Table 41: Comparison of design measures with estimated costs and anticipated effectiveness

Design Measure	Description	Type of Analysis	Estimated Cost (2014 Dollars)	Effectiveness	Concerns
Baseline Condition (see Section 4.3)	Existing condition at project site (June 2009 to May 2010).	Numerical modeling of scenario with Coastal Modeling System (CMS).	Not Applicable.	None.	Beach and bluff erosion will continue to threaten infrastructure. Shoaling will impact navigation in Pillar Point Harbor.
1. Maximum Beach Fill	Remove 200,000 to 250,000 yd^3 from Pillar Point Harbor and construct 180 foot wide beach berm at Surfer's Beach.	GIS-based computations of dredge and fill quantities. Numerical modeling of measure with CMS.	$6,386,000*, assumes use of pipeline dredge and 20 percent contingency. Unit cost of per yd^3	High. Meets both design objectives. Might provide protective benefits to Surfer's Beach for up to 50 years.	Environmental concerns regarding removal of sand from vegetated sub-aerial beach in Pillar Point Harbor. Relatively high cost.
2.Medium Beach Fill	Remove 140,000 to 150,000 yd^3 from Pillar Point Harbor and construct 125 foot wide beach berm at Surfer's Beach.	GIS-based computations of dredge and fill quantities. Numerical modeling of measure with CMS.	$5,009,000*, assumes use of pipeline dredge and 20 percent contingency	High. Meets both design objectives. Might provide protective benefits to Surfer's Beach for up to 40 years.	Relatively high cost and uncertainty regarding performance of beach fill under persistent stormy conditions (e.g., El Niño event).
3. East Breakwater Modification: Seal Voids	Seal voids along a 2,500 ft long section to prevent sand from surging through the breakwater.	Numerical modeling of measure with CMS.	$400,000 to $600,000 to seal breakwater with concrete, based on a previous estimate (1978) to seal a 1,600 ft long section.	Medium. Meets the design objective of improving navigation in the harbor, but does not mitigate beach and bluff erosion.	Constructability. Past experience demonstrates that it will be very difficult to completely seal the breakwater.
4. East Breakwater Modification: Notch	Modify the East Breakwater by removing a 200 foot long section to create a notch that facilitates transport of sand.	Numerical modeling of measure with CMS.	$240,000 to $320,000 to remove 150 to 200 ft of breakwater, based on a previous estimate (2006) to remove 170 linear ft of breakwater.	Low to Medium. Modest decrease in rate of shoaling in harbor, but does not mitigate beach/bluff erosion.	Changes in hydrodynamics in harbor, which could interfere with navigation.
5. Alternative Dredged Material Placement	Continuous removal of sand from the shoal along the east breakwater with placement near the harbor entrance.	Utilized outputs from CMS simulation of baseline condition.	$2.3 million to $4.7 million, based on costs from Oakland MHEA and Moss Landing Harbor. Note uncertainty associated with continuously operating pipeline.	Low. Likely does not meet both design objectives.	Interference with navigation, high maintenance costs and project complexity.
6. Spur Breakwater	Construct 600 ft long spur breakwater extending from east breakwater.	Review of design developed by USACE (1971), which was based on physical modeling.	$2.5 million to $3.2 million, based on 2006 and 1971 estimates, respectively	Low to Medium. Limited benefits to a small section of beach. Uncertainty regarding impact (if any) on navigation in harbor.	Impacts to surfing resources and nearshore environment.
7. Managed Retreat	Remove infrastructure from areas vulnerable to erosion. Realign a 4,400 ft long section of Highway 1	GIS-based analysis of projected bluff retreat. Review of conceptual plans and infrastructure data from Ocean Beach.	Over $16 million to realign Highway 1, assuming a cost of $3,700 per linear ft of highway.	Low. Does not meet the design objective of improving navigation in harbor, and does not reduce rate of beach/bluff erosion.	High cost. Complex planning process involving multiple stakeholders.

* Costs estimated by USACE San Francisco District Cost Engineering Section based on guidance in ER 1110-2-1302

7 Conclusions and Recommendations

There are 2 key findings from this study, which informed development of the design objectives and formulation of design measures.

First, a GIS-based analysis of coastal bluff retreat supports the well established hypothesis that the construction of the east breakwater has induced additional erosion of the unprotected coastal bluff and beach between the Caltrans and Mirada Road revetments. The analysis suggests that bluff erosion rates in the immediate vicinity of the east breakwater are more than 1 foot per year greater than the background erosion rates in nearby geologically similar sections of coastal bluff. Therefore, it is reasonable to assume that presence of the east breakwater will continue to induce additional erosion in the absence of any erosion mitigation efforts.

Second, construction of the breakwaters has resulted in deposition of at least 150,000 yd^3 of sand along the harbor side of the east breakwater, which has limited the available maneuvering and anchoring area in the harbor. Previous studies, observations, and numerical modeling with the CMS suite strongly suggest that most of this sand originates outside of the harbor, and is deposited on the harbor side of the east breakwater via surging of waves through and over the structure. It is anticipated that sand will continue accumulate in this shoal in the absence of a measure to prevent sand from surging through and over the structure.

These 2 findings served as the basis for developing the two design objectives, which in turn informed the design measure formulation process. As a result, 7 design measures were evaluated to determine which would be the most effective at addressing the design objectives of mitigating beach and bluff erosion between the 2 revetments and improving navigation in the harbor. The evaluation process involved simulations with the CMS modeling suite for 4 of most promising the measures, and other methods (e.g., GIS-based analysis) for the other 3 measures.

Of the 7 measures, the Medium Beach Fill design (150,000 yd^3) will likely be the most effective from an engineering perspective as it directly addresses both of the design objectives. However, detailed cost and economic analyses are necessary to determine if this and other design measures are economically viable and should be carried forward in the Detailed Project Report.