

**NORTHERN HALF MOON BAY SHORELINE IMPROVEMENT PROJECT
PILLAR POINT HARBOR, CA**

**SECTION 216
REVIEW OF COMPLETED PROJECTS**

**INITIAL APPRAISAL
JULY 2009**

1. INTRODUCTION

PURPOSE

The purpose of this Initial Appraisal is to review the existing United States Army Corps of Engineers (Corps) project Pillar Point Harbor (authorized in 1948 with initial breakwater construction from 1959 to 1961) to determine whether it is appropriate for the Corps to participate in the resolution of documented shoreline erosion and structural damage along the northern open-coast shoreline of Half Moon Bay. The non-federal sponsor has stated that the negative shoreline impacts in that area can be attributed to the original Corps project. The area of concern (proposed project area) starts at the root of the East Breakwater and extends southward a distance of approximately one mile to Arroyo de en Medio, which is near the southern end of Miramar Beach. Because of its relative stability since breakwater construction, the Half Moon Bay shoreline between Arroyo de en Medio and Miramontes Point is not included in this Initial Appraisal. Federal interest will be based on two factors: (1) the extent of the post-construction shoreline change beyond the natural change that would have been expected without the Pillar Point Harbor project and (2) the economic viability of a potential project to mitigate for such physical changes. Based on the evaluations of these factors, the Corps will determine Federal interest, and, if positive, will recommend a further study that could lead to the design and execution of a remedial project.

SCOPE

This Initial Appraisal describes the Pillar Point Harbor project, the shoreline erosion problem in the specified coastal stretch and related existing conditions, potential solutions to the erosion problem and with and without future project conditions, the economic analysis for the project, views of the stakeholders and general public, and the conclusions and recommendations regarding this project. Due to the time and funding limitations under the Section 216 authority, this Initial Appraisal is limited to reviewing existing information and conducting small-scoped analyses using existing data. If there is potential Federal interest in the project, the next phase of the project would include policy clarifications as well as additional studies requiring data collection and detailed analyses.

2. PROJECT

Pillar Point Harbor, California

Congressional District 14 (San Mateo), Representative Anna Eshoo

Local interests solicited the assistance of the Federal Government to develop a harbor in Half Moon Bay. The Corps conducted a preliminary examination of the project and produced a favorable report in November 1945. A survey report of the area was produced in August 1947 recommending the construction of two breakwaters to form the harbor. The project was authorized by Congress in 1948, and initial breakwater construction commenced in April 1959 and ended in June 1961. Subsequent changes to correct other induced problems are delineated below.

In FY08, the San Mateo County Harbor District requested that the Corps investigate shoreline erosion immediately south of Pillar Point Harbor to determine if the Corps should participate in a shoreline restoration project. Corps involvement would be appropriate if the East Breakwater has contributed to erosion of that stretch of shoreline. The Harbor District asserts that the shoreline was relatively stable prior to breakwater construction and that the Corps project has induced significant beach and sea-cliff erosion immediately south of the root of the East Breakwater and deposition of sand immediately north of the root (inside the harbor). They contend that the East Breakwater stopped the unimpeded flow of sand in the littoral zone thus preventing replacement of beach sand in the eroding coastal stretch. If the Corps acknowledges that its breakwater has played a major role in the shoreline erosion, the Corps could initiate a reconnaissance study for a new shoreline project. Potential solutions include (a) transferring clean, non-contaminated harbor sand from the eastern shoreline of Pillar Point Harbor to the beach immediately outside and adjacent to the East Breakwater; (b) creating a sand "reef" just offshore of the beach to reduce the amount and need for periodic sand replenishment on the beach; (c) modifying the root of the eastern breakwater to better manage longshore sand transport, or (d) constructing a hard structure along the face of the sea cliff to prevent further shoreline retreat. Any project would have to be economically viable or address associated navigational issues in the project area.

STUDY AUTHORITY

This Initial Appraisal is authorized by Section 216 of the River and Harbor and Flood Control Act of 1970 as amended, which reads:

"The Secretary of the Army, action through the Chief of Engineers, is authorized to review the operation of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures or their operation, and for improving the quality of the environment in the overall public interest."

The Section 216 process starts with the preparation of an Initial Appraisal. As stated in Engineer Regulation ER 1105-2-100, the cost of preparing an Initial Appraisal report is limited to \$20,000. The U.S. Army Corps of Engineers, San Francisco District allocated

\$20,000 in Fiscal Year 2008 Operation and Maintenance funds to conduct this Initial Appraisal.

EXISTING AUTHORIZED PROJECT

The existing authorized project consists of the construction of two rubble-mound breakwaters (referred to as the East and West Breakwaters, or collectively as the Outer Breakwaters), a rubble-mound extension to the seaward end of the West Breakwater, a short parapet wall with stone cover extension to the root of the West Breakwater, and the maintenance of these structures.

Project Description

Pillar Point Harbor is located at the northern end of Half Moon Bay (Fig. 1), approximately 25 miles south of San Francisco. The easternmost portion of Pillar Point Harbor (including the East Breakwater) and the shoreline from the breakwater south to Miramontes Point are within the boundary of the City of Half Moon Bay (the city's downtown district is five miles to the southeast of the harbor). The closest communities to the harbor are Moss Beach (two miles to the northwest), El Granada (across Highway 1 to the east), and Princeton (which borders the northwestern portion of the harbor).

The 0.9 miles of shoreline from the root of the East Breakwater to Arroyo de en Medio—comprising El Granada Beach (habitually called Surfer's Beach), Vallejo Beach, and Miramar Beach—is the project area. Rubble-mound revetments front the low-lying coastal cliffs at both ends of this stretch of shoreline. This protection is necessary at the northern end to protect Highway 1 and at the southern end to protect homes and businesses built up to the edge of the sea cliff. The middle stretch, Vallejo Beach, is not rocked, possibly because there are no structures along the bluff edge and Highway 1 is turns away from the shore.

The Pillar Point Harbor project consists of two rubble-mound breakwaters. The East Breakwater is 4,420 feet in length, and was constructed from April 1959 to June 1961. The West Breakwater was originally 2,620 feet in length when it was built (April 1959 to September 1960). Because of larger than expected wave energy entering the harbor, during 1966 and 1967 a rubble-mound dogleg extension 1,050 feet in length was added to the seaward end of the West Breakwater. In 1996 a concrete parapet wall measuring 109 feet long by 3 feet high by 3 feet thick was added to the root of the West Breakwater with additional protection being provided by one layer of armor stone covering the parapet wall. In January 2006, the Corps prepared a 216 Initial Appraisal to respond to non-federal concerns about erosion of the Princeton shoreline inside Pillar Point Harbor. That Initial Appraisal concluded that, though not definitively proven, it was likely that the erosion was caused by focusing incident wave energy that entered through the harbor entrance onto the shoreline.



Figure 1: Google Earth image of Half Moon Bay. Arrows mark the bounding headlands (Pillar Point and Miramontes), the southern end of the urbanized area (Poplar Street), and the extent of the project area (Root of the Breakwater to Arroyo de en Medio). Station numbers for Table 1 are shown in white.

Following construction of the outer breakwater, the erosion rate of the sea cliff immediately south of the East Breakwater increased dramatically suggesting a cause-and-effect relationship between construction and erosion. As part of its completed projects (Section 216) authority, the Corps can review completed projects when found advisable due to changed physical conditions. The increased erosion rate in the project area south of the breakwater represents a change in physical condition for the Pillar Point Harbor project.

Project Authority

Pillar Point Harbor (under the project name of Halfmoon Bay, California), as described in House Document No. 644, 80th Congress, 2nd Session, was authorized in the River and Harbor Act of 1948:

*“The following works of improvement of rivers and harbors and other waterways for navigation, flood control, and other purposes are hereby adopted and authorized to be prosecuted under the direction of the Secretary of the Army and supervision of the Chief of Engineers, in accordance with the plans and subject to the conditions recommended by the Chief of Engineers in the respective reports hereinafter designated: **Provided**, That the provisions of section I of the River and Harbor Act approved March 2, 1945 (Public, Numbered 14, Seventy-ninth Congress, first session), shall govern with respect to projects authorized in the title, and the procedures therein set forth with respect to plans, proposals, or reports for works of improvement for navigation or flood control and for irrigation and purposes incidental thereof, shall apply as if herein set forth in full: ...Halfmoon Bay California; House Document Numbered 644, Eightieth Congress;”*

The recommendations authorized by this act are described in the report from the San Francisco District Engineer dated 1 August 1947:

“The district engineer recommends that Halfmoon Bay, Calif., be improved by the construction of two rubble-mound breakwaters, each approximately 4,400 feet long, substantially as shown on the plan of improvement submitted herewith, at an estimated cost of \$4,512,000 for new construction, and \$43,800 annually for maintenance, subject to conditions that local interests establish a competent and properly constituted public body, empowered to regulate the use, growth and free development of the harbor facilities with the understanding that such facilities shall be open to all on equal and reasonable terms, ...”

3. EXISTING CONDITIONS AND PROBLEMS

EXISTING CONDITIONS

The existing conditions along the shoreline south of Pillar Point Harbor were evaluated in regards to significant changes in physical processes and economic conditions since the construction of the outer breakwaters. This section evaluates the physical processes. Due to the limited scope of a Section 216 Initial Appraisal, the information regarding changes in physical processes is based upon data taken entirely from previous studies; no additional data was collected for this study.

Shoreline Configuration

Half Moon Bay extends a distance of 6.5 miles from Pillar Point on the north to Miramontes Point on the south (Lajoie and Mathieson, 1985, p. 163). Before construction of the outer breakwater, the bay had a smoothly arcuate shoreline comprising a continuous sandy beach backed by a sea cliff cut into a low terrace of loosely consolidated sand and gravel (Table 1). The terrace tilts upward from north to

south with an elevation range of approximately 10 to 60 feet. In the central part of the bay, small coastal sand dunes replace the terrace. The San Mateo County geologic map shows that the terrace consists of Holocene unconsolidated fine- to coarse-grained sand, silt, and gravel to the north and Pleistocene poorly consolidated and poorly indurated well- to poorly-sorted sand and gravel to the south.

Table 1: Shoreline type between Miramontes Point and Pillar Point (Krumbein, 1947). See Figure 1 for Station locations.

Station	Miles north of Miramontes Point	Shoreline Description
1	0.25	Rock reefs abundant, sand very coarse, beach fairly narrow, cliffs 60 feet high, erosion evident.
2	0.80	Occasional rock reefs, coarse sand, cliffs 50-60 feet high, erosion evident.
3	1.20	Well developed berm, cliffs 40 feet high.
4	1.80	Well developed berm, cliffs 20 feet high.
5	2.20	Well developed berm, sand moderately coarse, sand dunes on terrace.
6	2.60	Berm present, stream parallels cliff inland of beach. Cliff 15 feet high.
7	3.20	Well developed berm, prominent dune belt' parallels wide beach.
8	3.70	Well developed berm, dune belt ends just north of station.
9	4.10	Partially eroded berm, wide beach, sand moderately fine. Cliffs 10 feet high.
10	4.60	No berm present, wide beach, sand rather fine. Some erosion evident. Cliffs 10 feet high.
11	5.10	No berm present, active erosion along cliffs, which are 20 feet high.
12	5.50	Small trace of berm in re-entrant. Wide beach, very fine dark sand. Very active' erosion along cliffs, which are 15 feet high.
13	6.10	No berm present. Very wide beach, very fine dark sand, always moist. Cliff here about 1 to 2 feet high.

Pillar Point Harbor sits at the northern end of the bay (Fig. 2), enclosing 1.6 miles of the shore and creating a safe haven for private and commercial marine operations. Along the open coast, most of the beach access is north of Poplar Street (3.6 miles south of the root of the East Breakwater), which is the southern limit of the urban area of the city. Miramar, Naples, Dunes, and Francis California State Beaches lie between Arroyo de en Medio and Kelly Street (2.95 mi south of the breakwater). To the south, the area has been sparsely developed, being mostly used for agriculture; however, private residences, hotels and a golf resort are becoming more common (Griggs et al., 2005).



Figure 2: 1971 aerial photograph of Half Moon Bay looking south with the East Breakwater in the foreground and Miramontes Point in the distance. Note the sand accumulation adjacent to the harbor side of the root of the East Breakwater. Photograph by N. Prime, USGS.

Pillar Point and Miramontes Point constrain littoral transport to the Half Moon Bay embayment (Lajoie and Mathieson, 1985). Between those rocky headlands, waves move beach sand both across shore and alongshore. Over recent geologic time, the prevailing northwest swell refracted around the Pillar Point headland, eroding the shoreline into a simple log spiral shape (Fig. 3) that evenly distributed wave energy along the shoreline (Lajoie and Mathieson, 1985). Once the shoreline reached this shape, incoming wave crests paralleled the coast, reducing shoreline retreat to times when storms stripped sand from the beach and both directly attacked the sea cliff and removed material that had crumbled from the cliff face because of ground water saturation (Hampton 2002, Collins and Sitar 2008). In other words, the shoreline had reached an equilibrium configuration with a low, but finite, rate of cliff retreat (Griggs et al., 2005).

Grain size, beach slope, and wave energy all increase from north to south. Numerous field studies have quantitatively demonstrated that beaches composed of coarse particles have steeper slopes (Komar, 1998, p. 285). The studies also show that beach slope increases with increasing wave energy for a given grain size. Since the northern end of Half Moon Bay is protected from northwest waves while the southern end is fully exposed to all wave directions, wave energy is lowest close to the headland and progressively increases to the south. In response to the increasing energy level, the beaches farthest from the headland are coarsest—there is a systematic increase in grain size in that direction (0.17 mm mean diameter near Princeton to 0.65 mm at Miramontes

Point according to Bascom, 1951). Consequently, beach-face slope increases from north to south.

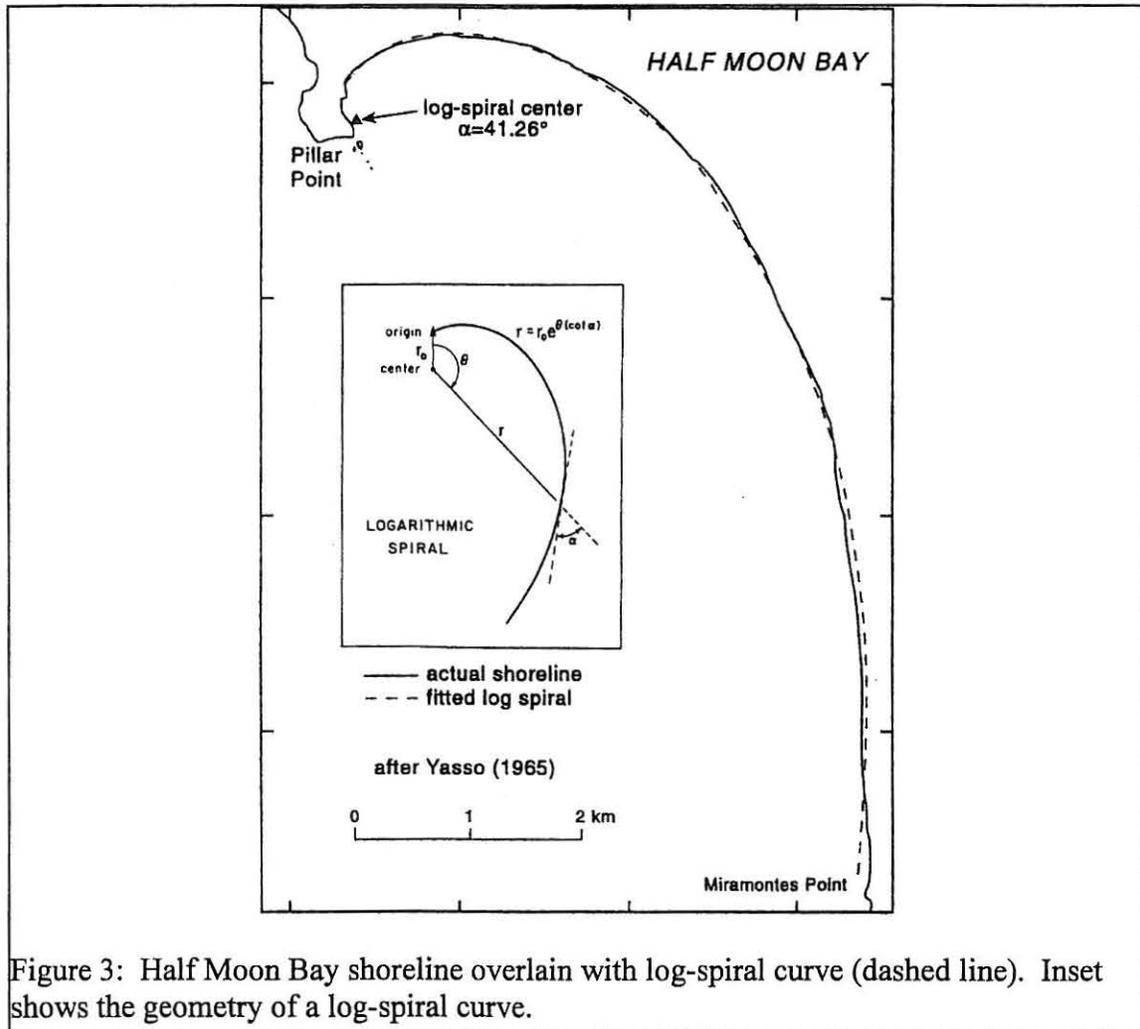


Figure 3: Half Moon Bay shoreline overlain with log-spiral curve (dashed line). Inset shows the geometry of a log-spiral curve.

Winds

The central California Coast sits on the eastern edge of a high-pressure system over the eastern North Pacific Ocean. The location of that system throughout the year determines the predominant meteorological conditions for the region. Normally, the North Pacific high-pressure system shifts north during the summer and south during the winter. The position of the high pressure offshore in combination with lower pressure in the warm inland areas results in west-northwest to northwesterly winds throughout much of the year (Mass and Bond, 1996; Renard, ND).

Between May and October, when the high-pressure system is at its more northern location, the mean wind direction is from the west northwest/northwest (Halliwell and Allen, 1987). Between November and April, when the high-pressure region shifts south,

the mean wind direction is from the west (Halliwell and Allen, 1987; Dorman et al., 1995; Dorman and Winant, 1995).

Besides the North Pacific high-pressure system, migratory weather systems produce local variations in the climate throughout the year. During the winter months, southeasterly to southwesterly winds form in advance of extratropical storms that cross the region. During the summer months, the development of higher pressure over the interior part of the state results in offshore flow (Mass and Bond, 1996).

Land and sea breezes constitute an important component of the local wind regime. Cooler air over land than over the ocean creates a land breeze (offshore flow); warmer air over land than over the ocean creates a sea breeze (onshore flow). Typically, the land warms up during the day with a maximum air-temperature difference in the early to mid afternoon. This produces a surface pressure differential between the ocean (high) and land (low) resulting in a strong, steady sea breeze. Subsequently, the land cools until sometime after sunset the two temperatures are equal and the wind dies. Further cooling can result in a land breeze. In central California, this pattern can occur at any time of the year.

The wind climate at Pillar Point Harbor has not changed significantly since the construction of the outer breakwaters. The average wind speed over a year is between five to fifteen miles per hour. While the predominant winds come from the northwest, the most severe winds come from the south. The fastest mile wind speed for a return period of fifty years is estimated to be sixty-one miles per hour.

Currents and Tides

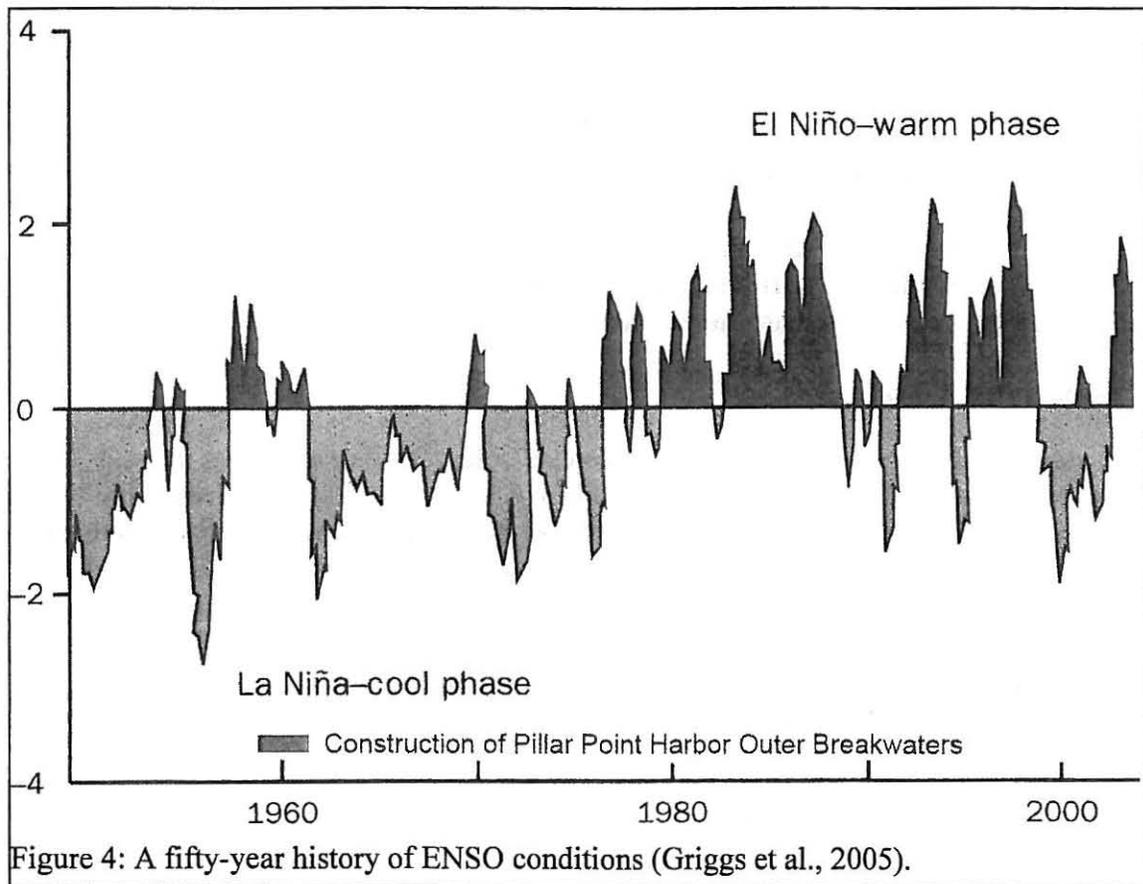
The currents offshore of Half Moon Bay consists of the California Current flowing southward throughout the year and the Davidson Current that flows northward shoreward of the California Current, typically in the fall and the winter. These currents do not have a direct effect on the nearshore circulation, which is dominated by tides, waves, and wind-driven circulation. Eddies rotating counterclockwise in the northern portion and clockwise in the southern portion of Half Moon Bay were believed to exist, prior to the construction of the outer breakwaters. The construction of the outer breakwaters probably altered this circulation pattern by either shifting the eddies to the south and/or eliminating them altogether

Sea-Level Fluctuations and Storms

Sea-level fluctuations include tidal cycles, set up during storms, and long-term rise due to natural processes and human impacts. The tides at Half Moon Bay are mixed semidiurnal tides with a great diurnal tide range of 5.5 feet, and a mean sea level elevation of 3.0 feet relative to Mean Lower Low Water. The construction of the outer breakwaters should not have affected the tidal amplitudes, but they could have had a major effect on the tidal currents. The state of the tide is important with respect to coastal erosion because storms that strike the coast during high spring tides are more likely to inflict major damage than they would during lower parts of the tidal cycle. For example,

the California coast suffered significant storm damage during 1982-83 and 1997-98, both ENSO years (El Niño-Southern Oscillation). Although several indices suggest that the 1997-98 ENSO was stronger than the 1982-83 ENSO, the latter caused far more coastal damage (Griggs et al., 2005). A major difference between the two ENSOs is that the largest two storms of the earlier ENSO hit during high spring tides while the largest two storms of the later ENSO hit during lower tides.

Coastal erosion and storm damage along the California coast are maximized when several processes occur simultaneously. Historical reviews focused on the central California coast have shown that about 75 percent of the storms that caused significant erosion or structural damage between 1910 and 1995 occurred during ENSO events (Griggs et al., 2005). ENSOs are cyclic, and along the California coast, they were less severe during the period between mid-1940s and 1978 than during the period between 1978 and 1998 (Fig. 4).



Waves

The construction of the outer breakwaters has had a dramatic effect on Pillar Point Harbor and the northern portion of Half Moon Bay. While the head of Pillar Point provided some natural protection from waves traveling from the north to west directions, the magnitude of wave reduction became much less after the construction of the outer breakwaters and the West Breakwater extension. Prior to the construction of the

breakwaters waves originating from the northwest would refract around Pillar Point. However, the construction of the breakwaters altered the wave refraction causing the waves to have a head-on impact on the Surfer's Beach. Consequently, waves from the northwest direction have a more dramatic effect on Surfer's Beach now than prior to the breakwater construction.

Tributary Streams and Sediment Supply

Streams that enter Half Moon Bay include from north to south Denniston Creek, Deer Creek, Arroyo de en Medio, Frenchman Creek, and Pilarcitos Creek. Denniston Creek and Deer Creek drain into Half Moon Bay Harbor; the rest directly enter the ocean through the beach. The total drainage area for those creeks is approximately 31 mi² of which the Pilarcitos Creek drainage area is 22 mi².

Littoral Drift

The littoral drift at Half Moon Bay is thought to move to both northward and southward depending on the wave conditions with the net drift being from northwest to southeast due to the predominate northerly to westerly wave climate. This reversing alongshore movement is superimposed on the onshore-offshore transport that occurs throughout the year. In general, local storms create high-energy, short-period waves that keep sand in suspension while it moves offshore (winter conditions). Lower energy, longer period waves slowly push the sand back onto the beach (summer conditions). If there is net longshore transport, sand from local creeks and from bluff erosion are available to maintain a sandy beach. Before breakwater construction, the Pillar Point cliffs, the Princeton shoreline, and the creeks that feed that part of the bay were all sources of sand for beaches to the south.

Because Half Moon Bay is essentially a closed system (littoral cell) and there is a continuous sand supply from cliff erosion and creek input, littoral sand must either be lost to the offshore or dunes unless beach width increases. Studies show that the bay's beaches are not accreting, and in the project area there is no beach at higher tides. Krumbein (1947) concluded that little sand moved into the dune field, but approximately 30,000 yd³ moved offshore annually.

EROSION OF THE SURFER'S BEACH SHORELINE

Studies Prior to Breakwater Construction

All previous studies and historical anecdotal observations have indicated that the Half Moon Bay shoreline has been eroding since at least the 1860s. This erosion is believed to have been caused by natural processes; however, the rate of retreat was low due to the presence of a permanent broad sandy beach and an equilibrium shoreline shape relative to the incident waves (Griggs et al., 2005).

Influence of Pillar Point Harbor

Table 2 summarizes the major construction events at Pillar Point Harbor. Also given in the table is the condition in the project area at the time of various construction events based on all available data. The results shown in the table indicate that the construction of the outer breakwaters may have contributed to an increased erosion rate of the adjacent shoreline, warranting further investigation.

Date	Event	Beach Condition
Prior to 1959	Natural Conditions	Minimal erosion with broad sandy beach
1959 to 1965	Two Outer Breakwaters Built	Increase in erosion with a loss of approximately 75,000 yd ³ per year (USACE, 1971)
Prior to 1971	500 ft revetment built starting at root of East Breakwater	Stopped local cliff retreat (USACE, 1971)
1982	Two Inner Breakwaters Built	No impact on erosion south of the East Breakwater
1965 to present	Various remedial actions including rubble-mound revetments	Erosion rates increased from 3 in per year to as much as 80 in per year (Griggs et al., 2005) where sea cliff is exposed.

Effects of the East Breakwater on the Adjacent Shoreline

Inside the harbor, sediment has accumulated adjacent to the East Breakwater (Fig. 5), creating a beach containing, in April 1998, at least 73,000 yd³ of sand above water¹. This volume does not take into account the tide level, which ranged from MLLW to +4 ft during the day of the LIDAR survey, and changes in volume since 1998 are not known. Between that beach and the inner breakwater, sufficient sand has accumulated to elicit concern from the Harbor District about restricted small-boat access to the inner harbor via the east entrance. That sand probably comes from erosion of the Princeton shoreline and material coming down Denniston Creek and Deer Creek. Pre-breakwater, that sand would have moved alongshore to the south. It is also possible that some of the sand in the delta comes from the south, being driven through the breakwater during large storms. Once inside the harbor, there is insufficient wave energy to move the sand back through the breakwater and into the littoral system. The importance of sand transport through the breakwater needs to be evaluated before a management plan for the delta sand can be properly implemented.

¹ Calculation made using data from the 1998 Spring West Coast Post-El Niño LIDAR flights. NAVD88, which is the same as MLLW in the area (MLLW is -0.08 ft higher), is the datum. Flight time was not given, so tidal level cannot be included.



Figure 5: East end of Pillar Point Harbor showing East Breakwater, inner breakwaters, and inner beach adjacent to the root of the East Breakwater.

Construction of the East Breakwater disrupted the equilibrium wave pattern and focused wave energy at the low cliffs south of the breakwater causing rapid cliff erosion along the shoreline in area of this project (Lajoie and Mathieson, 1985). Post-breakwater construction in that area, a county road was destroyed, state Highway 1 threatened, and the rate of sea cliff retreat increased from three inches per year to 80 inches per year (Fig. 6; Lajoie and Mathieson 1985). Specifically, by 1985 the sea cliff had eroded far enough into the terrace to destroy Mirada Road, which paralleled the cliff edge (Fig. 7). The most likely causes of the increased erosion are shifting the center of the log-spiral to the south and cutting off the sand supply from the north. Shifting the center of the spiral creates a different wave-energy dynamic along the length of Half Moon Bay as the shoreline tries to return to an equilibrium configuration. The greatest change will be where the spiral is the tightest, which is adjacent to the south side of the East Breakwater (Fig. 8). The effect will taper off downcoast, and erosion will, consequently, be less. Because the net littoral transport is to the south, the combined impact of eliminating the sand supply from north of the project area and increasing the wave energy in that area will accelerate the erosion. As stated in USCE (1971): *"The document that led to the law which set forth the details for the original construction of the breakwaters, contained a discussion of the effect of the proposed improvement on the shoreline. It was stated that maximum realignment of the shore would probably occur immediately south of the East Breakwater, which has been the case."*

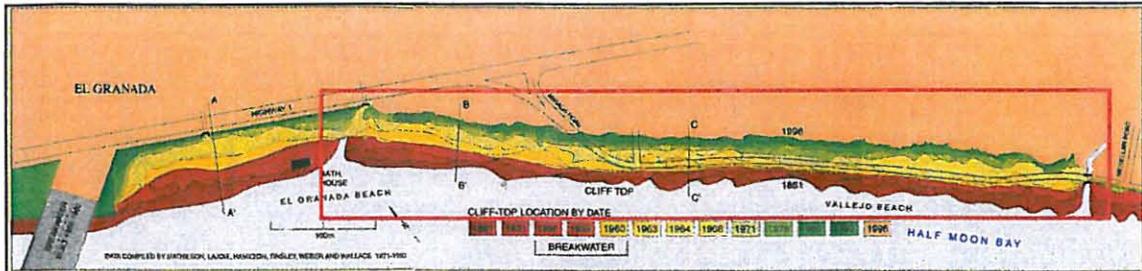


Figure 6: Cliff top retreat between 1861 and 1996 show increased rate after construction of the Pillar Point breakwaters (Lajoie and Mathieson, USGS poster). Shoreline inside of the red box consists of a sandy beach fronting unprotected sea cliff. Shoreline to the north of the box has no beach at higher tides and the sea cliff is faced with a rubble-mound sea wall constructed by Caltrans to protect Highway 1. Shoreline to the south of the box (to Arroyo de en Medio, outside the figure) has no beach and the sea cliff is faced with a rubble-mound seawall to protect homes and businesses.



Figure 7: 1971 photograph of Mirada Road looking south from near the root of the East Breakwater. Subsequently, the road was destroyed. Rip-rap can be seen along the sea cliff starting at about the white house and going south. Photograph by K. Lajoie, USGS.

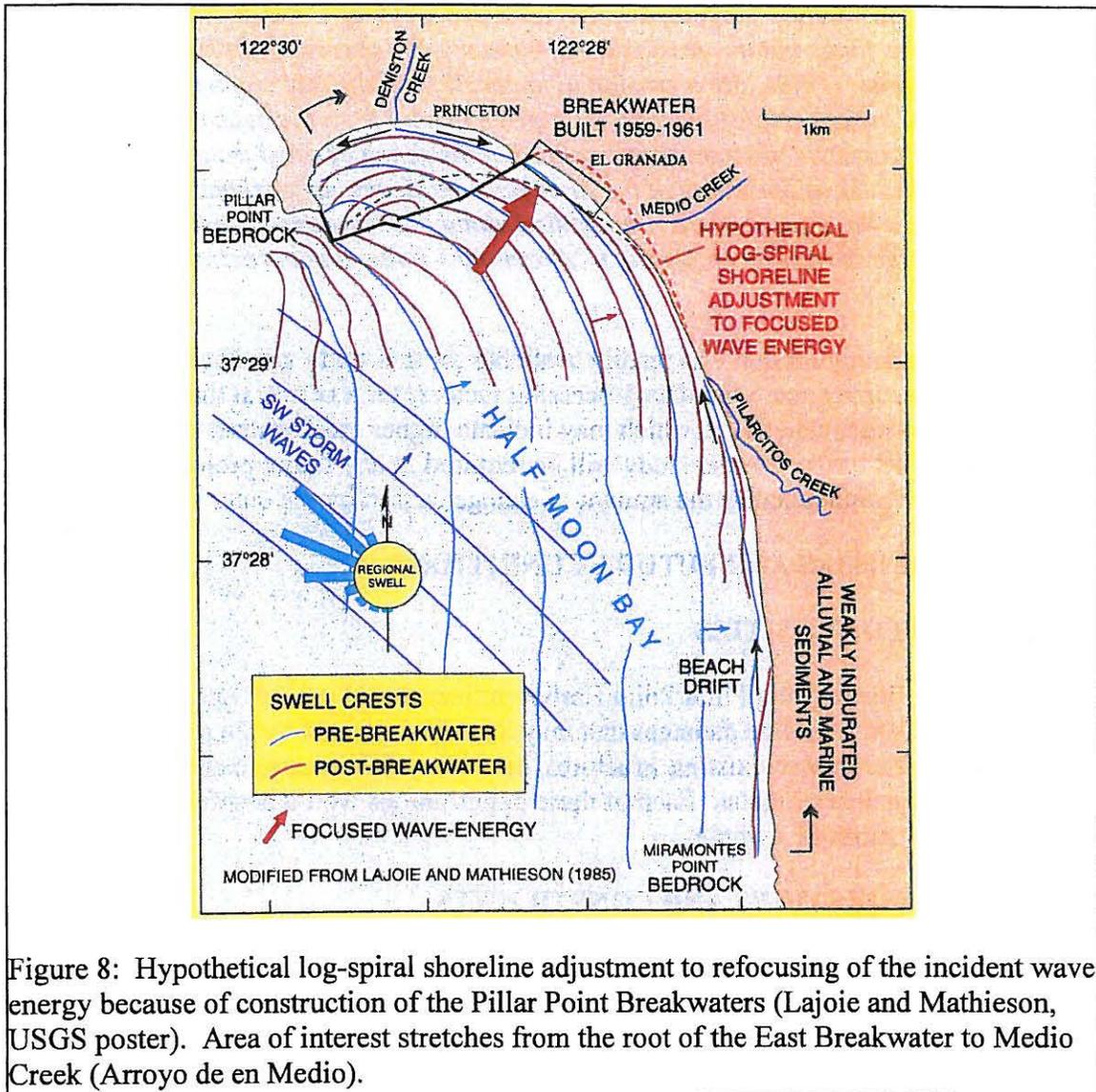


Figure 8: Hypothetical log-spiral shoreline adjustment to refocusing of the incident wave energy because of construction of the Pillar Point Breakwaters (Lajoie and Mathieson, USGS poster). Area of interest stretches from the root of the East Breakwater to Medio Creek (Arroyo de en Medio).

Surfer's Beach Change Investigation

In conclusion, a preponderance of evidence substantiates the claim that the construction of the outer breakwaters led to a dramatically increase in the erosion rate of the shoreline between the root of the East Breakwater and Arroyo de en Medio. Other causal effects, such as changes in weather patterns, are thought to have made a minor contribution at best to the increased erosion rate. Construction of the Outer Breakwaters and the subsequent increase in erosion took place during a time of less severe ENSOs (Fig. 4). By the start of the more severe ENSOs (1978), parts of the shoreline in question had been protected by rock and concrete periodically dumped between 1959 and 1981. However, the erosion continued and a more substantial rubble-mound revetment was constructed in 1983 to protect Highway 1 where it passes within 30 ft of the cliff edge (Griggs et al., 2005).

Consequently, this review supports the conclusion reached by USACE (1971): *“The District Engineer finds that the erosion problem along the shores of El Granada Beach exists in two forms: (1) the direct erosion of material from the low bluffs immediately landward of the beach, and (2) the loss of littoral material from the beach backshore. He also finds that protective measures are required in the reach of coast from the Half Moon Bay East Breakwater to the mouth of the Arroyo de en Medio, approximately 4,600 feet to the southeast. No improvements are justified along the remaining coastline studied as the shoreline from Arroyo de en Medio to Miramontes Point is not eroding substantially at this time.”*

Note that the information that was readily available for this study was not quantified in regards to its accuracy and other data processing factors, such as tide at time of photograph and seasonal effects, which may indicate higher erosion rates than what really exist on an annual basis. Further study will be required in any future project to confidently prove and quantify the amount of change caused by the outer breakwaters.

4. OPPORTUNITIES AND FUTURE CONDITIONS

PROJECT OPPORTUNITIES

Modification of the existing Pillar Point Harbor project would provide opportunities to prevent or mitigate shoreline damages that may have been caused by the outer breakwaters, better protect existing structures, increase public access, increases recreation use, and improve beach habitat. Each of these opportunities would benefit the local area, region, and the nation as a whole.

PLANNING OBJECTIVES AND CONSTRAINTS

This study of a potential shoreline improvement project at Pillar Point Harbor has the following planning objectives for the area between the root of the East Breakwater and Arroyo de en Medio:

- Prevent or mitigate beach erosion and sea cliff retreat that are attributable to the existing Pillar Point Harbor Project.
- Improve protection of State Highway 1 and coast-side commercial and private structures.
- Increase the quality and quantity of public access and public recreation to that stretch of coast.
- Improve beach habitat in the project area.
- Improve small-boat navigation between the inner harbor and the root of the East Breakwater by transferring sand from the beach and adjacent shoal inside the harbor to the nearshore south of the breakwater.

The constraints from existing Corps policy and the usual State of California and Federal regulatory agencies and authorities, such as the Monterey Bay National Marine Sanctuary, would apply to this potential project. Beyond those, there are no special project-specific constraints for the potential shoreline improvement project.

POTENTIAL ENGINEERING SOLUTIONS

The extent to which each of the above opportunities is realized will be dependent on the proposed engineering solution. Potential engineering solutions must be technically feasible and economically viable. Conceptual level solutions that meet these two criteria can be categorized into four groups: beach fill, beach fill with artificial sand "reef", shoreline armoring, and altering the East Breakwater to allow sand to move southward along the shoreline through it. The Corps Beach Erosion Control Report (USACE 1971) considered four alternate plans:

- a. Beach fill. The minimum plan from the standpoint of first cost is that of beach nourishment on a continuing basis. In this alternative, no protective structures would be built. A protective beach, about 100 feet in width, would be provided initially. As there would be no means of retaining the sand, movement of the beach material out of the area would be rather rapid. Thus, although the initial cost for placement of the beach fill is not high, the cost incurred for maintaining the beach on an annual basis is very high, even for the first few years. Thereafter, unknown factors enter the picture making maintenance costs in future years very difficult to estimate. Some sand could come from inside the breakwater, but other sources would have to be identified for the long term.
- b. Rubble-mound revetment. Another possible alternative that would provide the required protection to the shoreline from the East Breakwater to Arroyo de en Medio would be a rubble-mound revetment. Included in this alternative is a program of periodic beach nourishment. At present, approximately one-half of the sea cliff in the project area has been protected by rubble-mound revetments although they may not be built to Corps standards.
- c. Spur breakwater, groins and beach fill. This alternative consists of a spur breakwater about 600 feet in length extending from the existing East Breakwater, 4 groins each about 750 feet in length, and beach fill. In addition to providing protection from wave erosion to areas landward of the beach, this alternative would significantly enhance the areas recreational beach use potential by the provision of an additional 1,100,000 square feet of beach area.
- d. Spur breakwater, groin, beach fill and rubble-mound revetment. The fourth alternative is essentially a combination of all the previous alternatives. Realizing the justifiable demand for new and good beaches in the Half Moon Bay area, it appeared desirable to include a less costly plan incorporating a portion of the original 4-groin plan features. By including the spur breakwater, first groin and enclosed fill in combination with a rubble-mound revetment for the remaining distance, sizable beach use benefits as well as those benefits attributable to erosion prevention are generated.

Other possible plans include the construction of a hard structure offshore to reduce the amount of sand needed for periodic beach nourishment and modifying the root area of East Breakwater to allow sand to move alongshore from the harbor to the project area.. These hard structures can be placed parallel or perpendicular to the beach, depending on their function to either reduce cross-shore or longshore movement of sand. Finally, the

eastern breakwater could be altered to allow for the sediment accumulating within the Harbor to drift towards Surfer's Beach as it did prior to the construction of the breakwater. The increased flow of sediment may begin to accumulate on Surfer's Beach decreasing the effect of the erosion. This could be accomplished with sand bypassing or a culvert through the breakwater at the shoreline. This last option, being a novel solution, would have to be studied in detail and might be a candidate for a demonstration project.

Should a federal interest be determined, one option could include submitting a request to the Corps to initiate a Feasibility Study so that a thorough review of the existing Pillar Point Harbor project could be conducted and if appropriate, any mitigation options identified. In addition, there is an interest in including the site as a demonstration project as part of the Regional Sediment Management program. This would include dredging clean sediment from the harbor side of East Breakwater and placing it downcoast along Surfer's Beach as well as creating an offshore sand berm to mitigate the need for future replenishment. Project planning would include coordination with several local, state and federal agencies including the CA Coastal Commission and the Monterey Bay National Marine Sanctuary.

Field data collection would be an important part of any future study. Updated elevation data, including both bathymetric and topographic, and aerial photographs would be needed to assist in documenting historic and future changes. Other field data of interest would include wave, current, geotechnical and sediment transport related measurements. The mapping of any biological resources will also be important in determining the feasibility of any future projects. This data would be used in conjunction with various analytical techniques, including hydrodynamic and sediment transport numerical modeling. These tools would be used to evaluate the shoaling within Pillar Point Harbor and the erosion along Surfer's Beach, identifying the various factors influencing those changes and defining the options available to minimize, eliminate or offset any negative impacts.

Environmental impacts associated with these potential engineering solutions include long-term changes to the existing habitats and short-term impacts from construction. The most likely long-term change would be the conversion of existing sub-tidal habitat to sandy inter-tidal habitat, mudflats, or rocky inter-tidal habitat. An environmental assessment would have to be conducted to determine the nature and magnitude of the anticipated change as a result of the proposed project. A determination would have to be made to assess the need for mitigation. In addition, the Corps will ensure compliance with all the applicable environmental laws and regulations by obtaining the necessary authorizations for the proposed work.

POTENTIAL NON-STRUCTURAL SOLUTIONS

In addition to the potential engineering solutions, non-structural solutions would also need to be considered during the feasibility phase of the potential project to ensure that a full array of possible solutions is evaluated. Non-structural solutions could include relocating existing structures, adapting existing land uses, or property acquisition. Non-structural solutions would not prevent shoreline erosion, but would rather reduce or

eliminate the adverse impact of the erosion. While these solutions were not evaluated in this Initial Appraisal, they would be evaluated during the feasibility study.

FUTURE WITHOUT PROJECT CONDITIONS

Except that Caltrans will not let Highway 1 fail under any circumstance, it is likely that no public agency or organization will pursue a shoreline improvement protection in the project area if the Corps does not participate in the project. Consequently, the unprotected part of the sea cliff will continue to erode at a rate that could be as high as the 3 to 6 feet per year that occurred after breakwater construction. Once the exposed sea cliff has retreated far enough relative to the protected sea cliff, erosion will occur behind the ends of the revetments, requiring more, and continuing revetment construction. Furthermore, if either of the rubble-mound revetments fails, the shoreline could erode landward past Highway 1 and some of the existing structures within several years. It is further assumed that property owners will try to prevent losing their existing structures and will apply for and receive individual permits to armor of the bluff seaward of their structures. It is noted that certain existing shoreline protection structures that are not permitted may have to be removed, but it is assumed that they will be replaced by acceptable structures. Therefore, the future without project conditions are assumed to be continued erosion of the shoreline until it is within a state-designated distance of an existing structure. At that point, the shoreline will be armored.

These future without project conditions will result in a continued decrease in available beach for recreational purposes, the loss of public and private lands, and additional costs to some businesses with property along the shoreline.

The future without project economic conditions are assumed to be similar and follow the same trend as the existing economic conditions and are described in the next section.

5. ECONOMIC ANALYSIS

INTRODUCTION

Purpose

The primary purpose of this preliminary Economic Analysis is to identify the potential future economic damages caused by shoreline erosion (coastal storm damage) at several locations within the vicinity of Pillar Point Harbor in San Mateo County, CA. This analysis primarily references the evaluation of economic impacts made as part of the Reconnaissance Report that was completed in March 1996 by the Corps of Engineers San Francisco District. This primarily qualitative analysis includes discussion of the expected future economic damages. The intent is to provide a preliminary indication of the economic feasibility of a federal project in the vicinity of Pillar Point Harbor.

Guidance and References

The approach taken by this Economic Analysis is in accordance with current principles and guidelines and standard economic practices, as outlined in the Planning Guidance

Notebook-ER 1105-2-100, as well as the Institute for Water Resources (IWR) Report 91-R-6, *National Economic Development Procedures Manual, Coastal Storm Damage and Erosion*. Other documents reviewed as part of this damage analysis include: *Reconnaissance Report*, USACE San Francisco, March 1996.

Methodology and Delimitation

Given the limited scope and funding of a Initial Appraisal Report, this analysis makes numerous simplifying assumptions. These assumptions enable the analysis to move forward by discussing the categories of potential without-project damages. Should this Initial Appraisal Report lead into a feasibility-level study, estimates of with-project economic damage reductions (i.e. benefits) at each location would be compared to the expected cost of project alternatives that would slow or arrest coastal erosion and damages caused by wave attack. The economic analysis considers only what are considered National Economic Development (NED) impacts, as defined by USACE Engineering Regulation (ER) 1105-2-100.

In the absence of a coastal erosion model, the analysis generally describes the types of damages that would occur assuming erosion continues into the foreseeable future. The damage estimates will focus on expected near-term impacts, but acknowledge potential longer-term impacts.

It is important to note that out of necessity this economic analysis only considers those types of damages that can be readily quantified. It is recognized, however, that there is additional value inherent in a stable coastline that will not be captured in this analysis. For a coastal community such as Pillar Point Harbor, the coastline is a large part of the character of the community. A stable coastline helps preserve the identity around which the community has developed, and has significant value to the community that cannot be readily quantified – including aesthetic value and existence value.

Study Area

Pillar Point Harbor is a small craft harbor located 20 miles south of San Francisco in San Mateo County, CA; the nearest incorporated city is Half Moon Bay (inc. 1959). The harbor serves commercial fishing vessels and recreational boats. Half Moon Bay comprises approximately 6.5 square miles of land. According to the California Department of Finance, since 2000 the population of the city has increased by roughly 10% and currently has approximately 13,000 residents. The city has a higher median household income than the county (\$78,500 versus \$70,800 in 1999 dollars) but a slightly higher overall poverty rate (6.1% compared to 5.8%). The top employing industries in the city are: a) Accommodation and food services; b) Retail trade; and c) Arts, entertainment, and recreation.

ECONOMIC IMPACT OF COASTAL EROSION

Defining the Without-Project Condition

To fully understand the value of federal participation in potential projects in the study area, it is necessary to clearly define the conditions that would exist in the foreseeable future in the absence of the implementation of a federal project. The planning period of analysis for Corps studies is typically fifty years, and defining the future without-project conditions should include predicting to the extent possible any actions reasonably expected to be taken by other parties, including the San Mateo County Harbor District, City of Half Moon Bay, the State of California, or other Federal agencies such as the U.S. Department of Transportation. Citing from page 98 of Institute for Water Resources (IWR) Report 91-R-6: *“As long-term erosion occurs, individuals and communities will respond by taking action to protect, relocate, or abandon existing properties. In addition, action may be taken to limit future development. During the development of the forecast of future conditions, the economist must determine the most likely course of action, which will then become the basis for the analysis and forecast... The most likely action should be based on institutional factors which may vary greatly from state to state, and the assumption of rational economic behavior (e.g., property will be protected as long as the perceived incremental cost of protection does not exceed the perceived remaining value of the property). ”*

Given the limited scale and intent of this initial appraisal study however, no thorough analysis has been conducted of the expected future without-project conditions. Instead, as discussed previously, the analysis will, where reasonable, estimate likely near-term damages from coastal storm-induced erosion under the assumption that no other actions are taken to prevent the damages, and will discuss the potential future long-term damages as well as identifying when rational economic behavior would indicate action by property owners, the city, or others. Given the value of the properties at risk at the various coastal sites, it is expected under the assumption of rational economic behavior that property owners would take action to prevent significant impacts to their properties, so that a loss of the property would be prevented.

It is expected that actions by other parties to prevent damages would be in response to the impending loss of land or property that, if allowed to occur, would cause significant economic or financial loss. Of course, because the time value of money is an important variable in the quantification of damages and project net benefits, the timing of any such actions is typically an important factor of an economic analysis. The timing of the action at any particular location is, of course, tied to the particular erosion rate that actually occurs at the site. For this report, no coastal erosion model was developed to forecast future erosion rates.

POTENTIAL ECONOMIC IMPACTS

The stretch of coastline under investigation as part of the *Initial Appraisal Report* extends from a sandy area just inside the East Breakwater barrier and adjacent to a mobile home park south to Arroyo de en Medio. Traveling along the Cabrillo Highway (CA State

Route 1), the project extends from the mobile home park to Miramar Drive in Half Moon Bay, CA.

IWR Report 91-R-6, *National Economic Development Procedures Manual for Coastal Storm Damage and Erosion*, identifies the major benefit (damage) categories for coastal storm damage studies. The manual separates benefits into two main categories: those benefits related to storm damage alleviation, and those related to erosion protection. Given the nature of the coastal processes and the characteristics of the property along these study reaches, the damages expected are classified as primarily the result of coastal erosion.² Listed below are the primary benefit categories considered for this analysis.

- Transportation Delay Costs
- Maintenance of Existing Structures (Property)
- Loss of Land
- Property Damage
- Emergency Costs
- Recreation Impacts

The extent to which the benefit categories apply varies by location per the characteristics at the site and the information available. The benefit categories are briefly described below.

Transportation Delay Costs – This impact is calculated as the sum of a) the time value of driver and passenger delay, and b) the additional vehicle operating costs as a result of a delay or detour. Only those delays and road closures that could actually be avoided by the proposed project may be counted, as the presence of the damaging storms with or without a project may be sufficient to precipitate road closure or delays.

The primary coastal highway (CA State Route 1 or Cabrillo Highway) appears susceptible to this category of benefits from the East Breakwater wall to approximately Point Alabama Avenue. Recent aerial photographs show that in this sub-area, there is only an ordinary highway berm between the ocean and the road. There does seem to be some rip-rap and/or rock embankment here, and at this time there is no available information as to how often these measures require repair or maintenance. Still, Transportation Delay Costs can be reasonably expected to yield some benefits should this study proceed to a feasibility stage. Mirada Road also looks susceptible to eventual erosion damage but is not considered a major transportation artery for purposes of this damage category.

Maintenance of Existing Structures – Benefits can be claimed to the extent that a project would reduce the maintenance requirements associated with existing property that is affected by recurring incidents of erosion or storm damage.

² For more details on storm damage alleviation versus erosion protection, see IWR Report 91-R-6, pages 62-71

<http://www.iwr.usace.army.mil/inside/products/pub/pubsearch1.cfm?idocID=626>

For Pillar Point Harbor, this category could apply to the repair and/or maintenance costs of the rubble-mound revetment that protects California Highway 1. There is similar protection along Mirada Road from slightly north of Magellan Avenue to Arroyo de en Medio and seaward of a beach-front condominium near the intersection of Mirada Road and Balboa Boulevard in Half Moon Bay.

Loss of Land – Land is typically assumed to be presently used at its highest value and best use. The value lost as a result of erosion is thus a function of the value associated with that use. For example, the value of lost parkland is the decrease in recreation value to the public, which can be calculated various ways but regardless of how it is calculated the value is intended to represent the willingness of users to pay for use of the recreational resource. For residential land loss, the value lost is directly related to the market value of the land, but is net of any transfer of property value to other properties that gain value as the coastline recedes – destroying some coastal properties while creating new ones.

Starting at Magellan Avenue and proceeding generally southeastwardly along Mirada Road until it departs the coastline (just short of its intersection with Miramar Drive), there is a mixed commercial and residential area that could be reasonably expected to fall into this category.

Between the point where Highway 1 intersects Mirada Road (across from Point Alabama Avenue) and Magellan Avenue, there is a 15 acre parcel of undeveloped land, the Mirada Surf Property, abutting the ocean. At this time, San Mateo County owns the property, and plans to develop it as a public beach park. The nature of the park and possible structures and parking areas is unknown. Still, this damage category could apply.

Property Damage – The prevention of costs associated with repair, relocation, or abandonment (if damage is severe enough) of property would all be considered benefits of a project. Also, the cost of measures taken by property owners to prevent damage is relevant to the evaluation of potential project benefits. That is, if a project would preclude property owners from incurring costs associated with preventing damage to the property, the value of those expenses would be considered a benefit of a project.

The community of buildings between Magellan Avenue and Miramar Drive could reasonably be expected to accrue project benefits under this category. The aerial photographs show that approximately 15 – 25 buildings are located extremely close to the coastline. At the present time, the types of buildings include restaurants, art galleries, inns, and private residences. The large buildings at the intersection of Mirada Road and Coronado Avenue are the Miramar Beach Restaurant to the north and Landis Shores Oceanfront Inn to the south. There also is a sizeable condominium complex at the intersection of Mirada Road and Balboa Boulevard as well as the smaller condominium on the edge of the sea cliff.

Emergency Costs – Any emergency costs, such as the actions taken by police or other officials to reroute traffic around an eroded stretch of roadway, that would be avoided by the existence of a project would be considered a relevant benefit.

Such costs could be expected to adversely affect the budgets of San Mateo County and the City of Half Moon Bay, depending upon the jurisdictional lines of each along the study area reach.

Recreation Impacts – The value of recreation land lost due to erosion is typically calculated as the lost recreation value to users in accordance with their willingness to pay for the recreation experience. Unfortunately, little is known about the correlation at these beach parks between incremental land loss and recreation value. For example, what is the impact on overall recreation value of the loss of ten percent of an existing beach park area? This information is important because it is needed to accurately estimate recreation value loss on a year-to-year basis (when there are relatively small changes).

Although it is unlikely that the initial land loss would have a significant impact on the overall value of the beaches in the study area, once a significant portion of the area is claimed by erosion, the carrying capacity, the facilities, and the quality of the recreation experience would be adversely affected. Furthermore, there would be more use of the beach if it were widened with the addition of sand. In nice weather, the present beach is quite crowded, so a larger beach would accommodate more visitors or improve the experience of those who would go under present conditions. The amount of recreation value³ represented by the beach parks in feasibility studies is a function of the number of visitors and the quality of the recreational experience provided by the site. Using the Unit Day Value (UDV) method, general recreation experience is valued at between \$3.40 and \$10.20 per user per day⁴. No estimate of the number of annual visitors to the beaches in this study is available, but El Granada beach is often congested with surfers and Vallejo Beach and bluff are commonly used for a variety of recreational activities.

Another factor in calculating lost recreation value at any particular site is that no net loss would be assigned to the loss of recreational land or facilities at a site if there was a transfer of value to other, presumably nearby, recreational resources. For example, holding all else constant, if the visitors to a particular beach were able to have an equivalently valuable recreational experience at an alternative site following the loss of the original beach to coastal erosion, assuming no additional transportation costs and assuming that the alternative beach could accommodate additional users, there will be little or no loss of recreational value assigned to the loss of the beach. In addition to any loss of recreation value, additional maintenance or relocation of the recreation features (sidewalks, fencing, benches, sprinkler systems, etc.) that are necessary as a result of the coastal erosion would be considered NED impacts.

PRELIMINARY CONCLUSIONS

This Initial Appraisal Report discussed in broad terms the types of benefits that could reasonably be anticipated to be included in subsequent feasibility-level investigations. Existing information for this study area pertaining to USACE economics analyses is scarce. Thus, this cursory analysis attempts to identify potential benefits of a future

³ Per USACE guidance and IWR Report 86-R-4, National Economic Development Procedures - Recreation

⁴ Per USACE Economics Guidance Memorandum (EGM) 08-02, Unit Day Values for Recreation, Fiscal Year 2008

project by relying on a combination of readily available information and professional judgment. None of the damage categories discussed should be assumed to remain upon closer inspection of the area. Likewise, this analysis does not preclude the possibility of discovering benefits not included in the preliminary appraisal.

6. VIEWS OF STAKEHOLDERS AND PUBLIC

The following notes have been supplied by the probable non-federal sponsor, the San Mateo Harbor District, which has been approached by community representatives who want the beach erosion problem to be fixed. The Harbor District wants to solve the problem, which it sees as originating with the construction of the Pillar Point breakwater by USACE to create a harbor of refuge.

The Harbor District plans to convene a working group to discuss the erosion problem. This idea of a working group was suggested by the Gulf of the Farallones National Marine Sanctuary (GFNMS) superintendent, Maria Brown (although the area is in the Monterey Bay Marine Sanctuary, GFNMS is its administrator). The Corps San Francisco District staff supports such collaboration and is willing to be a part of the working group if appropriate. Government agencies that would be invited include the CA Coastal Commission, CA Dept. of Boating and Waterways, CA Coastal Conservancy, San Mateo County, and City of Half Moon Bay (within whose jurisdiction the project area actually lies). The working group would consist of the above agencies, community representatives, and possible experts familiar with beach erosion issues.

The community interest is voiced by surfers, other beach users, property owners, fishermen, and other residents. They are the users of the beach who are most directly affected by the breakwater-caused beach impacts. Representatives have come before the Harbor Commission and the Farallones Sanctuary advisory Council to voice their concerns.

The GFNMS superintendent says they want to participate with Corps and Harbor District to find a solution to the erosion problem that does not adversely affect Sanctuary resources. They are sensitive to the strong local community concern with loss of beach and beach use, and see the community as Sanctuary constituents as well. GFNMS has the power to authorize disposal of dredged material in sanctuary waters, or to withhold such authorization. Strictly speaking, they do not have permit authority; they do not issue permits. Their concern is protection of sanctuary resources, including living marine creatures and marine habitats.

A GFNMS representative stated that there are not any obvious environmental restoration projects at Pillar Point and that the most obvious connection to a project fixing a problem created by an existing Corps structure. They did not express any major concerns with the Corps investigating a project in the area.

7. CONCLUSIONS AND RECOMMENDATIONS

All previous studies and historical anecdotal observations indicate that the Half Moon Bay shoreline has been eroding since at least the 1860s. Between 1959 and 1961, the

Corps built two breakwaters to form Pillar Point Harbor. Since that time, the erosion rate along the shoreline immediately south of the eastern breakwater has eroded at a substantially increased rate that several studies concluded has been caused by those breakwaters. Because that erosion destroyed one cliff-top road and threatened both California Highway 1 and several commercial and private structures, rubble-mound revetments were constructed by non-Corps agencies. However, the threat for future bluff erosion, structural damage, and increased loss of recreational public beach still exists. Potential engineering solutions mitigate these destructive coastal processes have been proposed that are technically feasible and should meet existing environmental standards. These solutions can be categorized into three types: beach fill, beach fill with retaining structures, and shoreline armoring. Governmental agencies and the public have expressed support for a Corps shoreline improvement project immediately south of the East Breakwater. Therefore, there is sufficient need and cause for potential Federal interest in a shoreline improvement project.

A shoreline improvement project along the designated shoreline could be conducted under a few different programs administered by the Corps. Table 3 summarizes the different options for a Corps administered shoreline improvement project and their advantages and disadvantages.

Based on the problem identification and existing criteria for the various Corps authorities, we recommend using the Section 111 Continuing Authorities Program (CAP) to proceed to the feasibility phase and produce a Detailed Project Report (DPR) for a potential shoreline improvement project from the root of the East Breakwater to Arroyo de en Medio, a distance of 0.85 miles. Depending on the chosen remedial approach, the harbor beach and adjacent shoal between the East Breakwater and inner breakwater also could be modified by moving sand from there to the nearshore. Because the goal would be to insure that the breakwater performs as intended, it may be appropriate for the project to include a demonstration component supported by Operations and Maintenance funds. The purpose of the Section 111 authority is described in the Corps Engineer Regulation 1105-2-100:

“This authority authorizes the planning and design of a justified level of work for prevention or mitigation of damages to both non-Federal public and privately owned shores to the extent that such damages can be directly identified and attributed to Federal navigation works located along the coastal and Great Lakes shorelines of the United States. This includes shore damage attributable to the Atlantic Intracoastal Waterway and the Gulf Intracoastal Waterway. The Corps is authorized to construct such a project if the Federal share of the first cost of construction is \$5,000,000 or less.”

The Section 111 authority appears to be the most applicable authority for addressing the existing conditions and shoreline erosion problems in the project area as well as the most efficient authority for the Corps to use to implement and construct a project. The DPR is necessary to confirm Federal interest in the project by taking a more detailed look at the problem and potential solutions. The end result of a DPR that recommends further Federal support should contain four important products: a project schedule, a baseline cost estimate, a preliminary plan for the selected alternative from many different

candidate engineering solutions, and environmental compliance documentation. A finding of no significant impact (FONSI) is expected, and an Environmental Assessment will be prepared and included with the DPR. The initial \$100,000 of the feasibility phase is a Federal expense that requires no cost share. Feasibility phase costs in excess of this amount are cost shared between the Corps and the non-Federal sponsor on a 50% to 50% basis.

The initial steps in this feasibility study should include the following tasks: (1) develop economic methodology and perform economic, (2) confirm the identity of the non-Federal sponsor, (3) prepare a Project Management Plan (PMP), and (4) negotiate and sign a FCSA between the Corps and the non-Federal sponsor for the funding requirements in excess of the initial \$100,000.

Table 3: Summary of Corps Authorities for a Shoreline Project at Princeton			
Short Title	Full Authority	Advantages	Disadvantages
Hurricane and Storm Damage Reduction, Shore Protection, Section 103	Section 3 of Act of 13 August 1946 and Section 103 of the 1962 Rivers and Harbors Act as amended by Sections 103, 402, and 915 of the Water Resources Development Act (WRDA) of 1986, Section 14 of WRDA 1988, Section 202 of WRDA 1996, Sections 215 and 226 of WRDA 1999, and Section 209 of WRDA 2000. This is a continuing authority	This authority allows the Corps to conduct the project without direct congressional approval, speeding up the project.	Federal costs for each project is limited to \$3 million and the entire program nationwide is limited to \$30 million, creating competition for the funds nationwide. The project should also be specifically named in an Appropriations Bill.
RECOMMENDED AUTHORITY TO CONDUCT FEASIBILITY PHASE & DPR:			
Navigation, Mitigation of Damages Caused by Federal Navigation Projects, Section 111	Section 111 of the 1968 Rivers and Harbors Act as amended by Section 940 of the Water Resources Development Act (WRDA) of 1986 and Section 214 of	This authority allows the Corps to conduct the project without direct congressional approval, speeding up the project.	Federal costs for each project is limited to \$5 million. No set limit is given for the program nationwide, but HQUSACE will most likely set a

Short Title	Full Authority	Advantages	Disadvantages
	the WRDA 1999. This is a continuing authority.		limit based on available funding. The project should also be specifically named in an Appropriations Bill.
Review of Completed Projects, Section 216	Section 216 of the 1970 Flood Control Act, as amended by Sections 103, 105, and 905 of the Water Resources Development Act of 1986.	Does not need congressional approval to initiate feasibility study, and there is no limit on the amount of funds the Corps can spend on the project.	The authority requires the Corps district to produce a report to Congress and obtain their approval before constructing the project, which may delay the project.

REFERENCES

- Bascom, W. N. (1951). "The relationship between sand-size and beach-face slope," Trans. American Geophysical Union 32, 866-874.
- Collins, B. D. and Sitar, N. (2008). "Processes of coastal bluff erosion in weakly lithified sands, Pacifica, California, USA," Geomorphology 97, 483-501.
- Dorman, C. E. and Winant, C. W. (1995). "Buoy observations of the atmosphere along the west coast of the United States, 1981-1990," Journal of Geophysical Research, 100, 16029-16044.
- Dorman, C. E.; Enriquez, A. G., and Friehe, C. A. (1995). "Structure of the Lower Atmosphere over the Northern California Coast during Winter," Monthly Weather Review, 123, 2384-2404.
- Griggs, G., Webber, J., Lajoie, K. R., and Mathieson, S. (2005). San Francisco to Año Nuevo," in Griggs, G., Patsch, K., and Savoy, L. (eds.). "Living With the Changing California Coast," University of California Press, Berkeley, 540 pp.
- Halliwell, G. R. and Allen, J. S. (1987). "Wavenumber-frequency domain properties of the coastal sea level response to alongshore wind stress along the west coast of North America, 1980-84," Journal of Geophysical Research, 92, 11761-11788.
- Hampton, M. A. (2002). "Gravitational failure of sea cliffs in weakly lithified sediment," Environmental and Engineering Geoscience 8(3), 175-192.

- Komar, P. D. (1998). "*Beach Processes and Sedimentation*," Prentice-Hall, Upper Saddle River, NJ, 544 pp.
- Krumbein, W. C. (1947). "Shore Processes and Beach Characteristics," Beach Erosion Board, Tech. Memo. No. 3, 34 pp.
- Lajoie, K. R. and Mathieson, S. A. (1985). "*San Francisco to Año Nuevo*," in Griggs, G. and Savoy, L. (eds.). "*Living with the California Coast*," Duke University Press, Durham, NC, 394 pp.
- Mass, C. F. and Bond, N. A. (1996). "*Wind Reversals along the United States West Coast during the Warm Season. Part II: Synoptic Evolution*," Monthly Weather Review, 125, 1692-1694.
- Renard, R. J. ND. "*1996 and earlier years. Monterey Peninsula Monthly Weather Summaries*," Unpublished documents. Available from Department of Meteorology, Naval Postgraduate School, Monterey, CA 93943.
- USACE 1971. "*Beach Erosion Control Report on the Shores of El Granada Beach, San Mateo County, California*," District Engineer, San Francisco District, 35 pp plus appendices.