Preface

2007: Port of Redwood City Ferry Terminal Locational Analysis, Environmental Assessment, & Conceptual Design

In 2007, the Water Transit Authority and the Port of Redwood City completed an evaluation of three potential ferry locations to determine if there were any issues that made either site impractical. This report is called the "Port of Redwood City Ferry Terminal Locational Analysis, Environmental Assessment and Conceptual Design" (Report). The Report identified which of the three sites was most optimal for a ferry service. It also performed a preliminary review to determine if there were any significant planning, legal, operational or environmental obstacles preventing the use of the most optimal location. The Report did not evaluate the feasibility of ferry service, which is typically done through a financial feasibility study (see below).

While the Report included environmental assessments, it did not include an Environmental Impact Report (EIR). A Biological Resources Assessment and Preliminary Wake Wash Impact Analysis were prepared to identify potential major obstacles in any of the three potential ferry locations. An EIR is an in-depth document that is required as part of the California Environmental Quality Act to identify potential significant adverse environmental impacts and propose mitigations or alternatives to reduce the impacts of a potential project. While an EIR was not included in the 2007 Report, the Report identified the need to prepare one in future analysis.

2019: Financial Feasibility Study and Cost Benefit & Economic Impact Analyses

In February of 2019, the City initiated a Financial Feasibility Study and Cost Benefit & Economic Impact Analyses (Study). The goal of this Study is to understand if a ferry service to and from Redwood City is viable based on ridership. In other words, it seeks to answer whether there will be enough riders. Additionally, the Study will estimate operational costs, capital costs, and look to see if there are added societal benefits for providing a ferry service. If the Study shows potential ridership is significant enough, then City Council and the Port Commission will consider how to proceed with the next step in pursuing a ferry service. Next steps may include a Business Plan (required by the San Mateo County Transportation Authority) and a Conceptual Design, followed by an EIR.

COAST & HARBOR ENGINEERING

Technical Memorandum

Preliminary Wake Wash Impact Analysis
Redwood City Ferry Terminal, Redwood City, CA

1. Introduction

The following preliminary wake wash impact analysis was initiated by the Port of Redwood City to preliminarily determine the level and location of potential environmental impacts along the proposed ferry route from San Francisco to Redwood City, California. An additional objective of the analysis was to determine a preliminary slow-down location (if required) for vessels approaching and departing Redwood Creek during both preliminary ferry service and future expanded ferry service.

The areas of analysis include both the shorelines of Greco Island and Bair Island, along the western shoreline of South San Francisco Bay. Figure 1 shows the bottom elevations in South San Francisco Bay (in color contour format) and the proposed ferry route through Redwood Creek superimposed on a satellite photograph including Greco and Bair Islands. It was assumed that the Redwood City Ferry Terminal would be serviced by a catamaran ferry operating at 35 knots between San Francisco and Redwood City (Michael Fajans, personal communication 2007). Two different ferry service scenarios were evaluated: 1) initial service conditions, which were assumed to consist of 220 round-trips per month; and 2) future service conditions, which were assumed to consist of 600 round-trips per month (Michael Fajans, personal communication 2007).

The analysis methodology consisted of characterization of the shoreline based on site visit observations and analysis of existing data, numerical modeling and statistical evaluation of base conditions, analysis and characterization of the proposed ferry wakes, and comparison of ferry wake potential impacts with impacts calculated for base conditions. This methodology is typical for wake wash analysis.

The potential impacts of ferry wake wash on shorelines or biological resources near the site were evaluated using calculations of swash zone sediment transport. Swash zone sediment transport shows changes in expected sediment transport at the shoreline with increases or reduction of wave/wake energy delivered to the shoreline. In other words, swash zone sediment transport indicates potential for shoreline response to different hydrodynamic impacts through different levels of sediment transport in the system. The impact assessment methodology includes computing transport for both existing and post-project conditions, and finally comparison between them.

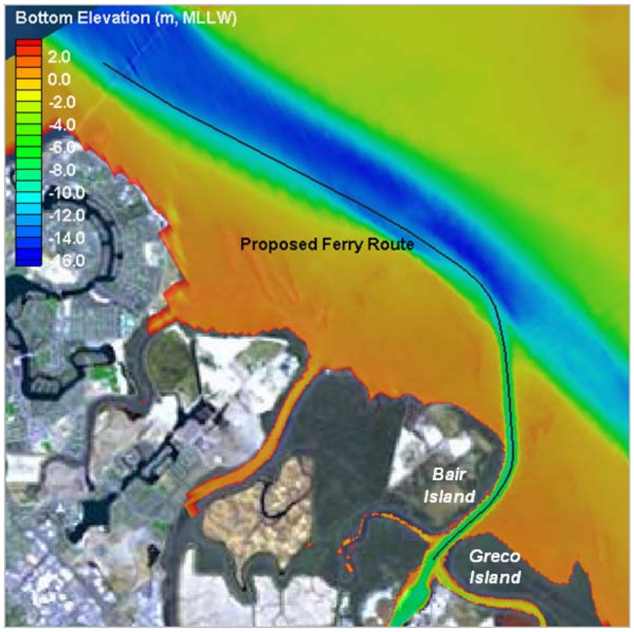

Figure 1. Proposed ferry route to Redwood City Ferry Terminal with color bottom elevation contours

Existing hydrodynamic forces at the site that contribute to sediment transport consist primarily of wind-waves. Other hydrodynamic factors, such as existing vessel traffic and tidal currents, have been determined to be insignificant within the project area. Tidal currents were observed to be low in magnitude in the area and a previous baseline study concluded that vessel wakes from ongoing traffic do not contribute significantly to the existing wave energy in the project area (URS 2004).

2. Baseline Conditions

2.1. Site Characterization Based on Site Visit

The shorelines of interest are located along Greco and Bair Islands, and were characterized based on field observations, ground photography, and visual evaluation of beach material. The site visit occurred during high tide (approximately +8.0 feet, MLLW) on February 20th, 2007. Figure 2 shows a photo of a typical section of beach on Bair Island taken from near Channel Marker 6. Coarse-grained material covers the visible beach profile. These beach profiles were observed to be relatively steep (between approximately 10H:1V and 4H:1V) and typically without erosive scarps. Based on field trip observations and review of previous data, it appears that the shoreline along Bair Island is relatively stable.

Figure 3 shows a photo of the shoreline of Greco Island near the overhead power cables crossing the channel. The shoreline in front of Greco Island is mostly comprised of fine sediment (Young Bay Mud) that forms extensive mudflats that were submerged during high tide. Although the mudflats were submerged during the site visit, erosive scarps were visible along the marsh fringe. It appears that the shoreline along Greco Island is relatively sensitive and is presently in an erosive state due to the wind-waves and wakes from existing vessel traffic.

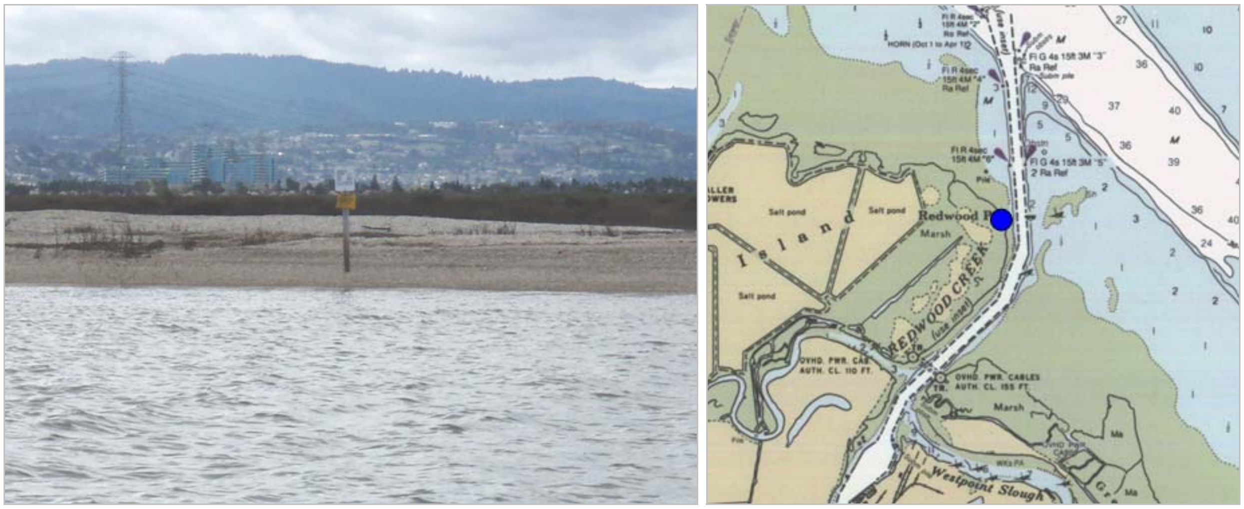

Figure 2. Shoreline of Bair Island (left) and photo location (right)

Figure 3. Shoreline of Greco Island (left) and photo location (right)

2.2. Wind Analysis

Wind-waves near Redwood City are primarily governed by wind speeds, wind directions and tidal elevations. The Redwood City wind climate and tidal elevation climate were analyzed to determine forcing conditions for generation of wind-waves at the site. Wind analysis was conducted based on meteorological data collected on the roof of the USGS Marine Facility building located at the Port of Redwood City from 1992 to 2004 (Schemel 2002). These data consisted of wind speed and direction, in addition to other meteorological data, collected at an elevation of 15 meters (assumed relative to Mean Sea Level). These data were corrected to speeds at elevation 10 meters (MSL) and analyzed to determine wind climate statistics. Figure 4 shows a wind rose, which is a graphical display of the frequency of occurrence of measured winds at certain speeds and from certain directions.

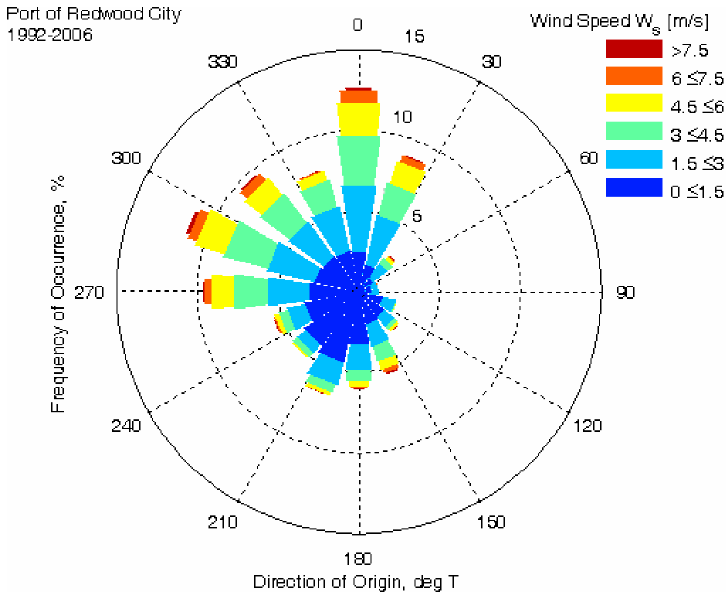

Figure 4. Wind climate measured at the Port of Redwood City, 1992-2006

2.3. Tide Analysis

Tidal elevations were analyzed for the latest 19-year tidal epoch using predicted tides at Redwood City, Wharf 5 (NOAA Station ID 579). Tidal elevation statistics were developed and are shown as a histogram in Figure 5. At this location, Mean Sea Level is approximately 1.31 meters (MLLW) and Mean Higher High Water is approximately 2.43 meters (MLLW).

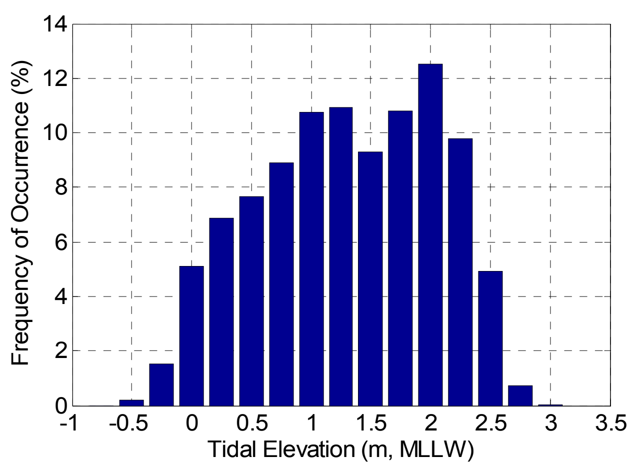

Figure 5. Tide distribution at Redwood City, Wharf 5

2.4. Wind-Wave Generation and Transformation Modeling

Wind-waves were evaluated along the ferry route and shorelines of interest using the two-dimensional wind-wave generation and transformation model SWAN (Holthuijsen 2004). The SWAN model simulates generation of wind-waves and simultaneous wave transformation over variable bathymetry and includes wave refraction, shoaling, and bottom friction. The SWAN modeling domain was constructed based on bathymetric survey data obtained from previous CHE projects, and covered the area between the San Mateo Bridge and the Dumbarton Bridge. The SWAN modeling grid was constructed as a curvilinear domain with variable resolution to allow accurate evaluation of the variable wind-wave climate along the shoreline areas, while maintaining computational efficiency.

From the tide and wind statistics developed at the site, 584 wind-wave modeling scenarios were developed for input into the SWAN model. Each of these modeling scenarios consisted of a combination of wind speed, wind direction and tide, each with its own joint probability of occurrence. Wind speeds ranged between 0.9 and 10.0 m/s, and tidal elevations ranged between –0.5 and 2.8 meters (MLLW).

Figure 6 shows the wind-wave modeling domain and bottom elevations in color contour format (left), as well as the points of interest along the shoreline defined during the analysis (Points 1-45, right). Figure 7 shows an example wind-wave modeling result consisting of significant wave heights over the entire domain for a wind speed of 10.0 m/s from 0.0 degrees (True North) at tidal elevation +2.8 meters (MLLW). Wind-wave conditions were extracted at Points 1-45 from each SWAN modeling scenario and were used for computing swash zone sediment transport at Points 1-45. The results of the computations were used for comparison with swash zone sediment transport generated by vessel wakes in Section 4.

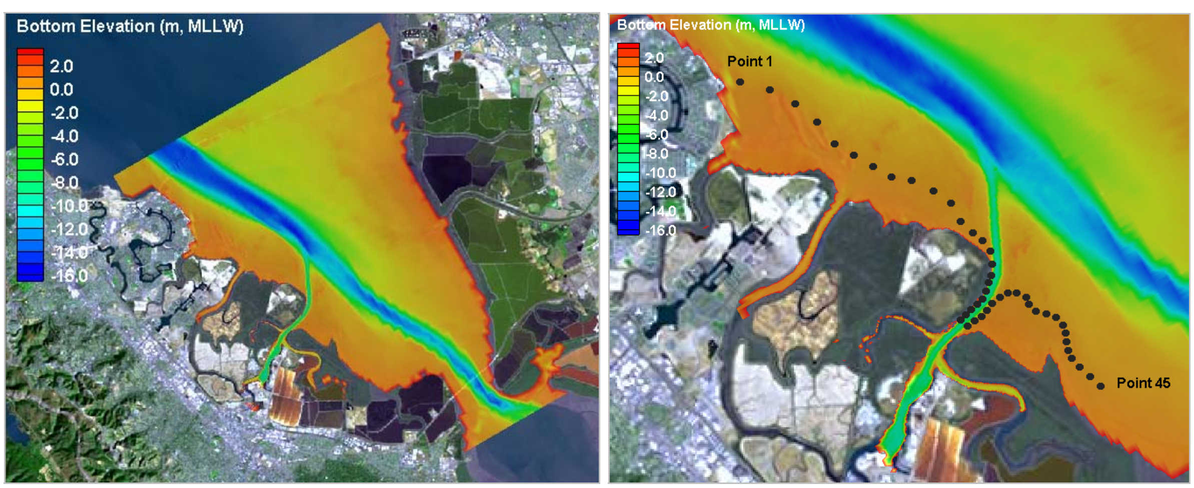

Figure 6. SWAN wind-wave modeling domain with bottom elevations (left) and shoreline Points 1-45 (right)

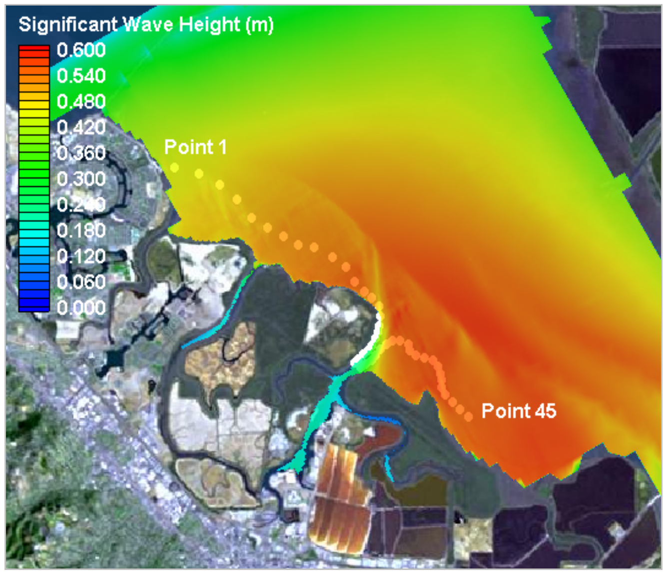

Figure 7. Significant Wave Heights predicted by SWAN model for example scenario of wind speed 10.0 m/s from 0.0 degrees (True North) at tidal elevation +2.8 meters (MLLW)

3. Wake Wash from Proposed Ferry Vessels

3.1. Ferry Vessels

For the purposes of the preliminary wake analysis, two different existing vessels were evaluated: the M/V "HARBOR BAY EXPRESS II" and the M/V "MENDOCINO." These two vessels were assumed to represent the lower and upper bounds of vessel wakes (in terms of impacts) that will be generated by the proposed ferry vessels on the Redwood City route. Table 1 shows each of the vessel's particulars.

Table 1. Vessel Particulars for Vessels used in Redwood City Wake Analysis

Vessel	Number of Passengers	Length Between Perpendiculars (m)	Beam (m)	Draft (m)
HARBOR BAY EXPRESS II	149	19.90	7.01	1.22
MENDOCINO	400	42.98	10.36	1.45

3.2. Ferry Wake Wash Generation

Wake data for both vessels were obtained from previous CHE studies performed for the San Francisco Bay Area Water Transit Authority (WTA). These data from previous studies have been used upon permission from WTA. Wake data for the HARBOR BAY EXPRESS II were obtained from results of computational fluid dynamics (CFD) modeling with the SHIPFLOW model (Glosten Associates 2005). Wake data for the MENDOCINO were obtained from field wake measurements.

Figure 8 shows a time series of wakes generated by the HARBOR BAY EXPRESS II taken from computational fluid dynamics (CFD) modeling results. This time series was extracted from the CFD data for a speed of 35 knots in 12-meter water depth (representative of a mid-tide transit in the Redwood Creek Channel), at a distance of 100 meters from the sailing line. The HARBOR BAY EXPRESS II generates small wakes when operating at high speeds in the supercritical flow regime.

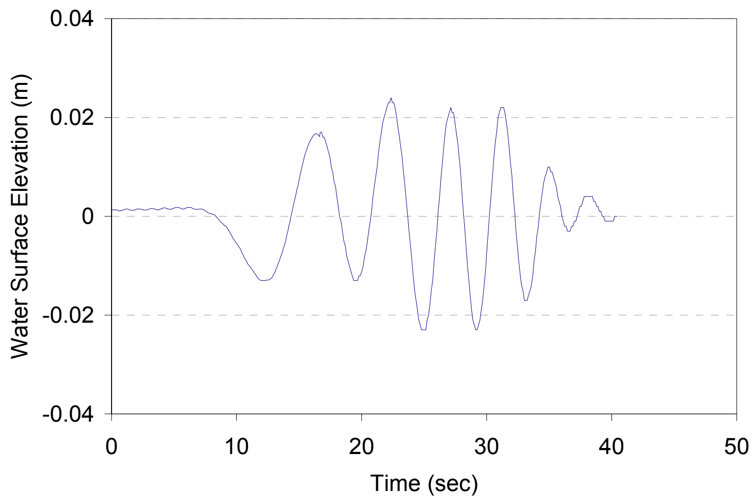

Figure 8. Ferry wake time series from HARBOR BAY EXPRESS II at 35 knots in 12-meter depth, taken from CFD results at a distance of 100 meters from the sailing line

Figure 9 shows a time series of wakes generated by the MENDOCINO as measured in the field at depth 22 meters (WTA 2002). The wakes were measured for ferry speed 36 knots at a distance of 210 meters from the sailing line. Although wake data were not available for the 12-meter depth expected on the Redwood City route, the data were considered sufficient for the preliminary analysis.

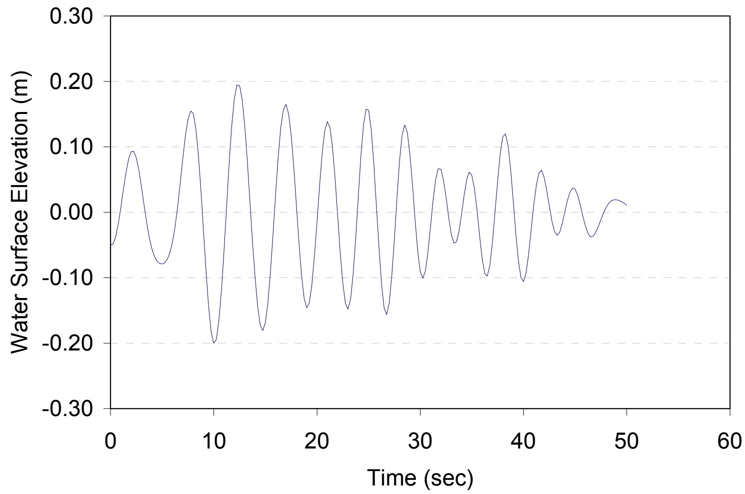

Figure 9. Ferry wake time series from MENDOCINO at 36 knots in 22-meter depth, measured in the field at a distance of 210 meters from the sailing line

3.3. Ferry Wake Wash Transformation to Shoreline

The HARBOR BAY EXPRESS II wakes (computed using CFD) and measured MENDOCINO wakes were transformed to the shallow-water shoreline points of interest (Points 1-45) using custom wave-tracking transformation routines. Due to the preliminary level of the analysis, a detailed two-dimensional wake wash transformation analysis in the time domain was not warranted and is beyond the scope of the analysis. The two different vessel wake time series were decomposed into a series of individual waves using zero-crossing analysis, each with their own wave height and period. The distances from each point of interest to the sailing line were calculated along the direction of wake travel, and linear wave theory was applied to refract and shoal the individual waves in the train to the shoreline. In addition, the individual wake wave heights and periods were scaled according to the distance from the route to each point of interest using relationships developed through CHE field wake measurements for ferries operating in supercritical (high speed, shallow water) conditions.

While it is understood that the use of simplified wave height decay analysis for vessel wake propagation introduces some error in calculation of parameters at the shoreline, it was determined to be a reasonable assumption in the absence of detailed transformation modeling during this preliminary analysis. The results of the transformation analysis included parameters such as wave height and period for each individual wave at the shoreline point of interest, which were then used to compute swash zone sediment transport at Points 1-45.

4. Ferry Wake Impact Analysis

The potential impact of ferry wakes along the Redwood City route was estimated by calculation of the expected swash zone sediment transport generated by the wakes, and comparison with the calculated ongoing swash zone sediment transport due to wind-waves. Swash zone sediment transport potential was calculated using the method of Puleo (2003), which is based on the individual wave parameters from the complete climate of wind-waves extracted from the SWAN modeling results, and the individual waves in each train of vessel wakes. The two different design vessels, HARBOR BAY EXPRESS II and MENDOCINO, were used to calculate swash zone transport resulting from both service scenarios.

Figure 10 shows swash zone sediment transport produced by wakes from the ferry HARBOR BAY EXPRESS II at Points 1-45 for both service scenarios as a percentage of future total swash transport (wind-waves + vessel wakes, left), and a map showing the locations of Points 1-45 (right). Figure 10 (left) indicates that at the majority of the Points, the sediment transport generated by wind-waves is significantly larger than that generated by vessel wakes due to the low percentage of future total contributed by wakes. The results of the analysis indicate that swash zone sediment transport due to ferry wakes would represent a small portion of the future total at most locations of interest outside the channel. Based on the results of the analysis, it is concluded that the potential impacts of the smaller vessel (HARBOR BAY EXPRESS II) are not likely to be measurable at the outer points; however, the wake-induced relative swash transport increases significantly as the vessel enters Redwood Creek and passes through the zone near Points 13-16 offshore of Bair Island. The relative importance of swash zone sediment transport due to vessel wakes increases sharply in this location due to sheltering from wind-waves at these locations, steeper beach slopes and the proximity of the route to the shoreline.

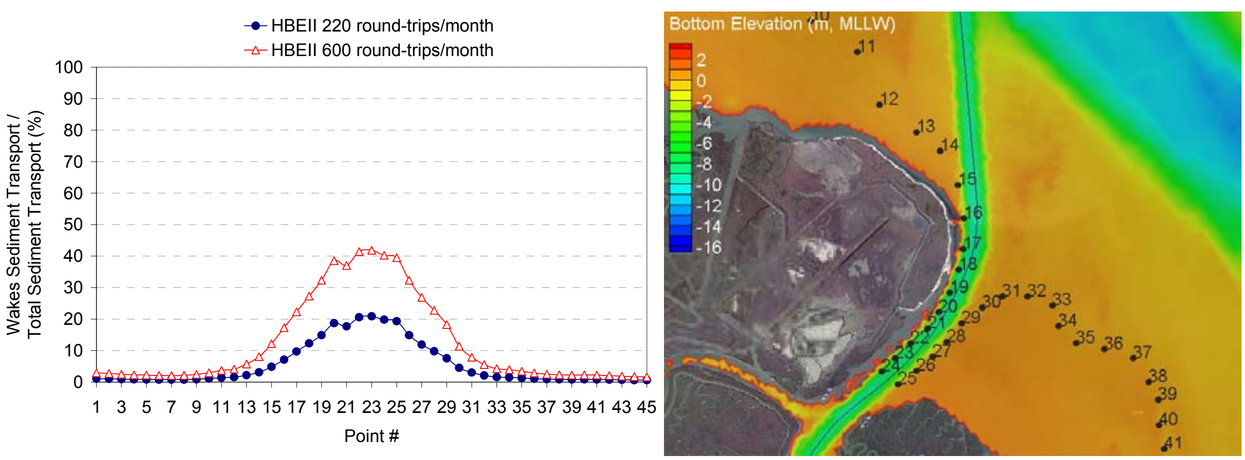

Figure 10. Swash zone sediment transport for HARBOR BAY EXPRESS II ferry wakes as a percentage of future total (wind-waves + vessel wakes, left), and locations of Points 1-45 (right)

Figure 11 shows swash zone sediment transport produced by wakes from the ferry MENDOCINO at Points 1-45 for both service scenarios as a percentage of the predicted future total swash transport (wind-waves + vessel wakes, left), and a map of Points 1-45 (right). Analysis indicates that wind-waves are typically larger at the outer locations of both Bair and Greco Island; hence, the ferry wakes from MENDOCINO make up a small portion of the total future swash zone sediment transport. Therefore, potential impacts from wakes are not likely to be measurable at these outer locations.

The wake-induced relative swash transport for the MENDOCINO also increases significantly as the vessel enters Redwood Creek and passes through the zone near Points 13-16 on Bair Island. However, since the MENDOCINO produces significantly larger wave heights than the HARBOR BAY EXPRESS II, its contribution to future total swash zone sediment transport is significantly higher at all locations, and specifically in Redwood Creek past the zone near Points 13-16.

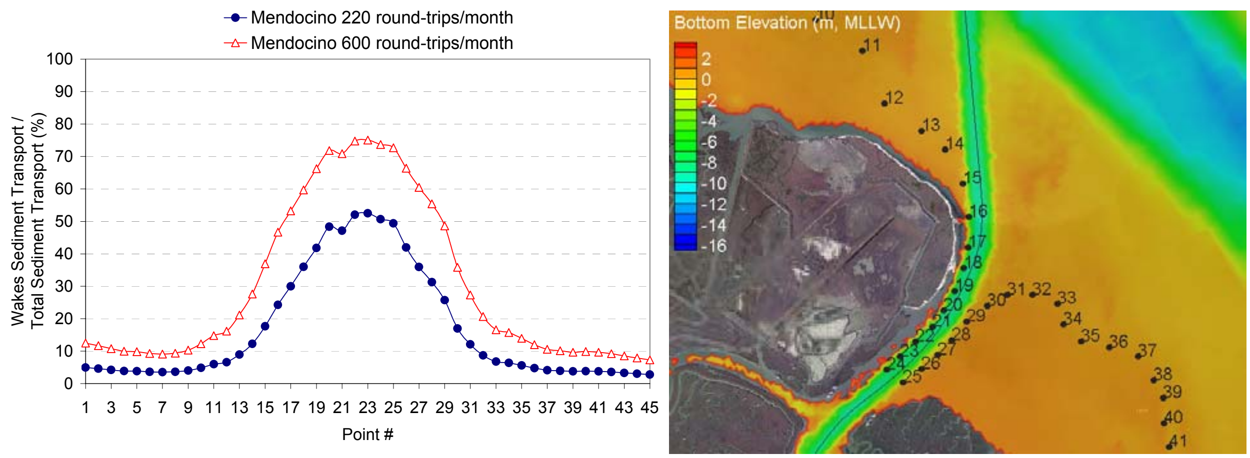

Figure 11. Swash zone sediment transport for MENDOCINO ferry wakes as a percentage of future total (wind-waves + vessel wakes, left), and locations of Points 1-45 (right)

Experience with vessels presently being designed and built for San Francisco Bay indicates that the wakes are expected to be larger than those produced by the HARBOR BAY EXPRESS II due to larger drafts required due to heavy emissions equipment and other factors. Therefore, until more detailed vessel information becomes available and additional analysis is performed, the recommendations in this preliminary analysis are based on results of the analysis with the MENDOCINO as the design vessel.

5. Operational Recommendations

The results of the analysis were used to develop preliminary operational recommendations for the proposed ferry service. The analysis indicates that full-speed ferry service (35 knots) is feasible until a certain location along the route marking the seaward end of the slow-travel zone. This slow-travel zone should be observed on both arrival and departure. The vessel speed within the slow-travel zone will vary depending on the vessel design; however it is not expected to exceed 8-12 knots. Operation at the slow-travel speed is not expected to generate significant wake wash energy, and this speed should be determined upon further analysis using the actual candidate vessel.

The swash zone sediment transport analysis indicates that the potential impacts of the MENDOCINO increase significantly at the zone surrounding Points 13-16. At Points 13 and 14, for example, the swash zone sediment transport at Bair Island is expected to be approximately 21 and 28% of the future total. Due to the relatively steep, stable configuration of the beach at Bair Island and the presence of coarse-grained material, additional swash transport at Point 13, for example, is not expected to result in measurable impacts in the form of beach erosion. Specifically, actual shoreline *response* (erosion) is not likely to be noticeably affected by this level of additional swash zone sediment transport. At Greco Island, however, the presence of fine-grained material and erosive scarps at the shoreline indicate a higher level of sensitivity to additional swash transport.

Based on the preliminary computed gross swash zone sediment transport at Points 1-45 along Greco and Bair Islands, it appears that ferry wakes are not likely to cause measurable impacts to the shoreline or mudflats of Bair or Greco Islands if the ferry reduces its speed to slow-travel speed near approximately Point 14, located a distance of approximately 2.44 kilometers (1.5 miles or 1.3 nautical miles) from the entrance to Westpoint Slough.

6. Conclusions

The preliminary wake impact analysis was performed to determine potential impacts from the proposed ferry service on shoreline and biological resources of Bair and Greco Islands and determine the preliminary location for the slow-travel zone seaward of the proposed ferry terminal sites.

The preliminary analysis indicates that for the most of the ferry route south of the San Mateo Bridge, no significant impacts on the shorelines of these islands are expected. However, a slow-travel zone during the approach to Redwood City is required to minimize potential impacts to the shoreline. The slow-travel zone should start at a location approximately 2.44 km (1.5 miles or 1.3 nautical miles) offshore of the confluence of Redwood Creek and Westpoint Slough (measured along the route). Preliminary analysis indicated that the swash zone sediment transport contribution from wakes along Greco and Bair Islands was likely to be measurable at the shoreline sites between the slow-down location and the terminal.

The preliminary analysis resulted in a conservative estimate of the slow-down location due to its exclusion of existing vessel traffic as an existing transport factor, as well as the consideration of only sediment transport as opposed to shoreline response. This is particularly true for Bair Island, where larger beach material may result in a beach configuration that is not sensitive to some additional swash transport. The shoreline of Greco Island appears to be sensitive to additional transport due to the fine beach material.

It is possible that the slow-down location may be refined and moved closer to the terminal if a smaller vessel or a vessel with different wake characteristics from those used in the preliminary analysis is put into service on the route. The results of the analysis should be revised using more detailed information and wake wash transformation analysis when the actual vessel dimensions and wake characteristics become available. To refine the slow-down location in the future, accurate vessel wake data for the vessels proposed on the route, as well as the shoreline *response* to the existing vessel wakes, wind-waves, and proposed ferry wake wash should be considered.

7. References

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