that the cable can be stored at a cable OEM facility throughout the life of the offshore wind project.

5.8. Summary of Ports Required to Meet 2045 Goals

Summarized in Table 5.17 are the number of port sites needed to achieve the 2045 deployment targets listed in Table 5.1, if all port sites were to be located within California.

Table 5.17. Required number of sites to meet 2045 planning goals

Type of Site	Low (8 GW)	Low-Med (17 GW)	Medium (25 GW)	Med-High (34 GW)	High (42 GW)
S&I Sites	1 to 3	2 to 4	3 to 5	4 to 6	5 to 7
MF Site (Blade)	1	2	2	3	3
MF Site (Tower)	1	1	1	1	2
MF Site (Nacelle Assembly)	1	1	1	1	1
MF Site (Foundation Assembly)	2	3	4	5	6
MF Site (Foundation Subcomponents)	2	3	4	5	3
SOV berths for O&M Activities	3 to 7	6 to 12	9 to 16	12 to 20	15 to 23
Mooring Line & Anchor Storage Sites	5 to 40 ac	10 to 50 ac	20 to 65 ac	25 to 75 ac	30 to 90 ac
Electrical Cable Laydown Sites	3 to 15 ac	6 to 20 ac	9 to 35 ac	12 to 42 ac	15 to 49 ac

Mooring line and anchor storage sites and electrical cable laydown sites can be integrated with S&I, MF, and/or O&M sites if the wharf size and strength requirements are met and adequate port space is available.

6. Offshore Wind Port Availability

In this section, port sites within California that can potentially be used for offshore wind development are identified. These identified sites will then be further evaluated in Sections 7 through 8.

It is important to note that currently, most existing port sites on the U.S. West Coast are not ready to serve the offshore wind industry from a port infrastructure perspective (i.e., wharf, navigation channel, backlands, etc.). All potential S&I and MF port sites will require some level of investment to upgrade existing facilities, such as constructing a new wharf to withstand heavier loading or dredging the navigation channel and/or berth pockets. In this report, port sites are identified such that displacement of any existing port operators/tenants does not occur. Using existing military port facilities was also not considered.

The following general criteria were utilized to assess each port:

- Distance to existing and future wind energy areas
- Availability of adequate acreage of uplands area with capability to support or be improved to support heavy loading operations
- Adequacy of existing navigation channel, including entrance channel depth and width, and channel depth and width for both existing and planned conditions including maintenance dredging requirements
- Existing and planned infrastructure projects (bridges, airports, tunnels) that may impact operations
- Air draft at bridges or other overhead obstructions (e.g., overhead power lines)
- Potential for port expansion or development of a new in-water area

6.1. Staging and Integration

6.1.1. Existing Port Sites

In the BOEM *California Floating Offshore Wind Regional Ports Assessment*, an assessment of the existing ports was performed, as well as outreach with the California ports to discuss potential sites that are or could be made available for offshore wind S&I sites (Moffatt & Nichol 2023a). S&I sites are where the turbine components, such as tower sections, nacelles, blades, and the floating foundations, are received via waterborne transport, stored in the uplands area, and then assembled and erected by a large crane along the wharf. These sites are more difficult to identify within existing ports because they require a large amount of space, need deep draft channels, and cannot have any air draft restrictions since the fully assembled turbine systems, which are 1,100 feet above water, need to be towed out to the installation site at the WEA. The following ports, ordered north to south, were identified as possible S&I sites:

- Port of Humboldt
- Port of Los Angeles
- Port of Long Beach

These three ports have potential sites that are in front of bridges so there are no air draft restrictions, have large amounts of acreage (greater than 100 acres), and have deep draft navigation channels. These S&I port locations can also be combined with MF and O&M facilities if space allows. All other port locations either don't have enough potential acreage available or have air draft restrictions, such as the ports within the Bay Area behind bridges, and thus could not serve as S&I sites.

The Port of Humboldt is actively in the process of redeveloping a 180+ acre site on the Samoa Peninsula to provide a new multipurpose, heavy-lift marine terminal facility to support the offshore wind energy industry. The Port of Humboldt's project will primarily serve as an S&I site but may also include on-site MF and O&M facilities. An additional 300 to 600+ acres of available coastal dependent industrial lands exist with Humboldt Bay with direct access to the Federal Navigation Channel. These additional sites have the potential to serve offshore wind port development (i.e., S&I, MF, and O&M).

The Port of Long Beach finished the conceptual design phase for a 400-acre offshore wind project that can provide S&I and MF sites to the offshore wind industry. The Port of Long Beach is moving forward with field investigations, permitting, and detailed engineering for their project.

6.1.2. Alternative Central California Sites

In the CSLC study titled *Alternative Port Assessment to Support Offshore Wind*, a high-level desktop screening was performed on the California coast between San Francisco and Long Beach to identify potential greenfield, or undeveloped, sites of 30 to 100 acres for S&I (Moffatt & Nichol 2023c). This preliminary screening removed areas that were already developed with populations adjacent to the water; designated as protected lands for resources; or had security restrictions, as the case with military bases or airfields. Based on an environmental, engineering, and workforce assessment the three following greenfield sites were identified as potential S&I sites:

- China Harbor
- Port San Luis
- Gato Canyon

All three sites would require extensive infrastructure improvements to meet the offshore wind S&I site requirements (e.g., a heavy lift wharf that can withstand 6,000 psf, 80 acres of heavy lift upland area, dredging for a 38-ft berth depth, a breakwater for metocean protection, etc.) and would require significant environmental impact mitigation.

6.1.3. Challenges of Development within the Coastal Zone

Any alternative site within the Coastal Zone would need to comply with the California Coastal Act (CCA) and/or the federal Coastal Zone Management Act (CZMA). Future project specific CEQA and NEPA analyses will be needed to demonstrate compliance with Federal, State, and local laws, regulations, and policies.

Note, port development within the Bay Area is under jurisdiction of the San Francisco Bay Area Conservation and Development Commission, and port development outside of the Bay Area is under the jurisdiction of the CCC.

6.1.4. California State Lands Granted Authority

The State of California acquired sovereign ownership of all tidelands and submerged lands and beds of navigable lakes and other waterways upon its admission to the United States in 1850. The CSLC is the primary land manager for state marine waters and has the authority to lease state lands for uses that are consistent with the *public trust* protections involving navigable waterways. The California Legislature has periodically transferred portions of the state's sovereign waterfront lands to cities, counties, and harbors for management purposes. The lands are known as *granted lands* , and the trustees include the major ports of Los Angeles, Long Beach, San Diego, San Francisco, Oakland, Richmond, Benecia, and Eureka. CSLC staff monitors the granted lands to ensure the trustee's management of the lands is consistent with the terms of the statutory trust grants, the California Constitution, and the Public Trust Doctrine.

Land use permissions to develop an S&I site would either come from the trustees of granted lands or CSLC, depending on the location of the potential S&I site:

1. Port of Humboldt, Port San Luis, Port of Los Angeles, and Port of Long Beach: S&I site is under jurisdiction of an existing port/harbor authority and land use permissions would come from the port/harbor authority.
2. China Harbor and Gato Canyon: S&I site is under jurisdiction of CLSC and will need to obtain a lease from CSLC to operate. See below for further explanation.
3. China Harbor and Gato Canyon: S&I site is under jurisdiction of CSLC and the California legislature could grant the lands to a new port/harbor authority that is established.

For China Harbor and Gato Canyon, obtaining a lease from CSLC or creating a new port/harbor authority can add significant schedule to developing an S&I site. The timeline to obtain a lease from CLSC can range from 6 months to several years depending on several factors and the complexity of the project. The process required to establish a new port authority may require at least 10 years.

Figure 6.1 summarizes the potential S&I sites, both within existing ports and alternative greenfield locations.

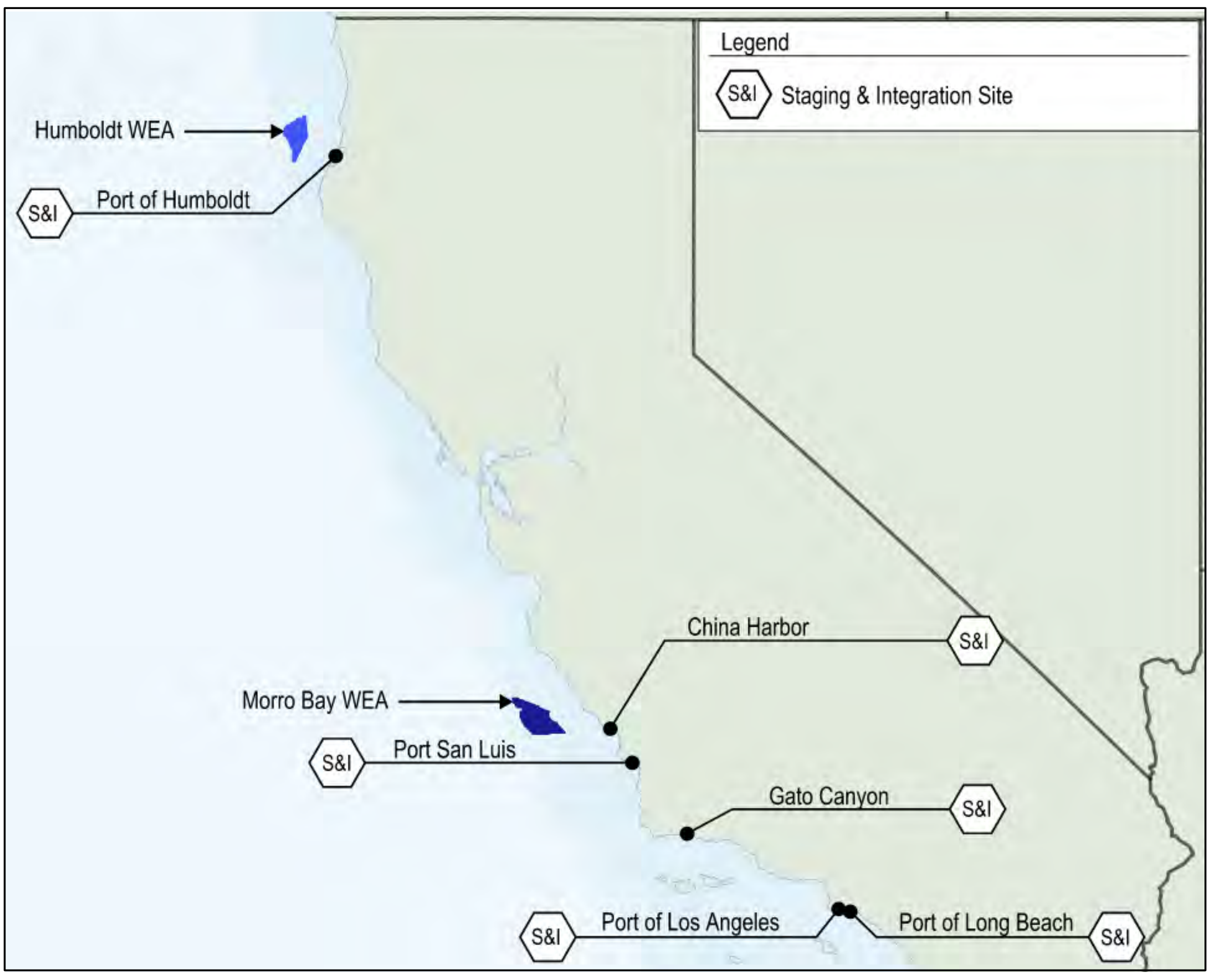

Figure 6.1. Potential staging and integration (S&I) sites

6.2. Manufacturing / Fabrication

In the BOEM *California Floating Offshore Wind Regional Ports Assessment*, an assessment of the existing ports was performed, as well as outreach with the California ports to discuss potential sites that are or could be made available for offshore wind MF sites (Moffatt & Nichol 2023a). Since this report, some additional ports have expressed renewed interest and identified additional acreage to support the offshore wind industry. MF sites receive raw materials via road, rail, or waterborne transport and create larger components in the offshore wind supply chain that will be exported via waterborne transport on a vessel or barge. These sites can occupy less space than S&I sites and be at locations with air draft restrictions since the components (e.g., tower sections, nacelles, blades, and floating foundations) can be transported horizontally via vessel or barge. Therefore, ports located behind bridges, such as those in the Bay Area, are candidates for offshore wind development as MF sites.

The following locations, ordered north to south, were identified as potential MF sites:

- Port of Humboldt
- Port of San Francisco
- Port of Oakland
- Port of Richmond
- Port of Benicia
- Port of Stockton
- Port of Redwood City
- Port of Los Angeles
- Port of Long Beach
- Port of San Diego

All other port locations don't have enough potential acreage available and thus are not MF candidate sites. In addition, it was noted that the Bay Area has a number of additional terminals along navigable waterways that could serve as potential MF port sites. Outreach was performed to the following industrial waterfront terminals to assess their interest and site suitability for offshore wind development. Of these, two potential MF sites were added to this study: Antioch AMPORTs and a site within the City of Pittsburg.

- Selby (Selby Crockett) – Not included, site has challenges meeting design criteria
- City of Vallejo (Mare Island) – Not included, site is not available
- City of Pittsburg – Added to study as a potential MF site
- Antioch (AMPORTS) – Added to study as a potential MF site

- Antioch (Georgia Pacific) – Not added to study, site is not available

Figure 6.2 shows the potential MF sites on a map.

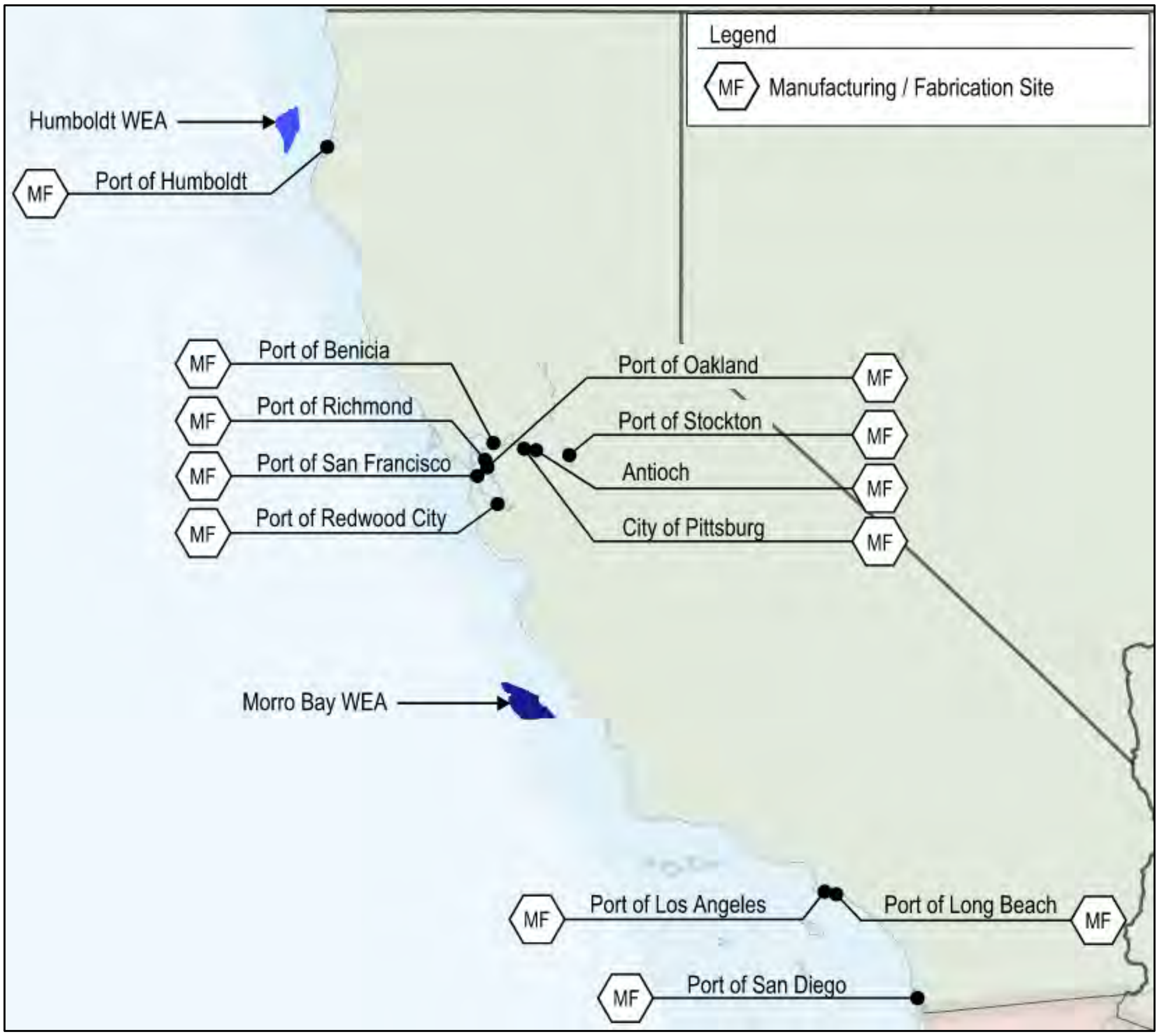

Figure 6.2. Potential manufacturing / fabrication (MF) sites

6.3. Operations and Maintenance

In the BOEM California Ports Assessment study, an assessment of the existing ports was performed, as well as outreach with the California ports to discuss potential sites that are or could be made available for offshore wind O&M sites (Moffatt & Nichol 2023a). Additionally, the CSLC Alternative Ports Assessment study (Moffatt & Nichol 2023c) and REACH Central Coast study identified and assessed potential O&M sites within existing small craft harbors.

In general, SOVs are assumed to be the main O&M support system for WEAs, with CTVs providing additional flexibility and fast response when needed. Therefore, the potential O&M sites that can accommodate SOVs were focused on for this study. Note, other maintenance activities where the integrated WTG needs to be towed back to port from the WEA, would be performed at the S&I sites where the appropriate infrastructure and equipment is located.

The following locations, ordered north to south, were identified as potential O&M sites:

- Crescent City Harbor District
- Port of Humboldt
- Port of San Francisco
- Port of Oakland
- City of Alameda
- Port of Richmond
- Pillar Point Harbor
- City of Morro Bay
- Diablo Canyon Power Plant
- San Luis Obispo Bay
- Ellwood Pier
- Port of Hueneme

All other sites not listed are not ideal O&M sites due to the substantial distance to the WEAs and/or inadequate physical characteristics or infrastructure. Figure 6.3 summarizes the potential O&M sites.

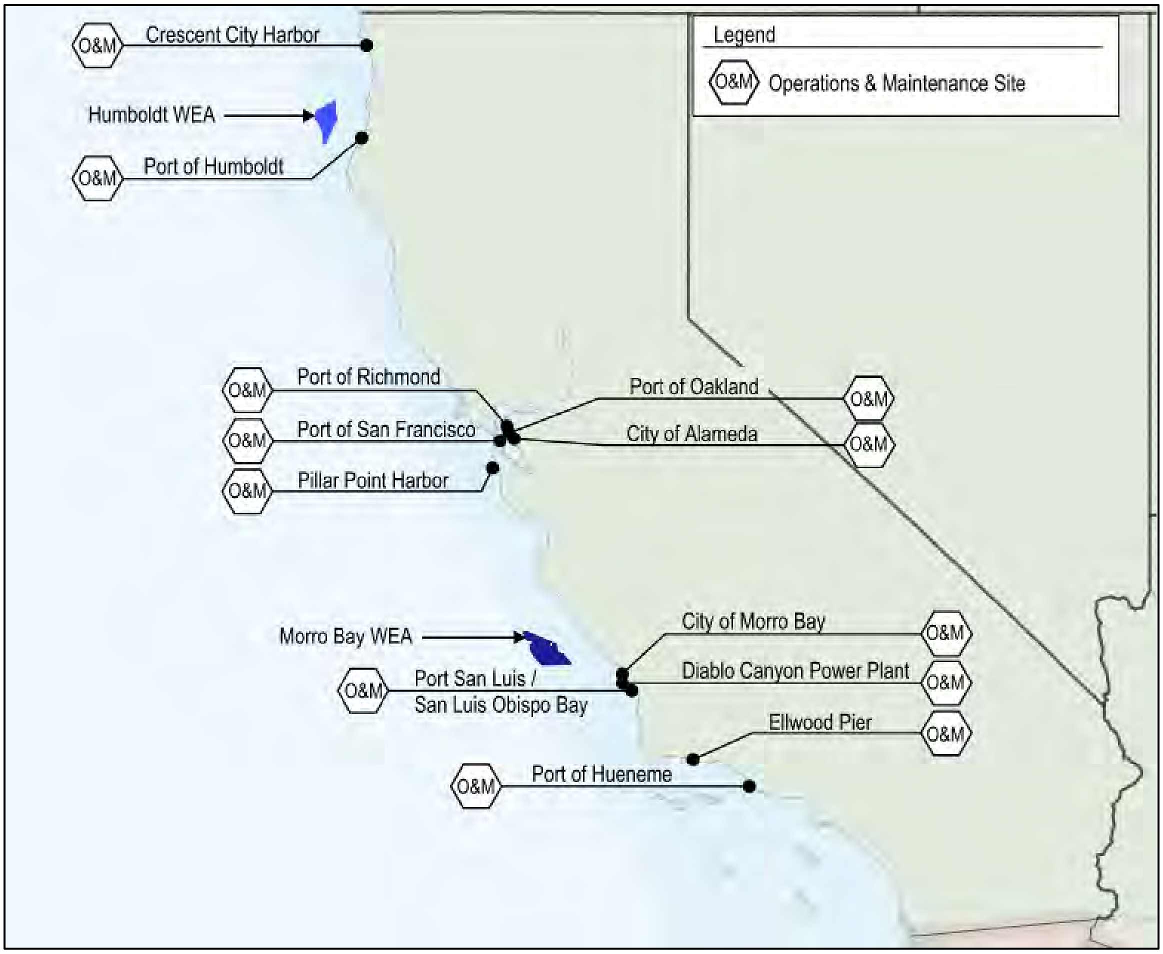

Figure 6.3. Potential operations and maintenance (O&M) sites

6.4. Mooring Line and Anchor Storage

To meet the floating offshore wind energy deployment target of 25 GW by 2045, acreage will be needed in both Northern California and Central California to store and deploy mooring components for floating offshore wind foundations. The total acreage requirements will vary based on the number of S&I sites in operation at any given time, however, to support three to five installation projects, 20 to 65 acres of laydown area will be required. This space is not required to be all at one facility, however it will likely be located close to the WEAs to reduce anchor handling and towing vessel (AHTV) transit time. Each mooring line and anchor storage site will require access to a wharf that can accept an AHTV. This wharf could be shared with any type of the offshore wind port sites and locations discussed above (S&I, MF, or O&M).

The following locations, ordered north to south, were identified as potential mooring line and anchor storage sites, as shown in Figure 6.4:

- Crescent City Harbor District

- Port of Humboldt
- Port of San Francisco
- Port of Oakland
- City of Alameda
- Port of Richmond
- Port of Benicia
- City of Pittsburg
- City of Antioch
- Port of Stockton
- Port of Redwood City
- Pillar Point Harbor
- City of Morro Bay
- Diablo Canyon Power Plant
- Port San Luis
- Port of Hueneme
- Port of Los Angeles
- Port of Long Beach
- Port of San Diego

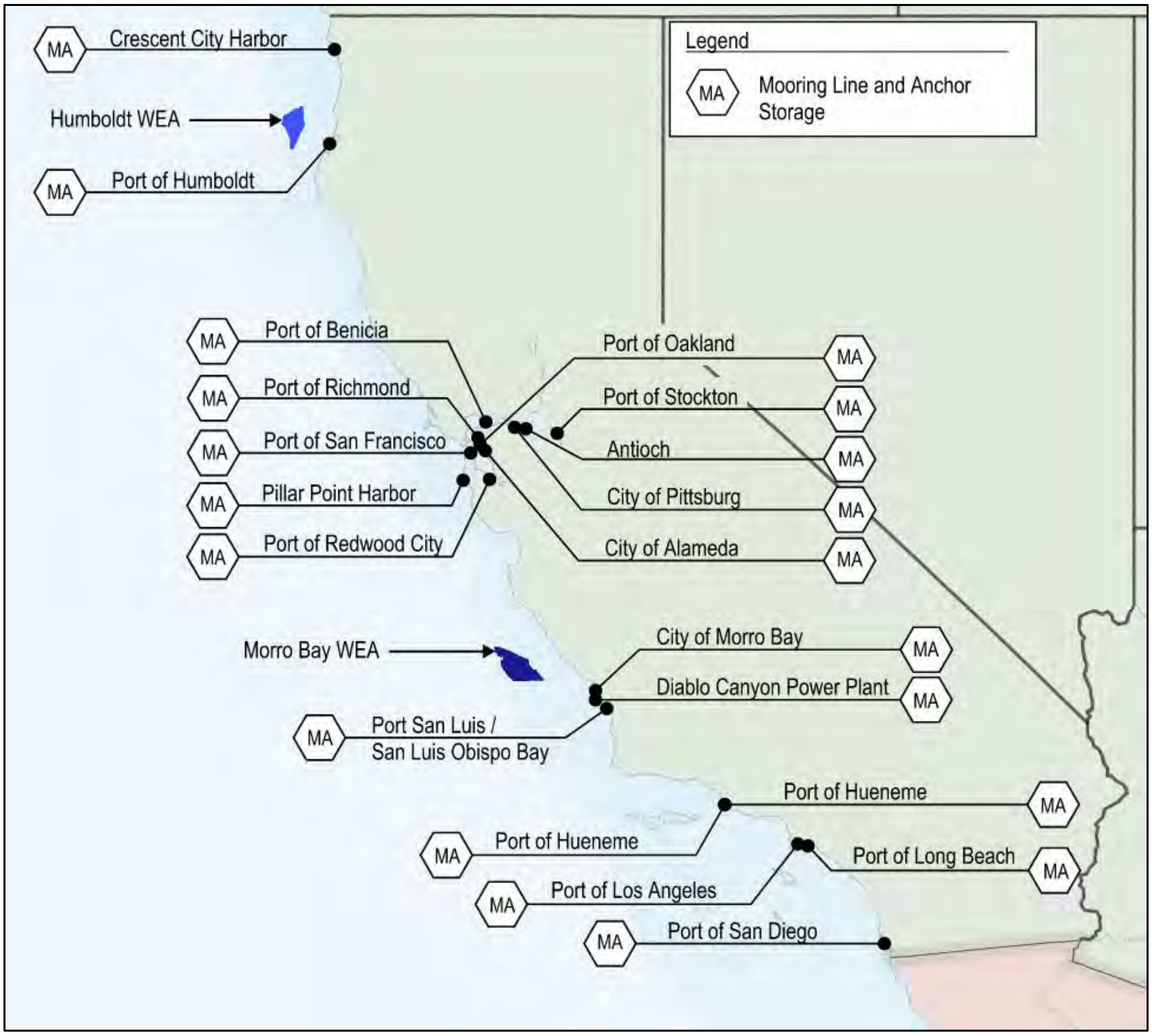

Figure 6.4. Potential mooring line and anchor storage sites

6.5. Electrical Cable Laydown

Yard space and marine terminal facilities will be required to store and deploy export and array electrical cables for Northern California and Central California WEAs. These laydown areas will store carousels of electrical cable and have the ability to transfer these cables to a cable lay vessel (CLV). The total acreage requirements will vary based on the number of S&I sites in operation at any given time. For example, for the State's planning goal of 25 GW by 2045, three to five S&I sites are needed and thus 9 to 35 acres of storage space for electrical cables will likely be needed to support these. Each Electrical Cable Laydown site will require access to a wharf that can accept a CLV. This wharf could be shared with any of the S&I and MF offshore wind port sites discussed above, if the wharf size and strength requirements are met and if, operational conflicts between the CLVs and other offshore wind vessels are mitigated. The laydown area could also be a part of a cable manufacturing facility, as these facilities have berths that accept CLVs and remaining at this facility would reduce the number of carousel transfers for the cable.

The following locations, ordered north to south, were identified as electrical cable laydown sites, as shown in Figure 6.5:

- Port of Humboldt
- Port of San Francisco
- Port of Oakland
- Port of Richmond
- Port of Benicia
- City of Pittsburg
- City of Antioch
- Port of Stockton
- Port of Redwood City
- Port San Luis
- Port of Los Angeles
- Port of Long Beach
- Port of San Diego

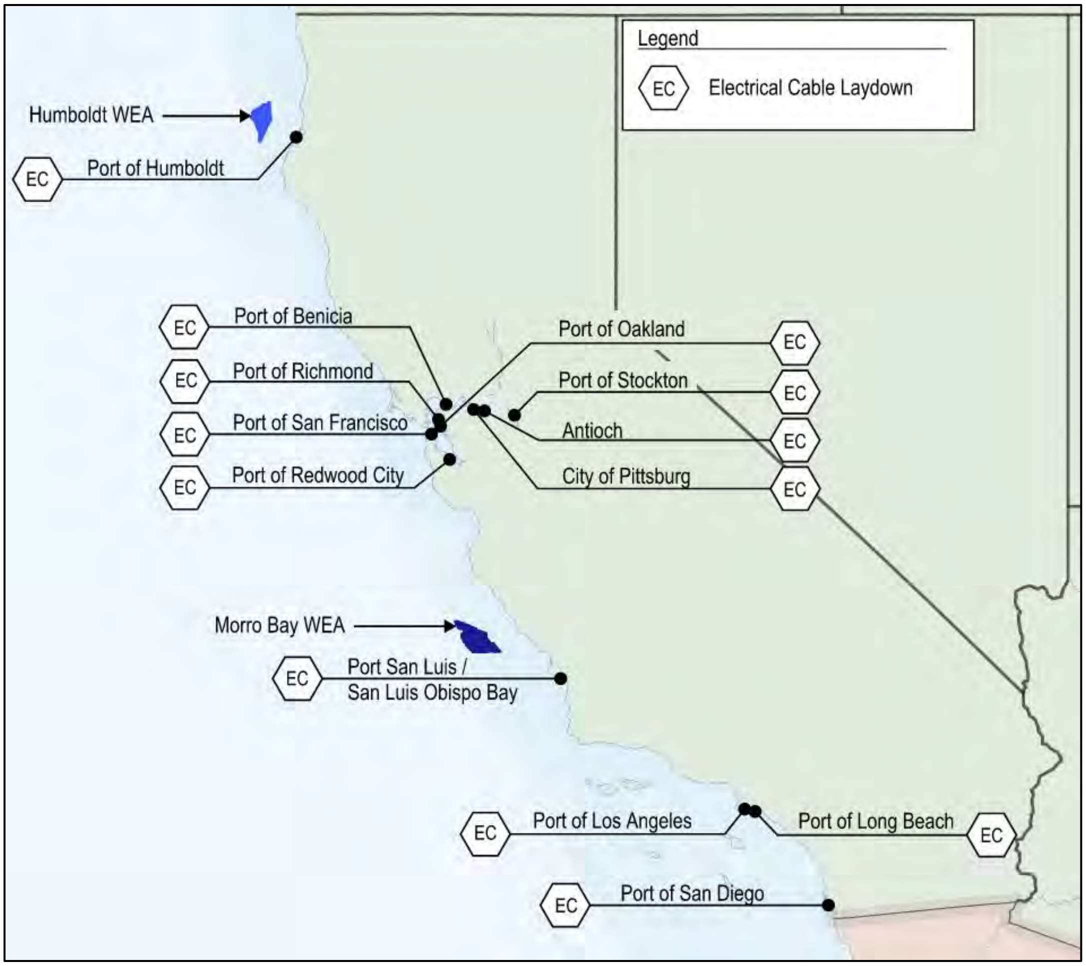

Figure 6.5. Potential electrical cable laydown sites

6.6. Summary

Table 6.1 summarizes the following:

- Bridge clearances
- Distance to Humboldt and Morro Bay WEAs
- Channel depths
- Site types considered
- Number and size of potential sites at each port

Based on the inventory of potentially available port sites, California has enough potential port sites to meet the State's offshore wind planning goals. The offshore wind port sites require a significant amount of investment to upgrade and improve the existing infrastructure to serve the offshore wind industry. Cost estimates and project timelines for developing these offshore wind port sites can be found in Section 8.

Table 6.1. Summary of potential California offshore wind port sites

Port Location	Bridge Vertical Clearance (ft)	Distance to Humboldt WEA (Nautical Miles)	Distance to Morro Bay WEA (Nautical Miles)	Channel Depth (ft)	Possible Site Types	Potential Sites
Antioch	132	295	200	35	MF	(1) 100-acres MF site
China Harbor	None	425	30	See ****	S&I	(1) 80-acres S&I site
City of Alameda	174	255	160	20-30	O&M	(1) O&M site
City of Morro Bay	None	430	55	15-24	O&M	(1) O&M site
City of Pittsburg	132	290	195	35	MF	(1) 100-acres MF site
Crescent City Harbor District	None	50	400	14-20	O&M	(1) <10-acres O&M site
Diablo Canyon Power Plant	None	445	70	< 25	O&M	(1) O&M or construction support site
Ellwood Pier	None	595	150	See ****	O&M	(1) O&M site
Gato Canyon	None	590	145	See ****	S&I	(1) 80-acres S&I site
Monterey Harbor	None	345	75	< 10	O&M	(1) O&M site
Moss Landing Harbor	None	340	85	15	O&M	(1) O&M site
Pillar Point Harbor	None	280	115	20	O&M	(1) O&M site
Port of Benicia	132	275	180	45	MF	(1) 20-acres MF site
Port of Hueneme	None	570	200	30-45	O&M	(1) O&M site. Not a candidate for MF, however an assessment of military uses was not addressed in this study.
Port of Humboldt	None	25	360	38 - 48	S&I, MF, O&M	(4) 80-acres S&I / MF sites and (6+) <10-acres O&M sites
Port of Long Beach	See **	580	225	> 50	S&I, MF	(1) 400-acres S&I / MF site (1) 20-acres MF site
Port of Los Angeles	See *	580	225	> 50	S&I, MF	(1) 100-200-acres S&I / MF site (2) 10-30-acres MF sites

Port Location	Bridge Vertical Clearance (ft)	Distance to Humboldt WEA (Nautical Miles)	Distance to Morro Bay WEA (Nautical Miles)	Channel Depth (ft)	Possible Site Types	Potential Sites
Port of Oakland	174	255	160	50	MF, O&M	(1) 40-60-acres MF site
Port of Redwood City	135	275	180	30	MF	(1) 20-acres MF site
Port of Richmond	210	255	160	38	MF, O&M	(1) 40-acres MF site
Port of San Diego	175	700	340	> 35	MF	(1) 40-acres MF site (1) Floating Foundation MF site (1) Steel component fabrication/ship repair site
Port of San Francisco	190	255	160	> 40 ***	MF, O&M	(1) 95-acres MF site (2) O&M sites
Port of Stockton	132	295	200	35	MF	(1) 20-40-acres MF site (1) 150-200-acres MF site (<1 mile from the water)
Port San Luis	None	410	60	< 40	S&I, O&M	(1) 80-acres S&I site or (2) O&M site

* There are sites available in front of the Vincent Thomas Bridge (185 feet) at the Port of Los Angeles, so there are no air draft restrictions for these sites.

** There are sites available in front of the Long Beach International Gateway Bridge (205 feet) at the Port of Long Beach, so there are no air draft restrictions for these sites.

*** There are potential sinking basin(s) with water depth 60 – 100 ft within the San Francisco Bay that may be feasible for offshore wind floating foundation use. Note, these potential sinking basin locations will need to be verified with the U.S. Coast Guard and the S.F. Bar Pilots.

**** No established channel. Site currently exposed to open water.

7. Environmental Considerations

Environmental evaluation and site ranking was completed using a comparative approach for the previously identified S&I, MF, and O&M ports sites in Section 5.8. Within each port site type, each potential site location was evaluated using a standard set of environmental factors, and then compared to the other potential locations of the same type. The potential site locations were then ranked in order of likely severity of potential environmental concerns.

Except for cultural resources, the evaluation process used only publicly available databases, Google Earth and available GIS data (e.g., topography), and mapping tools. The environmental factors were selected to allow a standardized comparison across all sites, and they were adjusted based on the conceptual size and extent of construction required for each port site type. The factors used in the environmental ranking process are described in Section 7.2.

The assessment of potential impact severity for cultural resources was based partially on confidential data provided to a Registered Archaeologist from the California Historical Resources Information System (CHRIS) maintained by the California State Parks Department, Office of Historic Preservation.

The environmental ranking process was not a formal environmental impact analysis in compliance with applicable regulatory requirements or standards [e.g., California Environmental Quality Act (CEQA)]. Rather, the evaluation process includes a high-level review of the potential effects that typically would be most severe from development of waterfront facilities, and the factors that would create more serious public concerns.

7.1. Constraints in the Environmental Ranking Process

The comparative ranking process completed for this study of potential waterfront facilities was based on data collected for the eight factors defined in Section 7.2. These factors were selected based on their relative importance in assessing severity of environmental effects.

This type of high-level comparative siting analysis must omit consideration of location-specific data in order to allow comparisons of equivalent data among all site locations within each port site type. The following discussion summarizes factors not considered and explains the rationale for these decisions.

7.1.1. Environmental Factors Not Considered

The comparative ranking process completed for this study of potential waterfront facilities was based on data collected for the eight factors defined in Section 7.2. These factors were selected based on their relative importance in assessing the severity of environmental effects.

The following are other factors that were not included in this comparative analysis:

- Potential cumulative effects were not considered. These effects can result when multiple projects or impacts, when considered together, can compound or increase environmental impacts. Because this study involved only comparative ranking of site locations, no consideration was given to developing multiple sites concurrently. In addition, no consideration was given to cumulative impacts of the development of offshore wind projects with other past, present, or potentially foreseeable future projects.
- The potential for development and operation of offshore wind port sites to create indirect environmental effects on resources in the surrounding area was not considered in the analysis of comparative effects.
- For visual resources, this study did not conduct a detailed analysis of views from sensitive land uses or receptors (e.g., recreation and residential uses) within the viewsheds affected.
- For Environmental Justice, the study did not prepare a formal analysis using detailed quantitative population and demographic characteristics and accurate screening criteria. This type of analysis would typically be completed using the *CalEnviroScreen* model, which would analyze effects based on nineteen factors.
- For land use concerns, the study did not incorporate site visits, detailed land use surveys, or detailed reviews of applicable planning and zoning requirements at or surrounding each site. The analysis was based on qualitative desktop review of existing land uses and a high-level screening of potential sensitive receptors.
- The analysis did not consider the following factors due to the lack of site specific or project data:
  - Air emissions from each site resulting from construction and/or transport of materials that could affect surrounding land uses.
  - Sensitivity of receptors around each site to nighttime lighting.
  - Sensitivity of receptors around each site to noise impacts.
  - Transport of construction and operation equipment/materials onshore (distance along local routes/street network and possible conflicts for local land uses).
  - Hazards concerns from fuel transport and storage (risk would vary depending on transport distance and proximity of surrounding land uses).

Biological surveys and delineations to assess shoreline habitats were not conducted. The following biological and aquatic data were not considered in the screening process:

- Site-specific data regarding listed, threatened, or species of concern was not reviewed. Only data on species readily available for the larger area through

California Natural Diversity Database (CNDDB) and DataBasin.org websites were used.

- Effects of sea level rise, storm wind/wave or changes to tidal heights and their potential impact on construction and thus biological resources were not included in the screening.
- Calculation of potential sound impacts to marine mammals and other aquatic species was not conducted. Site specific geotechnical data will be required to calculate sound impacts as well as specific size, number, and location of potential piles.
- Sediment quality information was not available. Specific site characterization of soil and sediment within the project boundary will need to be conducted to ascertain potential impacts from any contamination or physical (grain size) or conventional (percent solids, total organic carbon, ammonia, sulfides, etc.) test results.
- Calculations on the volume and area of fill were not conducted. Once conceptual designs are produced, then “fill” within the various regulatory agencies’ jurisdictions can be assessed and related compensatory mitigation can be estimated.

Another element not considered in facility rankings was the potential application of compensatory mitigation for severe effects. Federal and State regulatory agencies will require mitigation for short-term and long-term impacts on waters of the U.S. and State, biological resources, and other jurisdictional features in order for permit issuance. Preliminary impacts to habitat, aquatic vegetation, or biological resources that have been identified but not quantified due to the preliminary stage of the screening include, but are not limited to, some of the following:

- Sound impacts to biological resources from pile driving.
- Fill/excavation from construction of various structures.
- Dredging activities that can affect/disturb/remove existing habitat.
- Resuspension of sediment/turbidity issues with construction.
- Sediment transport and water quality effects.
- Removal or interference with existing structures such as pipelines, outfalls, submarine cables, etc.

7.2. Environmental Ranking Factors

The eight environmental factors considered in this analysis are presented in Table 7.1 and described below.

Table 7.1. Environmental ranking factors

Ranking Factor	Site Type
Factor 1: Federal, State, and regional parks and protected areas	S&I, MF, O&M
Factor 2: Existing infrastructure development at the site	S&I, MF, O&M
Factor 3: Compatibility of development with surrounding land use	S&I, MF, O&M
Factor 4: Environmental justice demographic index	S&I and MF – considered a five-mile radius O&M – considered a one-mile radius
Factor 5: Viewshed sensitivity	S&I, MF
Factor 6: Terrestrial biological resources	S&I, MF, O&M
Factor 7: Marine and aquatic resources	S&I, MF, O&M
Factor 8: Cultural resources	S&I, MF, O&M

The following is a description of the data considered within each ranking factor.

Factor 1: Federal, State, and Regional Parks and Marine Protected Areas

Data Assembled and Reviewed:

Maps and open-source data from resource agency websites were reviewed to identify the locations of federal protected lands (including National Marine Sanctuaries, Bureau of Land Management [BLM], California Coastal National Monuments, and other BLM recreation areas), Marine Protected Areas (including State Marine Conservation Areas and State Marine Reserves), State parks and State beaches, and regional parks. Locations within or near the proposed Chumash Heritage National Marine Sanctuary (CHNMS) were also identified.

Ranking Process:

Within each category the sites were ranked comparatively, with a lower score being assigned to sites near the fewest number of protected areas, and a higher score being assigned to sites near the greatest number of protected areas. Federally or State protected areas (including proximity to the proposed CHNMS) were given more weight in the ranking than a local or regional park.

Factor 2: Existing Infrastructure Development at the Site

Data Assembled and Reviewed:

Using geospatial data tools such as Google Earth Pro 7.3.6.9345, each of the S&I sites, MF sites, and O&M sites were evaluated to identify the types of infrastructure development within and surrounding the site. This evaluation considered whether the existing infrastructure could support the proposed use and the extent of new infrastructure development that would be required for proposed operations at the site.

Ranking Process:

Within each category, each site was ranked as low, middle, or high per the following metrics:

- A low score indicates that the site contains infrastructure development that can support the defined facility's use (e.g., existing ports).
- A middle score indicates that some degree of infrastructure exists at the site, but extensive development would be required to support operations at the site.
- A high score indicates that the proposed site is largely undeveloped and/or does not contain existing infrastructure that can already support the defined use of each site.

Factor 3: Compatibility of Development with Surrounding Land Uses

Data Assembled and Reviewed:

Using Google Earth Pro 7.3.6.9345, an informal desktop land use inventory was completed to define potential sensitive land uses within one mile of the site boundaries. The purpose of this inventory was to determine whether land uses surrounding each port site would be compatible with the industrial scale land use that would result from development of each port site type.

Sensitive land uses include residences, schools, recreational facilities, churches, and other similar facilities. These land uses are considered to be sensitive because they are susceptible to the adverse nuisance effects of large-scale development (i.e., air emission and greenhouse gas emissions, dust, construction and operational noise, traffic, environmental hazards, and degradation of views).

Ranking Process:

Within each port site category, each site was ranked for its compatibility of the potential port development with the existing land uses based on the following metrics:

- A low score indicates that the onsite and adjacent land uses would be compatible with the defined site's use.
- A middle score indicates that the onsite use would be compatible, but the adjacent land uses would not be compatible with the site/activity.
- A high score indicates that the onsite and adjacent land uses would not be compatible with the defined use of each site.

Factor 4: Environmental Justice Demographic Index

Data Assembled and Reviewed:

As a proxy for a detailed analysis of potential project effects related to disadvantaged populations, the US Environmental Protection Agency's EJ Screen model was used to generate the Demographic Index. The Demographic Index in EJ Screen is a combination of the percentage of low-income and the percentage of people of color (i.e., minority populations). These are the two demographic factors explicitly named in Presidential Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations). For each Census block group, these two numbers are averaged together (EPA 2023).

The Demographic Index is defined for a specific geographic area. In this study, the geographic areas were defined as follows:

- For S&I sites and MF sites, a five-mile radius was used for calculation of the Demographic Index. Five miles was considered appropriate because of the extent of construction and operational effects on already burdened disadvantaged populations.
- For O&M facilities, a one-mile radius was used for calculation of the Demographic Index. This smaller radius was used because the construction associated with O&M facilities is unlikely to create substantial effects on disadvantaged populations, especially those related to potential health effects often resulting from major industrial developments.

The ranking using the Demographic Index is narrow; it is not the rigorous analysis that typically would be conducted for an environmental review document (NEPA and some CEQA documents), in which the potential disproportionate burdens on disadvantaged populations would be identified. The effects of the offshore wind port sites studied are not yet defined in a detailed enough way that would allow this analysis to be completed.

Ranking Process:

The Demographic Index for each site was compared with the other sites in each category, and the sites were ranked from the lowest index (where facility construction and operation would have the least effect on disadvantaged populations) to the highest index (where a major project would have more potential to affect disadvantaged populations). A higher demographic index indicates the likelihood that a project would affect an area with a larger disadvantaged population (i.e., low-income and/or high minority) within the defined radius.

Factor 5: Viewshed Sensitivity

Data Assembled and Reviewed:

Using ArcGIS Pro 2.9.5, a 20-mile radius viewshed model was conducted and resultant maps were prepared for each of the S&I sites. The model evaluates the visibility of the tallest components likely to be present at each site and maps the topography around each facility, and the presence of sensitive viewing locations (e.g., proximity to California Highway 1, a designated State Scenic Highway).

Viewshed sensitivity around MF sites was determined using Google Earth Pro 7.3.6.9345 and a subjective assessment of the surrounding land uses and anticipated change with construction of MF sites.

No viewshed sensitivity ranking was completed for O&M sites due to the minimal level of visual change that would occur at these facilities.

Ranking Process:

S&I sites and MF sites were compared (within site categories) for their likely sensitivity to visual change that would result from the construction and operation of the defined facilities. The assessment was based on the technical team's knowledge of the sensitivity of each location. A lower score was given to sites that are not visually sensitive, a middle score was given to sites that are somewhat visually sensitive, and a higher score was given to sites that are visually sensitive.

Factor 6: Terrestrial Biological Resources

Data Assembled and Reviewed:

This analysis used mapping generated by a wide range of databases and lists, and evaluation of satellite photography (Google Earth Pro). Analysis considered the documented presence of protected species (State and Federal Endangered Species), the level of protection (indication of species rarity) for each species present, the presence of protected native plants, and presence of nearby drainages. The following specific data was assembled for each site:

- California Natural Diversity Database (CNDDB) data indicating the number of species likely present within a one-mile radius of each site based on previous surveys.
- The number of species within one mile of the site listed as threatened, endangered, or candidates under the federal Endangered Species Act.
- The number of species within one mile of the site listed as threatened, endangered, or candidates under the California Endangered Species Act.
- The number of species within one mile of the site considered "fully protected" by the California Department of Fish and Wildlife.
- The number of sensitive plants within one mile of the site (listed by the California Native Plant Society as Rank 1 or 2).
- The presence of sensitive habitat within one mile of the site (e.g., stabilized sand dunes, coastal brackish marsh).
- Critical habitat defined by the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS).
- Essential fish habitat defined by NMFS.

- Presence of wetlands.
- Other factors (e.g., nearby wildlife refuge, urbanization).
- Proximity to Important Bird Areas or birding hotspots defined by eBird.
- Proximity to native habitat.
- Number of nearby herbarium specimens.

Ranking Process:

Each of the factors listed above was ranked into three categories of likely impact severity: low, medium, and high. The aggregate of all rankings resulted in the overall site rankings within each offshore wind port site type.

Factor 7: Marine and Aquatic Resources

Data Assembled and Reviewed:

The team conducted a high-level screening assessment of potential critical issues related to aquatic physical and biological resources for each of the potential locations identified. This screening study explored the feasibility of developing or expanding already developed waterfronts for necessary floating offshore wind development. This analysis consisted of a high-level screening of aquatic resources and potential impacts from conceptual construction methods. This process was qualitative, but considered data available through a wide range of databases and mapping resources typically used in environmental analyses.

The ranking considers proximity to Marine Protected Areas (MPAs), followed by an evaluation of the potential presence (or potential absence) of protected species (State and Federal Endangered Species) or species of concern, or mapped in the area. The species considered include cetaceans (e.g., whales/dolphins); pinnipeds (e.g., seals); and fish, avian, and vegetation/other species (e.g., kelp beds, turtles, abalone etc.). The evaluation assumes that construction effects would result from dredging and associated testing and analysis, along with construction of breakwaters and pile driving.

Ranking Process:

The site ranking process for potential effects on marine and aquatic resources includes consideration of the following data:

- Location of the port site within an existing or proposed MPA or marine sanctuary (including the proposed CHNMS).
- Potential presence of cetaceans (e.g., whales, porpoises, dolphins), pinnipeds (seals, sea lions), and listed species of fish and other aquatic species of concern.
- Potential presence of coastal seabirds, especially those listed as threatened or endangered.

- Potential presence of important vegetation (e.g., kelp, eelgrass).
- Critical habitat for protected species.
- Likely extent of construction that would affect marine and aquatic species (dredging, testing, fill, construction of breakwaters, pile driving) and potential construction effects (turbidity, sound impacts, mitigation for fill and take of protected species).

This data assembled for each site allowed the team to rank sites into three categories of likely impact severity: low, medium, and high.

Factor 8: Cultural Resources

Data Assembled and Reviewed:

The California Historical Resources Information System (CHRIS) maintains a wide range of documents and materials relating to historical resources (e.g., buildings, structures, objects, historic and archaeological sites, landscapes, districts). CHRIS data is assembled from previous cultural resources surveys in which a team of archaeologists methodically physically evaluate a site to identify every potential resource of importance. Every time a property is surveyed in California by an archaeology team for the presence of cultural resources, sites found are recorded on forms that document all components of the site, including photographs and an assessment of the site’s likely eligibility for placement on the California Register of Historic Resources (CRHR).

Because CHRIS data relies on data from previous surveys, it cannot provide data for areas where surveys have not been performed. In addition, CHRIS data includes small specific potentially historic resources (e.g., a few tin cans from 1920) as well as regionally important landscapes and archaeological sites. As a result, CHRIS data has to be carefully reviewed by a registered archaeologist before it is used to help define potential site sensitivity.

As required by Assembly Bill 525, outreach, coordination, and formal government-to-government consultation with tribal governments is being conducted by State agencies during development of the Assembly Bill 525 Strategic Plan. However, because this study represents a conceptual, high-level screening of feasibility using desktop investigation methods, consultation with Native American tribal governments was not conducted as a specific part of the Port Readiness Plan effort. The inclusion of a particular S&I, manufacturing, or O&M site in this study does not imply a lack of cultural sensitivity or cultural resources. No site surveys were conducted for this effort.

In order to evaluate development at the port site locations for potential effects on resources important to Native American and Indigenous peoples and resources that contribute to knowledge of the history of each area, the following information was gathered for each site:

- Records of historic and prehistoric sites located within a one-half mile radius of each site, both onshore and offshore (for shipwreck data) from the CHRIS centers. The data provided includes GIS shapefiles for each site location; this data was used to evaluate the potential importance of each site based on its proximity to the facility location studied. The data also included copies of individual site records, which provided the archaeology team with information to assist in identifying site types and information as to the site's listing or eligibility for the CRHR or the National Register of Historic Places (NRHP).
- Information on Sacred Lands in the vicinity of the facility sites was acquired from the Native American Heritage Commission (NAHC).

In order to evaluate the potential for effects on marine archaeological resources (shipwrecks), the team reviewed the National Oceanographic and Atmospheric Administration (NOAA) shipwreck database for shipwrecks or obstructions within 0.5 mile of each site.

Ranking Process:

The cultural resources site ranking process included consideration of the following data:

- Prehistoric sites located within the port site boundaries.
- Historic sites within the port site boundaries.
- Prehistoric sites within 0.5 mile of the port site.
- Historic sites within 0.5 mile of the port site.
- Sites listed or eligible for the NRHP or CRHR within the port site boundaries.
- Sites listed or eligible for the NRHP or CRHR within 0.5 mile of the port site.
- Shipwrecks within/adjacent to the port site boundary.
- Shipwrecks within 0.5 mile of the port site boundary.
- Sacred Lands in proximity to the port site.

This data was assembled for each site, allowing the environmental team's archeologist to rank port sites into three categories of likely impact severity: low, medium, and high.

7.3. Comparative Environmental Ranking Results

The site rankings indicate only the likely *comparative* level of development challenges among the sites considered within each facility type. A less favorable ranking does not indicate that a project at that location would be infeasible. All of the sites evaluated could be successfully developed, with thoughtful planning and specific mitigation applied based on the effects identified through a future site-specific CEQA and/or NEPA analyses and coordination with permitting agencies and the public.

All eight factors defined in Section 7.2 were given equal weight in the ranking process. The overall comparative rankings within each port site type and ranking factors are presented in three tiers and defined with black dots as shown in Table 7.2.

Table 7.2. Definition of impact tiers

Ranking	Definition of Impact Tiers
Least impact	Least impact compared with other sites
Medium impact	Medium impact compared with other sites
Greatest impact	Greatest impact compared with other sites

Table 7.3 through Table 7.8 illustrate the comparative rankings for each site. For each port site type (S&I, MF, and O&M), the comparative site rankings are first presented for each factor, then an overall site ranking is presented.

- Table 7.3 presents the comparative rankings of each S&I site for each factor. Table 7.4 shows the overall comparative ranking of the S&I sites, considering all eight factors.
- Table 7.5 presents the comparative rankings of each MF site for each factor. Table 7.6 shows the overall comparative ranking of the MF sites, considering all eight factors. Note, the Port of Oakland and Port of San Diego are not included in this evaluation as these ports were added to the port assessment after the environmental evaluation was already completed.
- Table 7.7 presents the comparative rankings of each O&M site for each factor. Table 7.8 shows the overall comparative ranking of the O&M sites, considering all seven factors. Note, the Bay Area Ports are not included in this evaluation as these ports were added to the port assessment after the environmental evaluation was already completed.

Table 7.3. S&I site comparative rankings by factor

S&I Sites	State and Federal Protected Areas	Existing Infrastructure Development	Land Use Compatibility	Demographic Index (EJ 5-mi Radius)	Viewshed Sensitivity	Terrestrial Biology	Marine / Aquatic Biology	Cultural Resources
Ports of LA & LB	Least Impact	Least Impact	Least Impact	Greatest Impact	Least Impact	Medium Impact	Least Impact	Least Impact
Port of Humboldt	Least Impact	Least Impact	Least Impact	Medium Impact	Least Impact	Greatest Impact	Least Impact	Medium Impact
Port San Luis	Medium Impact	Medium Impact	Greatest Impact	Least Impact	Medium Impact	Least Impact	Medium Impact	Medium Impact
China Harbor	Greatest Impact	Greatest Impact	Medium Impact	Least Impact	Medium Impact	Medium Impact	Medium Impact	Least Impact
Gato Canyon	Greatest Impact	Greatest Impact	Medium Impact	Medium Impact	Greatest Impact	Least Impact	Greatest Impact	Medium Impact

Note: Rankings of Least Impact, Medium Impact, and Greatest Impact were determined only by comparing the analyzed sites to each other (i.e., the sites shown within this table).

Table 7.4. Overall S&I site comparative rankings

Staging & Integration Sites	Impact Tier
Ports of LA & LB	Least Impact
Port of Humboldt	Least Impact
Port San Luis	Medium Impact
China Harbor	Medium Impact
Gato Canyon	Greatest Impact

Note: Rankings of Least Impact, Medium Impact, and Greatest Impact were determined only by comparing the analyzed sites to each other (i.e., the sites shown within this table).

Table 7.5. MF site comparative rankings by factor

Manufacturing Sites	State and Federal Protected Areas	Existing Infrastructure Development	Land Use Compatibility	Demographic Index (EJ 5-mi Radius)	Viewshed Sensitivity	Terrestrial Biology	Marine / Aquatic Biology	Cultural Resources
Ports of LA & LB	Least Impact	Least Impact	Least Impact	Greatest Impact	Least Impact	Least Impact	Least Impact	Least Impact
Port of Benicia	Least Impact	Least Impact	Medium Impact	Least Impact	Medium Impact	Least Impact	Medium Impact	Medium Impact
Port of San Francisco	Medium Impact	Least Impact	Least Impact	Medium Impact	Least Impact	Medium Impact	Medium Impact	Least Impact
Port of Humboldt	Least Impact	Least Impact	Medium Impact	Least Impact	Medium Impact	Greatest Impact	Least Impact	Medium Impact
Pittsburg	Least Impact	Least Impact	Medium Impact	Medium Impact	Medium Impact	Medium Impact	Greatest Impact	Medium Impact
Antioch	Medium Impact	Least Impact	Least Impact	Medium Impact	Medium Impact	Medium Impact	Greatest Impact	Medium Impact
Port of Richmond	Least Impact	Least Impact	Least Impact	Greatest Impact	Greatest Impact	Least Impact	Medium Impact	Greatest Impact
Port of Stockton	Least Impact	Least Impact	Medium Impact	Greatest Impact	Greatest Impact	Least Impact	Greatest Impact	Medium Impact
Port of Redwood City	Greatest Impact	Least Impact	Medium Impact	Medium Impact	Greatest Impact	Medium Impact	Greatest Impact	Least Impact

Note: Rankings of Least Impact, Medium Impact, and Greatest Impact were determined only by comparing the analyzed sites to each other (i.e., the sites shown within this table).

Table 7.6. Overall MF site comparative rankings

Manufacturing Sites	Impact Tier
Ports of LA & LB	Least Impact
Port of Benicia	Least Impact
Port of San Francisco	Least Impact
Port of Humboldt	Medium Impact
Pittsburg	Greatest Impact
Antioch	Greatest Impact
Port of Richmond	Greatest Impact
Port of Stockton	Greatest Impact
Port of Redwood City	Greatest Impact

Note: Rankings of Least Impact, Medium Impact, and Greatest Impact were determined only by comparing the analyzed sites to each other (i.e., the sites shown within this table).

Table 7.7. O&M site comparative rankings by factor

O&M Sites	State and Federal Protected Areas	Existing Infrastructure Development	Land Use Compatibility	Demographic Index (EJ 1-mi Radius)	Terrestrial Biology	Marine / Aquatic Biology	Cultural Resources
Port of Hueneme	Least Impact	Least Impact	Least Impact	Greatest Impact	Medium Impact	Least Impact	Least Impact
Diablo Canyon	Greatest Impact	Least Impact	Least Impact	Least Impact	Least Impact	Medium Impact	Least Impact
Humboldt	Least Impact	Least Impact	Least Impact	Greatest Impact	Greatest Impact	Least Impact	Medium Impact
San Luis Obispo Bay	Greatest Impact	Medium Impact	Medium Impact	Least Impact	Least Impact	Medium Impact	Medium Impact
Pillar Point	Medium Impact	Medium Impact	Greatest Impact	Medium Impact	Medium Impact	Medium Impact	Medium Impact
Ellwood Pier	Medium Impact	Medium Impact	Greatest Impact	Medium Impact	Medium Impact	Greatest Impact	Least Impact
Crescent City	Medium Impact	Medium Impact	Greatest Impact	Greatest Impact	Medium Impact	Least Impact	Medium Impact
Morro Bay	Greatest Impact	Least Impact	Greatest Impact	Medium Impact	Greatest Impact	Medium Impact	Medium Impact

Note: Rankings of Least Impact, Medium Impact, and Greatest Impact were determined only by comparing the analyzed sites to each other (i.e., the sites shown within this table).

Table 7.8. Overall O&M site comparative rankings

O&M Sites	Impact Tier
Port of Hueneme	Least Impact
Diablo Canyon	Least Impact
Humboldt	Medium Impact
San Luis Obispo Bay	Medium Impact
Pillar Point	Greatest Impact
Ellwood Pier	Greatest Impact
Crescent City	Greatest Impact
Morro Bay	Greatest Impact

Note: Rankings of Least Impact, Medium Impact, and Greatest Impact were determined only by comparing the analyzed sites to each other (i.e., the sites shown within this table).

8. Offshore Wind Port Improvements

The potential S&I, MF, and O&M port sites identified in the Section 5.8 require significant infrastructure upgrades to serve the offshore wind industry. In this section, construction cost estimates and development timelines are provided for these infrastructure improvements.

It is unlikely that purpose-built port sites will be constructed for just mooring equipment and electrical cable laydown, as these can be co-located with larger offshore wind port sites or utilize existing port infrastructure. Therefore, these sites are not included in this section.

8.1. Construction Cost Estimates

Construction cost estimates were developed to an Association for the Advancement of Cost Engineering (AACE) Class 5 level of accuracy. For this level, the typical cost variation is -20% to -50% on the low range and +30% to +100% on the high range. Costs are based on prior project experience, conceptual engineering analyses, and professional judgement and developed with the following approach:

1. Determine the infrastructure improvements required based on the intended site type: S&I, MF, and O&M.
2. Calculate quantity take-offs for the various types of infrastructure improvements required (i.e., dredging, wharf construction, upland improvements, etc.)
3. Once quantifiable values are established for required infrastructure improvements, unit costs for each item based on the location of the site and information from previous studies/projects were applied.

All costs are in 2023 U.S. Dollars, escalation is not included. Cost estimates include all material, labor, and equipment to complete the work and indirect costs such as contractor supervision (general conditions), corporate overhead and profit, and bonds and insurance costs. A project contingency of 50% is applied to cover undefined items due to the level of engineering carried out at this time. The contingency is not a reflection of the accuracy of the estimate. It covers items of work that will have to be performed and elements of costs that will be incurred but are not explicitly detailed or described due to the level of investigation, engineering, and estimating completed. A contingency of 50% is a common assumption for this level of design for port structures.

Construction cost estimates exclude any above-grade construction (i.e., warehouses and buildings) to facilitate fair cost comparisons as each developer will determine the necessary above-grade improvements required for each site. In addition, the cost estimates do not include any costs for navigation channel improvements such as widening and deepening or wet storage. Additional assumptions are provided in Appendix D.

8.1.1. Staging and Integration

For the S&I sites listed in Section 6.1, an evaluation was completed to determine the required improvements and estimated cost to develop the site for offshore wind industry use. See Table 8.1 and the descriptions below for a detailed breakdown of the improvements and costs at the S&I sites.

Existing Port Sites

The required infrastructure improvements for the Port of Humboldt, Port of Los Angeles, and the Port of Long Beach to meet the requirements of an S&I site are as follows:

- Port of Humboldt:
  - Demolition: Demolition is included for any existing structures or features such as a wharf, buildings on site, or any pavement.
  - Wharf: A new wharf that can withstand 6,000 psf loading is required. The width is assumed to be 150 ft and the length is assumed to be 6,000 ft (1,500 ft per 80 acres).
  - Site Acreage: Based on previous outreach to the Port of Humboldt, potentially 320 acres of existing uplands space may be available for S&I and MF sites. The uplands area shall support at least 2,000 to 3,000 pounds per square feet (psf).
  - Berth Pocket Dredging: The berth pocket at the wharf shall be dredged to a minimum water depth of 38 ft.
  - Sinking Basin: Depending on the floating foundation technology, a sinking basin may be required to off-float the floating foundations. The cost for a sinking basin to various depths (water depth equal to 60 ft, 80 ft, and 100 ft) is included separately. The base of the sinking basin is assumed to be 600 ft by 1,000 ft to accommodate semi-submersible barges.
- Port of Los Angeles:
  - Site Acreage: Based on previous outreach to the Port of Los Angeles, potentially 160 acres of new land could be created within the port for S&I and MF sites. This is assumed to be achieved by dredging portions of the port to provide the necessary sediment to create 160 acres, the existing bathymetry is approximately -15 ft. The uplands area shall support at least 2,000 to 3,000 pounds per square feet (psf). Demolition is not required since the site is not on existing land.
  - Wharf: A new wharf that can withstand 6,000 psf loading is required. The width is assumed to be 150 ft and the length is assumed to be 3,000 ft (1,500 ft per 80 acres).

- Berth Pocket Dredging: Portions of the port will be dredged to produce enough material to create 160 acres, therefore the berth pocket could be approximately -60 ft.
- Sinking Basin: Depending on the floating foundation technology, a sinking basin may be required to off-float the floating foundations. Since there could be deep waters to approximately -80 ft available within the port after dredging for material to create the 160 acres, only a sinking basin cost to 100 ft is provided. The base of the sinking basin is assumed to be 600 ft by 1,000 ft to accommodate semi-submersible barges.

- Port of Long Beach:
  - Site Acreage: Based on previous outreach to the Port of Long Beach, potentially 400 acres of new land could be created within the port for S&I and MF sites. This would be achieved by dredging portions of the port to provide the necessary sediment to create 400 acres, the existing bathymetry is approximately -30 to -50 ft. The uplands area shall support at least 2,000 to 3,000 pounds per square feet (psf). Demolition is not required since the site is not on existing land.
  - Wharf: A new wharf that can withstand 6,000 psf loading is required. The width is assumed to be 150 ft and the length is assumed to be 7,500 ft (1,500 ft per 80 acres).
  - Berth Pocket Dredging: Portions of the port will be dredged to produce enough material to create 400 acres, therefore the berth pocket is anticipated to be approximately -60 ft.
  - Sinking Basin: Depending on the floating foundation technology, a sinking basin may be required to off-float the floating foundations. Since there will be deep waters to approximately -80 ft available within the port, only a sinking basin cost to 100 ft is provided. The base of the sinking basin is assumed to be 600 ft by 1,000 ft to accommodate semi-submersible barges.

The cost of an 80-acre S&I site at the Port of Humboldt ($700M) is less than an S&I site at the Port of Los Angeles ($1,000M) and Port of Long Beach ($1,100M) since it can utilize existing land within the port. The cost of a sinking basin is included as a separate cost and provided for various depths. Constructing a sinking basin within the Port of Los Angeles or Port of Long Beach costs less than that for the Port of Humboldt due to the existing deep waters available within these Southern California ports.

Note, the estimated costs and schedules provided are based on the assumed infrastructure improvements listed above, actual project costs and schedule may vary. The Port of Long Beach recently published a Conceptual Report dated April 20, 2023 that provides a more detailed evaluation of cost and schedule for their 400-acre facility (POLB 2023). Based on their concept design, the cost estimate for the Port of Long

Beach 400-acre facility is $4,700M, and thus an 80-acre S&I site is approximately $940M.

The construction duration to provide or upgrade an 80-acre S&I site with a 1,500 feet heavy lift wharf at the Port of Humboldt, Los Angeles, and Long Beach could be between 4 to 6 years.

Alternative Central California Sites

The required infrastructure improvements for Port San Luis, China Harbor, and Gato Canyon to meet the requirements of an S&I site are as follows:

- Port San Luis, China Harbor, and Gato Canyon:
  - Site Acreage: 80 acres of new land would be created at these three locations. It is assumed this would be achieved by importing material to create 80 acres. The uplands area shall support at least 2,000 to 3,000 pounds per square feet (psf). Demolition is not required since the site is not on existing land.
  - Wharf: A new wharf that can withstand 6,000 psf loading is required. The width is assumed to be 150 ft and the length is assumed to be 1,500 ft.
  - Sinking Basin: Depending on the floating foundation technology, a sinking basin may be required to off-float the floating foundations. The cost for a sinking basin to various depths (water depth = 60 ft, 80 ft, and 100 ft) is included separately. The base of the sinking basin is assumed to be 600 ft by 1,000 ft to accommodate semi-submersible barges.
  - Breakwater: A breakwater would need to be constructed around the site to protect the site from metocean conditions and to create safe harbor for offshore wind activities. It is assumed this could be achieved by importing material.

The construction duration to provide an 80-acre S&I site with a 1,500 feet heavy lift wharf at Port San Luis, China Harbor, or Gato Canyon could be 10 years due to limited road access, procurement of the material to construct a breakwater, and potential weather delays.

Table 8.1. S&I site infrastructure improvements and cost estimates

Item	Port of Humboldt	Port of Los Angeles	Port of Long Beach [2]	Port San Luis	China Harbor	Gato Canyon
Site Type	Staging & Integration	Staging & Integration	Staging & Integration	Staging & Integration	Staging & Integration	Staging & Integration
Site Acreage	320 acres Use Existing Land	160 acres Land Creation	400 acres Land Creation	80 acres Land Creation	80 acres Land Creation	80 acres Land Creation
Wharf Improvement	6,000 ft long wharf 6,000 psf capacity	3,000 ft long wharf 6,000 psf capacity	7,500 ft long wharf 6,000 psf capacity	1,500 ft long wharf 6,000 psf capacity	1,500 ft long wharf 6,000 psf capacity	1,500 ft long wharf 6,000 psf capacity
Berth Pocket Dredging	-38 ft	-60 ft	-60 ft	-38 ft	-38 ft	-38 ft
Breakwater	N/A [1]	N/A [1]	N/A [1]	Requires New Breakwater	Requires New Breakwater	Requires New Breakwater
Total Cost Estimate	$2,700M	$2,100M	$5,400M [2]	$2,700M	$2,500M	$3,000M
Cost Accuracy Range	$1,900M to $4,100M (-30% / +50%)	$1,500M to $3,200M (-30% / +50%)	$3,800M to $8,100M (-30% / +50%)	$1,900M to $4,100M (-30% / +50%)	$1,800M to $3,800M (-30% / +50%)	$1,800M to $3,800M (-30% / +50%)
Cost / 80 acres	$700M	$1,000M	$1,110M [2]	$2,700M	$2,500M	$3,000M
Sinking Basin to El. -60	$85M	Deep water to El. -80 is available within the harbor	Deep water to El. -80 is available within the harbor	$70M	$70M	$50M
Sinking Basin to El. -80	$215M	Deep water to El. -80 is available within the harbor	Deep water to El. -80 is available within the harbor	$200M	$200M	$150M
Sinking Basin to El. -100	$420M	$35M	$35M	$400M	$400M	$350M

[1] Existing breakwater in place or site is protected from metocean conditions.
[2] The Port of Long Beach recently published a Conceptual Report with a more detailed cost estimate and schedule for their 400-acre facility. The total cost estimate is $4,700M and for 80 acres it is $940M (POLB 2023).

8.1.2. Manufacturing / Fabrication

For MF sites listed in Section 6.2, an evaluation was completed to determine the required improvements and estimated cost to develop the site for offshore wind industry use.

See Table 8.2 and the descriptions below for a detailed breakdown of the improvements and costs at the MF sites.

- All Sites:
  - Demolition: Demolition is included for any existing structures or features such as a wharf, buildings on site, or any pavement.
  - Wharf: A new wharf that can withstand 6,000 psf loading is required. The width is assumed to be 150 ft and the length is assumed to be 800 ft for a delivery vessel.
- Port of Oakland, Port of Richmond, Port of Benicia, Port of Stockton, Port of Redwood City, and Port of San Diego:
  - Site Acreage: Based on previous outreach to the Port of Benicia and Port of Redwood City, potentially 20 acres of existing uplands space may be available for an MF site. For the Port of Oakland, Port of Richmond, Port of Stockton, and Port of San Diego, potentially 40 acres of existing uplands space may available for an MF site. The uplands area shall support at least 2,000 to 3,000 pounds per square feet (psf).
  - Berth Pocket Dredging: The berth pocket at the wharf shall be dredged to a minimum water depth of 38 ft.
- Port of San Francisco:
  - Site Acreage: Based on outreach to the Port of San Francisco, potentially 95 acres of existing uplands space may be available for an MF site at each port. The uplands area shall support at least 2,000 to 3,000 pounds per square feet (psf).
  - Berth Pocket: The berth pocket at the wharf is greater than 40 ft and meets the minimum requirement, therefore dredging is not required.
- Antioch and Pittsburg:
  - Site Acreage: Based on previous outreach to private terminals in Antioch and Pittsburg in the Bay Area, potentially 100 acres of existing uplands space may be available for an MF site. The uplands area shall support at least 2,000 to 3,000 pounds per square feet (psf).
  - Berth Pocket Dredging: The berth pocket at the wharf shall be dredged to a minimum water depth of 38 ft.

The cost for a 20 or 40-acre MF site within the Bay Area generally costs the same between the various ports/facilities.

The construction duration to provide a 40-acre MF site and 800 feet heavy lift wharf could be between 4 to 5 years.

- Port of Humboldt, Port of Los Angeles, and Port of Long Beach:
  - These three ports have identified a significant amount of acreage for both S&I and MF sites. The distribution of acreage for S&I sites versus MF sites is currently unknown and will be driven by the offshore wind industry needs. Since the infrastructure improvements are relatively similar for both site types (i.e., same capacity for the heavy lift wharf, upland acreage, and draft at berth) the cost for an 80-acre S&I site in Table 8.1 can be used for an 80-acre MF site for these ports.

Table 8.2. MF site infrastructure improvements and cost estimates

Item	Port of Redwood City	Port of Benicia	Port of Stockton	Port of Richmond	Port of Oakland	Port of San Francisco	Antioch	Pittsburg	Port of San Diego
Site Type	Manufacturing	Manufacturing	Manufacturing	Manufacturing	Manufacturing	Manufacturing	Manufacturing	Manufacturing	Manufacturing
Site Acreage	20 acres	20 acres	40 acres	40 acres	40 acres	95 acres	100 acres	100 acres	40 acres
Wharf Improvement	800 ft long wharf	800 ft long wharf	800 ft long wharf	800 ft long wharf	800 ft long wharf	800 ft long wharf	800 ft long wharf	800 ft long wharf	800 ft long wharf
Berth Pocket Dredging	-38 ft	-38 ft	-38 ft	-38 ft	-50 ft [1]	-40 ft [1]	-38 ft	-38 ft	-38 ft
Total Cost Estimate	$300M	$325M	$350M	$375M	$350M	$480M	$520M	$520M	$275M
Cost Accuracy Range	$200M to $450M (-30% / +50%)	$225M to $500M (-30% / +50%)	$250M to $525M (-30% / +50%)	$275M to $575M (-30% / +50%)	$250M to $525M (-30% / +50%)	$350M to $720M (-30% / +50%)	$375M to $800M (-30% / +50%)	$375M to $800M (-30% / +50%)	$200M to $425M (-30% / +50%)
Cost / 20 acres	$300M	$325M	$300M	$320M	$300M	$290M	$300M	$300M	$225M
Cost / 40 acres	Not Available[2]	Not Available[2]	$350M	$375M	$350M	$345M	$350M	$350M	$275M

[1] The existing berth pocket along the wharf for the is greater than 38 ft, therefore dredging is not required.
[2] For the Port of Benicia and Port of Redwood City, 40-acres for an MF site is not available.

8.1.3. Operations and Maintenance

To support their operation as O&M facilities, some existing waterfront facilities will need to be upgraded or converted. For this assessment, the O&M strategies for offshore WEAs are assumed to be primarily SOV-based, with some support from CTVs, where possible. These facilities are required to berth SOVs and potentially CTVs, as well as providing facilities (either nearby or at the marine facility) to serve as a base of monitoring and operations for an offshore wind energy area. SOVs are intended to support O&M activities by remaining in the wind energy area for approximately two weeks at a time. These vessels often utilize a “walk to work” functionality, allowing maintenance crews to walk directly from the vessel to the turbine foundation via a gangway. CTVs service single-day trips for maintenance workers from the O&M site to the wind energy areas.

Construction cost estimates for space for storage yards and space for operations and maintenance buildings were estimated for a total of 2 and 10 acres of space for comparison purposes. Upland availability and ease of grading/preparation varies between potential O&M site locations. Some locations, such as Port San Luis, do not have sufficient upland availability and so any expansion would require overwater construction or development of land away from the waterfront.

Due to the configuration of the existing basin at Diablo Canyon, it is likely that SOVs will not be able to use the basin. This study assumes that instead, only CTVs may utilize the basin. Four CTVs are assumed to berth in harbor for quick reaction purposes due to its close proximity to Central Coast wind lease areas and the long transit distances for other O&M sites.

For sites listed in Section 6.3, an evaluation was completed to determine the required improvements and estimated cost to develop the site for offshore wind industry use. See Table 8.3 and the descriptions below for a detailed breakdown of the improvements and costs at the O&M sites.

- Crescent City Harbor District, Port of Humboldt, Pillar Point, and City of Morro Bay:
    - Demolition: Demolition is included for any existing structures or features such as a wharf or buildings on site.
    - Site Acreage: Based on previous outreach to a minimum of at least 2 acres of existing nearshore space may be available for an O&M site.
    - Wharf: A new wharf that can withstand 500 psf loading is required. The width is assumed to be 65 ft and the length is assumed to be 300 ft for a Service Operation Vessel (SOV) and Crew Transfer Vessel (CTV).
    - Berth Pocket Dredging: The berth pocket at the wharf for Crescent City and Morro Bay shall be dredged to a minimum water depth of 25 ft to

accommodate an SOV. At the Port of Humboldt there are potential locations where dredging an O&M berth pocket is not required.

- San Luis Obispo Bay and Ellwood Pier:
  - Demolition: Demolition is included for any existing structures or features such as buildings on the nearshore area.
  - Site Acreage: Based on previous outreach to Port San Luis, Cal Poly, and Ellwood Pier, some onshore area is available, but may not be directly adjacent to the pier.
  - Wharf: At Harford Pier, Cal Poly Pier, and Ellwood Pier, an extension of the existing pier to accommodate an SOV is required. The extension of the pier is assumed to be 300 ft to accommodate an SOV and/or CTV.
  - Berth Pocket: The water depth at the end of the existing pier where the vessels will berth is approximately 35 ft and can accommodate an SOV and/or CTV, therefore dredging is not required.
  - Breakwater: For Ellwood Pier, a breakwater will be needed to support year-round O&M activities.
- Diablo Canyon Power Plant:
  - Demolition: Demolition is included for any existing structures or features such as a wharf or buildings on site.
  - Site Acreage: Based on previous outreach to Diablo Canyon Power Plant, some onshore area is available, but may not be directly adjacent to the pier.
  - Wharf: Due to existing site constraints, Diablo Canyon Power Plant may only be able to accommodate a CTV. Based on this the berthing structure could be docks that are 150 ft long.
  - Berth Pocket Dredging: The existing water depth at this site is greater than 12 ft and can accommodate a CTV, therefore dredging is not required.
- Bay Area Ports and Port of Hueneme:
  - Infrastructure improvements to best support O&M activities include paving improvements, upgrades to fendering systems, and structural repairs to existing wharf structures.

The configuration of an O&M site can vary depending on the developer’s strategy and potential collaboration with other developers. The costs provided in Table 8.3 represents one option for the required improvements.

The construction duration to provide an O&M site and 300 feet wharf for SOV or CTV operations could be approximately 3 years.

Table 8.3. O&M site infrastructure improvements and cost estimates

Item	Crescent City Harbor District	Port of Humboldt	Bay Area Ports	Pillar Point	City of Morro Bay	San Luis Obispo Bay	Diablo Canyon Power Plant	Ellwood Pier	Port of Hueneme
Site Type	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M
Site Acreage	2 to 10 acres	2 to 10 acres	2 to 10 acres	2 acres	2 to 10 acres	2 acres [2]	2 to 10 acres	2 acres	2 to 10 acres [8]
Wharf Improvement	300 ft long wharf	300 ft long wharf	Existing Wharf is adequate	300 ft long wharf	300 ft long wharf	300 ft long pier ext.[3]	150 ft long dock [5]	300 ft long pier ext.[7]	Existing Wharf is adequate
Berth Pocket Dredging	-25 ft	-25 ft [1]	-25 ft [1]	-25 ft [1]	-25 ft	-35 ft [4]	-12 ft [6]	-35 ft [4]	-33 ft [9]
Breakwater	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Requires New Breakwater	N/A
Cost / 2 acres	$35M	$15M	$15M	$60M	$50M	$30M	$10M	$140M	$15M
Cost Accuracy Range	$20M to $45M (-30% / +50%)	$10M to $25M (-30% / +50%)	$10M to $20M (-30% / +50%)	$42M to $90M (-30% / +50%)	$35M to $75M (-30% / +50%)	$20M to $45M (-30% / +50%)	$7M to $15M (-30% / +50%)	$98M to $210M (-30% / +50%)	$10M to $20M (-30% / +50%)
Cost / 10 acres	$37M	$17M	$20M	Not Available	$52M	Not Available	$12M	Not Available	$20M

[1] At the Port of Humboldt, Bay Area Ports and Pillar Point, dredging at the berth pocket may not be required for an O&M site.
[2] For San Luis Obispo Bay, the upland acreage may not be directly adjacent to the pier.
[3] San Luis Obispo Bay has two existing piers (the Harford Pier and Cal Poly Pier) that would require extensions to accommodate SOVs. Cost shown is for an expansion at either pier.
[4] For Port San Luis and Ellwood Pier, the existing berth water depth is -35 ft, therefore dredging is not required.
[5] For Diablo Canyon Power Plant, the dock would be only able to accommodate CTVs and not SOVs due to site constraints.
[6] For Diablo Canyon Power Plant, the existing berth water depth is -12 ft, therefore dredging is not required.
[7] For Ellwood Pier, the berthing structure will be an extension of the existing pier.
[8] For Port of Hueneme, potential onsite acreage available, with preference for offsite acreage staging as well.
[9] For Port of Hueneme, the existing berth water depth is approximately -33 ft, therefore dredging is not required.

8.2. Project Development Timelines

To meet the offshore wind deployment goals of 2 to 5 GW by 2030 and 25 GW by 2045, the timing of when these offshore wind port sites are available for offshore wind industry use is critical. S&I sites are the most critical since there are only a few sites that have the capability to perform final turbine assembly activities, and these sites will require significant and costly upgrades before they are ready to serve the offshore wind industry. Offshore wind port sites will need to meet the following timelines to achieve offshore wind deployment goals:

- S&I Sites
  - Based on outreach to the Port of Humboldt and Port of Long Beach, who have started the project planning and design process for their sites, are targeting to have portions or phases of their sites ready by late 2020s to early 2030s to meet the offshore wind industry needs.
- MF Sites
  - If a domestic supply chain is to be established within California, MF sites would need to be available by late 2020s to mid-2030s to supply components to the initial and future offshore wind projects.
- O&M Sites
  - To service the offshore wind turbines that are installed, O&M sites would need to be available for offshore wind industry use around the same time S&I sites are available: late 2020s to early 2030s.

To plan, design, and construct these offshore wind port sites, the following general stages are involved:

1. Secure funding for project implementation
2. Project planning, conceptual design, site data collection, and vetting of project alternatives
3. Consultation with Native American Tribes
4. Federal and/or State environmental review and compliance
5. Coordination with permitting agencies and affected stakeholders; detailed engineering
6. Obtaining project permits and environmental approvals
7. Construction

After project funding has been secured, and the conceptual design has progressed to allow for the development of a project description, the environmental review process can be initiated by the applicable federal, State, and/or local lead agencies. In addition to compliance with the National Environmental Policy Act (NEPA) for offshore wind deployment, port improvements in California will require compliance with the California Environmental Quality Act (CEQA). Depending on the location of the project and the resources affected, agencies with permitting authority for the proposed California port improvement projects may include one or more of the following:

- United States Army Corps of Engineers (USACE)
- United States Environmental Protection Agency (USEPA)
- United States Fish and Wildlife Service (USFWS)
- National Marine Fisheries Service (NMFS)
- California Air Resources Board (CARB)
- California Coastal Commission (CCC)
- California Department of Fish and Wildlife (CDFW)
- Department of Toxic Substances Control (DTSC)
- California State Lands Commission (CSLC)
- San Francisco Bay Conservation and Development Commission (BCDC)
- State Historic Preservation Office (SHPO)
- State Water Resources Control Board (SWRCB)
- Applicable Air Quality Management District (AQMD)
- Applicable Port or Harbor Authority
- Local County or City (for Coastal Development Permit and all applicable ministerial permits)

Federal and/or State environmental review processes are similar, both in intent and in their requirements (i.e., public engagement and preparation of environmental analyses documents to help support permit issuance by multiple agencies). When a project requires multiple federal, State, regional, and/or local approvals, joint NEPA/CEQA environmental review processes are encouraged to streamline the review process by helping avoid redundancy, improving efficiency and interagency cooperation, and making it easier for applicants and citizens to navigate the project review and approval process. NEPA and/or CEQA compliance documents process will be used by multiple agencies with jurisdiction over the project to support decisions on their respective permits.

After the permit application package is submitted to each applicable federal, State, regional, and local agency, agency coordination can be initiated. Agencies typically respond to permit submittals with multiple rounds of data requests to the applicant before project permit applications are deemed complete. After the permitting agency deems each application to be complete, the agency can begin the environmental review process to support processing its permit, and subsequent permit approval.

The typical timeline associated with securing all required permits and approvals for large in-water projects in California could be considerably longer than the timeline that has been identified for meeting California's goal of producing 2 to 5 GW of offshore wind generation by 2030 and 25 GW by 2045. Projects developed on the coast of California of similar size and scale to the sites considered in this study have taken from 3 to 10 years from project planning to securing all permits for construction. Considering the regulatory environment in California, the window for securing all required approvals could range from 4 to 10 years for S&I sites, 4 to 8 years for MF sites, and 4 to 7 years for O&M sites. Development of facilities within existing ports and in areas with existing industrial land uses may be permitted more quickly, but controversial projects that result in legal challenges to the agency approvals and the adequacy of the environmental documents relied upon may require longer timeframes.

Strategies for expediting the processes for environmental review and permitting can be developed through legislative action, through multi-agency agreements of Memoranda of Understanding (MOUs), or through direct agreements with agencies or the applicants. While each strategy would need to be based on site-specific conditions for each project or group of projects, the following approaches could help streamline the environmental review and permitting process, and may limit the timeframe for legal challenges to projects after approval:

- Early development of mitigation programs and strategies through coordination with resource agencies.
- Early initiation of community engagement and outreach to identify project effects, alternatives, and mitigation. An effective outreach and involvement program that considers community concerns may lead to more effective mitigation presented in the environmental documents and may reduce the risk of legal challenges after project approval. This type of community engagement also provides opportunities to define and address environmental justice issues and leverage investments that could provide local jobs and expand community resources.
- Development of a legislative program similar to that defined in the Judicial Streamlining provisions of California's Environmental Leadership Development Program, as defined in Senate Bill 7 (Atkins, 2021) that would apply to port developments supporting offshore wind could reduce the timeframe for legal challenges to agency decisions and adequacy of environmental documents.

9. Offshore Wind Port Lessons Learned

On the U.S. East Coast there are approximately thirty active offshore wind leases in the Atlantic Ocean. Due to the bathymetry on the East Coast— the continental shelf drops off gradually, making for shallower waters closer to shore —the use of fixed bottom foundations (i.e., monopile, bucket,) was possible. Since fixed bottom foundations have been successfully implemented on commercial scale projects in Europe and the East Coast could use the same technology, the offshore wind industry developed sooner on the East Coast. Therefore, East Coast states initiated several offshore wind projects before the West Coast, triggering the rapid development of port infrastructure. The ongoing development of ports and the supply chain has resulted in key takeaways that can be utilized for the development of an offshore wind industry (industry) in California.

- The State's procurement approach for offshore wind power will ultimately set the timeline for port development.
    - Port capacity needs will flow backwards from the State's targeted commercial operations dates.
    - Bid submission and award schedules drive commercial agreement timelines for port facilities.
    - A clear procurement schedule is critical to providing certainty for port offtake, which in turn will help draw private finance into port development projects.
    - The number of awards made in each state power procurement and federal lease sale will have a big impact on the size and quantity of port sites required.
- The State's decision on how much it values local content in procurements will significantly impact port development.
    - A clear commitment to support local content and job creation will increase the need for a broader network of local ports, especially the demand for MF sites. MF sites will maximize economic benefit for the State.
    - A strong focus on a lower levelized cost of energy (LCOE) may lead to less investment in California ports for manufacturing resulting in a missed opportunity for job creation and economic impact.
    - Local content policies should be utilized as a partnership mechanism to fund industrial and port development within the State, and must co-exist within a regional cooperation framework.
- A strong focus on lower LCOE can put the State's offshore wind projects and schedule at risk. Projects that focus on lower LCOE are more susceptible to economic fluctuations in the market and can cause developers to seek rebidding the project or withdrawing altogether.

- Announcing a schedule for future offshore lease areas will further signal to developers and OEMs that there will be sufficient project demand to justify accelerated local supply chain development.
- Almost no offshore wind port development projects will be commercially viable on their own; the State's port development strategy must include a plan for how it will subsidize the various port site developments from the beginning.
  - Attempting to fund all port development through the power procurement process will be highly complicated and will push offshore wind developers to also become full-scale port developers, which is not their core business.
  - Timing of when private equity is available (during the power procurement process) does not match up with timing of when funding is needed to support port development.
- Realistic upfront estimates for the cost of building an offshore wind port network will accelerate the identification of appropriately-sized State and Federal funding solutions.
- The State should consider establishing programs to incentivize early-stage port development work (site readiness, concept design, engineering, permitting, etc.)
  - The availability of potential port sites when developers are bidding in power procurement solicitations will be a big driver for the pace of supply chain development.
- The State should also focus on flexible laydown and Tier 2 and Tier 3 manufacturing locations in its port plans in addition to traditional S&I, Tier 1 MF, and O&M sites.
  - Tier 1: Finished components that are purchased by the developer (i.e., wind turbine, foundations, cables, etc.).
  - Tier 2: Subassemblies that have a specific function for a Tier 1 component (i.e., pitch system for blades).
  - Tier 3: Subcomponents are commonly available items that are combined into Tier 2 subassemblies (i.e., motors, belts, and gears). (NREL 2023a)
- The first project in the region sets precedence for future projects. It is imperative that the first project not be delayed nor have major hangups during permitting.
  - To meet the State's planning goals, the permitting process needs to be streamlined. Strategies for accelerated approvals are recommended for timely project development.
- Port development will be one of the first places where the offshore wind industry creates local jobs.
  - Port development is a great example of how power procurement spending can turn into jobs and opportunities for the communities.

10. Recommended Port Development / Investment Plan

Of the port site types that were studied (S&I, MF, O&M, mooring and cable laydown), the S&I sites are most critical that require urgent funding. These sites must be developed as soon as possible to provide the State the best opportunity to achieve the offshore wind planning goals and get these offshore wind projects underway.

The recommendations provided in this report are based on the best information that is known to date. Industry trends, technological advancements, seasonality of operations, developer strategies, and/or other items may cause the findings and recommendations from this report to change. Competition for port sites may cause an increase in the number or demand for port sites.

10.1. Staging and Integration

S&I sites are most critical to identify and develop because only a few port sites within the State have the key characteristics required to support these activities. These sites play a critical role to execute the final step in the manufacturing process to assemble the full turbine system before being towed out to the final installation site. These sites require a significant amount of acreage and funding to be developed. Within this study, six ports were assessed. Three are within existing ports (Port of Humboldt, Port of Los Angeles, and Port of Long Beach) and three locations are within Central California (Port San Luis, China Harbor, and Gato Canyon).

The towing assessment outlined in Section 5.2 and Appendix B determined that S&I sites in Northern California (i.e., Port of Humboldt) can tow fully assembled turbines to WEAs off the North and Central Coast and vice versa, and that S&I sites in Central and Southern California (i.e., Port San Luis, China Harbor, Gato Canyon, Port of Los Angeles, or Port of Long Beach) can tow fully assembled turbines to WEAs the North and Central Coast. In addition, when comparing S&I sites within Central California to those in Southern California, similar annual throughput goals can likely be achieved if more towing vessels are used to leverage the large amount of wet storage available in Southern California ports.

To construct an 80-acre S&I site, it will cost approximately $700 million in the Port of Humboldt, $1 billion at the Port of Los Angeles, $1.1 billion at the Port of Long Beach, $2.5 billion at China Harbor, $2.7 billion at Port San Luis, and $3 billion at Gato Canyon. This excludes the cost for a sinking basin. The cost and schedule to develop S&I sites within China Harbor, Port San Luis, or Gato Canyon are significantly more and longer than those developed within existing port sites because a new protected harbor has to be created. Per the assessment performed in Section 5, three to five 80-acre S&I sites are needed to meet the State's 2045 offshore wind planning goal of 25 GW. Currently, both the Port of Humboldt and Port of Long Beach are pursuing port development projects to provide 180+ and 400 acres, respectively, for provide space for both S&I and MF activities. Between these two projects, the three to five S&I sites can be provided to meet the State’s 2045 offshore wind planning goals.

To achieve the State’s offshore wind planning goals for 2030 and 2045, S&I sites need to be ready for industry use by late 2020s to early 2030s. This requires an aggressive schedule to fund, plan, permit, and construct these port facilities.

Funding offshore wind port development projects and obtaining timely environmental approvals are critical challenges to solve. In general, floating offshore wind port development projects are not commercially viable solely within the traditional port business model. As they require large upfront investments and have slower returns due to timing of revenue (power purchase agreements), cyclical operations, and downtime between offshore wind projects. Therefore, the State’s port development strategy must include a plan for how it will subsidize the various port site developments from the beginning. Multiple funding sources (State, Federal, and potentially private investment) will need to be identified. In addition, the traditional timelines for obtaining permits and environmental approvals within California is time-consuming. There is a need to accelerate review and approval timelines to ensure these port development projects are completed in time for industry use to meet the State’s offshore wind planning goals.

Figure 10.1 shows a map of the S&I ports assessed in this study and their categorization. China Harbor, Port San Luis, and Gato Canyon are shown as moderate candidates (displayed in yellow) due to the higher cost, longer schedule, and greater environmental impacts. The Port of Humboldt, Port of Los Angeles, and Port of Long Beach are shown as good candidates (displayed in green).

Figure 10.1. S&I site categorization

10.2. Manufacturing / Fabrication

Having MF sites located within California is not necessarily required to complete these offshore wind projects. However, if manufacturing facilities were to be established within the State, it would maximize economic benefits and job creation. Based on developer and industry outreach, a strong project backlog is required for manufacturers to justify making a long-term investment and to establish a manufacturing facility in California. Therefore, it is important to provide the industry clarity on both the auctioning schedule for the wind energy areas and the process for offtake.

If the State wants to focus on the price of power instead of local content and supply chain, this may lead to the industry procuring components outside of California and seek more flexible laydown sites to stage and assemble these imported components, rather than a manufacturing facility. The MF Sites identified in this study could still be used for this type of activity if additional space is needed.

Figure 10.2 identifies locations within California that could provide an MF site. Sites that provide more acreage are typically more favorable. Therefore, MF sites are shown green if they can provide 40 acres or more. Note, some MF sites (foundation assembly, blades, and tower) are assumed to required 80 acres or more, refer to Section 5.4 to site acreage assumptions.

The Port of Redwood City and Port of Benicia are considered moderate candidates because only 20 acres is potentially available at these locations and significant dredging is required at the berth. The cost for a 20-acre site at the Port of Redwood City is approximately $300 million and $325 million for the Port of Benicia.

For the other ports within the Bay Area, the cost to provide a 40-acre MF site is within a similar range of approximately $345 to $375 million. The cost for a 40-acre MF in the Port of San Diego is approximately $275 million. Antioch and the City of Pittsburg have identified sites that could provide 100 acres. A 100-acre MF site at these locations it costs approximately $520 million. The Port of San Francisco is currently undergoing a conceptual study for a 95-acre MF site, which could cost approximately $480 million. If all MF sites were to be located within California, the state would need two blade MF sites (100 acres each), one tower MF site (100 acres), one nacelle assembly site (25 acres), four foundation subcomponent MF sites (40 acres each), and four foundation assembly sites (40 acres each) to meet California’s planning goal of 25 GW by 2045. These sites could be provided at the Port of Humboldt, Bay Area Ports, Port of Los Angeles, Port of Long Beach, and Port of San Diego. Investments into ports to create MF sites will maximize economic benefits and job creation within the state.

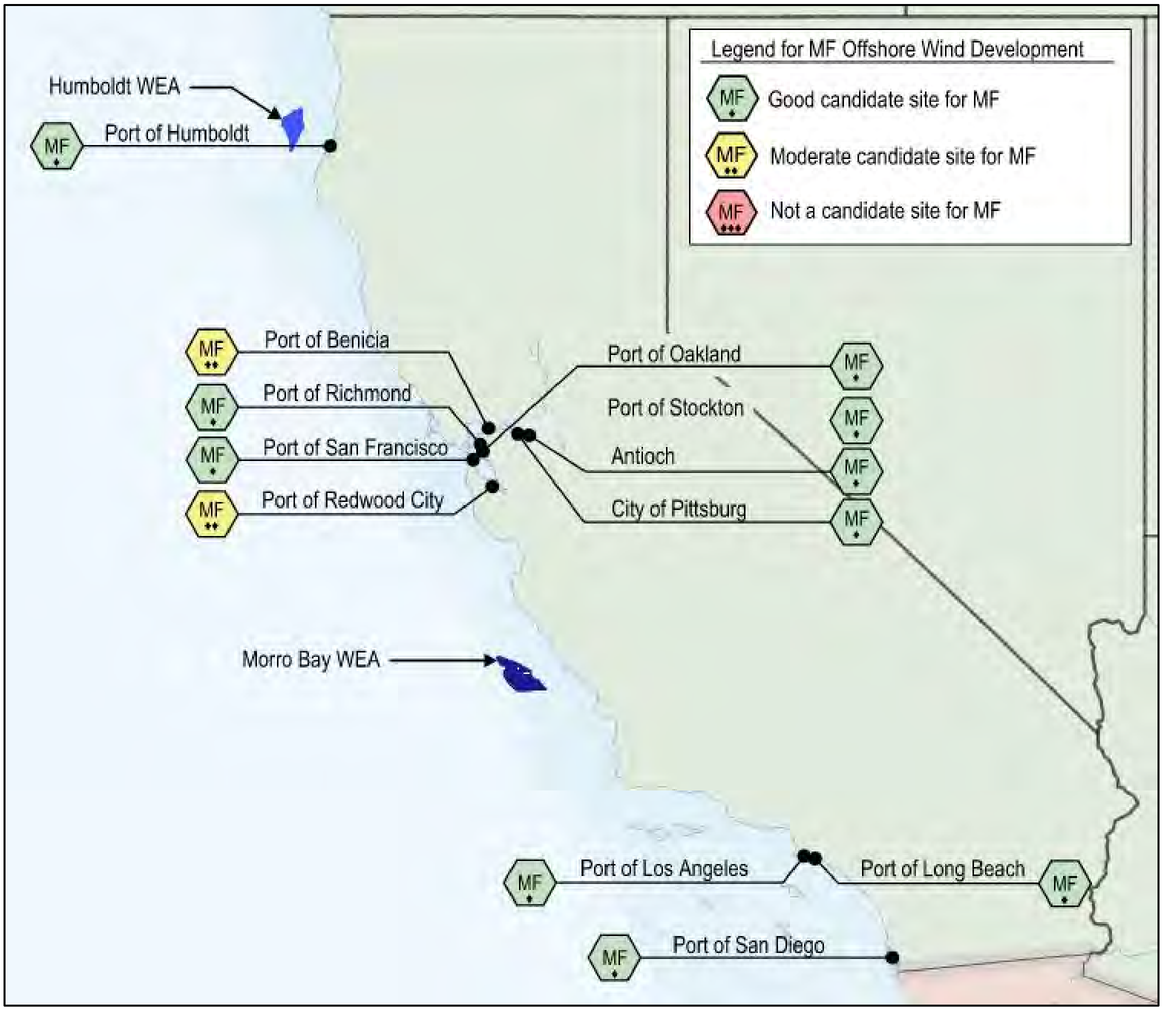

Figure 10.2. MF site categorization

10.3. Operations and Maintenance

O&M sites also play a critical part in the offshore wind industry. O&M sites support minor maintenance and repair for offshore wind turbines by providing a facility from which crews can travel to the turbines and work on them in situ. Major repairs and maintenance are assumed to be performed at S&I facilities. O&M sites will host SOVs, CTVs, and an operations base consisting of offices, warehouses, and a storage yard. The scale and functionality of these O&M sites will vary depending on wind energy area size, distance, and strategy of the contractor executing the Service and Maintenance Agreement (SMA).

Developers will want their O&M sites to be located near the WEAs to minimize travel time. Since the future WEA locations are not known at this time but are most likely to be off the North and Central Coast, the categorization shown in Figure 10.3 is based more on the type of infrastructure upgrades needed at each site rather than their location. For example, Ellwood Pier would require a new breakwater to be constructed and therefore is shown as red and not a candidate site. An O&M site at Ellwood Pier could cost approximately $140 million. Pillar Point requires a significant amount of dredging and the cost for an O&M site could cost approximately $60 million. Since the existing configuration for the Diablo Canyon Power Plant cannot serve SOVs, this site was deemed a moderate candidate. The cost of an O&M site in other locations ranges from approximately $10 million to $50 million.

Locations that could serve as O&M sites have been identified, and it is anticipated that developers will mainly determine which locations will be made their O&M site based on their operations plan. SOVs can remain in the field for over two weeks at a time, so there may be opportunities for more than one SOV to share a berth. This will reduce the need for berth space, and therefore, construction costs. Based on the assessment in Section 5, the State could need between 9 and 16 berths to support the 14 to 24 SOVs needed to meet the State's offshore wind planning goals.

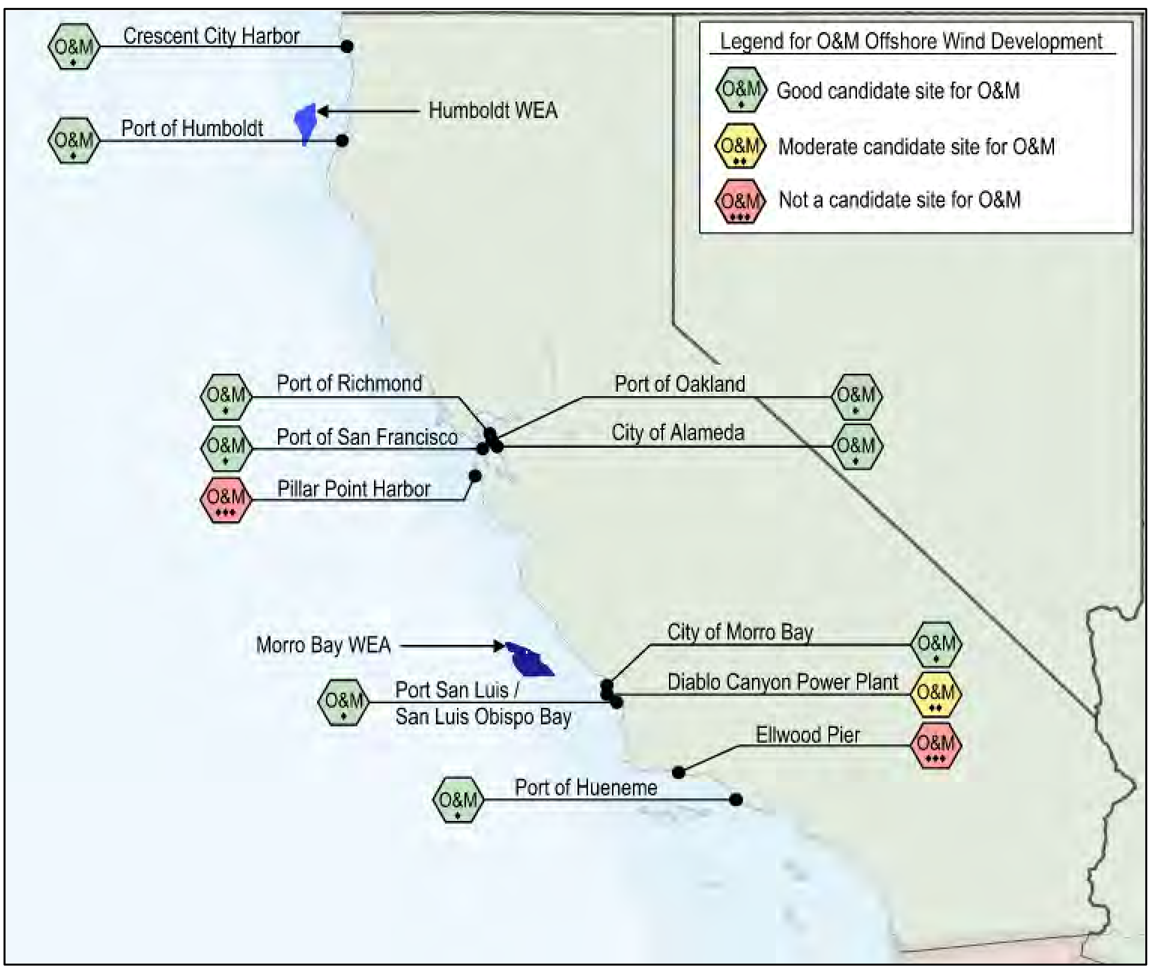

Figure 10.3. O&M site categorization

10.4. Summary and Next Steps

Based on this study, there are several port sites within the State that can be used to help achieve the State's offshore wind planning goals of 25 GW by 2045 offshore wind planning goal. Obtaining adequate funding and environmental approvals for these projects are critical challenges to resolve. An S&I site would have to be available for industry use by the very beginning of 2028 to meet the 2 to 5 GW by 2030 goal. As it stands today, achieving this target will be very challenging.

To meet the State's offshore wind planning goals, a multi-port strategy is needed and an investment of approximately $11 to $12 billion (in 2023 US Dollars) would be required to upgrade existing port infrastructure. Note, there are several different port development scenarios that will allow the State to achieve its 2045 offshore wind planning goals. Table 10.1 presents one example, among many, of these port development scenarios. The purpose of Table 10.1 is to provide an approximate total investment required to meet the State's offshore wind planning goals.

Table 10.1. Potential port development summary

Site Type	Location	Assumed Ready Date	Cost * ($ in millions)
S&I	Port of Humboldt	2028	$700
S&I	Port of Humboldt	2031	$700
S&I	Port of Long Beach	2031	$1,100
S&I	Port of Long Beach	2035	$1,100
MF (Foundation Assembly)	Port of San Francisco	2030-2032	$520
MF (Foundation Assembly)	Port of Long Beach	2033	$1,100
MF (Foundation Assembly)	Port of Long Beach	2035	$1,100
MF (Foundation Assembly)	Port of Long Beach	2035	$1,100
MF (Foundation Subcomponents)	Port of San Diego	2030-2035	$275
MF (Foundation Subcomponents)	Bay Area Port	2030-2035	$375
MF (Foundation Subcomponents)	Bay Area Port	2030-2035	$350
MF (Foundation Subcomponents)	Bay Area Port	2030-2035	$350
MF (Blades)	Bay Area Port	2030-2035	$520
MF (Blades)	Bay Area Port	2030-2035	$520
MF (Tower)	Port of Humboldt, Bay Area Port, or Port of Los Angeles	2030-2035	$1,000
MF (Nacelle Assembly)	Bay Area Port	2030-2035	$350
O&M	Assume 10 sites at $50M each	2028-2045	$500
Mooring Line & Anchor Storage	Port of Humboldt & Bay Area Port	2030-2035	<$50
Electrical Laydown Sites	Port of Humboldt & Bay Area Port	2030-2035	<$50
Total			$11,760

* Cost is in 2023 dollars. Escalation is not included. Estimate accuracy is -30% / +50%.

The estimated port investment cost of $11 to $12 billion is to prepare the port sites to grade including on-site utilities and lighting. The cost of above-grade improvements such as warehouses, buildings, equipment, cranes, etc. is not included. Similarly, any improvements required outside the footprint of the offshore wind port site to provide adequate access or utility service to the site are not included. Navigation channel improvements such as widening or deepening, if required, are also excluded from this estimate.

Based on the NREL West Coast ports strategy study (NREL 2023b), it is estimated that a capital investment of $4 million is required for every 1 MW of installed floating offshore wind energy. Therefore, 25 GW of floating offshore wind requires a capital investment of approximately $100 billion. This number includes procurement and installation costs for all major components (turbines, platforms, cables, mooring, anchors, onshore substation, offshore substation) but does not include cost of port investments, transmission grid investments, cable landings, or vessel fleet construction. To put the required port investment into perspective, it is anticipated the capital investment into ports will represent approximately 10% to 15% of the cost of the wind energy area. If MF facilities are not provided in the State, the total capital investment in ports represents approximately 5% of the wind energy area project cost. When full project costs are considered (wind energy area, cable landing, transmission improvements, and vessel fleet construction) the port investment is a relatively small portion of the overall capital investment.

Some recommendations for next steps include:

- The State's port development strategy should consider how ports will be subsidized for project development and construction costs. Funding sources will need to be identified. The funding strategy should include incentivizing and funding early-stage port development work (site readiness, conceptual design, engineering, permitting, etc.) as this will be important to prepare the port sites in time to meet the State's goals.
- The State's offshore wind procurement approach coupled with the availability and timing of port funding will drive the schedule for availability of port sites for the offshore wind industry.
- The State's approach to incentivizing local content and job creation within the state will significantly impact manufacturing investments into ports.
    - A clear commitment to support local content and job creation increases the need for a broader network of California ports, especially the demand for MF sites. MF sites can maximize economic benefit and job creation in the State.
    - A strong focus on a lower levelized cost of energy (LCOE) may lead to less investment in California ports for manufacturing resulting in a missed opportunity for job creation and economic impact.

- Committing to a schedule for future offshore leases and providing insight into the power procurement process will signal to developers and OEMs a strong backlog of projects to justify local supply chain development and manufacturing investments into California.

Based on the work performed in this study, several items were identified that need to be further studied. The following topics are recommended for additional study:

- Evaluate the capacity of U.S. shipyards to construct the required fleet of vessels in time to support the offshore wind industry and to meet California's deployment targets. Many new and purpose-built vessels will need to be constructed to support the offshore wind industry and meet existing requirements such as the Jones Act and CARB regulations.
- Evaluate the port space required for the fleet of tugs and other construction support vessels that will need home port and re-supply services.
- Evaluate the space needed within ports to support offshore wind end of life decommissioning activities.
- Evaluate escalation costs and distribute the port investment costs over the deployment timeline to provide decision makers with a clear understanding of the actual investment costs and the likely years when the investments need to be made.
- In addition to the work performed in this study to evaluate S&I, Tier 1 MF, and O&M, evaluate the port space required for additional flexible laydown and Tier 2 and Tier 3 needs.
- Evaluate ideal locations to serve as cable landing sites.
- Evaluate port needs to support the construction and installation of offshore electrical substations required to support the wind energy areas.

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12. Appendices

Appendix A. Literature Review

The following lists the information and data gathered from a range of offshore wind industry, and government sources to provide a baseline of best available information on offshore wind and ports.

Bureau of Ocean Energy Management (BOEM):

- California Floating Offshore Wind Regional Ports Assessment (BOEM 2023-010)
- California Floating Offshore Wind Regional Feasibility Analysis (BOEM 2023-038)
- Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii [ICF International] (BOEM 2016-011)
- Floating Offshore Wind in California: Gross Potential for Jobs and Economic Impacts from Two Future Scenarios [NREL] (BOEM 2016-029)
- Floating Offshore Wind Turbine Development Assessment: Final Report and Technical Summary [ABSG Consulting Inc.] (BOEM 2021-030)
- Port of Coos Bay Port Infrastructure Assessment for Offshore Wind Development [Moffatt & Nichol] (BOEM 2022-073)
- Potential Offshore Wind Energy Areas in California: An Assessment of Locations, Technology, and Costs [NREL] (BOEM 2016-074)
- Presentation BOEM California Leasing Update – 10-6-22 (BOEM 2022)

California Energy Commission (CEC):

- AB 525 Goals – Resources Considered (as of March 3, 2022), March 10, 2022 (CEC 2022)
- Commission Report – Offshore Wind Energy Development off of California Coast, August 1, 2022, CEC-800-2022-001-REV (CEC 2022)
- Commission Report Preliminary Assessment of Economic Benefits of Offshore Wind, February 24, 2023, CEC-700-2023-002-CMD
- Energy Commission Report on AB 525 Offshore Wind Permitting Roadmap, April 28, 2023, CEC-700-2023-004
- Presentations – AB 525 Workshop, March 3, 2022 (CEC 2022)
- Presentation – Preparing a Strategic Plan for Offshore Wind Energy Development Staff Workshop 10-6-22, October 6, 2022 (CEC 2022)

California State Lands Commission (CSLC):

- Alternative Port Assessment to Support Offshore Wind Feasibility Assessment Report [Moffatt & Nichol] (CSLC 2023)

National Renewable Energy Laboratory (NREL):

- 2014-2015 Offshore Wind Technologies Market Report (NREL 2015)
- 2016 Offshore Wind Energy Resource Assessment of the United States (NREL 2016)
- 2017 Offshore Wind Technologies Market Update (NREL 2018)
- 2019 Offshore Wind Technology Data Update (NREL 2019)
- An Assessment of the Economic Potential of Offshore Wind in the United States from 2015 to 2030 (NREL 2017)
- Cost of Floating Offshore Wind Energy Using New England Aqua Ventus Concrete Semisubmersible Technology (NREL 2020)
- Definition of the IEA Wind 15-Megawatt Offshore Wind Turbine (NREL 2020)
- Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers (NREL 2010)
- The Cost of Floating Offshore Wind Energy in California Between 2019 and 2032 (NREL 2020)
- The Demand for a Domestic Offshore Wind Energy Supply Chain (NREL 2022)

Schatz Energy Research Center (Schatz):

- American Jobs Project: The California Offshore Wind Project: A Vision for Industry Growth (Schatz 2019)
- California North Coast Offshore Wind Studies (Schatz 2020)
- Del Norte County Offshore Wind Preliminary Feasibility Assessment: Final Report (Schatz 2021)
- Port Infrastructure Assessment Report (Schatz 2020)

U.S. Department of Energy (USDOE):

- Assessment of Ports for Offshore Wind Development in the United States (USDOE 2014)
- National Offshore Wind Strategy (USDOE 2016)
- Offshore Wind Market Report: 2021 Edition (USDOE 2021)

Additional California Regional Port Assessment Studies:

- California Offshore Wind: Workforce Impacts and Grid Integration (UC Berkeley Labor Center 2019)
- California's Offshore Wind Electricity Opportunity (USC Schwarzenegger 2021)
- Economic Impact of Offshore Wind Farm Development on the Central Coast of California (Cal Poly SLO 2021)
- Scenarios for Offshore Wind Power Production for Central California Call Areas (Cal Poly SLO 2020)
- Supply Chain Contracting Forecast for U.S. Offshore Wind Power – The Updated and Expanded 2021 Edition (The Special Initiative on Offshore Wind 2021)

Appendix B. Towing and Installation Assessment

This appendix assesses how towing distance and metocean conditions affect potential routes between different S&I ports and WEAs, and if these conditions constrain the rate at which WTGs can be installed. The operations considered in these comparisons are the towing and hookup of integrated WTGs from an S&I site to a designated WEA and are shown in Figure B.1. The assessment does not consider O&M vessel operations or vessel logistics for other parts of the offshore wind energy area supply chain (i.e., cable shipment or foundation towing from fabrication site to S&I site).

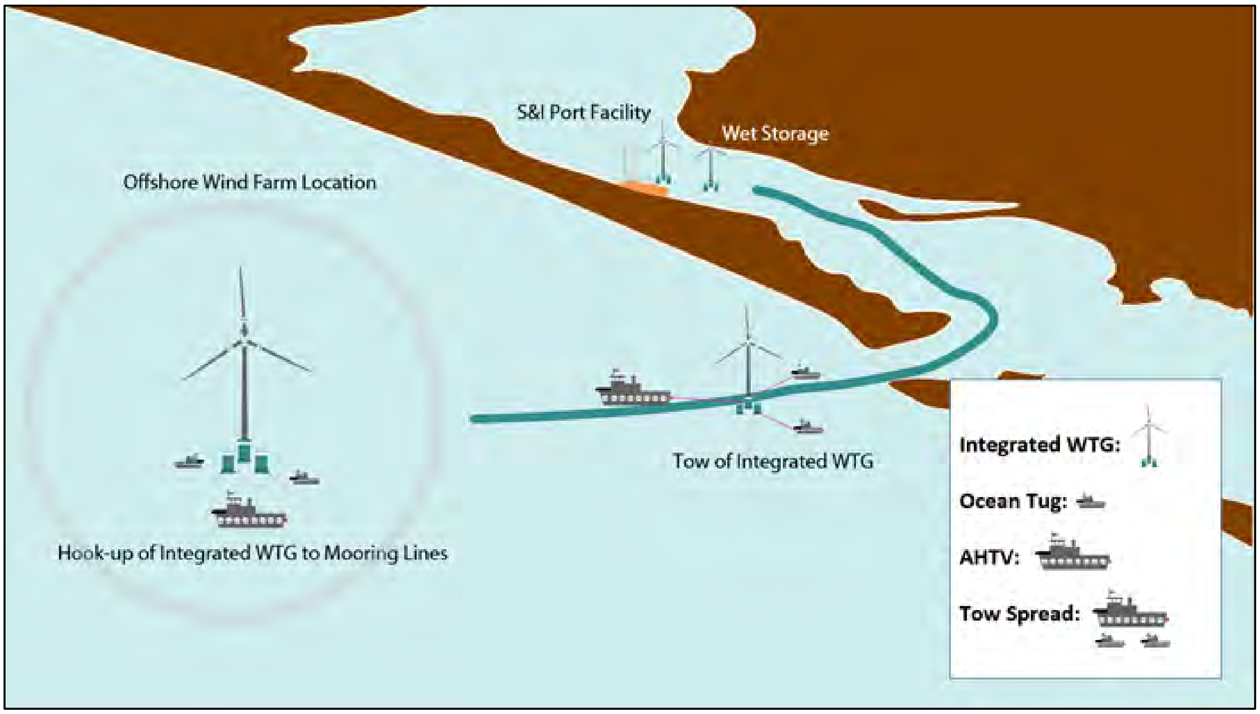

Figure B.1. Operations and facilities considered in metocean conditions and towing assessment

Potential constraints due to distance and metocean conditions are assessed to:

- Compare constraints relative to the range of OSW deployment goals (low to high per Section 5.1)
- Outline tradeoffs between S&I sites with respect to the towing and hook-up operations in the Northern and Central Coast regions of California

This assessment focuses on the comparison between three potential S&I sites: Northern California (Humboldt Bay), Central California (San Luis Obispo Bay), and Southern California (Port of Long Beach). This assessment is intended to provide relative assessments for individual annual throughputs. It is not meant to capture inefficiencies over a multi-year period such as transitions between developers utilizing the port, vessel maintenance, and other factors. Statewide throughput is expected to vary from year to year due to these and other factors. These variances in annual throughput are considered when determining the total number of S&I sites needed to meet the state offshore wind planning goals. Broadly, these operations are governed by four factors:

- Towing distance from S&I site to WEA
- Metocean conditions (a combination of meteorological and oceanographic factors, such as wind, wave, and climate conditions)
- Towing logistics and limitations (such as how many vessels are available)
- S&I port logistics and limitations (such as how much wet storage is available and how quickly WTGs are integrated to the foundations).

This chapter contains three sections:

1 Basis of Assessment:
   - Assumptions and methodology for development of criteria.

2 Metocean Downtime Analysis:
   - Characterize the metocean conditions at WEAs in Northern and Central California.
   - Estimate the potential effect of metocean conditions on installation of the integrated WTG at the WEA during different months of the year, prior to assessing towing between the port and the WEA.
   - Outline potential towing route distances and towing times between S&I sites and WEAs.
   - Estimate the effect of metocean conditions on at-sea towing operations for different routes and installation operations at the WEAs.

3 Tow Spread Effect on Integrated WTG Towing and Hook-up:
   - Estimate the effect of distance to/from the WEA from the S&I port with respect to variables such as number of tugs (tow spreads), wet-storage, and integration rate.
   - Estimate how many tow spreads may be needed to support longer tows, and if there are potential limitations on overall WTG throughput considering downtime and wet-storage capacity. In this assessment, a tow spread is a group of vessels that are used to tow a single WTG.

Basis of Assessment

This section discusses the framework for evaluating existing conditions and developing assessment criteria.

General

- Scope: The scope of operations included in this assessment includes the WTG and foundation integration at an S&I site, wet storage of the integrated WTG, towing to a WEA, and hook-up of mooring lines to the floating foundation.
- Ports: Port-specific limitations for wet storage and towing logistics were developed in coordination with Section 5 and marine transport contractors. S&I sites (80 acres) assume a constant WTG integration rate of 1 WTG per week per heavy lift crane.
- Emissions: Emissions from towing and hook-up operations may be a consideration for selecting S&I sites, however the emissions from these operations are only a percentage of the total offshore wind project emissions. For a comprehensive assessment on total emissions refer to the NREL report titled *Impacts of Port Development on Floating Offshore Wind for the West Coast of the United States* report (NREL 2023b).
- Exclusions:
  - Downtime between projects (e.g., between developer use, this assessment idealizes constant use of terminals for a specific year)
  - Dedicated periods for tow-back of integrated turbines for maintenance – which may require integration operations to pause while major component replacement occurs quayside.
  - Seasonal operations (e.g., planned downtime during winter months due to limiting installation opportunities or other factors)
  - WTG component supply chain
  - Delivery or transport of foundations prior to integration (e.g. foundations fabricated in Asia for delivery to California, or transport and launching/floating of foundations between ports in California)
  - Electrical connections and mooring pre-lay
  - O&M and crew transfer
  - Anchor installation
  - Export or array cable installation
  - Offshore substation installation

Operational Criteria

- Criteria Development Methodology: Assumptions on operational metocean criteria and requirements are based on a combination of literature review, experience of marine transport contractors, industry engagement, and coordination with on-going parallel technical studies. Where consensus for specific factors could not be found, the assumptions made in this report are intended to be a conceptual middle-ground of data from these sources.

- Tow Distance: In coordination with marine transport contractors, tow distances within California are assumed to be feasible. That is, towing between Long Beach and Humboldt or Central California and Humboldt is assumed to be feasible if the wave and wind conditions are met.
- Metocean Criteria Categories: Wave height and wind speed along towing route and at hook-up sites were considered as limiting metocean criteria. Wave period will affect downtime but was not considered at this level of assessment.
- Activities:
    - Installation at WEA:
        - Description: Assumed to include the installation and tensioning of mooring lines. The same vessels that towed the unit are assumed to stay on site to support positioning of the foundation for installation.
        - Background: Installation of floating offshore wind energy areas at the scale assessed in this report has not been conducted globally, and criteria gathered from different sources did not reach a consensus. The installation criteria set in this report are intended to be a reasonable mid-point of several data points. Actual installation criteria will vary based on the equipment and vessels available at the time of installation, foundation and project specific criteria, risk tolerances, and lessons learned as the market and industry develops.
    - Towing to WEA:
        - Description: Towing of the integrated WTG from the wet-storage location within a port, to the WEA for installation. Assumed tow speed is 3 knots (not including any additional weather allowances).
        - Background: Similar to installation at the WEA, there is not a consensus on the number of tugs required for this tow (which may vary depending on foundation), or the limiting wave height/wave period/wind speed. Limiting criteria may change over time.

Towing Routes

The towing and navigation assessment considered eight different towing routes. The routes considered towing from S&I ports in Northern California (Humboldt Bay), Central California (San Luis Obispo Bay), and Southern California (Port of Long Beach) to WEAs in Northern and Central California. In this assessment, the two WEAs designated in the 2022 California wind energy lease sale (Humboldt WEA and Morro Bay WEA) were used as representative locations for Northern and Central California. It should be noted that towing to different areas in each region may produce different results, but it is expected that the results of this assessment will largely be representative of the two regions where future sea space is anticipated to be located.

Table B.1 shows the distance of these routes and the time required for one integrated WTG installation. This assumes a tow speed of 3 knots and a return speed of 7.5 knots. The 3-knot tow speed is an assumed average speed during a 24-hour towing operation and is expected to vary due to external factors such as wind direction, wave condition, or ocean current direction. This includes the time towing the integrated WTG to the installation site at the WEA and the tow spread returning to the S&I site – which is considered one round trip. It should be noted that installation time and downtime are not included in this calculation. Two different tow routes were considered from the Port of Long Beach: one route traveling south of the Channel Islands and one route traveling north of them. The tow routes travelling south of the Channel Islands are labelled as “Alternate.” These routes are shown in Figure B.2 and Figure B.3.

Table B.1. Total vessel time for towing routes

S&I Site	Wind Energy Area	Transit Length [nautical miles]	Round Trip Transit Time [days]
Humboldt Bay	Humboldt WEA	23	0.46
San Luis Obispo	Humboldt WEA	410	7.98
Port of Long Beach	Humboldt WEA	576	11.21
Port of Long Beach (Alternate)	Humboldt WEA	592	11.51
Humboldt Bay	Morro Bay WEA	350	6.81
San Luis Obispo	Morro Bay WEA	59	1.15
Port of Long Beach	Morro Bay WEA	224	4.36
Port of Long Beach (Alternate)	Morro Bay WEA	241	4.69

Figure B.2. Tow routes to Humboldt WEA

Figure B.3. Tow routes to Morro Bay WEA

To add context to tow lengths, Table B.2 includes examples from previous floating offshore wind projects in Europe – Windfloat Atlantic located off the coast of Viana de Costello, Portugal and Kincardine Phase 2 located off the coast of Aberdeen, Scotland.

Table B.2. Tow lengths from other floating offshore wind projects

Floating Offshore Wind Project	Structure Being Towed	Transit Length [nautical miles]
Windfloat Atlantic, Portugal	Floating Foundation	380
Kincardine Phase 2, Scotland	Floating Foundation	780
Windfloat Atlantic, Portugal	Fully Assembled WTG	150
Kincardine Phase 2, Scotland	Fully Assembled WTG	380

As shown above, total vessel times for each route vary significantly. Towing to the Morro Bay WEA from the Port of Humboldt is approximately 6 times longer than towing from San Luis Obispo, and 4 times longer than from the Port of Long Beach. Likewise, the vessel time required to tow to the Humboldt WEA increases by a factor of 17 to 25 when towing from San Luis Obispo and Port of Long Beach, respectively, in comparison to the Port of Humboldt.

Data Sources

Metocean data for assessing each WEA was collected from the National Data Buoy Center (NDBC) buoys. One buoy was selected to represent each region. Figure B.4 shows the selected buoys used for this assessment and their locations relative to the WEAs designated in the 2022 BOEM lease auction. This assessment used 20 years (2003–2022) of NDBC data for Central California wind energy areas (NDBC Buoy 46213), and 19 years (2004–2022) of data for Northern California (NDBC Buoy 46028).

Metocean data for assessing conditions along each route was collected from NDBC and used five years of NDBC data from multiple buoys along a given route. The data considered was from 2017 through 2022. Data from 2019 was omitted due to significant gaps found in the reported wind speeds and wave heights. The California Coast was split into seven zones, with each zone's metocean conditions being represented by one NDBC buoy. The buoys were selected based on location within the zones, water depth with respect to expected tow routes, and quality of available wind and wave data. In some zones, no buoys fulfilled all of these requirements, and so a secondary buoy was selected to fill in any data gaps in the primary buoy's data. Figure B.4 shows the zones used for the assessment and the selected buoys.

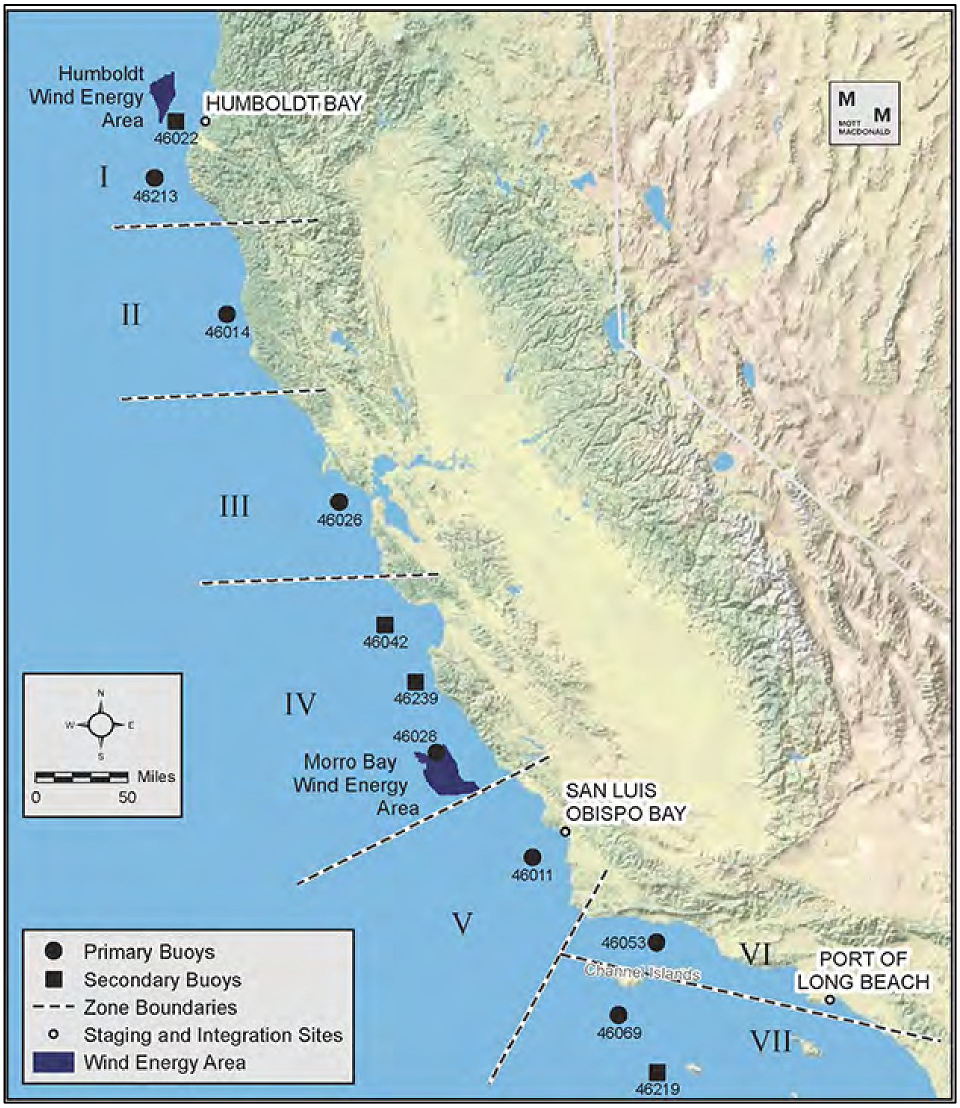

Figure B.4. Buoys used for metocean assessment

Metocean Downtime Analyses

The installation of an integrated WTG is one of the most weather sensitive operations in the development of a WEA. The metocean conditions at the installation site need to meet certain criteria for an extended period of time to allow for the mooring equipment to be hooked up to the integrated WTG. This assessment characterizes the opportunities for these operations in both Northern California and Central California WEAs. This section includes:

- Characterization of monthly wave conditions at the WEAs
- Presentation of assumed operational requirements
- Total annual and monthly installation uptime as a function of limiting wave height criteria

- The average number of distinct installation windows within each month
- The average number of possible tow routes per month between the S&I port and WEA

Assumed Operational Requirements

The assumed operational requirements for towing and installation are included in Table B.3 and Table B.4.

Table B.3. WTG installation criteria

WTG Installation at WEA	Assumed Parameter Value
Limiting Significant Wave Height	2.5 m (8.2 ft)
Limiting Wind Speed	15.4 m/s (30 knots)
Operational Duration	35 hours
Allowances	Up to 8 hours of weather downtime was allowed in addition to this hook-up window, resulting in a maximum window of 43 hours.

Table B.4. WTG towing criteria

WTG Hook-Up at WEA	Assumed Parameter Value
Limiting Significant Wave Height	3 m (9.8 ft)
Limiting Wind Speed	15.4 m/s (30 knots)
Tow Speed	3 knots
Return Speed	7.5 knots
Allowances	50% of towing time was accounted for on top of the tow duration at 3 knots per DNV guidelines.

An example of acceptable hook-up windows is shown in Figure B.5. Though the wave height for the first hook-up window does exceed the hook-up criteria, the exceedance is less than 8 hours and so the hook-up can still occur.

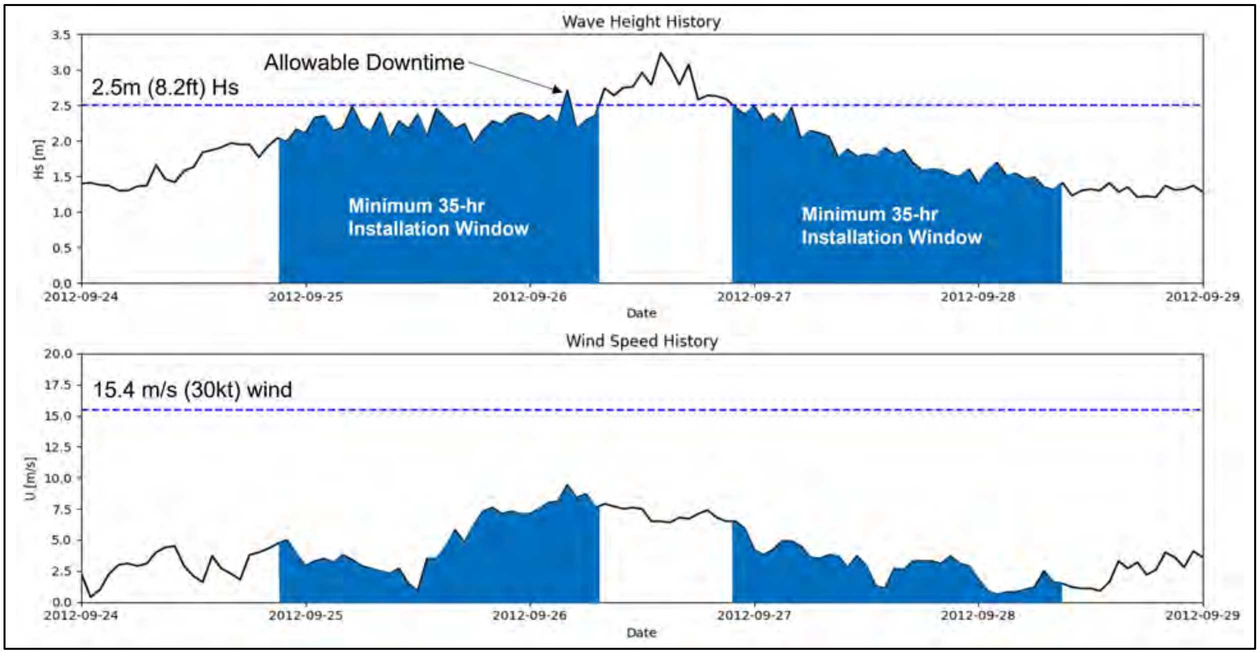

Figure B.5. Example WTG installation window

Wave Conditions at WEAs

The average significant height varies seasonally for both the Central and North Coasts. The wave climate at buoy 46213 (Northern Coast) is typically more energetic than buoy 46028 (Central Coast) with the exception of May and June. The difference is more pronounced in the winter months than in the summer months. The average significant wave height at each WEA is shown in Figure B.6. Wave period will also vary, though it was not a focus of this study, it is expected to be in the range of 8 to 16 seconds, with larger wave periods in more extreme events.

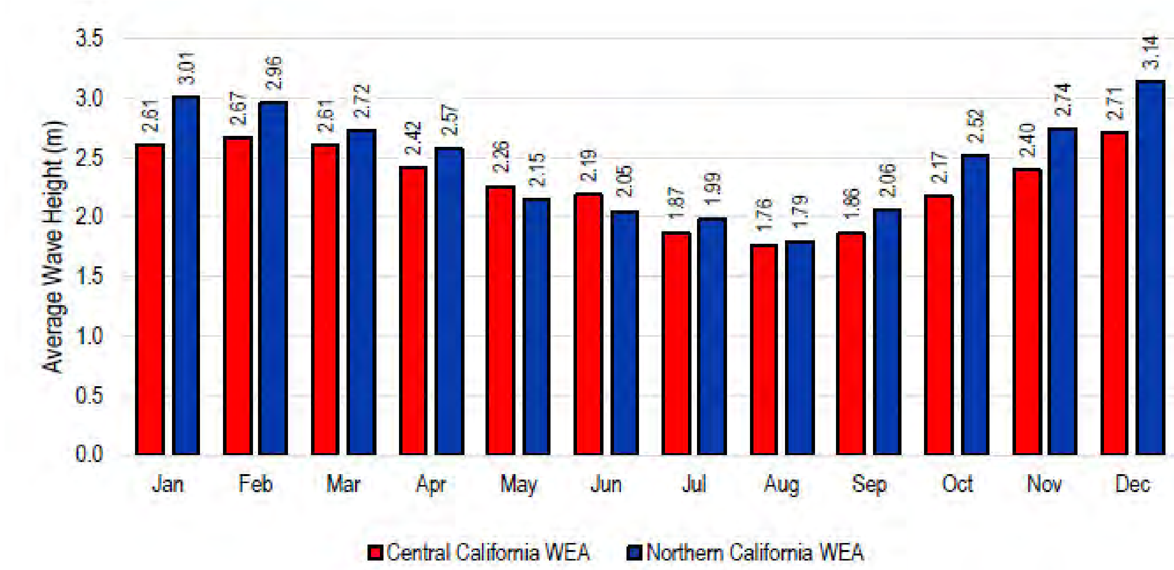

Figure B.6. Monthly average wave height for each WEA region (See Appendix Table C.1. for source data)

Metocean Analysis at WEA

This section evaluates WTG installation opportunities for each month at the WEA. Uptime (or the percentage of time that operations may occur), was estimated both on an annual basis and monthly basis.

Annual installation time at the WEAs based on experienced wave height (installation can occur when waves are less than 2.5m) is presented in Figure B.7. This shows a cumulative distribution plot of the expected uptime at each WEA as a function of limiting significant wave height (Hs). The x-axis shows the significant wave height. The y-axis is the percent likelihood that at any given moment the significant wave height is less than that value. Therefore, it identifies that Central California historically has more potential hook-up uptime than Northern California. For example, for the assumed 2.5m (8.2ft) significant wave height as the limiting criteria for installation, Central California has 67.2% uptime and Northern California has 58.4% uptime.

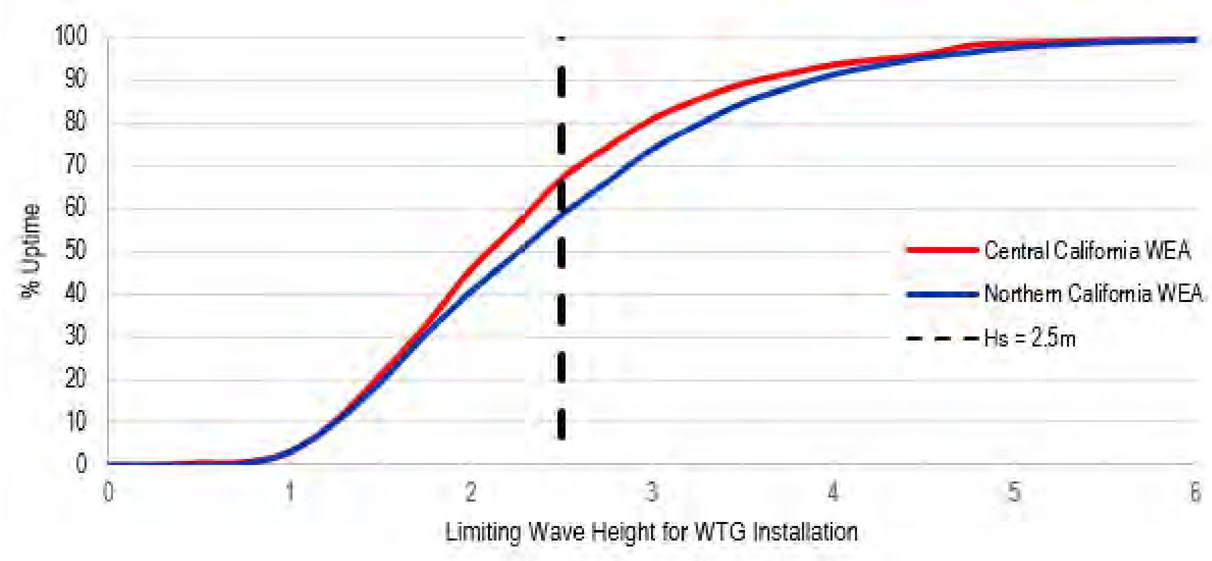

Figure B.7. Average annual installation uptime for each WEA (See Appendix Table C.2. for source data)

Figure B.7 does not consider potential installation windows. As installation operations require 35 hours of favorable metocean conditions with minimal downtime, the total installation uptimes are not directly reflective of the available windows for installation. Figure B.8 shows the number of windows available on average, following the methodology in Figure B.5.

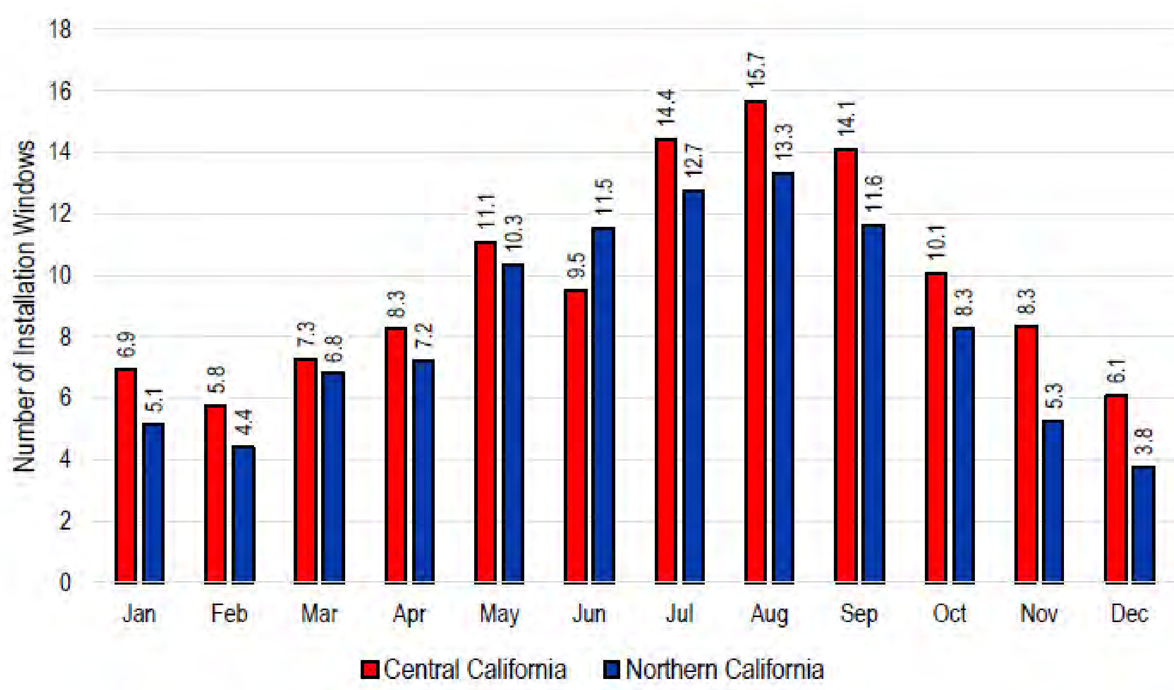

Figure B.8. Average distinct 35-hour installation windows per month (2003-2022) (See Appendix Table C.3. for source data)

Each region is shown to have installation opportunities each month of the year, with Central California posing more opportunities per month. On average, Central California has enough installation windows to maintain pace with the baseline S&I integration rate of one WTG every seven days (equivalent to about 4.3 per month). Northern California, however, shows that the winter months may not have enough installation windows to maintain this pace. Maintaining integration throughput could be achieved by adding wet storage to allow the S&I site to continue operations when towing and installation is limited due to weather. Note that the number of windows presented in Figure B.3 does not consider turbine availability or towing limitations from an S&I site.

Metocean Analysis Along Tow Routes

The next step of this assessment was to estimate the number of successful tows and hook-ups for several potential towing routes. The assessment was conducted by developing a simplified discrete-event simulation analysis in Python. This assessment included the following steps:

- The 5 years of data were assessed for towing and installation availability at 1-hour intervals
- For each of the 8 tow routes, a potential tow was begun at each hour
- The metocean conditions at each 1-hour time step were extracted from the zone which the towing spread was in at that point of the assessment and compared with the towing metocean criteria
- If at any point along the tow route the metocean conditions exceeded the towing criteria, the tow was marked as an unsuccessful tow, as to represent the case where the forecast for wave heights exceeding the limiting criteria, and the tow would have never left the port
- If the tow reached the installation site (Morro Bay WEA or Humboldt WEA), then the assessment checked for a 35-hour window where metocean conditions remained below installation criteria, with a maximum allowable weather downtime of 8 hours (as described in Wave Conditions at WEAs above). If an installation window is found, then the tow was marked as a successful tow

Though the integrated WTG towing and installation assessment was conducted at every hour, the results presented in this section show the number of days in a given month where a successful tow was simulated. Presenting each hour may have resulted in misinterpretation of the number of opportunities each month, as it would be unlikely that up to 24 different tow-outs could occur in a single favorable day, for each hour of the day. The results of this assessment are provided in Figure B.9 and Figure B.10.

These graphs show the average number of days with a successful tow per month, using a 3m (9.8ft) limiting wave height for towing operations. Tows to Humboldt and Morro Bay WEA from Humboldt Bay, San Luis Obispo Bay, and the Port of Long Beach (both through the Santa Barbara Channel, and the alternative route around the Channel Islands).

Days with successful tows were counted if a successful tow began on that day, while the hook-up may occur in the following month due to transit time. This may lead to non-intuitive monthly total comparisons between two routes, where hook-ups may occur on the same day, but the tows were recorded in different months due to the start dates.

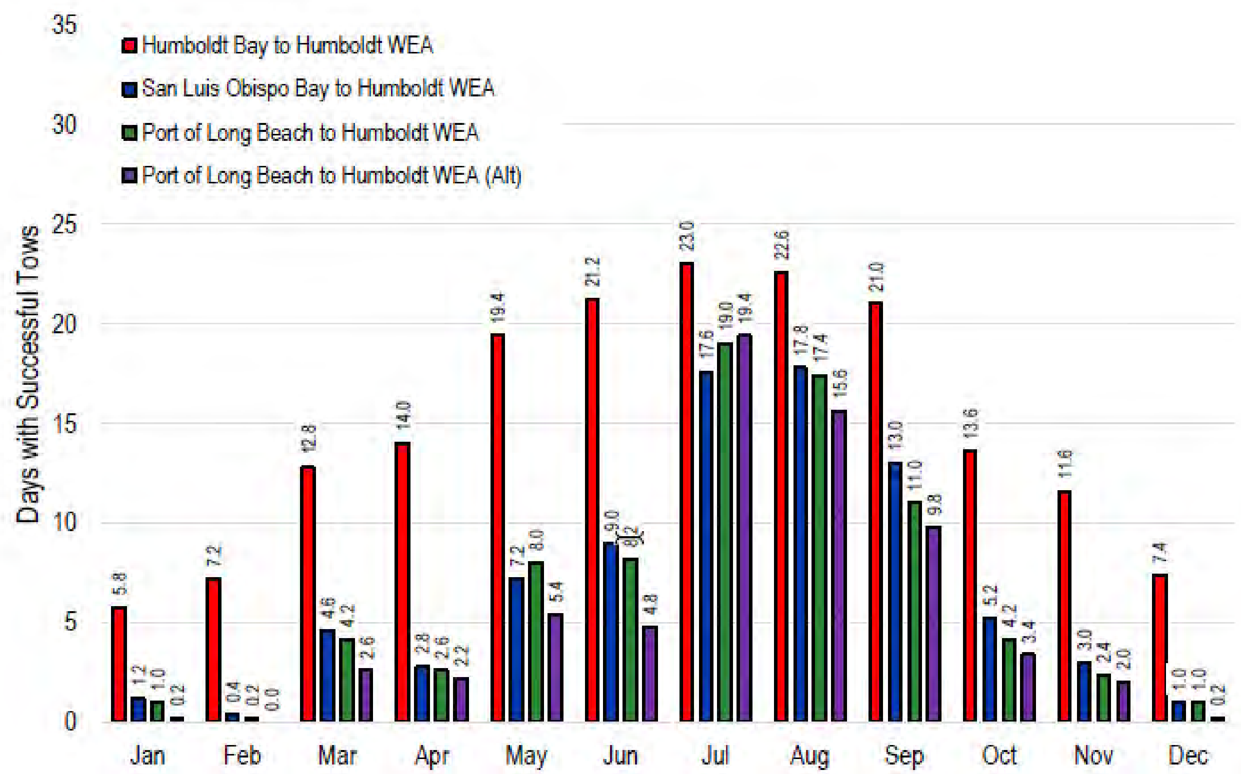

Figure B.9. Average number of days with towing windows to Humboldt WEA, 3m wave towing limitation (See Appendix Table C.4. for source data)

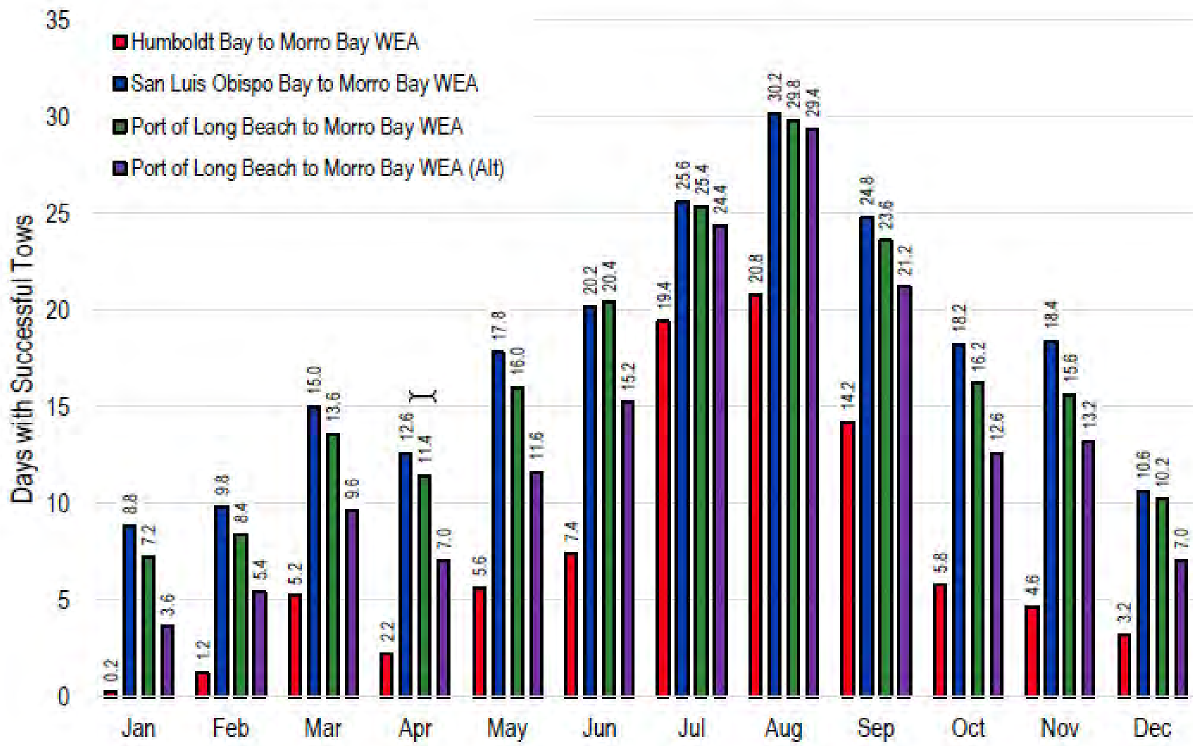

Figure B.10. Average number of days with towing windows to Morro Bay WEA, 3m wave towing limitation (See Appendix Table C.5. for source data)

The results presented in Figure B.9 and Figure B.10 indicate there is significant tow route length dependence on the average number of towing and hook-up windows available.

- Tow routes crossing between North and Central/Southern California:
  - Tow routes from Northern California to Central California, and tow routes from Central/Southern California to Northern California show fewer available windows than towing routes that stay within the same region.
  - These longer tow routes are also shown to be more seasonally dependent, with relatively few windows available in the winter months. For example, there would be on average 1 or fewer days per month between Southern CA/Central CA and Humboldt during December, January, and February, which would meet the study criteria.
- Central and Southern California:
  - There is a small difference in available towing and installation windows when comparing tows from the Port of Long Beach versus tows from the Central Coast of California.
  - Travelling south of the Channel Islands from the Port of Long Beach, as opposed to travelling through the Santa Barbara Channel, results in fewer

installation windows. On average, travelling south of the Channel Islands results in 3.1 fewer tow windows per month when performing installation in Morro Bay WEA and 1.1 fewer tows per month when performing installation in Humboldt WEA.

The analysis presented in Figure B.9 and Figure B.10 is an average over five years, thus the actual number of towing and hook-up windows in a given year will vary. Figure B.11, Figure B.12, Figure B.13, and Figure B.14 show the range of data used to calculate the average values presented in Figure B.9 and Figure B.10. In each figure below, there are sometimes months where no towing window is available for all tow routes.

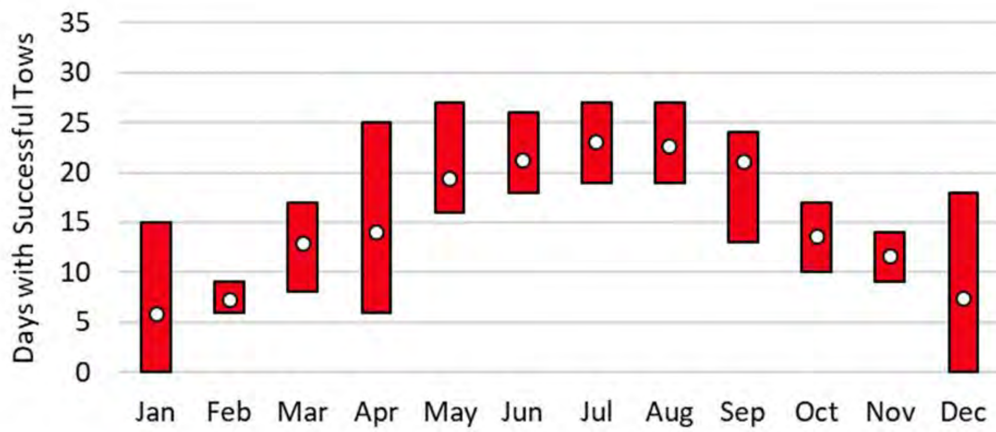

Figure B.11. Range of days by month for five years of data assessed for towing from Humboldt Bay to Humboldt WEA (See Appendix Table C.6. for source data)

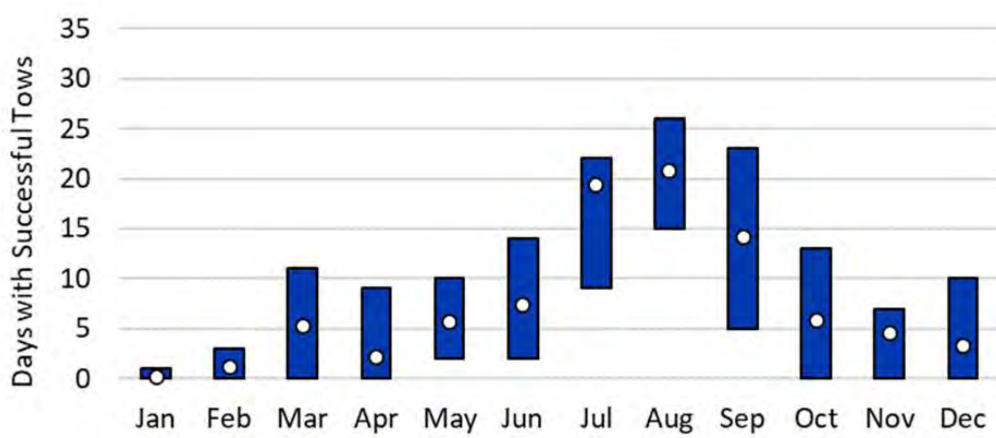

Figure B.12. Range of days by month for five years of data assessed for towing from Humboldt Bay to Morro Bay WEA (See Appendix Table C.7. for source data)

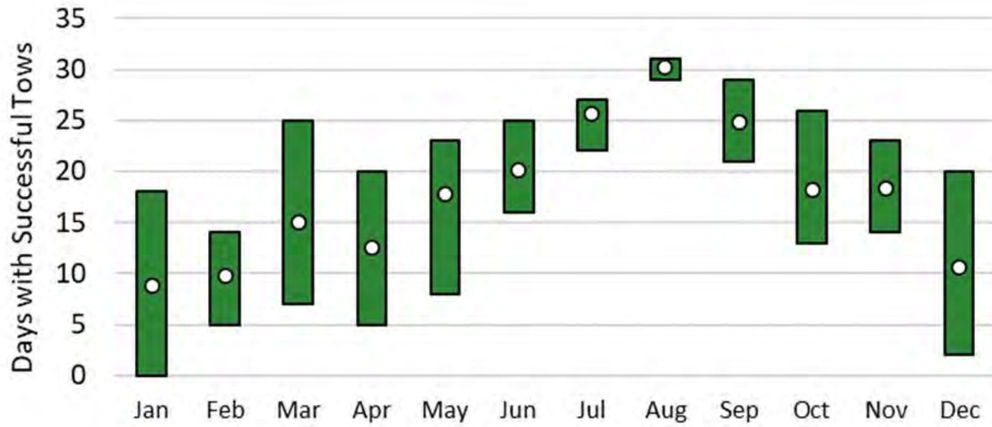

Figure B.13. Range of days by month for five years of data assessed for towing from San Luis Obispo to Morro Bay WEA (See Appendix Table C.8. for source data)

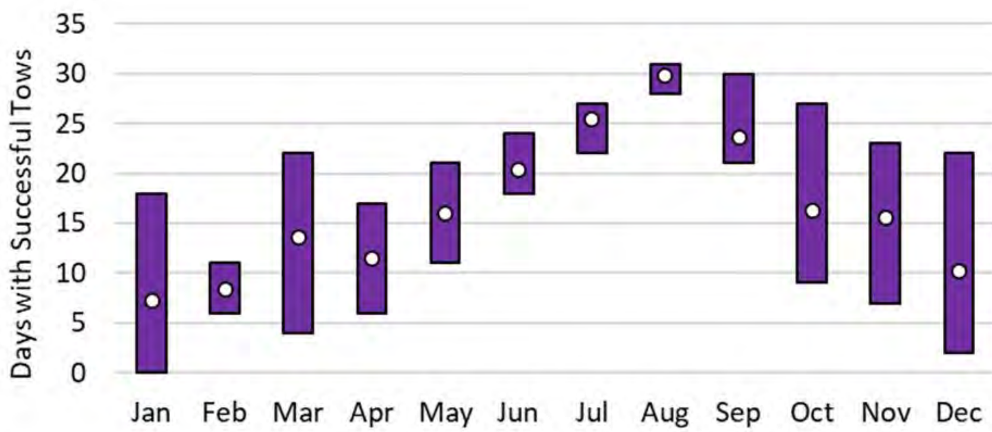

Figure B.14. Range of days by month for five years of data assessed for towing from Port of Long Beach to Morro Bay WEA (See Appendix Table C.9. for source data)

The analysis results presented thus far assume a 3m (9.8ft) maximum towing wave height, however, the actual limiting wave height during hook-up is not well defined. Therefore, a sensitivity test was conducted to provide context as to how a change in this could affect available towing windows. Figure B.15, Figure B.16, Figure B.17, and Figure B.18 show a comparison between available towing and hook-up windows to the Humboldt and Morro Bay WEAs when considering a 3m (9.8ft) and 4m (13.1ft) towing wave limitation. Note that based on contractor and industry engagement, a voyage is unlikely to be planned in 4m seas. This sensitivity assessment is intended to provide an upper limit with the understanding that the conditions limiting towing may be somewhere between 3 and 4 meters.

The data shows that the tow route from Humboldt Bay to the Morro Bay WEA is much more sensitive to wave height than the other routes, and thus any potential increase in towing criteria could result in a significant increase in available towing and hook-up windows.

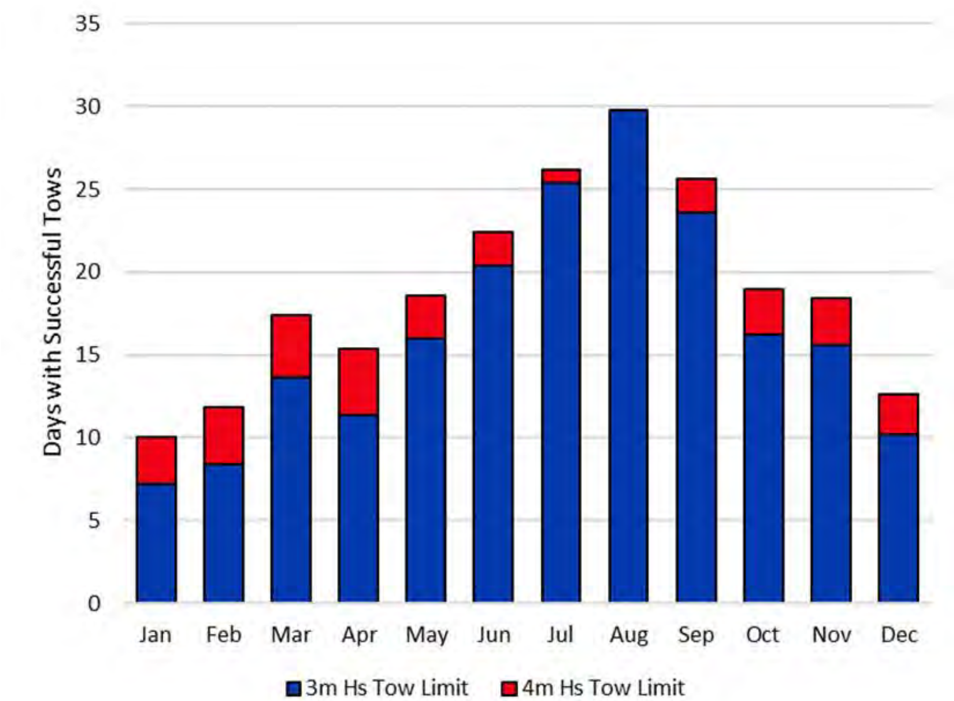

Figure B.15. Wave height limitation sensitivity – Port of Long Beach to Morro Bay WEA (See Appendix Table C.10. for source data)

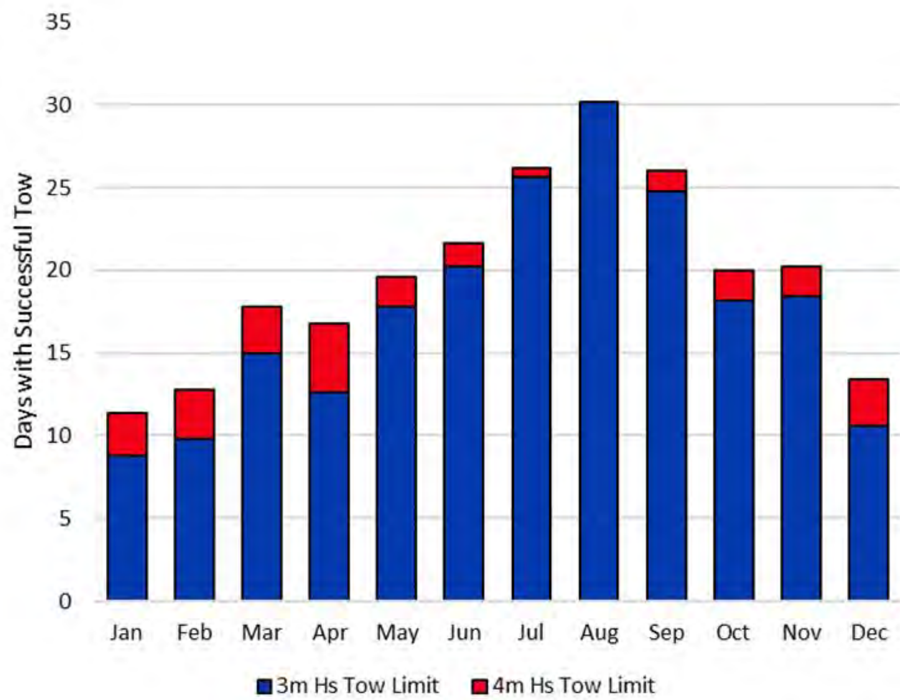

Figure B.16. Wave height limitation sensitivity – San Luis Obiso to Morro Bay WEA (See Appendix Table C.11. for source data)

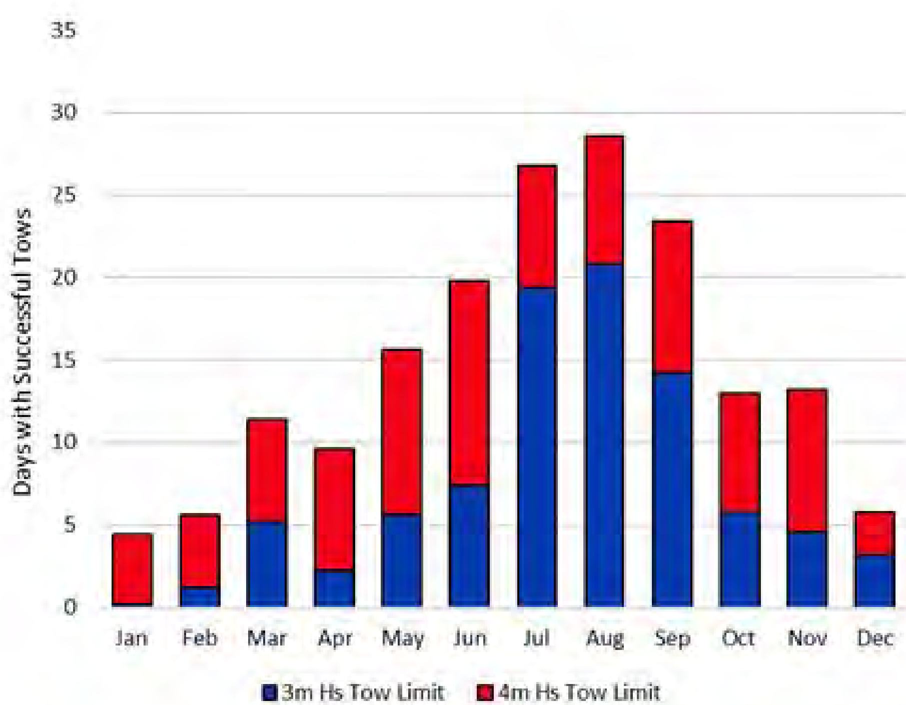

Figure B.17. Wave height limitation sensitivity – Humboldt Bay to Morro Bay WEA (See Appendix Table C.12. for source data)

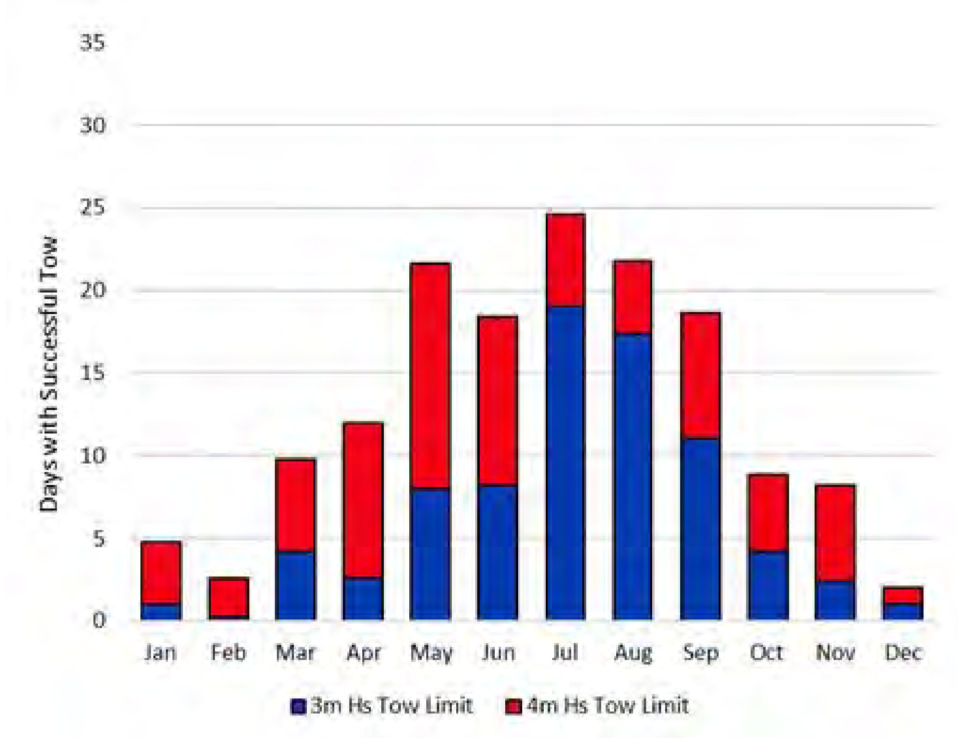

Figure B.18. Wave height limitation sensitivity – Port of Long Beach to Humboldt WEA (See Appendix Table C.13. for source data)

Summary of Metocean Assessment Takeaways

Key Takeaways:

- Seasonal Sensitivity: On average, installation windows are available in each region, each month of the year, though with significantly fewer opportunities in the winter. Following the study criteria, it should be expected that during some years, no tow and installation windows may be available for one or more months per year.
- Effect of Tow Distance: Tow routes between Central/Southern CA and Northern CA are more sensitive to seasonality and metocean conditions than shorter tows and could be limited to a shorter season depending on project specific factors.
- Limiting Criteria: The limiting wave height for towing and installation is a significant driver of how many tows and installation windows are likely available. Wind speed is a less critical limiting criteria.
- Wet Storage and Vessel Availability: The availability of wet-storage and multiple tow spreads (multiple vessel groups to tow a foundation) is likely to be a major factor in order to maintain annual throughput goals, due to reduced operational windows in the winter, and in order to take advantage of more favorable weather windows (assessed in the next section)

- Central Coast Port: There are more likely to be more tow windows from San Luis Obispo Bay to the Morro Bay and Humboldt WEAs than from Long Beach due to the shorter distance. However, the relative increase in available towing windows varies by month and is typically on the order of 0% to 20%.
- Santa Barbara Channel: Transiting south of the Channel Islands (not in the Santa Barbara Channel) has a significant effect on towing windows in the winter, as compared to transiting through the Santa Barbara Channel, which is faster.

Tow Spread Effect on Integrated Towing and Hook-up

As indicated in the Metocean Assessment, there are likely to be limitations on how many favorable tow and installation windows are available by season due to wave climate. However, multiple tow spreads—as shown in Figure B.19—and the use of wet storage at an S&I site may be able to make up for that downtime. Therefore, the objective of this assessment is to determine how the quantity of tow spreads and wet storage affects S&I port deployment rates. This assessment was conducted utilizing the findings from the Metocean Assessment, and within the context of overall deployment goals.

This section discusses methodology, input parameters (fixed and variable), and outputs. Outputs shown include estimates of the total number of tow spreads needed to support certain deployment targets for specific routes, which are then rolled up into estimated total tow spreads needed to support the overall buildout goals for California. It should be noted that the shown throughput levels are meant to represent potential annual targets for each S&I site and that several additional factors may reduce the average annual throughput over a multi-year period.

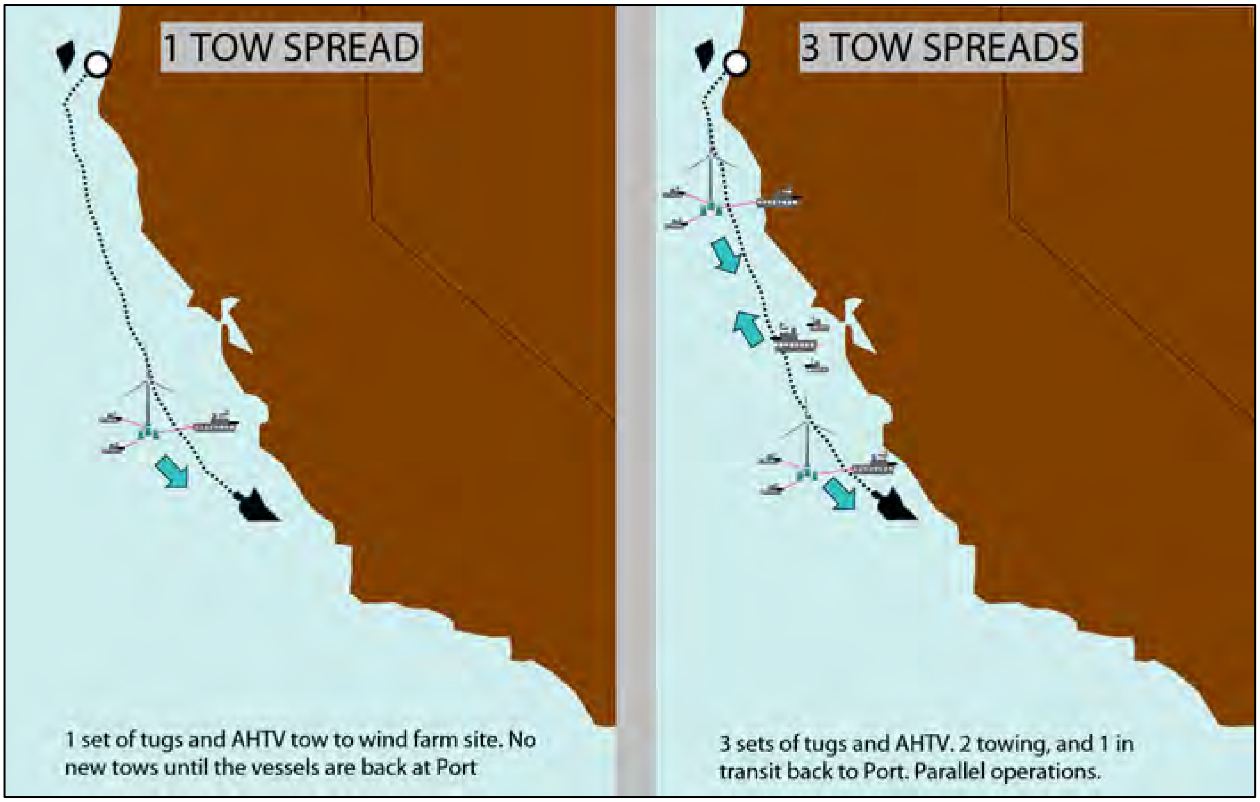

Figure B.19. Schematic of tow spreads

Methodology

The Tow Spread Assessment was a time-based discrete event analysis simulating WTG integration, wet storage, tow-out to WEA, installation, and tow spread return journey. The assessment estimated annual throughput of integrated WTGs, and considered towing and installation weather windows, S&I site operations, port logistics, and tow spread operations. Each towing route was considered in a separate assessment, aligning with the assumption that a single S&I site would be supporting one WEA installation project at a time. The model stepped through time and at each time step checked if a tow and installation could occur, based on established criteria. The simulation continued for the full 5 years of data, and all successful tows were recorded. The following general assumptions were made:

- WTGs were integrated at a steady rate at an S&I site
- An S&I site had a limited amount of wet storage to store WTGs if a weather window was not available, or if a towing spread was not available
- An S&I site had a limited number of tow spreads to perform towing and installation operations
- S&I sites operated year-round with no long-term downtime for turbine maintenance activities or seasonal operations

In addition to the availability of a towing window determined in the Metocean Assessment, several other criteria were required before a tow could occur:

- An integrated WTG was available in wet storage
- A tow spread was available in port
- A tow was allowed at that time per port-specific limitations

The same criteria for towing and hook-up presented in Table B.3 and Table B.4 were applied for towing operations in the marine spread assessment. As with the Metocean Assessment, the Humboldt WEA and Morro Bay WEA were used to represent the Northern and Central Coast regions of California. Results of the assessment would vary for future WEAs within the same region.

Inputs and Outputs

The towing assessments for each route were conducted using a set of constant inputs, along with variable inputs to characterize sensitivity. Constant inputs are simulation parameters used for each tow spread simulation. The tow spread makeup, tow speed and allowances, and towing/installation criteria were assumed consistent for all routes considered in the assessment. Each S&I port had different logistical considerations, which were consistent for all routes leaving that port.

Humboldt Bay is assumed to only average one tow per day out of port due to wave and tidal conditions of the bar.

Table B.5 shows the constant inputs for the tow spread assessment and The variable parameters listed below were tested to evaluate sensitivity on the number of WTGs, and therefore total MW (megawatt) each S&I site would be able to support, considering the fixed assumptions above. The key input for interpreting how the results relate to the total California deployment goals is the number of tow spreads. While the output for each simulation is the total throughput for that given scenario, the number of tow spreads required to meet that throughput will be how each S&I port is compared.

The wet storage variable represents total wet storage available in a given port. The wet storage available to a single S&I site will depend on both total wet storage and number of S&I sites in that port. Wet storage assumptions for Humboldt Bay and Port of Long Beach were based on the announced projects for each port. Wet storage assumptions for Central California S&I sites were based on estimates for potential S&I sites.

This assessment assumes year-round operations for each S&I site. It should be noted that these operations assume that navigation channels are not closed due to sedimentation for any significant portion of time and that any maintenance dredging for this area is completed to maintain operability during all months of the year.

Table B.6 shows the variable inputs. The parameters shown made up the total assessment matrix.

Constant Inputs

Constant inputs are simulation parameters used for each tow spread simulation. The tow spread makeup, tow speed and allowances, and towing/installation criteria were assumed to be consistent for all routes considered in the assessment. Each S&I port had different logistical considerations, which were consistent for all routes leaving that port.

Humboldt Bay is assumed to only average one tow per day out of port due to wave and tidal conditions of the nearby sand bar. If two S&I sites are operating within the port, availability is assumed to be shared, thus only one of the S&I site will be able to make a tow each day.

Table B.5. Constant inputs for tow spread assessment

Constant Inputs	Assumptions
Tow Speed/Duration	3 knots. 50% increase on towing times is assumed per DNV voyage planning guidance (DNVGL-ST-N001).
Hook-Up Criteria	35 hours, 2.5m Hs, 30-knot wind
Towing Metocean Criteria	3m Hs, 30-knot wind
Tow Spread Makeup	1 AHTV, 2 ocean tugs
Port Logistical Limitations	Humboldt: Maximum of 1 tow per day total for the port San Luis Obispo: Minimum 6 hours between tows, maximum of 2 tows per day Port of Long Beach: Minimum 6 hours between tows for each S&I site, maximum of 2 tows per day for each S&I site

Variable Inputs (Sensitivity Testing)

The variable parameters listed below were tested to evaluate the effects of sensitivity on the number of WTGs, and therefore the total MW (megawatt) that each S&I site would be able to support, considering the fixed assumptions above. The key input for interpreting how the results relate to the total California deployment goals is the number of tow spreads. While the output for each simulation is the total throughput for that given scenario, the number of tow spreads required to meet that throughput will be used to compare how each S&I port is compared.

The wet storage variable represents total wet storage available in a given port. The wet storage available to a single S&I site will depend on both total wet storage and number of S&I sites in that port. Wet storage assumptions for Humboldt Bay and Port of Long Beach were based on the announced projects for each port. Wet storage assumptions for Central California S&I sites were based on estimates for potential S&I sites.

Table B.6. Variable inputs for Tow Spread Assessment

Variable Inputs	Assumptions
Number of Tow Spreads	1 – 6 Tow Spreads
Wet Storage	Humboldt Bay: 5 or 10 WTGs Port San Luis: 2 or 5 WTGs Port of Long Beach: 20 WTGs
WTG Integration Rates	5, 7, or 10 Days per WTG
Number of S&I Sites in One Port	Humboldt Bay: 1-2 S&I sites San Luis Obispo: 1 S&I site Port of Long Beach: 1-3 S&I sites

Outputs

The two primary outputs from the Tow Spread Assessment are:

- Average Annual Throughput: For each assessment, the average number of WTG hook-ups per year over the five (5) assessed years is calculated. These results can be compared with annual throughput targets using an assumed average turbine rating for that route.
- Estimated Tow Spread Requirements: The estimated number of tow spreads required to meet annual throughput goals is calculated by using assumed WTG ratings, annual average throughput results for each assessment, and available tow spread input.

Tow Spread Analysis Outputs

This section provides results of the analysis to estimate the WTG integration and installation throughput for different S&I sites and WEAs considering variable tow spreads. In addition to the variable number of tow spreads, the parameters in Table B.7 have been tested across various scenarios to evaluate sensitivity. The results of this assessment are intended to support how many tow spreads may be needed to meet various deployment goals, considering variable inputs, and the context behind the ranges developed.

Included in this section are:

- Baseline: A set of assessments using baseline criteria, where the only variables are the number of tow spreads
- Sensitivities: A set of assessments varying the baseline criteria. Parameters checked for sensitivity were available wet storage, and WTG integration rate.

Baseline Assessment

This section includes assessment of throughput relative to increasing numbers of tow spreads following the baseline assumption criteria. The assessment has been segmented into two time periods:

- Pre 2035: This assumes that up until 2035, S&I sites are located at Humboldt Bay and the WTG size is 15 MW. All departure points are from Humboldt Bay, see Figure B.20.
- Post 2035: This assumes that after 2035, additional S&I sites are online and available for offshore wind industry use and the WTG size is 20 MW. Departure points may be from Humboldt Bay, San Luis Obispo Bay, or Port of Long Beach[1], see Figure B.21.

Results of the assessment for these time periods are included in Figure B.20, Figure B.21, and Figure B.22. These figures represent estimated throughput for a single S&I site, and so additional sites at each port would result in more output from that port. Each of these three figures applies the following constant criteria to each scenario.

Table B.7. Baseline parameters for Tow Spread Assessment

Constant Inputs - Baseline	Assumptions
Limiting Tow Conditions	Hs < 3m (9.8ft), Wind Speed < 30 knots
Hook-Up Criteria	35 hours, Hs < 2.5m (8.2ft), Wind Speed < 15.4 m/s (30 knots), 8 hours of allowable downtime
Port Logistics Limitations	Humboldt: Maximum of 1 tow per day total for the port San Luis Obispo: Minimum 6 hours between tows, maximum of 2 tows per day Port of Long Beach: Minimum 6 hours between tows for each S&I site, maximum of 2 tows per day for each S&I site
Wet Storage	Humboldt Bay: 10 WTGs San Luis Obispo: 5 WTGs Port of Long Beach: 20 WTGs
Seasonality of WTG Integration	Year-round
WTG Integration Rates	1 WTG integrated along the wharf every 7 days

[1] Since this assessment, the Port of Long Beach has released a concept study stating that 200 acres will be ready for industry use by 2031 (POLB 2023). This will serve to further help the state achieve its offshore wind planning goals.

Pre 2035 – Baseline

Figure B.20 shows the potential number of WTG installations that are estimated to occur per year as a function of the number of tow spreads available, for either the Humboldt WEA or the Morro Bay WEA. All tows in this figure originate from Humboldt Bay. Figure B.20 shows:

- Humboldt WEA: The throughput is not sensitive to increased tow spreads. A single tow spread is likely sufficient for each S&I site supporting projects in the Humboldt WEA.
- Morro Bay WEA: Throughput is sensitive to the number of tow spreads. More tow spreads will likely improve annual throughput to a certain extent. Returns begin to diminish as other factors, such as wet storage and available towing windows, begin to limit the annual throughput. If baseline conditions are assumed, each project in Morro Bay WEA with staging out of Humboldt Bay may need 3 or more tow spreads to take advantage of favorable weather windows and install 35 to 40 WTGs per year.

Table B.8. Humboldt S&I: Conceptual Marine Spread Requirements for Single S&I Site, Base Case Scenario

S&I Port	WEA	Tow Limit	WTG Rate	Season	Wet Storage
Humboldt Bay	Variable	3m Hs	7 Days/WTG	Full Year	High

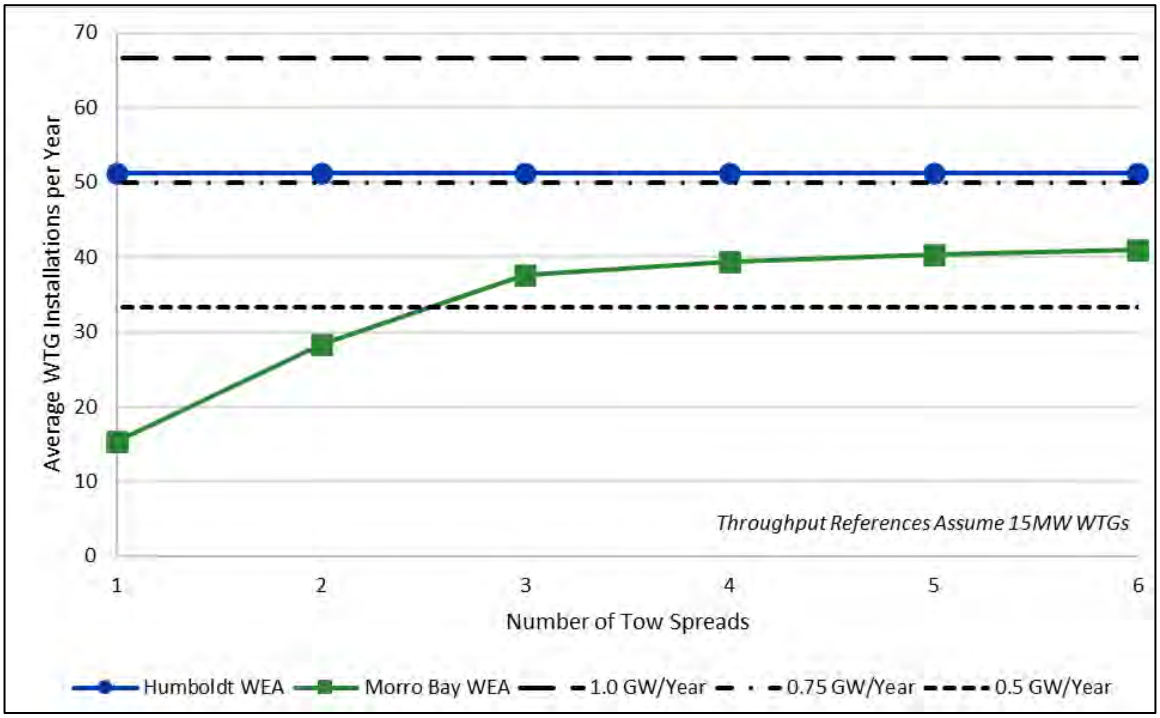

Figure B.20. Average WTG installations per year for one S&I site from Humboldt Bay to either Morro Bay or Humboldt WEAs (See Appendix Table C.14 for source data)

Post 2035 – Baseline

Figure B.21 shows the estimated potential throughput for different S&I ports supporting the Humboldt WEA, with increasing numbers of tow spreads. This is different than the Pre-2035 assessment where the assessment focused on how an S&I port in Humboldt could serve different WEAs. Figure B.21 shows:

- Humboldt Bay: The throughput is not sensitive to increased tow spreads. A single tow spread is likely sufficient for each S&I site supporting projects in the Humboldt WEA and will perform over 50 installations per year. This may differ for other future lease areas from Humboldt Bay.
- San Luis Obispo: Throughput is sensitive to number of tow spreads. More tow spreads will likely improve annual throughput. The assumed wet storage will limit ultimate throughput, and 3 to 4 tow spreads will likely be needed to reach 35 WTG installations per year.

- Port of Long Beach: Throughput is sensitive to the number of tow spreads and returns for additional spreads do not diminish until utilizing 6 or more tow spreads. Throughput from Port of Long Beach is likely to not be able to match that of Humboldt Bay to support the Humboldt WEA. However, utilizing multiple tow spreads can bring the throughput estimate relatively close, to about 45 WTGs per year. Travelling around the Channel Islands will likely reduce throughput in all scenarios for this route.

Table B.9. Humboldt WEA: Conceptual Marine Spread Requirements for Single S&I Site, Base Case Scenario

S&I Port	WEA	Tow Limit	WTG Rate	Season	Wet Storage
Variable	Humboldt	3m Hs	7 Days/WTG	Full Year	High

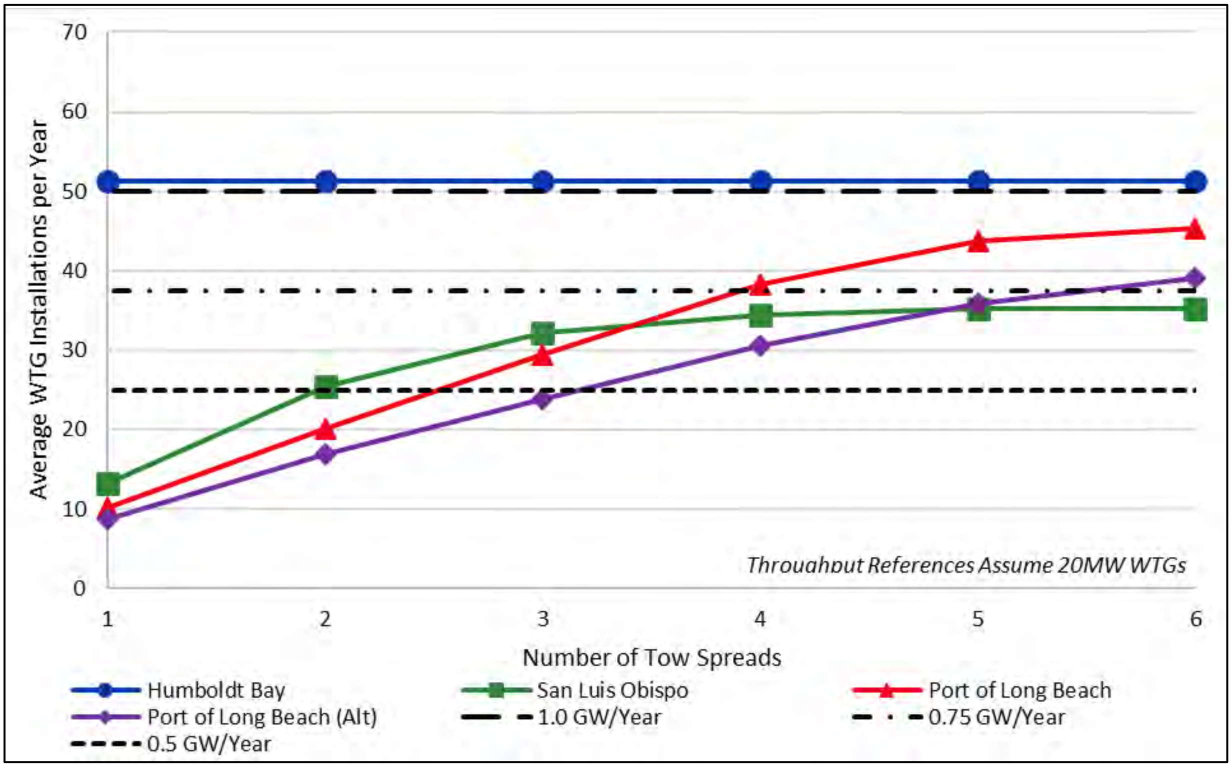

Figure B.21. Average WTG installations per year at Humboldt WEA from one S&I site from different ports (See Appendix Table C.15 for source data)

Figure B.22 shows the estimated potential number of WTG installations for the Morro Bay WEA per year based on the number of tow spreads available. Tows originating from each considered port are included in this figure. Figure B.22 shows:

- Humboldt Bay: Throughput is sensitive to number of tow spreads. More tow spreads will likely improve annual throughput. If assuming the baseline conditions, each project in Morro Bay WEA with staging out of Humboldt may need 3 or more tow spreads to take advantage of favorable weather windows and install 35 to 40 WTGs per year.

- San Luis Obispo: Throughput is not sensitive to increased tow spreads. A single tow spread is likely sufficient to support an S&I site supporting projects in Morro Bay WEA and install 50 or more WTGs per year.
- Port of Long Beach: Throughput is sensitive to the number of tow spreads when increasing from one to two spreads and is not sensitive to any further increases in tow spreads. Traveling around the Channel Islands reduces throughput when using one tow spread but does not show much difference when using more. One tow spread is likely to be able to support a single S&I site at Port of Long Beach towing to Morro Bay WEA for lower deployment scenarios, but two tow spreads will likely be able to match throughput from San Luis Obispo at 50 or more WTGs per year.

Table B.10. Morro Bay WEA: Conceptual Marine Spread Requirements for Single S&I Site, Base Case Scenario

S&I Port	WEA	Tow Limit	WTG Rate	Season	Wet Storage
Variable	Morro Bay	3m Hs	7 Days/WTG	Full Year	High

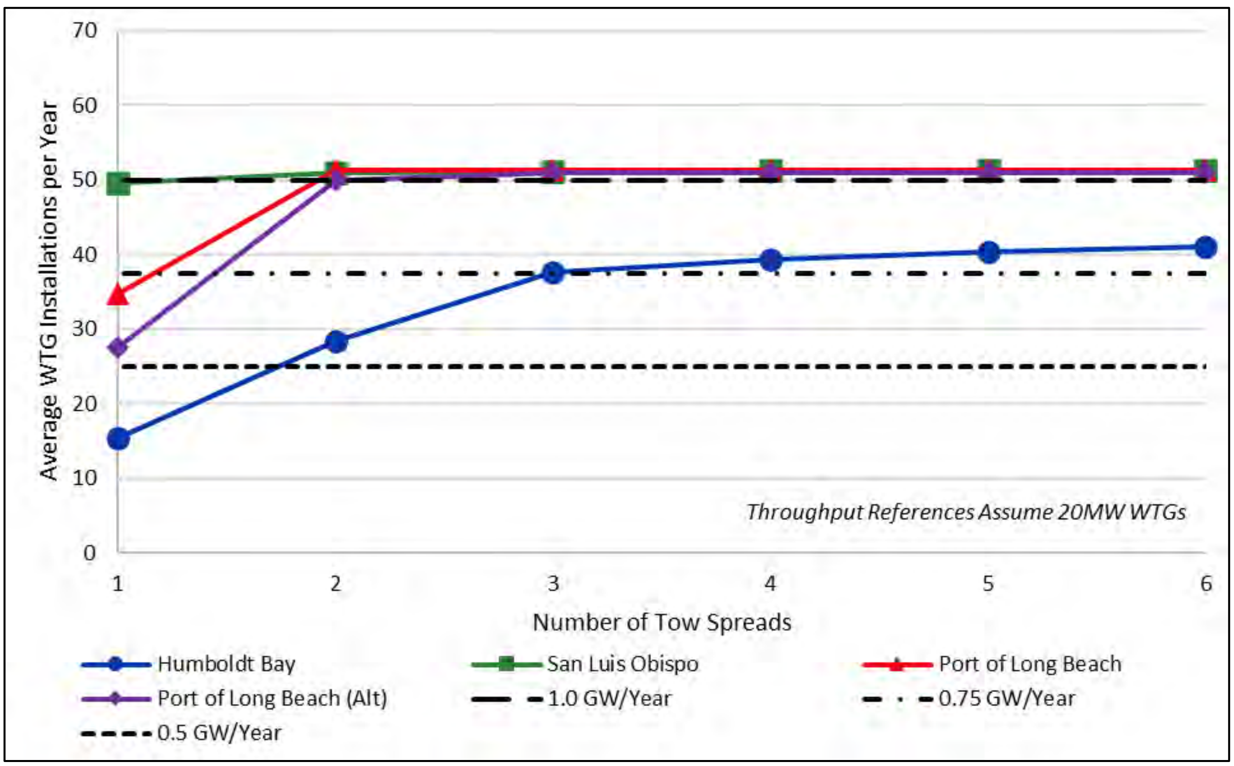

Figure B.22. Average WTG installation per year at Morro Bay WEA from one S&I site from different ports (See Appendix Table C.16 for source data)

Baseline Conditions Takeaways

Listed below are the major takeaways from the Baseline Condition Tow Spread Assessment:

- First Round Projects (Pre-2035): The Port of Humboldt S&I sites appear to be able to support projects either in Northern or Central California. This assumes wet storage is sufficient, enough marine spreads are available, and the navigation channel is not constrained due to parameters outside this assessment (such as sedimentation).
- First Round Projects (Pre-2035): Installing over 2 GW by the end of 2030 may be possible if the first S&I site in Humboldt Bay is operational by the beginning of 2028 and most WTGs are installed in the Northern WEAs. This would only occur under the most optimistic range of assumptions in this assessment. Achieving this goal is less likely if:
  - The S&I site becomes operational later than this
  - The S&I site primarily supports the Central Coast WEAs, or
  - Any long-term integration downtime is expected due to maintenance activities or seasonal operations
- Future Projects (Post 2035): The construction of additional S&I sites will allow for greater annual throughput, if wet storage is sufficient and enough marine spreads are available. S&I sites in the Central Coast or Port of Long Beach could likely support development in Northern California. Utilizing three or more S&I port sites (>80 acres each) may have the potential to supply a rate of WTG installation that can meet the State's deployment goal of 25 GW by 2045. However, additional factors such as downtime between projects, seasonal operations, and dedicated time for maintenance at S&I sites may necessitate the need for up to five total sites.
- Tow Spread Effect on Throughput: Increasing the available tow spreads generally increases annual throughput, but the returns eventually diminish due to wet storage limitations and availability of towing windows. Compared to longer tow routes, shorter tow routes have less benefit from additional towing spreads. This is due to towing and installation time not being a driving factor for throughput.
- Tow Route Distance: Tow routes that transit between Northern and Central/Southern California are shown to require more tow spreads than routes that remain in the same region, such as the route between Humboldt Bay and Humboldt WEA, due to the increased probability of encountering higher wave conditions on longer journeys. The tow routes between regions will also require more wet storage than routes that remain in the same region, as downtime considering weather windows may be longer. With additional tow spreads and

sufficient wet storage, tow routes going between regions may meet annual throughput rates needed to meet state offshore wind planning goals.

- Central and Southern California: While towing to both Morro Bay and Humboldt WEAs, similar throughput goals can be achieved from either Central or Southern California. While the towing distance is shorter for routes to both regions from San Luis Obispo when compared to the Port of Long Beach, the significant wet storage at Port of Long Beach allows for more flexibility and compensates for the added distance.

The baseline parameters for wet storage and WTG integration rate were assumed based on input from developers and other industry sources. However, to better understand the effects of these parameters a sensitivity study was conducted and is presented below.

Sensitivity Assessment

Several factors significantly affect the total throughput for various routes, such as:

- Wet storage availability at a port
- WTG integration rate of a single S&I site

Wet Storage

Figure B.23 and Figure B.24 show the wet storage sensitivity of towing and installation operations to Humboldt WEA and Morro Bay WEA, respectively. It should be noted that at the Port of Long Beach and Humboldt Bay, the reduced wet storage for a single S&I site is a result of more than one S&I site operating out of the port. Humboldt Bay and San Luis Obispo also have sensitivity applied to the total wet storage available at the port. The two lines plotted for each port represent the high and low expected cases for wet storage at a single S&I site.

Generally, wet storage allows for more flexibility if towing and installation windows are scarce. Increased wet storage will typically support more annual throughput, if enough tow spreads are available to take advantage of these windows.

Figure B.23 shows the estimated average number of WTG installations at Humboldt WEA as a function of the number of tow spreads and wet storage available. Both the maximum and minimum assumed available wet storage for a single S&I site are shown. This plot shows:

- Humboldt Bay to Humboldt WEA: Annual throughput has a low sensitivity to the number of tow spreads used for this route; only one tow spread is likely needed to keep pace with WTG integration. In addition, wet storage has a relatively minor effect on annual throughput for this route, with the throughput reducing 5 to 10% when comparing the higher and lower assumed available wet storage numbers.

- San Luis Obispo to Humboldt WEA: Due to the larger tow distance than the route from Humboldt Bay, annual throughput is shown to have a relatively high dependence on the number of tow spreads used and available wet storage. If wet storage capacity is more limited in this area, the total throughput potential is lower than that of Port of Long Beach or Humboldt Bay.
- Port of Long Beach to Humboldt WEA: Due to the length of the tow, annual throughput is shown to have a relatively high dependence on the number of tow spreads used and available wet storage. The total amount of available wet storage (20+ berths) allows for more annual throughput when serving the North Coast than San Luis Obispo (assumed to have between 2-5 berths), despite the tow route being longer.

Table B.11. Humboldt WEA: Sensitivity to Wet Storage for Single S&I Site

S&I Port	WEA	Tow Limit	WTG Rate	Season	Wet Storage
Variable	Humboldt	3m Hs	7 Days/WTG	Full Year	High

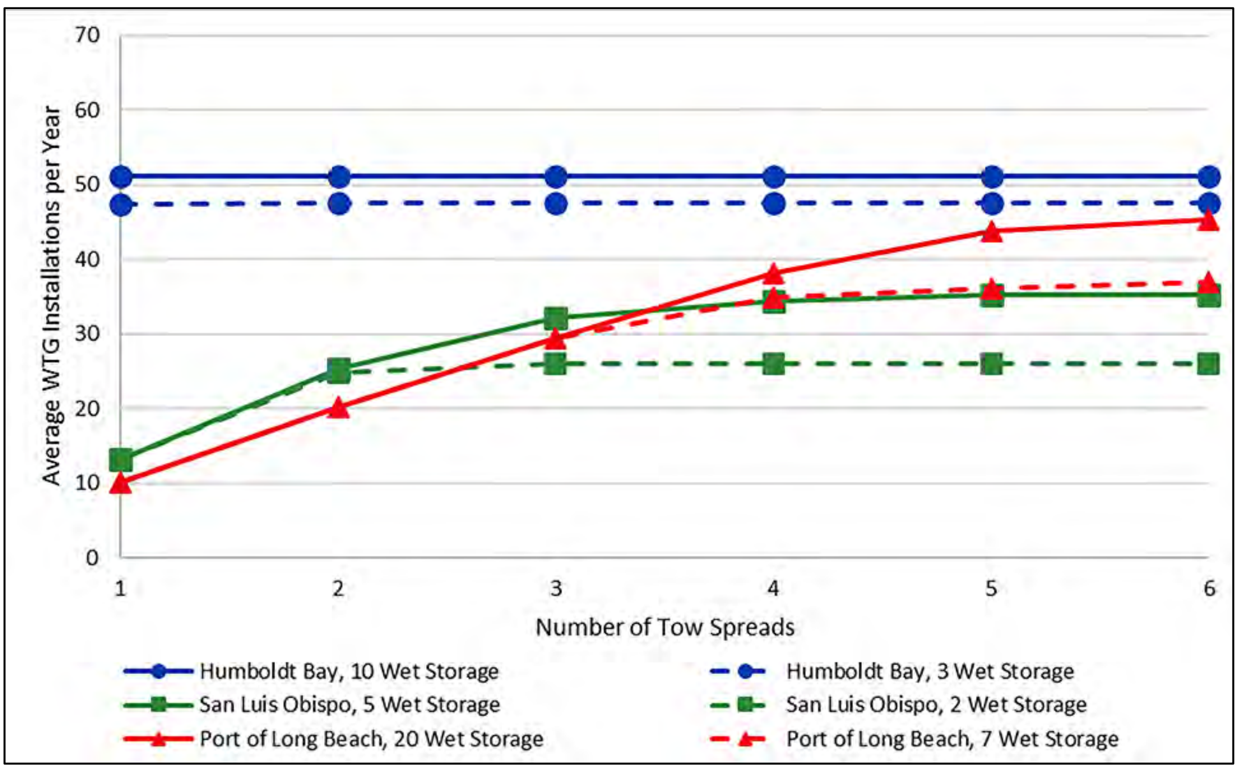

Figure B.23. Wet storage sensitivity of towing and installation to Humboldt WEA from one S&I site from different ports (See Appendix Table C.17 for source data)

Figure B.24 shows the potential number of WTG installations that are estimated to occur per year at Morro Bay WEA as a function of the number of tow spreads and wet storage available. Results assuming both the maximum and minimum assumed available wet storage for a single S&I site are shown. Figure B.24 shows:

- Humboldt Bay to Morro Bay WEA: Due to the long tow distance from Humboldt Bay to Morro Bay WEA, annual throughput is shown to have a relatively high dependence on the number of tow spreads used and available wet storage. Limited wet storage may result in as much as a 25% reduction in annual throughput.
- San Luis Obispo to Morro Bay WEA: Wet storage is shown to have some effect on the throughput when supporting Morro Bay WEA. High annual throughput can be achieved with either wet storage, though using two wet storage spots instead of five is shown to reduce throughput by an estimated 5 to 10%.
- Port of Long Beach to Morro Bay WEA: Wet storage is shown to have minimal effect on throughput to Morro Bay WEA. These results show that seven wet storage spaces versus twenty per S&I site provide similar results and is sufficient when supporting Morro Bay WEA.

Table B.12. Morro Bay WEA: Sensitivity to Wet Storage for Single S&I Site

S&I Port	WEA	Tow Limit	WTG Rate	Season	Wet Storage
Variable	Morro Bay	3m Hs	7 Days/WTG	Full Year	High

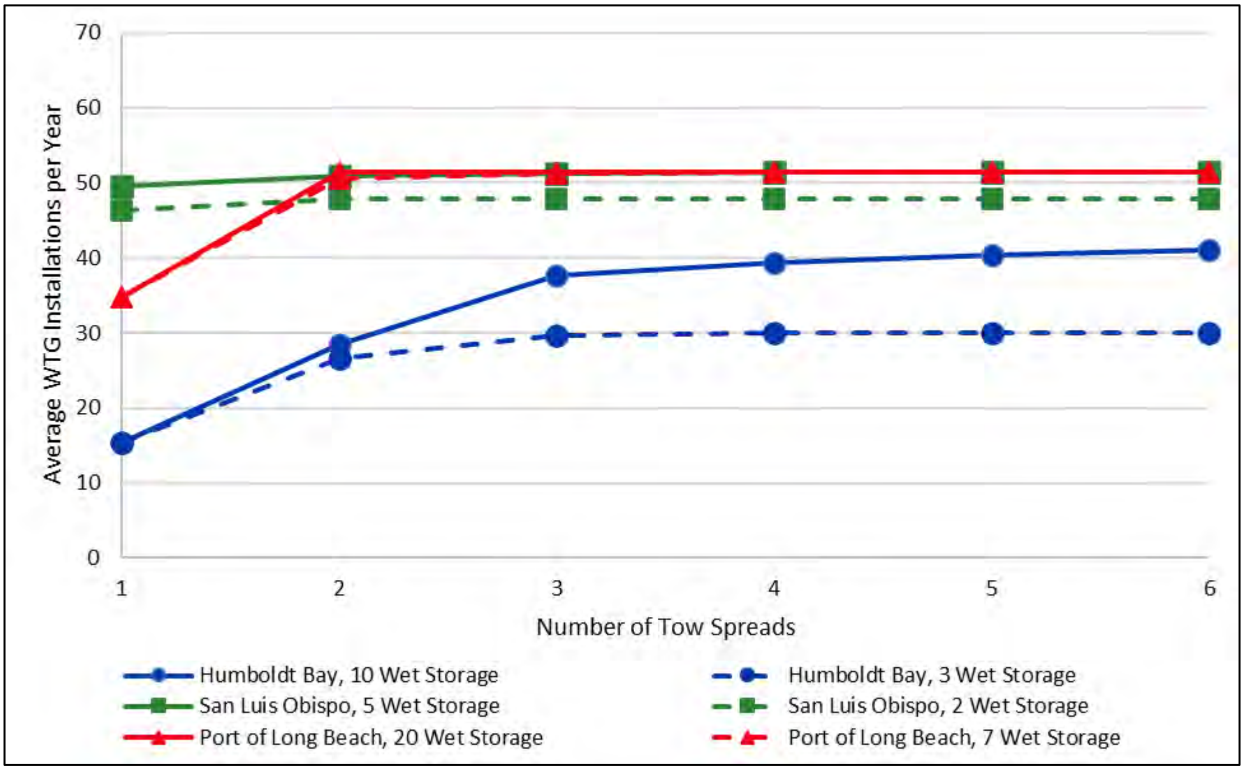

Figure B.24. Wet storage sensitivity of towing and installation to Morro Bay WEA from one S&I site from different ports (See Appendix Table C.18 for source data)

Figure B.23 and Figure B.24 show that the wet storage becomes a more critical factor for longer towing routes. Tow routes within the same region, such as Humboldt Bay to Humboldt WEA and Port of Long Beach to Morro Bay WEA, do not see a significant change in annual throughput with reduced wet storage. The results do show that Humboldt Bay is more sensitive to reduction in wet storage for tow routes within the same region, due to the more challenging metocean conditions and limiting port logistic factors in this area. When wet storage is reduced, longer routes such as San Luis Obispo to Humboldt WEA, can see a reduction of annual throughput of up to 25%.

WTG Integration Rate

The final integration rate at an S&I site will depend on several variables and at this point in time is not very well established. Therefore, sensitivity to the integration rate at each S&I site was conducted, see Figure B.25. For this assessment, the baseline integration rate of seven days per WTG is compared with both faster and slower rates. Figure B.25 shows the estimated average number of WTG installations at Humboldt

WEA as a function of the number of tow spreads available, assuming three different integration rates per S&I site. Figure B.25 shows:

- General: The integration rate is a controlling factor in the annual throughput of an S&I site. Changing this value will typically have a significant impact on the rate for any S&I site. The integration rate will likely be the main limiting factor in annual throughput, unless other limitations, such as too few tow spreads or scarce towing and installation weather windows, become severe.
- Humboldt Bay: Annual throughput is sensitive to the WTG integration rate when using any amount of tow spreads. Due to the short tow distances, tow spreads are usually available, and the limiting factor is the integration rate, so the integration rate is about equal to the towing and installation rate.
- San Luis Obispo: Integration rate becomes a limiting factor only when three or more tow spreads are used, as the tow spread availability drives the possible annual throughput before that point.
- Port of Long Beach: Integration rate becomes a limiting factor only when four or more tow spreads are used, as the tow spread availability drives the possible annual throughput before that point.

Table B.13. Humboldt WEA: Sensitivity to WTG Integration Rate for Single S&I Site

S&I Port	WEA	Tow Limit	WTG Rate	Season	Wet Storage
Variable	Humboldt	3m Hs	7 Days/WTG	Full Year	High

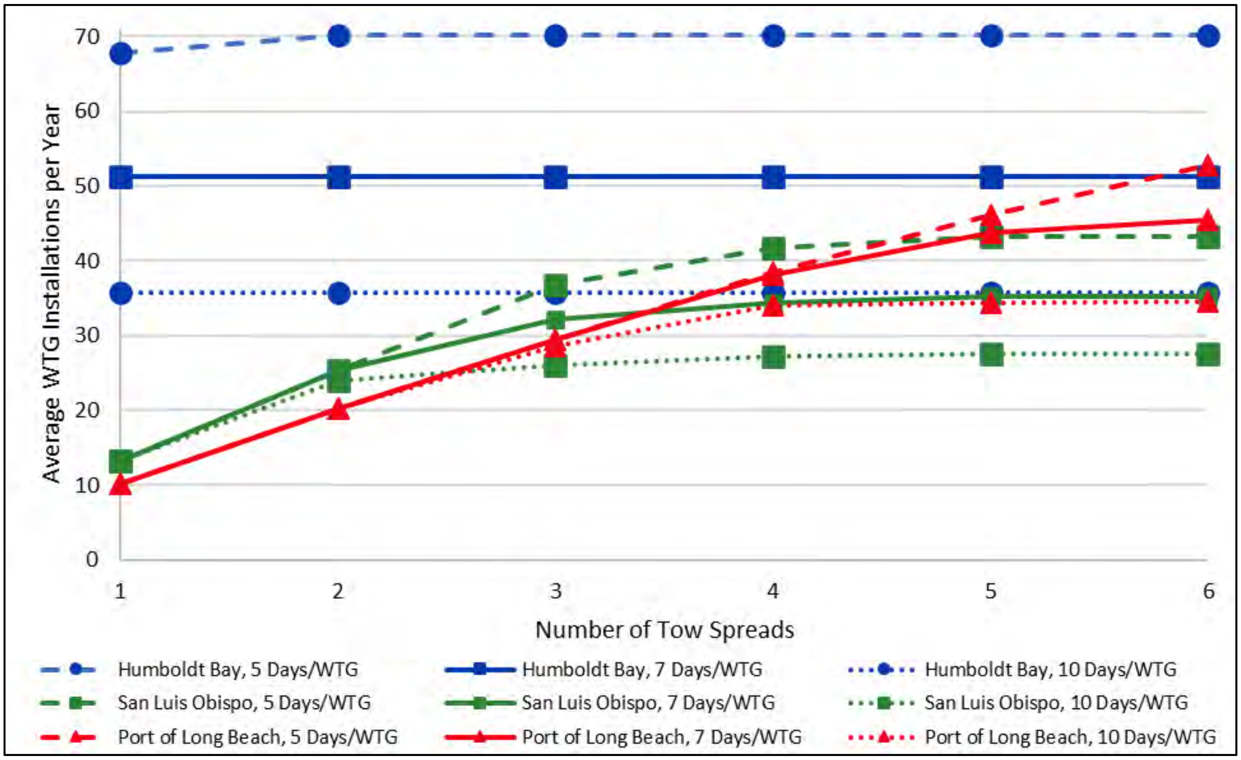

Figure B.25. WTG integration rate sensitivity for routes to Humboldt WEA from one S&I site from different ports (See Appendix Table C.19 for source data)

Sensitivity Assessment Takeaways

Listed below are the major takeaways from the tow spread sensitivity assessment:

- Wet Storage: Wet storage is essential for longer tow routes to allow for flexibility when fewer weather windows are available. Shorter tow routes do not see as large an effect from wet storage, as more towing windows are typically available, and WTGs do not need to sit in wet storage as long.
- WTG Integration Rate: Integration rates that are faster or slower than the baseline have a larger effect on shorter routes than on longer routes, since the towing and installation operations can typically keep pace with the integration operations. Longer tow routes, where factors such as wet storage and limited weather windows typically drive the annual throughput, do not see as large an

effect when few tow spreads are used, but do see some effect when multiple tow spreads are used.

Tow Spreads – Estimated Total Requirements

Each S&I site in operation will contribute to the total throughput rate for the state of California. Statewide throughput rates will depend on the total number of S&I sites in operation and the individual throughput of each S&I site, which is partially governed by the number of tow spreads at each site. Table B.14 outlines the estimated number of tow spreads to be required to meet different potential statewide throughput rates, assuming year-round integration operations. The data below assumes S&I sites beginning operation in alignment with Table 5.5, with two Northern California S&I sites becoming operational before any in Central or Southern California. It should be noted that these values represent potential annual throughput rates and may not be representative of multi-year averages due to operational downtimes.

As the locations of future WEAs are unknown, two potential development scenarios are provided: one with a combination of Northern California and Central California WEAs, and one with only Northern California WEAs. The scenario where only Northern California WEAs are considered still considers the Morro Bay WEA from the 2022 lease auction as being developed, however only Northern California leases will be available beyond that.

Note, it is assumed that about 65% of WEAs will be in Northern California in the scenario where both regions are active.

Table B.14. Tow spread requirements to meet state-wide deployment goals

Total Throughput (GW/Year)	No. of S&I Sites	Location of S&I Sites	No. of Tow Spreads Future WEAs in Northern & Central CA	No. of Tow Spreads Future WEAs in Northern CA Only
0.5	1 to 2	Northern CA	1 to 4	1 to 4
1.0	1 to 2	Northern CA	2 to 5	2 to 5
1.5	2 to 3	Northern CA and Central/Southern CA	3 to 6	4 to 7
2.0	2 to 4	Northern CA and Central/Southern CA	4 to 9	7 to 13
2.5	3 to 5	Northern CA and Central/Southern CA	5 to 14	10 to 17

The tow spread assessment indicates the assumed S&I ports are likely to be able to support the different state-wide development scenarios, if enough tow spread support is available. The estimated vessel support does not scale linearly with the total annual throughput, as larger annual throughput goals will likely require more tow routes between Central/Southern and Northern California, and thus require more vessel spreads to keep pace with S&I throughput.

Summary of Tow Spread Assessment Takeaways

Below is a summarized list of the major takeaways from the tow spread analysis:

- State Throughput Goals: Three to five S&I sites are likely required to meet the State's offshore wind planning goal of 25 GW by 2045. A consistent rate of deployment through 2045 is unlikely (as assumed in this analysis), and flexibility may be needed to accommodate variations in annual throughput. This analysis showed that assuming no constraints in supply chain, no downtime between developer use, full vessel availability, and a constant integration rate of one WTG per week, three S&I sites could achieve the state's offshore wind planning goals. However, with these variables and inefficiencies the potential variations in annual throughput could require up to five S&I sites.
- WEA distance from S&I Sites: S&I sites in both Northern and Central/Southern California are likely to be able to support WEAs in both Central and Northern areas. For example, the Port of Humboldt can likely support build-out of development on both the Northern and Central Coast WEAs and an S&I site within Central California or Southern California can likely support both the Central and Northern California WEAs.
- Central & Southern Coast S&I Sites: S&I sites in either Central California or Southern California can likely achieve similar annual throughputs for projects in either Central California or Northern California WEAs. Central California S&I sites have some advantage at lower throughput rates due to shorter tow distances and the use of fewer vessels; however, the large amount of wet storage available at Port of Long Beach can help make up for the disadvantages caused by increased tow distance.
- Multiple Tow Spreads: To meet similar installation rates, longer tow routes (e.g., between Southern CA and Northern CA) and will likely require multiple tow spreads (multiple vessel groups to tow an integrated WTG). This is due to the longer route duration, and an increased risk of weather induced downtime. Shorter routes typically did not benefit from multiple tow spreads.
- Wet Storage and Vessel Availability: The availability of wet-storage and multiple tow spreads are likely to be major factors in maintaining annual throughput goals. This is due to reduced operational windows in the winter and the ability to take advantage of more favorable weather windows.
- Seasonality: Towing and installation in the winter may be possible, but there are significantly fewer installation windows. This assessment assumed installation could continue in the winter if windows were possible, however, it may not be efficient in practice (depending on the route). A pause in installations in the

winter could be offset in part by wet-storage of integrated units and multiple tow-spreads. However, a full pause in integration would result in a reduction of annual throughput.

- Vessels Needed: Similar to O&M, significant specialized vessels will be needed to support integration and installation. Though not addressed specifically in this assessment, there are currently few vessels on the US West Coast that can support the tow-out of these structures.
- Vessel Emissions: The varying distances and tow durations for each route will affect the vessel emissions for a given construction project; however, these emissions are only a small part of the total emissions for a single project and are not presented here.

This work is intended to provide a comparison between potential annual throughputs, and the following study limitations are important to note:

- This towing assessment is a desktop analysis preliminarily assessing the future potential of California S&I sites to support the offshore wind industry without considering long-term downtime and should not be used for project-specific planning purposes.
- This towing assessment does not consider long-term integration operational downtime that may be a result of seasonal operations, dedicated maintenance on integrated WTGs, or downtime between projects. These factors will need to be considered when estimating the total throughput over the course of multiple years.
- The metocean conditions that limit towing and installation were estimated for this study; actual values may differ and change with time.
- This study assumes constant integration rates over the course of the year. These may differ. Rates may increase over time as supply chain and integration operations become more efficient.
- This towing assessment does not review project-specific needs and only looks at total throughput. During a change from one developer to the next at an S&I port, some period of transition may be expected when no integration is occurring. 100% port utilization should not be expected, which may require adjustment of the final results outlined in this study.
- Port-by-port towing limitations and wet storage estimates are very high-level and need to be refined/confirmed.
- More detailed marine traffic assessments at specific ports may be needed to evaluate the conflict risk between commercial/recreational users based on tow operations and potential exclusion zones.

- Additional resolution of future lease area locations may result in different findings, as this study referenced Humboldt and Morro Bay WEAs as representative locations for North and Central Coast areas, respectively.

Appendix C. Source Data Tables for Figures

Table C.1. Monthly average wave height for each WEA region (Figure B.6.)

Month	Central California	Northern California
Jan	2.61	3.01
Feb	2.67	2.96
Mar	2.61	2.72
Apr	2.42	2.57
May	2.26	2.15
Jun	2.19	2.05
Jul	1.87	1.99
Aug	1.76	1.79
Sep	1.86	2.06
Oct	2.17	2.52
Nov	2.40	2.74
Dec	2.71	3.14

Table C.2. Average annual installation uptime for each WEA (Figure B.7.)

Hs	Central California	Northern California
0	0.0%	0.0%
0.25	0.0%	0.0%
0.5	0.6%	0.0%
0.75	0.8%	0.3%
1	3.1%	3.0%
1.25	10.3%	9.8%
1.5	21.1%	19.2%
1.75	32.7%	30.5%
2	45.9%	40.5%
2.25	56.2%	49.3%
2.5	67.2%	58.4%
2.75	74.5%	66.1%
3	81.1%	73.8%
3.25	85.7%	79.5%
3.5	89.4%	84.6%
3.75	91.8%	88.1%
4	93.9%	91.3%
4.25	95.1%	93.4%
4.5	96.2%	95.2%
4.75	98.4%	96.4%
5	99.0%	97.6%

Hs	Central California	Northern California
5.25	99.3%	98.3%
5.5	99.5%	98.8%
5.75	99.6%	99.1%
6	99.8%	99.4%

Table C.3. Average distinct 35-hour installation windows per month (2003-2022) (Figure B.8.)

Month	Central California	Northern California
Jan	6.9	5.1
Feb	5.8	4.4
Mar	7.3	6.8
Apr	8.3	7.2
May	11.1	10.3
Jun	9.5	11.5
Jul	14.4	12.7
Aug	15.7	13.3
Sep	14.1	11.6
Oct	10.1	8.3
Nov	8.3	5.3
Dec	6.1	3.8

Table C.4. Average number of days with towing windows to Humboldt WEA, 3m wave towing limitation (Figure B.9.)

Month	Humboldt Bay	San Luis Obispo Bay	Port of Long Beach	Port of Long Beach (Alt)
Jan	5.8	1.2	1	0.2
Feb	7.2	0.4	0.2	0
Mar	12.8	4.6	4.2	2.6
Apr	14	2.8	2.6	2.2
May	19.4	7.2	8	5.4
Jun	21.2	9	8.2	4.8
Jul	23	17.6	19	19.4
Aug	22.6	17.8	17.4	15.6
Sep	21	13	11	9.8
Oct	13.6	5.2	4.2	3.4
Nov	11.6	3	2.4	2
Dec	7.4	1	1	0.2

Table C.5. Average number of days with towing windows to Morro Bay WEA, 3m wave towing limitation (Figure B.10.)

Month	Humboldt Bay	San Luis Obispo Bay	Port of Long Beach	Port of Long Beach (Alt)
Jan	0.2	8.8	7.2	3.6
Feb	1.2	9.8	8.4	5.4
Mar	5.2	15	13.6	9.6
Apr	2.2	12.6	11.4	7
May	5.6	17.8	16	11.6
Jun	7.4	20.2	20.4	15.2
Jul	19.4	25.6	25.4	24.4
Aug	20.8	30.2	29.8	29.4
Sep	14.2	24.8	23.6	21.2
Oct	5.8	18.2	16.2	12.6
Nov	4.6	18.4	15.6	13.2
Dec	3.2	10.6	10.2	7

Table C.6. Range of days by month for five years of data assessed for towing from Humboldt Bay to Humboldt WEA (Figure B.11.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	5.8	7.2	12.8	14	19.4	21.2	23	22.6	21	13.6	11.6	7.4
Max	15	9	17	25	27	26	27	27	24	17	14	18
Min	0	6	8	6	16	18	19	19	13	10	9	0

Table C.7. Range of days by month for five years of data assessed for towing from Humboldt Bay to Morro Bay WEA (Figure B.12)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	0.2	1.2	5.2	2.2	5.6	7.4	19.4	20.8	14.2	5.8	4.6	3.2
Max	1	3	11	9	10	14	22	26	23	13	7	10
Min	0	0	0	0	2	2	9	15	5	0	0	0

Table C.8. Range of days by month for five years of data assessed for towing from San Luis Obispo to Morro Bay WEA (Figure B.13.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	8.8	9.8	15	12.6	17.8	20.2	25.6	30.2	24.8	18.2	18.4	10.6
Max	18	14	25	20	23	25	27	31	29	26	23	20
Min	0	5	7	5	8	16	22	29	21	13	14	2

Table C.9. Range of days by month for five years of data assessed for towing from Port of Long Beach to Morro Bay WEA (Figure B.14.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	7.2	8.4	13.6	11.4	16	20.4	25.4	29.8	23.6	16.2	15.6	10.2
Max	18	11	22	17	21	24	27	31	30	27	23	22
Min	0	6	4	6	11	18	22	28	21	9	7	2

Table C.10. Wave height limitation sensitivity – Port of Long Beach to Morrow Bay WEA (Figure B.15.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3m Hs Tow Limit	7.2	8.4	13.6	11.4	16	20.4	25.4	29.8	23.6	16.2	15.6	10.2
4m Hs Tow Limit	10	11.8	17.4	15.4	18.6	22.4	26.2	29.8	25.6	19	18.4	12.6
Difference	2.8	3.4	3.8	4	2.6	2	0.8	0	2	2.8	2.8	2.4

Table C.11. Wave height limitation sensitivity – San Luis Obispo to Morrow Bay WEA (Figure B.16.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3m Hs Tow Limit	8.8	9.8	15	12.6	17.8	20.2	25.6	30.2	24.8	18.2	18.4	10.6
4m Hs Tow Limit	11.4	12.8	17.8	16.8	19.6	21.6	26.2	30.2	26	20	20.2	13.4
Difference	2.6	3	2.8	4.2	1.8	1.4	0.6	0	1.2	1.8	1.8	2.8

Table C.12. Wave height limitation sensitivity – Humboldt Bay to Morrow Bay WEA (Figure B.17.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3m Hs Tow Limit	0.2	1.2	5.2	2.2	5.6	7.4	19.4	20.8	14.2	5.8	4.6	3.2
4m Hs Tow Limit	4.4	5.6	11.4	9.6	15.6	19.8	26.8	28.6	23.4	13	13.2	5.8
Difference	4.2	4.4	6.2	7.4	10	12.4	7.4	7.8	9.2	7.2	8.6	2.6

Table C.13. Wave height limitation sensitivity – Port of Long Beach to Humboldt WEA (Figure B.18.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3m Hs Tow Limit	1	0.2	4.2	2.6	8	8.2	19	17.4	11	4.2	2.4	1
4m Hs Tow Limit	4.8	2.6	9.8	12	21.6	18.4	24.6	21.8	18.6	8.8	8.2	2
Difference	3.8	2.4	5.6	9.4	13.6	10.2	5.6	4.4	7.6	4.6	5.8	1

Table C.14. Average WTG installations per year for one S&I site from Humboldt Bay (Figure B.20.)

Tow Spreads	Humboldt WEA	Morro Bay WEA
1	51.2	15.4
2	51.2	28.4
3	51.2	37.6
4	51.2	39.4
5	51.2	40.4
6	51.2	41

Table C.15. Average WTG installations per year at Humboldt WEA from one S&I site from different ports (Figure B.21.)

Tow Spreads	Humboldt Bay	San Luis Obispo	Port of Long Beach	Port of Long Beach (Alt)
1	51.2	13.2	10.2	8.8
2	51.2	25.4	20.2	17
3	51.2	32.2	29.4	23.8
4	51.2	34.4	38.2	30.6
5	51.2	35.2	43.8	35.8
6	51.2	35.2	45.4	39

Table C.16. Average WTG installation per year at Morro Bay WEA from one S&I site from different ports (Figure B.22.)

Tow Spreads	Humboldt Bay	San Luis Obispo	Port of Long Beach	Port of Long Beach (Alt)
1	15.4	49.6	34.8	27.6
2	28.4	51	51.4	50
3	37.6	51.2	51.4	51
4	39.4	51.4	51.4	51
5	40.4	51.4	51.4	51
6	41	51.4	51.4	51

Table C.17. Wet storage sensitivity of towing and installation to Humboldt WEA from one S&I site from different ports (Figure B.23.)

Tow Spreads	Humboldt Bay, 10 Wet Storage	Humboldt Bay, 3 Wet Storage	San Luis Obispo, 5 Wet Storage	San Luis Obispo, 2 Wet Storage	Port of Long Beach, 20 Wet Storage	Port of Long Beach, 7 Wet Storage
1	51.2	47.4	13.2	13.2	10.2	10.2
2	51.2	47.6	25.4	24.8	20.2	20.2
3	51.2	47.6	32.2	26	29.4	29.4
4	51.2	47.6	34.4	26	38.2	35
5	51.2	47.6	35.2	26	43.8	36.2
6	51.2	47.6	35.2	26	45.4	37

Table C.18. Wet storage sensitivity of towing and installation to Morro Bay WEA from one S&I site from different ports (Figure B.24.)

Tow Spreads	Humboldt Bay, 10 Wet Storage	Humboldt Bay, 3 Wet Storage	San Luis Obispo, 5 Wet Storage	San Luis Obispo, 2 Wet Storage	Port of Long Beach, 20 Wet Storage	Port of Long Beach, 7 Wet Storage
1	15.4	15.4	49.6	46.4	34.8	34.8
2	28.4	26.6	51	47.8	51.4	50.6
3	37.6	29.6	51.2	47.8	51.4	51.2
4	39.4	30	51.4	47.8	51.4	51.4
5	40.4	30	51.4	47.8	51.4	51.4
6	41	30	51.4	47.8	51.4	51.4

Table C.19. WTG integration rate sensitivity for routes to Humboldt WEA from one S&I site from different ports (Figure B.25.)

Tow Spreads	Humboldt Bay, 10 Wet Storage	Humboldt Bay, 3 Wet Storage	San Luis Obispo, 5 Wet Storage	San Luis Obispo, 2 Wet Storage	Port of Long Beach, 20 Wet Storage	Port of Long Beach, 7 Wet Storage	Port of Long Beach, 5 Days/WTG	Port of Long Beach, 7 Days/WTG	Port of Long Beach, 10 Days/WTG
1	67.8	51.2	35.8	13.2	13.2	13.2	10.2	10.2	10.2
2	70.2	51.2	35.8	25.4	25.4	24	20.2	20.2	20.2
3	70.2	51.2	35.8	36.8	32.2	26	29.4	29.4	28.6
4	70.2	51.2	35.8	41.8	34.4	27.2	38.4	38.2	34
5	70.2	51.2	35.8	43.2	35.2	27.6	46.2	43.8	34.4
6	70.2	51.2	35.8	43.2	35.2	27.6	52.8	45.4	34.6

Appendix D. Construction Cost Estimate Assumptions

The cost estimates provided in this study were based on the following assumptions:

- This cost estimate is an 'Opinion of Probable Construction Cost' made by a consultant. In providing opinions of construction cost, it is recognized that neither the client nor the consultant has control over the cost of labor, equipment, materials, or the contractor's means and methods of determining constructability, pricing or schedule. This opinion of construction cost is based on the consultant's reasonable professional judgement and experience and does not constitute a warranty, expressed or implied, that contractor's bids or negotiated prices for the work will not vary from the estimate.
- The costs have been developed based on historical and current data using in-house sources, information from previous studies as well as budget price quotations solicited from local suppliers and contractors. All costs are in 2023 US Dollars. Estimate does not include escalation.
- Total Construction Cost includes all material, labor, and equipment to complete the work and indirect costs including Contractor Supervision (General Conditions), Corporate Overhead and Profit, and Bonds and Insurance cost.
- Total Construction Cost (with Contingency) includes a project contingency of 50%. The contingency amount has been included to cover undefined items, due to the level of engineering carried out at this time. The contingency is not a reflection of the accuracy of the estimate but covers items of work which will have to be performed, and elements of costs which will be incurred, but which are not explicitly detailed or described due to the level of investigation, engineering and estimating completed today.
- This cost estimate represents an AACE 18R-97 Class 5 Estimate with an accuracy of -30% / +50%.
- Volumes for uplands site preparation and required berth improvements are based on publicly available bathymetric and topographic information. Additional surveys and exploration will be required. Results of this additional exploration program may require quantity and price updates.
- Estimate does not include any improvements or facilities required by the developer or operator including buildings / warehouses / equipment / cranes / etc.
- Estimate assumes piles are driven to grade with no obstructions and does not include any associated costs due to pile driving/drilling into rock.
- Pricing assumes all resources are readily available locally.
- Estimate is based on unencumbered contractor access to the site.

- Estimate does not include any costs for construction site property lease or acquisition expenses.
- No extreme weather risk included (force majeure).
- Price does not include environmental restrictions.
- Price does not include any associated costs due to hazardous waste.
- Price does not include any costs for post construction site remediation or reconstruction.
- Estimate assumes federal navigation channel requires no additional dredging.
- Estimate assumes construction of a sinking basin with 100-foot depth is feasible and permittable.
- Estimate includes utilities designed to site limit of work and assumes adequate municipal water and electrical service is available and can be tapped for project needs. Additional offsite utility infrastructure costs are not included.
- Estimate assumes ring crane footprint extends past heavy lift wharf platform onto uplands.