COAST & HARBOR ENGINEERING

Technical Report
Pit-to-Pier Project Effects Evaluation Criteria
Existing Coastal Processes at Project Area

Introduction

This Technical Report presents the results of a study (Phase 1) by Coast & Harbor Engineering (CHE) to assess hydraulic/coastal processes and to develop feasibility level criteria that will be used for evaluating potential environmental effects of the installation and operation of the marine components of the Pit-to-Pier Project. Waves, currents, sediment, the natural transport of sediment, and nearshore and beach morphology are considered to be potentially affected by implementing the project, and are the subject of this Phase 1 study.

The overall study consists of two phases. Phase 1, documented here, has determined. the evaluation criteria to be used for assessing potential environmental effects of the Pit-to Pier Project on hydraulic and coastal processes. Phase 2, to be undertaken following Phase 1, will use the evaluation criteria to determine if environmentally significant effects are likely to result from constructing and operating the project.

The Phase 1 Technical Report consists of two major sections. Section 1 quantifies existing hydraulic and coastal processes and data that will be relevant to determining project effects. Section 2 uses the previously developed information and incorporates project experience with similar hydraulic and coastal processes, to identify evaluation criteria and level of engineering analysis needed to assess the potential environmental effects from the Pit-to-Pier Project. The report concludes with an outline of analyses and level of effort anticipated in Phase 2.

1. Project Site Existing Hydraulic and Coastal Processes

1.1. Project Site Description

Figure 1 is a location map showing the project site. Figure 2 is an aerial photograph of the general features of the project site at low tide, with the proposed structures drawn on the photograph. A steep bluff stands at the back of the beach. A broad sand flat extends seaward from the beach 700 feet. The edge of the sand flat is a steep slope down to deep water.

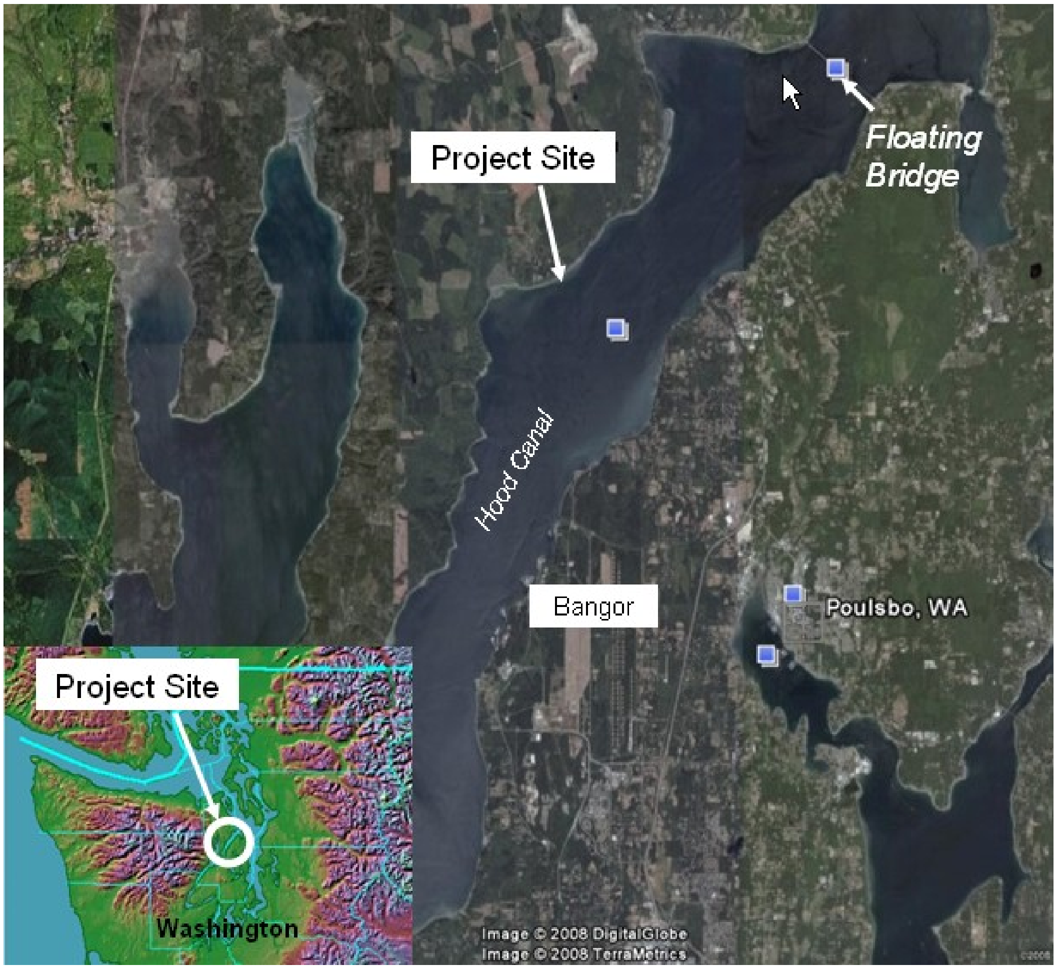

Figure 1. Location map of Pit-to-Pier Project area

Figure 2. Features of the project site with proposed project structures

1.2. Wind

Wind data are collected at the tower on the Hood Canal Floating Bridge. This location is adequate for analyzing wind related processes at the project. Wind recording stations are sparse in Hood Canal. Locations that report wind speed and direction are shown by site number in Figure 3. Data collected at the Hood Canal Bridge in December 1999, January – February 2000, December 2000, and June 2002 – September 2003 were processed to determine the directional characteristics of high wind speeds in the wave generating area in the vicinity of the project site. As shown in Figure 4 the strongest wind blew from the south at the project site in the data collection period. The data were also processed for hours per year occurrence, listed in Table 1 and plotted in Figure 5 for the two major wind directions at the site.

Figure 3. Wind recording stations in northern Hood Canal

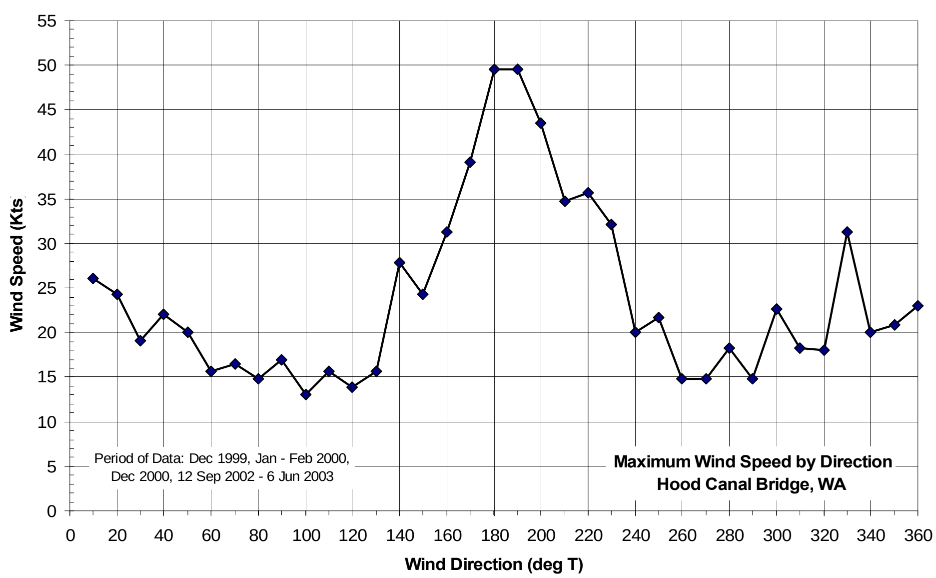

Figure 4. Maximum wind speed by direction measured at Hood Canal Bridge

Table 1. Wind speed and average hours per year occurrence adjusted to project site

Wind Sector	PIER Wind Dir. (deg T)	Wind Speed (kts) 1-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	≥40	TOTAL
Northeasterly	**040-090**	464.2	755.7	458.5	98.3	6.9	0.0	0.0	0.0	0.0	1783.6
Southerly	**150-220**	758.0	783.2	806.0	538.5	253.8	129.2	32.0	5.7	2.3	3308.8

Notes:
[1]Table is based on Hood Canal Bridge wind data for: Dec 1999, Jan-Feb 2000, Dec 2000, and 12 Sep 2002-6 Jun 2003.

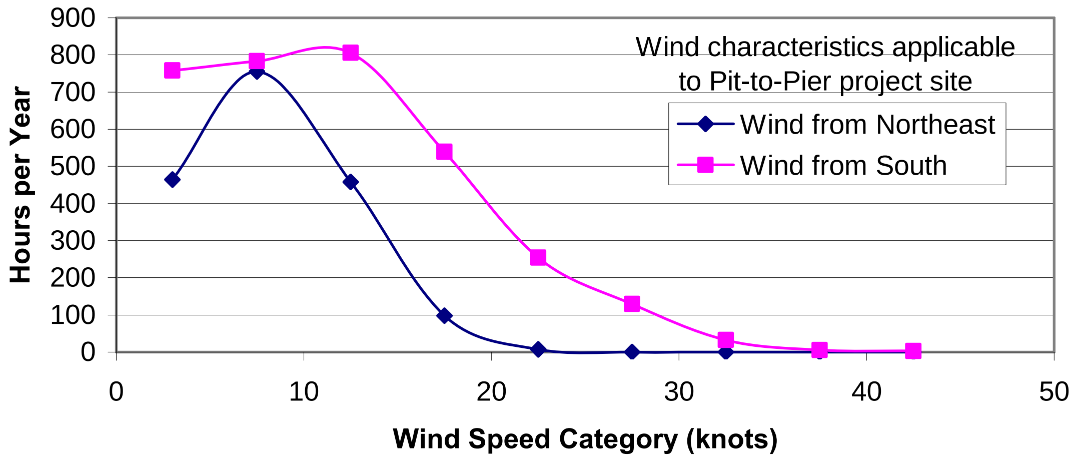

Figure 5. Hours per year of occurrence of wind speeds from northeast and from south adjusted to project vicinity

1.3. Bathymetry

Detailed bathymetry of the sand flat was developed from LiDAR data provided by the Puget Sound LIDAR Consortium. The data were processed to create elevation contours, and were used to refine the modeling grid for detailed wave modeling in the project area. Figure 6 represents the elevation contours from the lowest elevation available from the LiDAR data (+1 ft MLLW) up to +20 ft MLLW.

Figure 6. Elevation contours developed from LIDAR data

1.4. Tides and Tidal Datums

The project vertical datum is North American Vertical Datum of 1988. Tidal datum information published for a nearby site at Bangor is listed in Figure 7 below. NOAA tidal datums listed for the Bangor Pier show that the NAVD88 datum is 2.38 ft above MLLW, and the NGVD29 datum is 5.93 ft above MLLW. The location of Bangor relative to the project site is shown in Figure 1.

Bangor Pier, Hood Canal, Washington

	MLLW	NGVD29	NAVD88
Highest Observed Water Level	14.5	8.6	12.1
Mean Higher High Water	11.07	5.14	8.69
Mean High Water	10.18	4.25	7.80
Mean Tide Level	6.53	0.60	4.15
National Geodetic Vertical Datum	5.93	0.00	3.55
Mean Low Water	2.88	-3.05	0.50
North American Vertical Datum 88	2.38	-3.55	0.00
Mean Lower Low Water	0.00	-5.93	-2.38
Lowest Observed Water Level	-4.0	-9.9	-6.4

Figure 7. Tidal datums applicable to Pit-to-Pier Project (elevations in feet)

1.5. Sediments and Shoreline Morphology

The shoreline in the project area appears to be composed of sediment that has been eroded from bluffs or contributed by bluff collapse. Wave action has likely sorted the beach sediment as it moved the sediment along and across shore. A landslide that occurred between 1996 and 1999 (Hugh Shipman, Dept. Ecology, pers. communication) added material to the sand flat fronting the beach. Slides may have occurred at this spot previously. A surface expression that the slide made on the bluff is revealed in a LiDAR image shown in Figure 8. A series of older slides on the bluff eastward to Thorndyke Bay is interpreted to contribute to the area shoreline morphology and the sediment supply to the project site.

The storm berm at the upper extent of the beach is composed predominantly of a gravel-cobble mix, as shown in Figure 9. The combination of water seepage near the toe of the bluff and onshore movement of beach material has created wetlands at the upper beach. The surface of the sand flat is composed of a sand-gravel mix nearer the shore (Figure 10), and is predominantly sand at mid and outer locations (Figure 11).

Sediment was sampled from the underwater portion of the edge of the sand flat at depths of 10, 20, and 30 feet by GeoEngineers. GeoEngineers analyzed the samples for grain size. At depths of 10 and 20 feet the median grain size was about 0.2 mm. At 30-ft depth, the median grain size was less than 0.5 mm. The samples contained less than five percent silt.

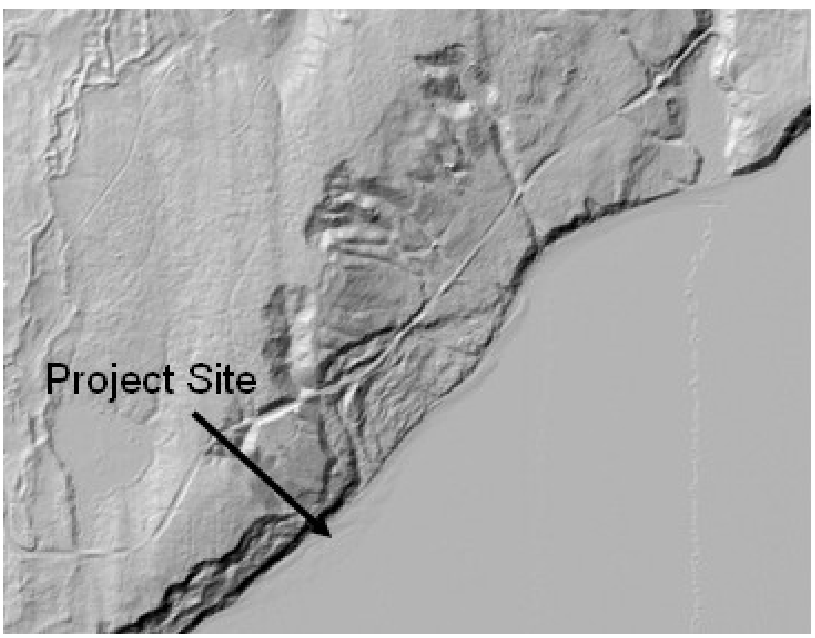

Figure 8. Bare earth LiDAR image of surface expression of land slides near project site

Figure 9. Composition of storm berm at project site (July 3, 2008)

Figure 10. Composition of sand flat near shoreward side (July 3, 2008)

Figure 11. Composition of sand flat near offshore side (July 3, 2008)

1.6. Tidal Currents

Results from previous tidal flow circulation numerical modeling available to CHE were used to characterize the hydraulics of tidal currents. No direct measurements of current velocities at the project site have been identified. The available modeling results have sufficient resolution for analyzing current related processes at the project site. Current speeds in the vicinity of the pier were extracted from output of a numerical tidal circulation model that was developed for a previous study that included the project area. A portion of the model grid is shown in Figure 12. Because the model grid was not developed specifically for the Pit-to-Pier Project modeled velocities at the site might be slightly less accurate than if the site was studied at a detailed level. The location where the velocity was extracted from the model results is shown in Figure 13. The modeled velocities for a 10-day simulation provide an estimate of the strength of the tidal current near the pier. The magnitude of the current speed is plotted in Figure 14. The peak speed in the modeled series at this nearshore location is 2.1 ft/sec and occurs on the ebb tide.

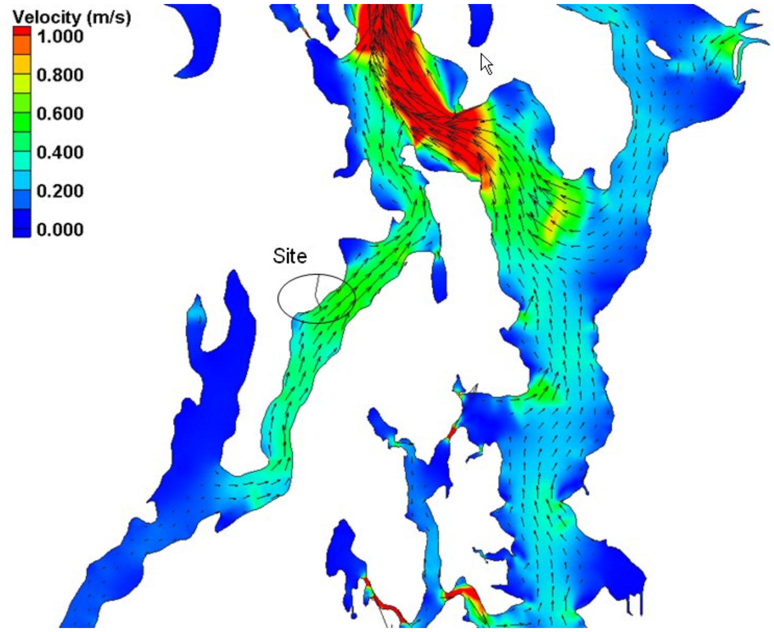

Figure 12. Portion of model grid of tidal circulation model

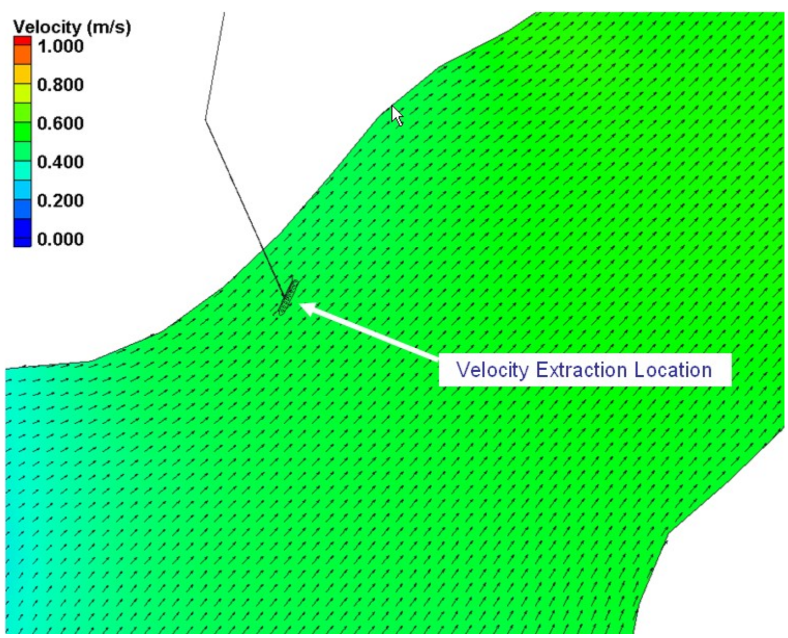

Figure 13. Location where velocities were extracted to approximate current speed at project site

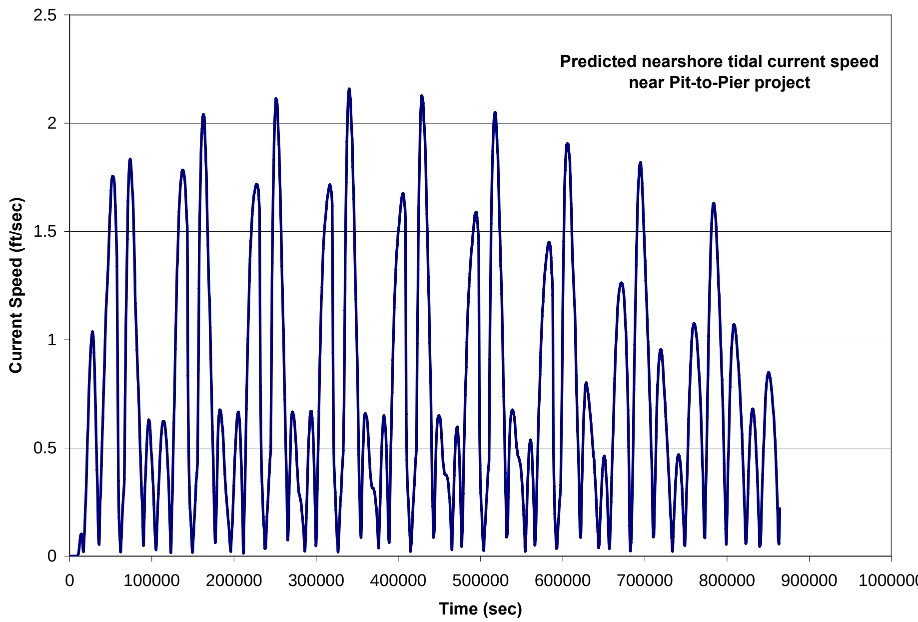

Figure 14. Time series of current speeds simulated near project site (both ebb and flood current speeds shown as positive magnitude)

1.7. Waves

CHE conducted numerical modeling (computer simulation) of wave generation, refraction, and diffraction to characterize wave conditions at the project site. No direct measurements of waves at the project site have been identified. The available modeling results have sufficient accuracy and resolution for analyzing wave related processes at the project site. Simulating the wave climate was accomplished in two steps. The SWAN model (Holthuijsen et al., 2004) simulated waves in the project area for each wind speed category for northerly and southerly directions. Near the project site the refined bathymetry grid was applied to the HWAVE model (Zheleznyak et al., 2005). SWAN model output corresponding to the edge of the refined grid was input to HWAVE to provide detailed modeling of waves at the location of the proposed project features and on the sand flat fronting the project shoreline. Wave modeling cases are summarized in Table 2. All cases were modeled at a tide level of MHHW. Wave information developed with HWAVE is the basis for analyzing wave-driven current and sediment process. Graphical representations of example HWAVE modeling results are shown in Figures 15 and 16 for cases 4 and 12, respectively. Wave forces for cases 1, 2, 3, 6, and 7 were shown to be insufficient to suspend sediment of the size observed on the nearshore profile. Those are cases of wind speed less than 12.5 knots.

Table 2. Wave modeling cases and corresponding wind speed and direction

Case	Wind Speed (kts)	Direction (0-North)
1	3.0	60
2	7.5	60
3	12.5	60
4	17.5	60
5	22.5	60
6	3.0	200
7	7.5	200
8	12.5	200
9	17.5	200
10	22.5	200
11	27.5	200
12	32.5	200
13	37.5	200
14	42.5	200

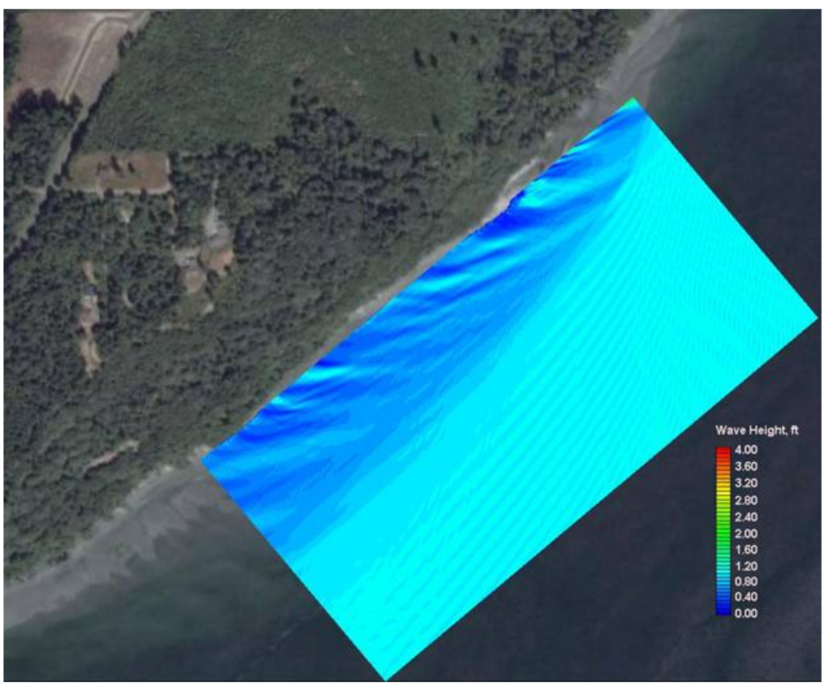

Figure 15. Wave heights in project area resulting from 17.5-knot wind from northeast (case 4)

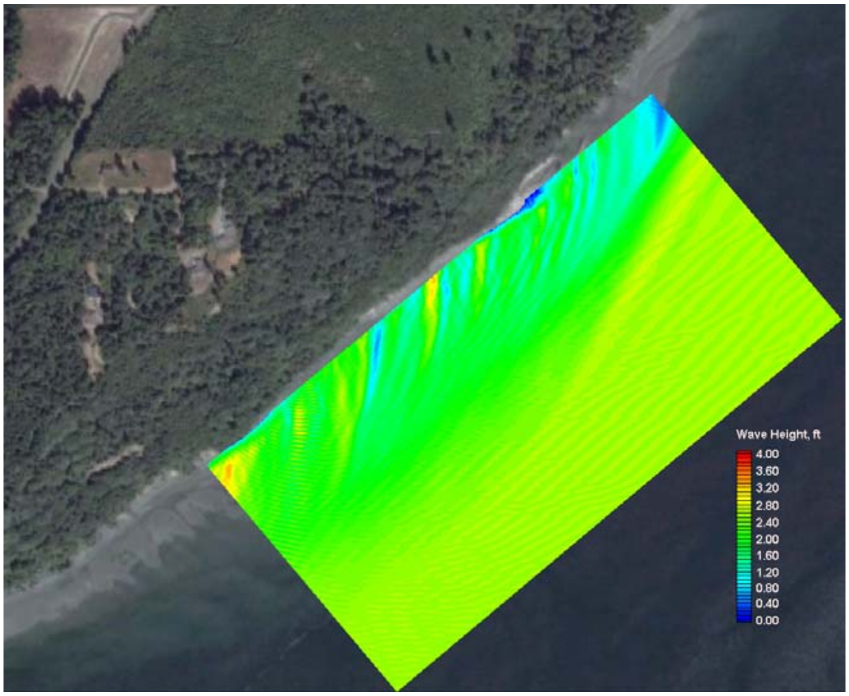

Figure 16. Wave heights in project area resulting from 32.5-knot wind from south (case 12)

Wave heights calculated at specific locations on the sand flat were tabulated for comparison with the with-project cases, which are to be modeled in the future Phase 2 of the project. Locations of five output points on the sand flat are shown in Figure 17. The proposed pier is shown relative to the output points in the figure. The modeled wave heights are listed in Table 3 by point number.

Figure 17. HWAVE model output points for determining wave height

Table 3. Wave height at output points for modeled cases, pre-project

	Significant Wave Height (ft)					
Point	Case 4	Case 5	Case 8	Case 10	Case 11	Case 12
1	0.50	0.71	0.68	1.45	1.69	2.25
2	0.63	0.72	0.65	1.13	1.70	1.87
3	0.63	0.89	0.66	1.51	1.87	1.70
4	0.85	1.10	0.72	1.73	1.88	1.37
5	0.74	1.00	0.67	1.40	1.71	1.74

Note: Wave extraction point locations shown on Figure 17

1.8. Wave Runup

Evidence of wave runup can be observed at the bluff toe. Runup elevation was calculated for existing conditions as a basis of determining if significant change in wave runup would occur in the with-project condition. The methodology for computing wave runup on barriers as recommended by FEMA (2005) was applied to determine the height to which waves would reach on the bluff in the project area. Wave information of the modeled cases listed in Table 3 was extracted at the location of the points shown in Figure 17 for use in runup analysis. The wave information was input to the runup procedure with an assumed tide level of 3 feet above MHHW. The nearshore profile was developed from the topography shown in Figure 6. The tide level accounts for storm surge and the possibility of a storm occurring at the time of a spring high tide. Wave runup under constant storm conditions has statistical variability. The standard methodology calculates the height of the highest 2 percent of the waves that run up on the bluff. Table 4 lists the cases and the resulting 2 percent runup elevations (R2%) at the bluff located landward from the proposed pier.

Table 4. Wave runup elevations on bluff, pre-project

	Wave Runup, R2% (ft)					
Point	Case 4	Case 5	Case 8	Case 10	Case 11	Case 12
1	12.8	13.2	13.2	14.8	15.3	16.5
2	13.0	13.2	13.1	14.2	15.4	15.8
3	13.0	13.6	13.2	14.9	15.7	15.4
4	13.5	14.0	13.3	15.4	15.7	14.7
5	13.3	13.8	13.2	14.7	15.4	15.5

Note: Wave extraction point locations shown on Figure 17
Runup at bluff face located landward from extraction points

1.9. Sediment Transport

Based on the foregoing data review and analysis it appears that wave generated hydrodynamic force is a major governing factor in sediment transport at the project area. Tidal current even at peak speed is insufficient to mobilize beach sediment of the type shown in Figure 10. The stability (or alternatively, the mobility) of bottom sediment in the nearshore zone is determined by sediment particle size and the hydrodynamic forces applied to it by waves. This understanding will direct the method of analysis of potential project effects on sediment transport and morphology.

The minimum stable size of sediment (the size below which it would be mobile) was determined at cross-shore locations for selected wave model cases. Cross-shore locations of three analysis transects are shown in Figure 18. The minimum stable size is plotted with cross-shore distance in Figures 19 and 20 for modeled cases numbered 5 and 12, respectively, for the without project condition. Those cases were selected only to represent wave conditions under moderate wind speeds from the northeast and from the south. In Figure 19, Transect 1, for example, the wave height diminishes with distance landward across the profile. Wave shear stress (the force that causes sediment movement) applied at the sediment surface of the profile increases as the wave approaches shore. The interaction of the wave with the bottom profile causes a shear stress maximum at about station 70 ft. The minimum particle size that is stable under these conditions is about 4 mm, as shown by the right-hand vertical axis. In Figure 20, Transect 1, the shear stress maximum is located at about station 90 ft and corresponds to a stable particle size of about 12 mm for the simulated conditions of wind speed and water depth.

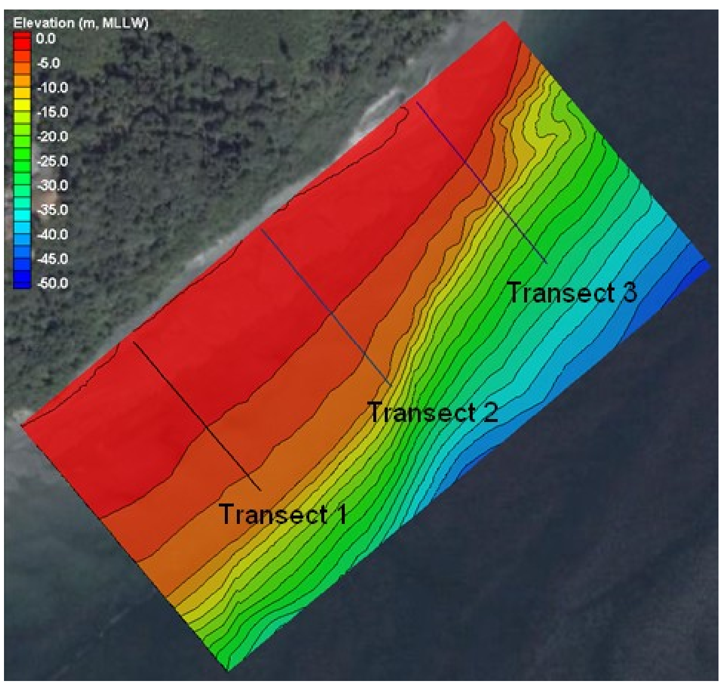

Figure 18. Locations of transects for determining stable sediment size

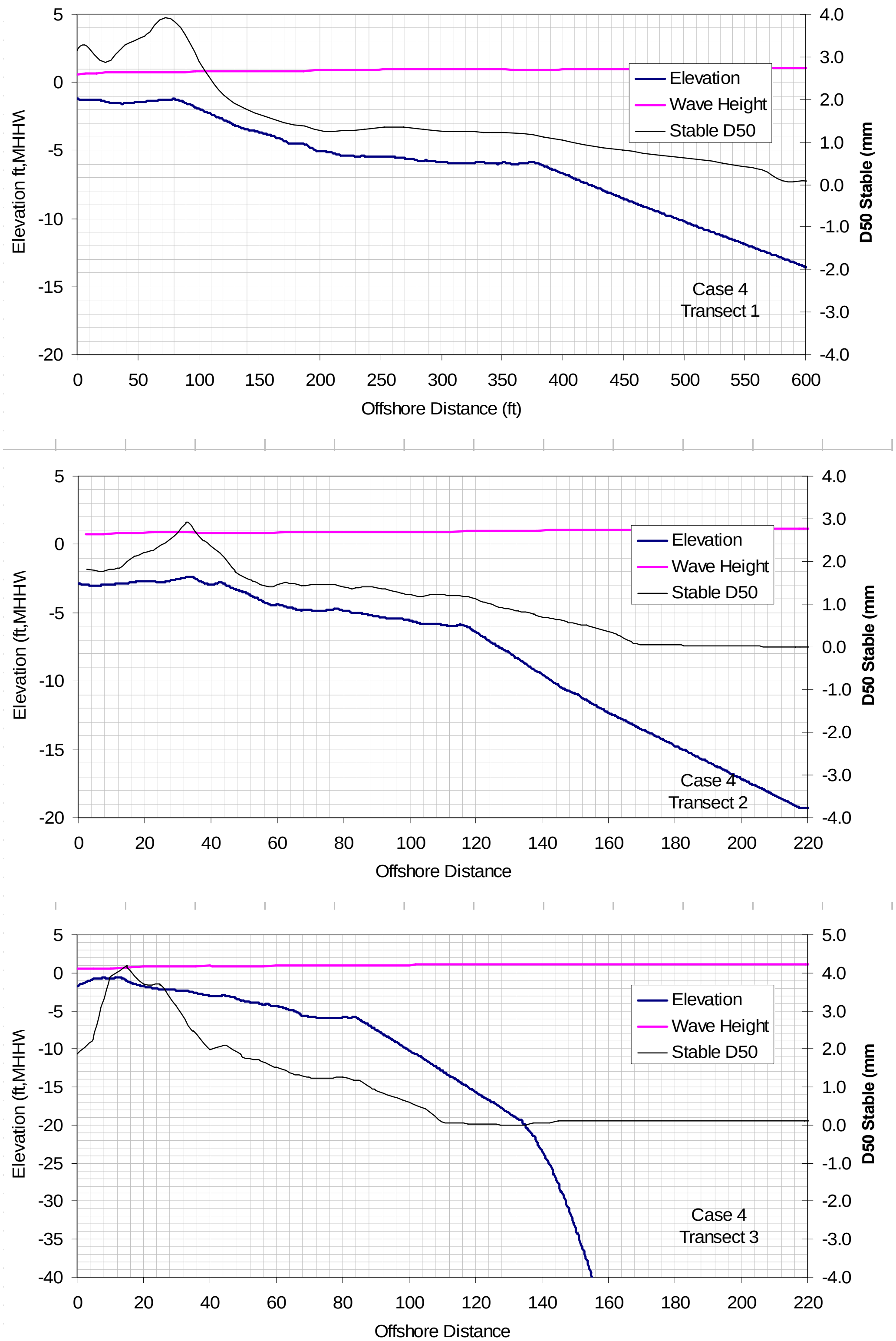

Figure 19. Minimum stable sediment size for 17.5-kt northeast wind, pre-project

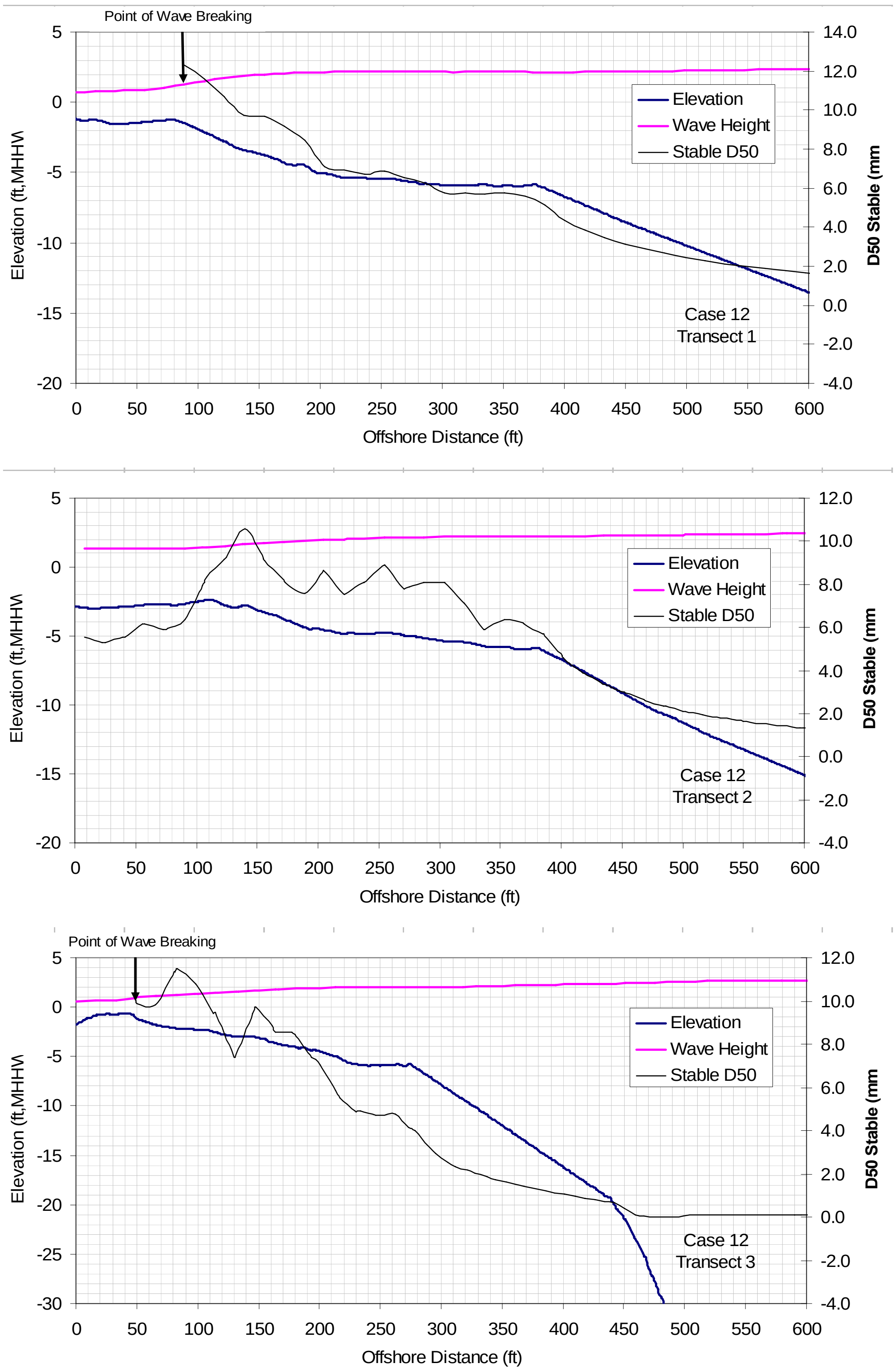

Figure 20. Minimum stable sediment size for 32.5-kt south wind, pre-project

2. Criteria and Methodology for Evaluating Project Effects

The environmental effect evaluation criteria and methodology were developed from quantifying hydraulic and coastal processes at the project site and the best practical experience from previous similar studies. The evaluation criteria also incorporate information from previous work conducted by Anchor Environmental (2003) and public and agency comments made during the scoping process and specifically expressed in the October 29, 2007 Scoping Meeting.

The evaluation criteria and methodology for evaluating project effects are presented in table format in Table 5. In the table each potential effect is matched with evaluation criteria and the level of engineering analysis required to determine if the potential effect would be environmentally significant. This evaluation is limited to physical environmental effects.

Table 5. Pit-to-Pier Project Effects Evaluation Criteria		
Issue or Potential Impact	Criteria for Determining Project Impact	Methodology to Evaluate Impact
1. Impact on sediment sources due to modification of the backshore bluff	Impact would occur if two criteria are met: the modified area of bluff interacts with storm waves and tides, and the hydrodynamic force applied to the bluff by this interaction is capable of eroding bluff material.	Two steps of analysis will be required. The first is to determine if there will be interaction between the modified bluff and waves. If the first step determines that interaction may occur, then the second step would evaluate wave and current forces on bluff material to determine erosion potential.
2. Impact to longshore transport and general beach profile due to the presence of the Pier	The presence of the pier may impact longshore transport and the beach profile if structural supports of the pier cause significant blockage of wave energy. Blockage of wave energy by pile supported structures may occur if any of the following two factors is not satisfied: (1) the openings between piles are less than half a wave length, and (2) diameter of any pile in the structure is larger than ¼ a wave length.	Waves in the project area will be modeled with a 2-dimensional numerical wave model for conditions that may generate longshore sediment transport. Wave length will be extracted at the project site and will be compared to the distances between piles and pile diameters.
3. Impact to longshore transport and general beach profile due to the mooring of vessels at the Pier and the presence of the breasting dolphins	The presence of a moored vessel at the pier and the breasting dolphins may cause a change in longshore sediment transport if the following conditions are met: (1) Total (integrated) longshore wave power during the period with no vessel at the pier is less than 75% of the wave power occurring when a vessel is at the pier (moored vessel), and (2) Vessel at the pier satisfies the USCOE criteria for tombolo formation calculated with waves of the yearly storm event.	Statistical characteristics of wave power with and without vessel at the pier will be analyzed and compared. Waves in the project area will be modeled with a 2-dimensional wave model. Wave height and period will be extracted at the project area to obtain the yearly wave power. Parameters of the yearly storm and pertinent dimensions will be computed for tombolo formation and compared to USCOE criteria.
4. Impacts to deep-water marine environment due to vessel propeller wash	Propeller wash from vessels operating at the Pier may impact the deep-water marine environment if propwash velocity exceeds sediment stability threshold.	The propeller wash velocity field will be modeled with JETWASH model and the maximum velocity impinging on the slope will be compared with threshold velocity for suspending the surface sediment.

Table 5. Pit-to-Pier Project Effects Evaluation Criteria		
Issue or Potential Impact	Criteria for Determining Project Impact	Methodology to Evaluate Impact
5. Impact on bluff and bank erosion and bulkhead/protection	Impacts to bluff erosion and shore protection structures may occur if either of the following conditions are met: (1) change of average annual longshore sediment transport occurs due to the pier or moored vessel, or (2) moored vessel results in undesirable reflection/diffraction of wave energy to the shoreline.	First condition will be tested upon resolving Issues 2 and 3 above. Second condition will be tested by conducting wave modeling with a 2-dimensional wave refraction/diffraction model. The pattern of wave heights at the shoreline will be compared for pre- and post-project conditions.
6. Impacts on drift cell sediment movement, and distribution. Drift cell containing the project area is shown in figure below.  	Impact on drift cell may occur if project changes sediment supply to the cell. The sediment supply change may occur if the project alters the rate of bluff erosion, or blocks or modifies existing longshore sediment transport.	Impact on bluff erosion will be determined upon resolving Issue 1. Impact on sediment transport will be determined upon resolving Issues 2 and 3.
7. Resulting impacts to structure and functioning of pocket estuaries	Pocket estuaries could potentially be impacted if either of the following occurs: (1) existing pattern of current velocities at the estuary are modified by the project (2) Wave height and direction at the estuary are modified by the project, and	No pocket estuaries appear to be within the drift cell that contains the project site. Therefore, the issue of the project impacting pocket estuaries is academic.

Table 5. Pit-to-Pier Project Effects Evaluation Criteria		
Issue or Potential Impact	Criteria for Determining Project Impact	Methodology to Evaluate Impact
	(3) the project changes sediment transport pattern at the pocket estuary entrance.	
8. Possible change in accretion or erosion patterns at South Beach	Possible change in erosion and accretion patterns could potentially occur if either of the following conditions is met: (1) shore location is within zone of waves diffracted or refracted by the project and (2) project modifies the sediment transport supply that feeds sediment at South Beach.	Waves will be modeled using a 2-dimensional wave model. Modeling results (wave heights and period) will be extracted at the location of South Beach for pre and post- project conditions and will be compared to determine the first condition. Possible modification to sediment transport by the project will be addressed upon resolving Issues 2 and 3.
9. Impacts from changes in wave energy (pier plus barges/ships) on subtidal sediment distribution, morphology, and bathymetry	See Issues 2 and 3.	Evaluation methodology will be similar as for Issues 2 and 3, but extended to subtidal elevations
10. Impact from piers and structures on change of shoreline currents	Impacts to shoreline currents may occur if both of the following occur: (1) shoreline current velocities under existing conditions are significant in sediment transport and (2) shoreline current velocities are modified in the with-project condition.	Current velocities will be determined from available hydrodynamic modeling developed for previous projects. If modeling shows that currents are significant to sediment transport under existing conditions, modeling will be repeated with the project and results will be compared.
11. Vessel wake damage to shoreline and bulkheads	Wakes of vessels serving the project could potentially impact shoreline and bulkheads if the following factors coincide: (1) Speed of deep draft vessels (barges and bulk carriers) exceed 5 knots in approach to the proposed pier and (2) Wave energy from these wakes exceed by more than 5% the wave energy of dominant wind wave. (Dominant implies the wave height and direction to which the morphology is adjusted.)	Vessel wakes will be modeled using industry-standard methods. Vessel wake energy will be calculated with the same procedure as for energy contained in wind waves.
12. Feasibility of use of material for beach	Coastal effects analysis is limited to project	Assessing feasibility of using aggregate

Table 5. Pit-to-Pier Project Effects Evaluation Criteria		
Issue or Potential Impact	Criteria for Determining Project Impact	Methodology to Evaluate Impact
restoration	structures and operations.	produced by the operation is outside the scope of coastal effects analysis of this project.
13. Silt impacts to Hood Canal	It is a non-specific question that is more academic than relating to the project.	Silt impacts to Hood Canal are outside the scope of coastal effects analysis of this project.
14. Effect of seismic events	Coastal effects analysis is limited to project structures and operations.	Assessing effect of seismic event on the project or the shoreline is outside the scope of coastal effects analysis of this project.
15. Impacts from temporary/emergency anchoring	Anchoring by project vessels could potentially impact bottom surface, but would have no impacts on nearshore sediments or morphology.	Effects of anchoring not related to coastal effects analysis.
16. Turbidity and sedimentation impacts from ongoing operations and gravel spills	Ongoing operations and gravel spills could potentially impact water turbidity if either of the following occurs: (1) suspension of bottom sediment occurs during operation at the pier and generates a plume that exceeds background levels and (2) gravel spills occur in amounts that generate turbidity exceeding the background level.	Conditions will be determined upon resolving Issues 5 and 6. Silt content of aggregate will be identified. Analysis of potential spillage will be identified by others and provided to CHE. Analysis of turbidity plume formation from the spill will be conducted and compared to background turbidity.
17. Preservation of natural character of shoreline	See Issues 5 and 6.	Waves in the project area will be modeled with a 2-dimensional model to simulate wave heights and directions for given hours in average year. Existing and with-project conditions will be similarly modeled. Model output at the shoreline and at locations of wave breaking will be compared.
18. Interference with recreational boaters/fishing at Salsbury Point	Effects analysis limited to project structures and operations	Assessing potential project-related interference of boaters related to Salsbury Point is outside the scope of coastal effects analysis of this project.
19. Climate change – rising sea levels, storm activities increase	Effects analysis limited to project structures and operations	Assessing climate change effects on the project or the shoreline is outside the scope of coastal

Table 5. Pit-to-Pier Project Effects Evaluation Criteria		
Issue or Potential Impact	Criteria for Determining Project Impact	Methodology to Evaluate Impact
		effects analysis of this project.
20. Safety navigation issues	Effects analysis limited to project structures and operations	Assessing navigation safety issues of the project is outside the scope of coastal effects analysis of this project.
21. General navigational hazard, potential for marine accident	Effects analysis limited to project structures and operations	Assessing potential navigational hazards related to the project is outside the scope of coastal effects analysis of this project.
22. Interference with nets, pots, and other fishing gear	Effects analysis limited to project structures and operations	Assessing potential project-related interference with fishing gear is outside the scope of coastal effects analysis of this project.

3. Conclusion

This memorandum documents Phase 1 of the evaluation of effects on coastal processes that could be attributed to the Pit-to-Pier project. Phase 1 reviewed data, site conditions, and project features; and specified criteria and methodology applicable for determination of significant environmental effects due to issues previously identified by agency staff. No impact evaluation was done in Phase 1. This document is to aid in gaining consensus on how impacts will be determined.

Phase 2 will apply the criteria and methodology to each issue or process listed in Table 5 above and determine if significant impacts will result from project implementation or operation. Whereas evaluation has not yet been done, understanding of the project features and site processes gained in Phase 1 is a basis for estimating the level of engineering analysis that will be required in Phase 2. Existing data are sufficient for Phase 2 evaluation with the exception of vessel and propulsion data needed for propeller wash analysis. Evaluating some of the processes listed in Table 5 will require application of advance numerical modeling. For example, processes associated with propeller wash and with interactions between project features and waves will require these high-level engineering tools. More simple analyses can conclude that many other effects on processes do not meet criteria for significant environmental effect.

Once agreement is reached on the criteria and methodology, CHE will complete evaluation of the issues and processes listed in Table 5. A scope of work, fee estimate, and schedule for completion of Phase 2 is presented as an attachment to this Technical Report.

4. References

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