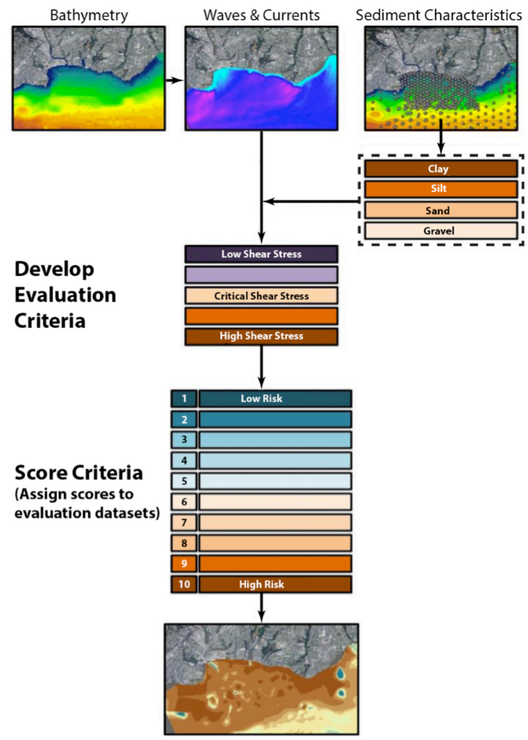
SAND2014-0791P

Offshore Wind RD&D: Sediment Transport

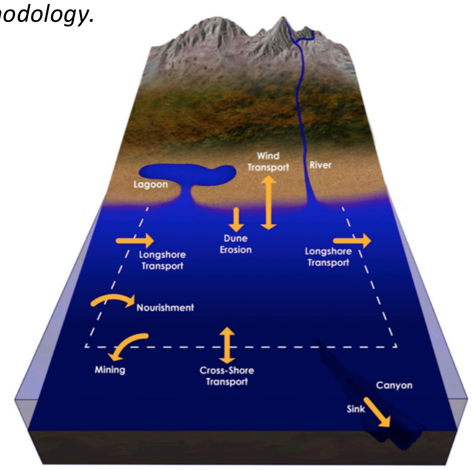
This project focuses on three technical areas

1. Reduce risk of offshore wind infrastructure failure, structural overdesign, or expensive maintenance and repairs caused by mobile sediment beds, by enabling developers to use [regional sediment stability risk maps (link1)] to design turbine array layouts and cable routes. [We will include more detail in a linked pop-up box. Now, that content is at the end of the file.]
2. Support determining the ecological risk imposed by operating a wind farm as a result of the intensity of [changes in wave propagation as well as flow and sediment circulation patterns (link2)] that are created when multiple obstructions are placed in the coastal environment.
3. Reduce risk of offshore wind infrastructure failure or expensive maintenance and repairs, caused by [local scour (link3)], by quantifying the potential extent (depth and width) of scour hole development around offshore wind foundations, cables, and other infrastructure.



Flow chart of sediment stability risk assessment methodology.

For a sustainable offshore wind (OW) industry, underwater OW structures and cables must be cost effective to deploy, and also able to perform with minimal maintenance requirements. A key OW project risk driver is the potentially detrimental interaction between OW substructures/cables and the seafloor. Present standards for cable burial are prescriptive, with little scientific basis, often leading to burial depths that are deeper than required, significantly driving up installation costs. In addition, foundations may be overdesigned to compensate due to inaccurately characterized local sediment transport.



Common coastal characteristic elements to consider in the near-shore sediment budget.

This work will

- reduce installation and lifecycle maintenance costs by contributing to intelligent OW farm array design by effectively considering ocean and seabed dynamics;
- reduce permitting time and costs by enabling prediction of site-specific environmental responses to OW farm designs;
- assess wind-farm and ecosystem risk potential from ocean dynamics, sediment mobilization, and any scour from seafloor-structure interactions;
- reduce deployment barriers by developing tools (and transferring those tools to industry) to improve our

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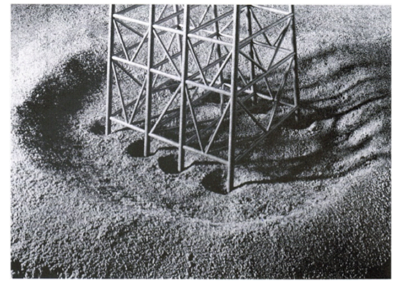
understanding of the interrelationship between ocean and sediment dynamics and commensurate effects on the seabed upon installation of OW farms; and

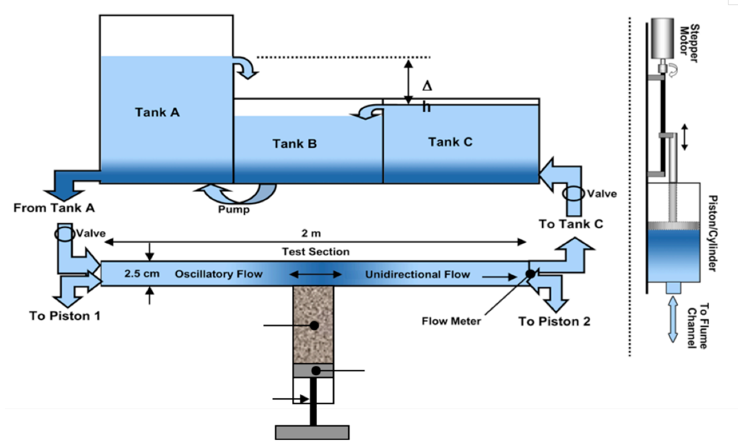
- yield advanced measurement tools, predictive tools, techniques, and methodologies for the OW industry that can be used for coupled wave/current seabed erosion characterization, site planning, design, and monitoring.



Example of local and global scour around a multiple pile structure (from Whitehouse, 1998; reproduced from Angus and Moore, 1982).

These activities will have direct, positive impacts on cost of energy and risk reduction for OW energy development, which will help jumpstart and support future U.S.-based projects. To ensure that the work outlined above is valued and used by developers and other offshore wind industry stakeholders, Sandia will concurrently pursue six supplemental activities.

1. Validate baseline sediment mapping tool outlined in technical area 1 (above).
   - Use available data at the Monterey Bay site to validate regional sediment transport behavior. This will lend credibility to the tool and methodology and increase industry confidence in the tool through this initial demonstration.
2. Develop 'peer reviewed' guidance documents.
   - Sandia has developed a first draft of a guidance document aimed at providing project management level guidance defining the important oceanographic and sediment stability considerations for offshore wind development. This guidance will need to evolve over time as new information is learned about offshore wind successes and failures, including lessons learned from the European experience. This guidance needs expert review to ensure that it meets its current and future goals.
   - Sandia will develop an engineering guidance documents that will enable readers to re-produce the analyses described in technical areas 1–3. This should include participating in co-development of scour standards for the offshore wind industry. This guidance needs expert review to ensure that it meets its current and future goals.

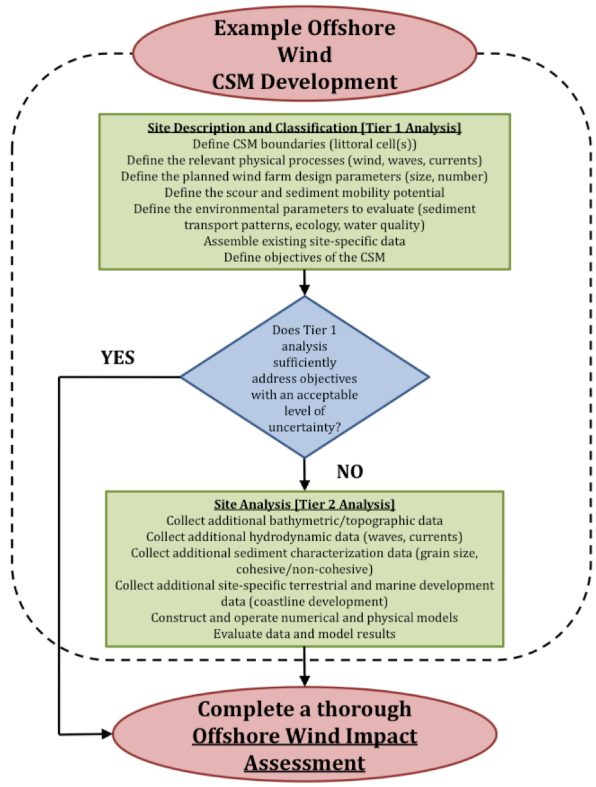


Sediment Erosion Actuated by Wave Oscillations and Linear Flow (SEAWOLF) flume schematic. SEAWOLF provides direct quantification of sediment mobility properties for coastal environments. Flow inside the SEAWOLF is time and directionally varying to mimic near bottom conditions in the ocean crated by the combination of wave induced orbital velocities and ocean currents.

3. Demonstrate the tool at a U.S.-based offshore wind site.
   - Apply the tool at one or more of the Offshore Wind Demonstration FOA award winning sites. Work with the developer to demonstrate model applicability and usefulness.
4. Further refine tool development around scour.

- Combine the regional and local scour effects outlined in technical areas 1–3.

5. Characterize flow and shear stress in SEAWOLF Flume and initiate erosion testing.
    - Use particle image velocimetry (PIV), pressure taps, and other high-resolution measurement techniques to determine the relationship between flow rate and shear stress time histories within the SEAWOLF facility erosion test section under oscillatory, unidirectional, and coupled oscillatory and unidirectional (modulated) flow conditions.
    - After completing preliminary SEAWOLF characterization, we will initiate testing to determine erosion behavior of sediment samples indicative of sediments in wave energy converter (WEC) development areas. The evaluation will consider sediment erosion with depth under wave/current conditions that are expected at WEC deployment locations.
6. With a working group of interested industry partners (e.g., Fugro, Global Marine, TetraTech, Mott MacDonald, Fishermen's Energy) quantify potential direct and indirect cost savings and risk reduction to better understand and communicate how the tools and methodology developed under this Task can lower the long term levelized cost of energy of individual offshore projects.



Offshore wind specific conceptual site model development flowchart example. A framework for understanding the influence that offshore wind and other anthropogenic activities have on the coastal zone.

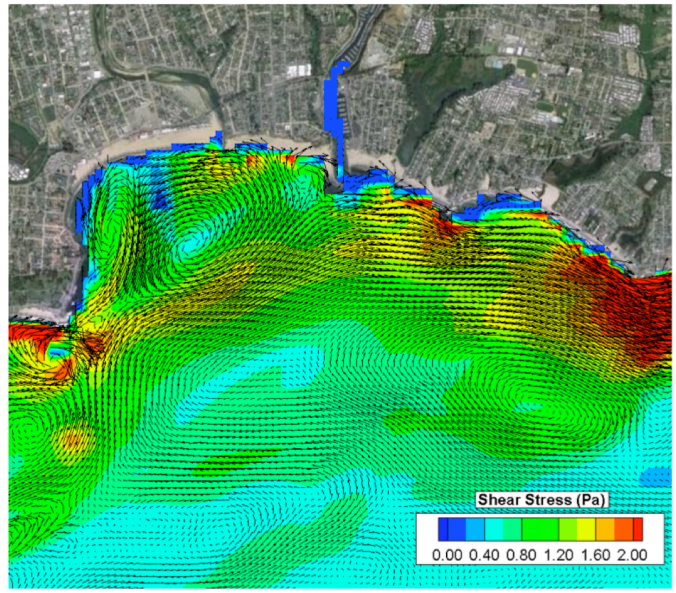
In FY14, Sandia will work to develop a local-scale scour tool by quantifying the potential extent (depth and width) of scour hole development around offshore wind foundations, cables, and other infrastructure. We will develop a methodology for building local models to simulate near foundation and near seabed velocities needed to quantify seabed shear stress and scour for both cohesive and noncohesive sediments.

Additionally, Sandia will work with NREL to identify ways that SNL-EFDC can integrate with the FAST tool set. It is anticipated that SNL-EFDC can inform FAST by providing input parameters for

- high-resolution wave and current loads (and load ranges) and
- sediment variations including scour potential and expected range of foundation exposure.

This activity will help identify existing OW standards as well as potential future standards that can be added or adapted based on the outcome of this work.

[link1] This project will conceptually define the methodology used to create these risk maps. With the baseline (absence of turbine infrastructure) regional sediment stability risk maps, developers can minimize turbine risk by placing turbine infrastructure in more stable locations and/or monitoring and mitigating for infrastructure scour if it is deemed more cost effective or otherwise appropriate to deploy in seabed conditions previously identified as unstable. This assessment process can also help developers define cable burial depths through knowledge of seabed mobility potential. Sandia will develop a methodology to understand the dominant hydrodynamic forces (i.e., waves and tides) and seabed conditions (i.e., bathymetry and particle size) of the site of interest and simulate typical and extreme weather conditions to develop a baseline understanding of localized wave propagation and flow/sediment circulation.



Combined wave and current induced shear stress and velocity vectors simulated in the Santa Cruz Bight, CA region of the Monterey Bay model domain. This model domain was used to demonstrate the utility of combining wave, circulation, and sediment transport modeling to predict near shore sediment stability in the presence of an offshore wind array.

[link2] Offshore wind farms will necessarily alter wave propagation and flow/sediment circulation due simply to their presence in the water column. These changes have the potential to alter fish/mammal behavior and benthic habitat. The extent of these effects will be dependent on site characteristics (i.e., wave, tidal, and seabed conditions) and the offshore wind infrastructure design (i.e., type, number, and size of foundations and other sub-structures). Sandia will build upon the work in technical area 1 above to develop a methodology and user tools enabling planners to simulate the presence of offshore wind infrastructure and qualify and quantify implied changes to the physical environment.

[link3] Building upon the work in technical areas 1 and 2 above, Sandia will develop a methodology of building local models to simulate near foundation and near seabed velocities needed to quantify seabed shear stress and scour. Scour in noncohesive sandy sediments is fairly well understood and analytical techniques are available to estimate scour extent given sufficient understanding of particle size, foundation diameter/width, and near field velocities. As water depths increase, an increased amount of finer sediment particles are often found in the sediment bed as these areas can be depositional for much of the year. Increased amounts of fine grained particles means that sediments become cohesive, and their erosion/scour behavior is not well understood. In this case, direct measurement of sediment erosion behavior as a function of hydrodynamic shear stress and depth below the sediment water interface is necessary to quantify scour. Sandia will use the SEAWOLF flume (once testing is completed), ASSET flume, and/or SEDflume for these measurements and incorporate into the methodology and resulting tools required to carry out scour predictions.