Basis of Design and Project Assessment Kuhio Beach Erosion Control Project and Small Scale Beach Nourishment

Waikiki, Oahu, Hawaii

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1. INTRODUCTION

1.1 Project Location

The project area is located in the approximate center of Waikiki Beach, adjacent to the Kuhio Beach western (Ewa) crib wall groin and seaward of the Duke Kahanamoku statue and the surfboard rental concessions. The project location and general area are shown in Figure 1-1.

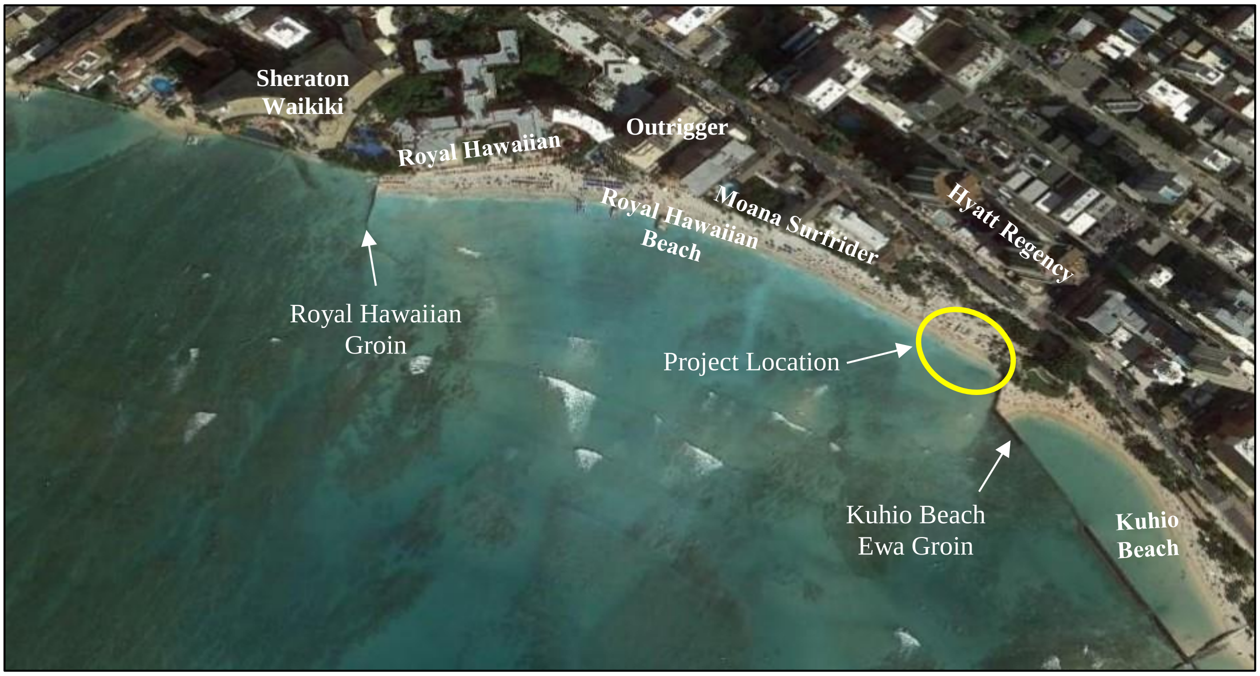

Figure 1-1. Overview of the project site

1.2 Problems, Needs, and Objectives

For the past several years, episodic sand loss at the east end of the Royal Hawaiian Beach sector of Waikiki Beach, adjacent to the western Kuhio Beach Park groin and seaward of the beach concessions, has exposed the concrete foundation of the old Waikiki Tavern. This concrete rubble and rusting reinforcing steel create an unsightly and hazardous shoreline condition. The proposed project is to install a demonstration sandbag groin utilizing borrowed beach fill from Kuhio Beach Park. The objective of the proposed project is to stabilize the east end of Royal Hawaiian Beach and maintain sand cover over the hazardous concrete foundation.

2. PROJECT SITE HISTORY

The project site is at the boundary of two discrete Waikiki beach sectors – Kuhio Beach Park and Royal Hawaiian Beach. Kuhio Beach encompasses 1,460 feet of shoreline extending from the Kapahulu storm drain to the Ewa crib wall groin, near the Duke Kahanamoku statue. Royal Hawaiian Beach extends from the Kuhio Beach Ewa groin 1,730 feet west to the Royal Hawaiian groin.

In 1938, a 700-foot long shore parallel breakwater was constructed, with shore return structures at each end to help retain sand ("crib wall"). This is the existing Kuhio Beach Park Ewa basin. In 1952 a 703-foot long extension was added to the southeast end of the crib wall breakwater to create the Diamond Head basin. Between 1972 and 1975, improvements were made to the Ewa crib wall and western groin, including increasing their height. Approximately 20,000+ cy of sand was placed on the beach. In 2000, approximately 1,400 cy of sand was pumped from an offshore deposit onto the Ewa basin, and in 2006 an additional 8,200 cy was pumped from offshore into the two basins.

The east end of Royal Hawaiian Beach fronts an open area used by beach concessionaires and was the site of the old Waikiki Tavern (ca. 1930s). This beach sector fronts the Moana Surfrider, Outrigger Waikiki, and Royal Hawaiian hotels. The Moana (1901) and Royal Hawaiian (1927) were the first of the currently existing beachfront hotels in Waikiki, and both had seawalls protecting them. There are no stabilizing structures along this reach, and the concave beach is held in place by the Royal Hawaiian groin, initially constructed in 1927 and rebuilt and lengthened in 1930. Photographs from the 1920s depict a long, narrow, sandy beach fronting the Royal Hawaiian and Moana Hotels. Between 1925 and 1970 there was a trend of sand accretion and beach widening. This was likely partially attributable to sand moving alongshore from east to west, and its impoundment by the Royal Hawaiian groin. Gains in beach width, however, were offset by volume loss due to the landward edge of the beach being pushed seaward by backshore development. Since about 1975 sand loss has been chronic, and beach width loss averages about 1.5 feet per year. The beach in this sector is very dynamic, and rapid sand movement and beach changes, particularly at the east and west ends, is common. In 2012, approximately 25,000 cy of sand was recovered from an offshore deposit and pumped ashore to nourish the beach. During this beach maintenance project, two short, old, and deteriorated cement-filled stacked bag groins were removed from the east end of the beach in the vicinity of the beach concessions. Figure 2-1 is an aerial image showing the location of the two removed groins and Figure 2-2 shows the groins from beach level.

Beach monitoring following the 2012 beach maintenance project shows steady erosion and beach recession of the east and west ends of the Royal Hawaiian Beach sector, with beach recession of about 4.5 feet per year at the east end fronting the beach concessions. This erosion has exposed the old concrete foundation of the Waikiki Tavern, creating a hazardous condition for beach users and swimmers, and has resulted in damage and flanking of the Kuhio Beach Ewa groin. The exposed foundation and the flanking of the Kuhio Beach Ewa groin are shown in Figure 2-3 and Figure 2-4, respectively.

Figure 2-1. 2008 aerial photo showing groins that were removed in 2012 (yellow circles)

Figure 2-2. Groins that were removed in 2012 (2005 photo courtesy Dolan Eversole)

Figure 2-3. Exposed Waikiki Tavern concrete foundation (August 21, 2017 photo)

Figure 2-4. Flanking of Kuhio Beach Ewa groin (May 2017 photo)

3. EXISTING BEACH CONDITION AND CHARACTERISTICS

Site investigations were conducted in March 2018 to determine the existing conditions and characteristics in the project area, including the east end of the Royal Hawaiian Beach sector fronting the beach concessions and the Kuhio Beach basins. Investigations included topographic and nearshore bathymetric surveys, beach sand sampling, and sand thickness probing and coring in the basins within the crib walls.

3.1 East End Royal Hawaiian Beach Sector

Investigation of the east end of the Royal Hawaiian Beach sector had sand that extended about 400 feet from the lifeguard stand/police station to the Ewa Kuhio Beach groin. The existing beach condition in March 2018 is shown in Figure 3-1. Topography and nearshore water depth are shown in Figure 3-2. The Waikiki Tavern concrete foundation and other concrete rubble were nearly buried in sand; however, the foundation was located. A sand-filled geotextile mattress landward of the old concrete foundation can be seen in Figure 3-1 (front of the yellow surfboard). This was installed by City crews in December 2017 to cover the eroding earthen backshore. The beach slope immediately west of the old foundation and sand mattress is 1V:7H, typical of the slope in this beach sector. Analysis of sand samples shows a typical median grain size of 0.34 mm, and it is well to moderately well sorted, again typical of this sector.

Figure 3-1. The project site shoreline (March 2018 photo)

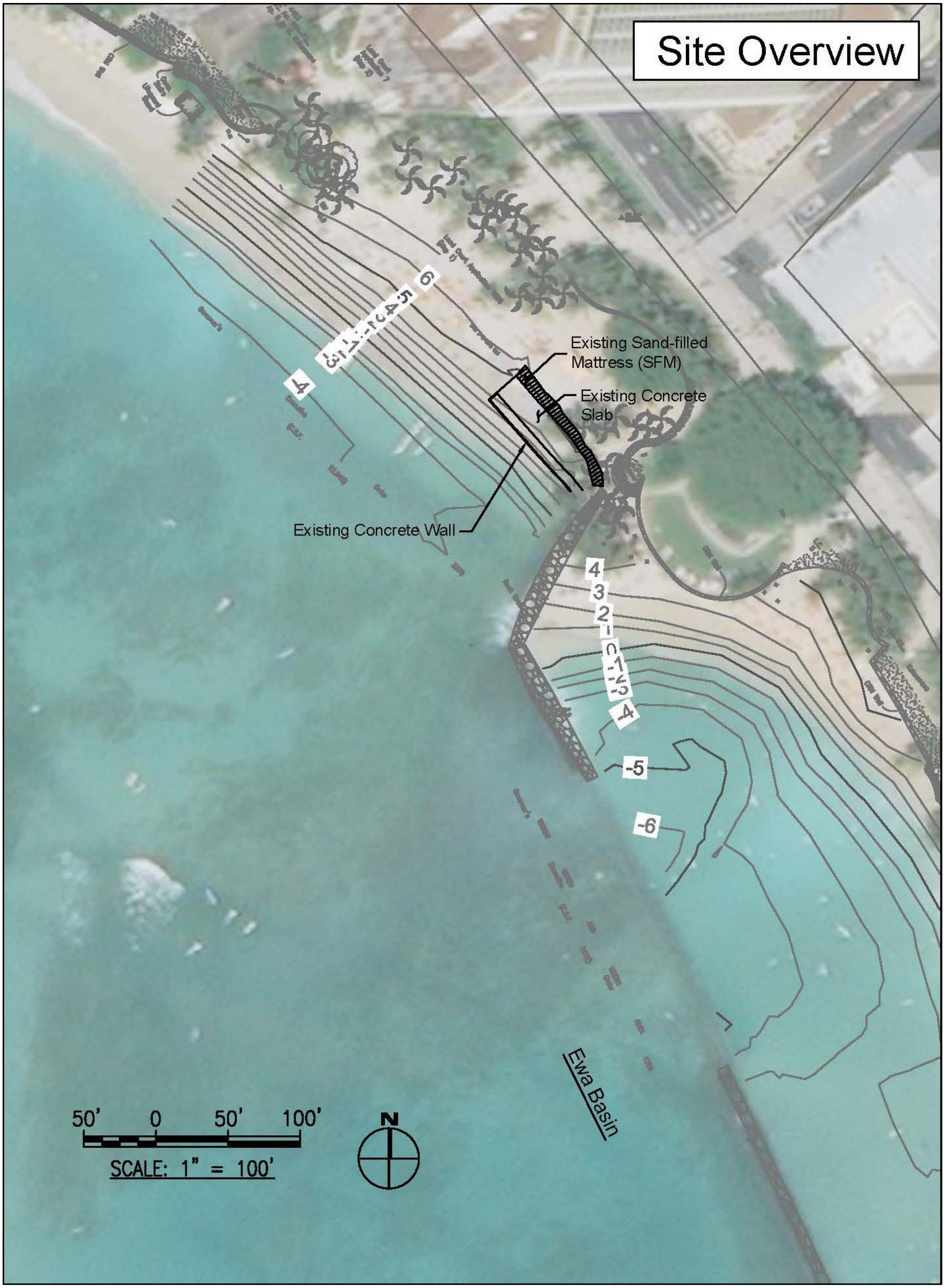

Figure 3-2. Project area shoreline features and topography

3.2 Kuhio Beach

Kuhio Beach Park is divided into two basins, Ewa and east (Diamond Head, DH) basins, which are surrounded by different types of "crib" walls. The crib walls provide beach areas that are protected from wave action. This lack of wave energy reaching the shore prevents typical beach slope formation. As a consequence, over time the sand slumps and moves from the shore into the basins. Thus, the beach face slopes in the basins are relatively flat, typically 1V:12H (as opposed to 1V:7H on the adjacent unprotected Royal Hawaiian Beach).

The sand bottom seaward of the beach toe was probed along three transects (North, Mid, South) in both the Ewa and Diamond Head basins, as shown in Figure 3-3. The transect profiles and the sand surface and hard refusal probe depth are shown in Figure 3-4 and Figure 3-5. Water depths in the basins were typically 1 to 3 feet, and the jet probe refusal depth (which often indicates hard bottom) was at elevations of -5 to -9 msl. Sand layer thickness ranged from about 5 to 8 feet (see Figure 3-3). Note that at the north end of the Ewa basin, seaward of which there is a gap in the crib wall and thus limited wave protection, there is virtually no sand overlaying the hard bottom and a steeper beach face of about 1V:8H. Hammer push core sand samples were taken in each basin at the locations shown in Figure 3-3, and illustrations of the core depths and in situ sand color are also shown. Significant variation in sand color was noted in the cores, ranging from light brown/tan to dark gray almost black. The sand color variation is shown in Figure 3-6.

The dark gray/black sample rapidly changed to light gray with exposure to air and sunlight. Grain size analysis of the core samples shows an average median grain size of 0.42, and percent fine material (<0.074mm) ranging from 1.2 to 3.2. The sand is moderately sorted.

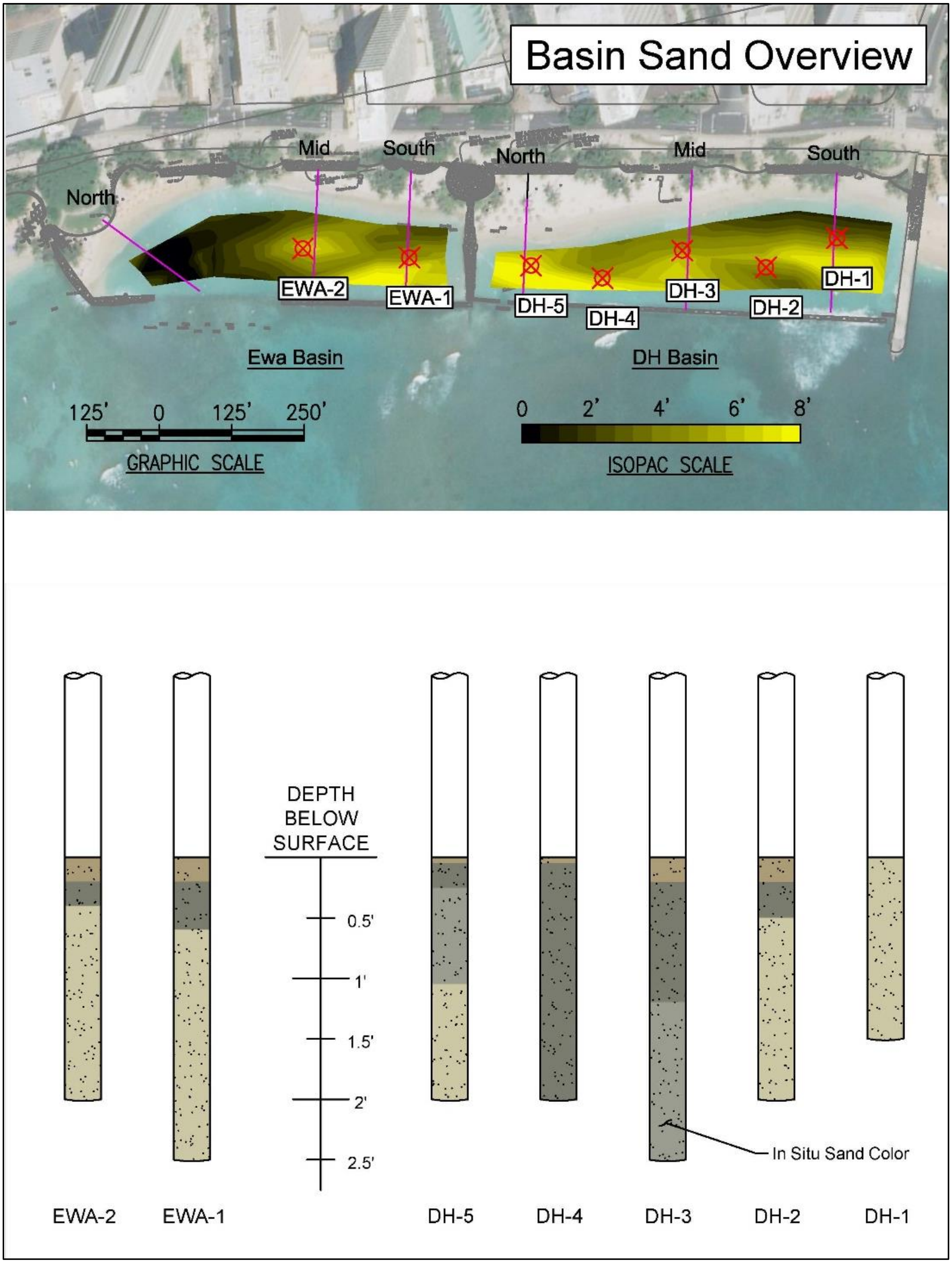

Figure 3-3. Transect line locations and sand thickness isopachs (top); sand core illustrations (bottom)

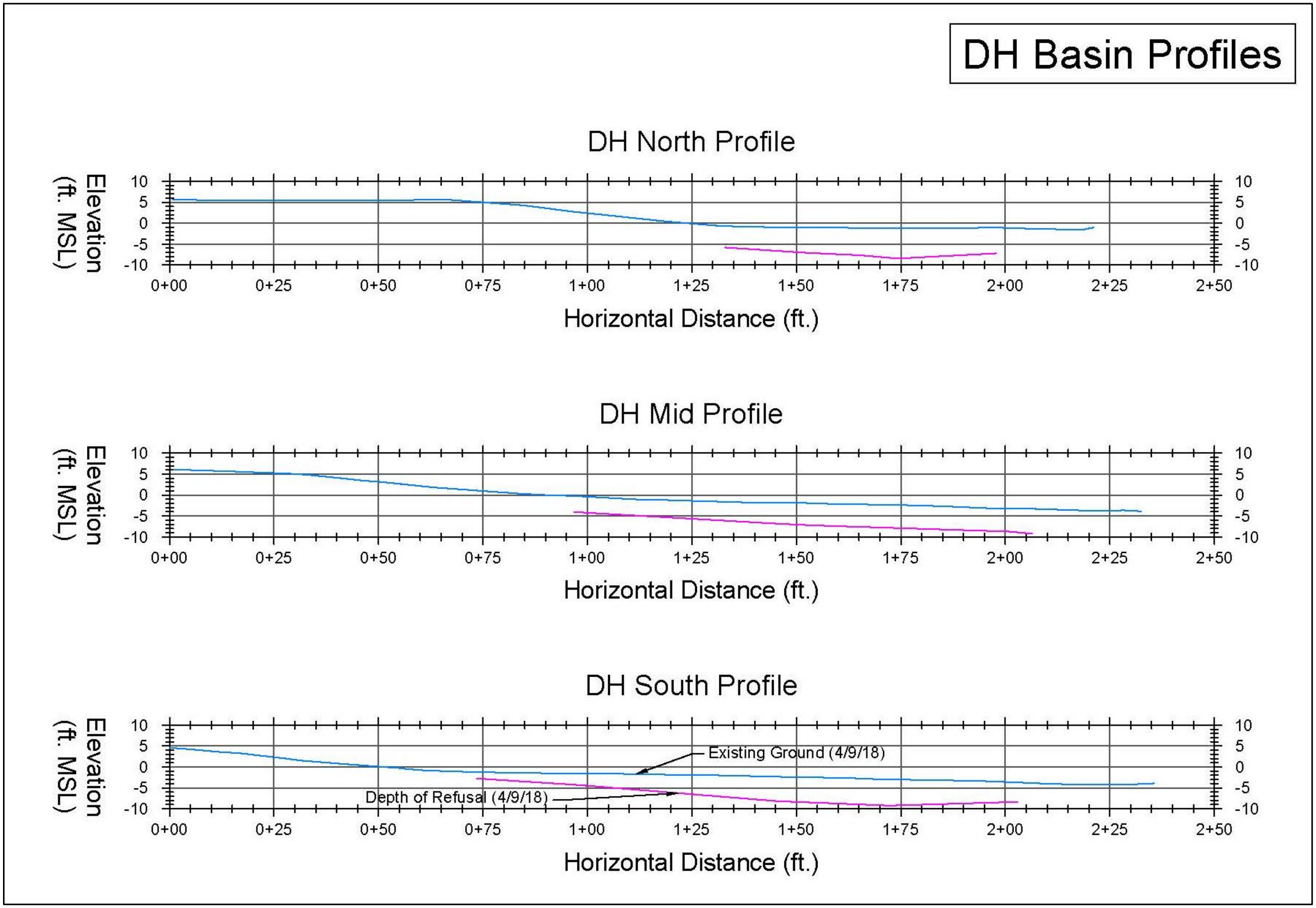

Figure 3-4. Diamond Head basin transect profiles

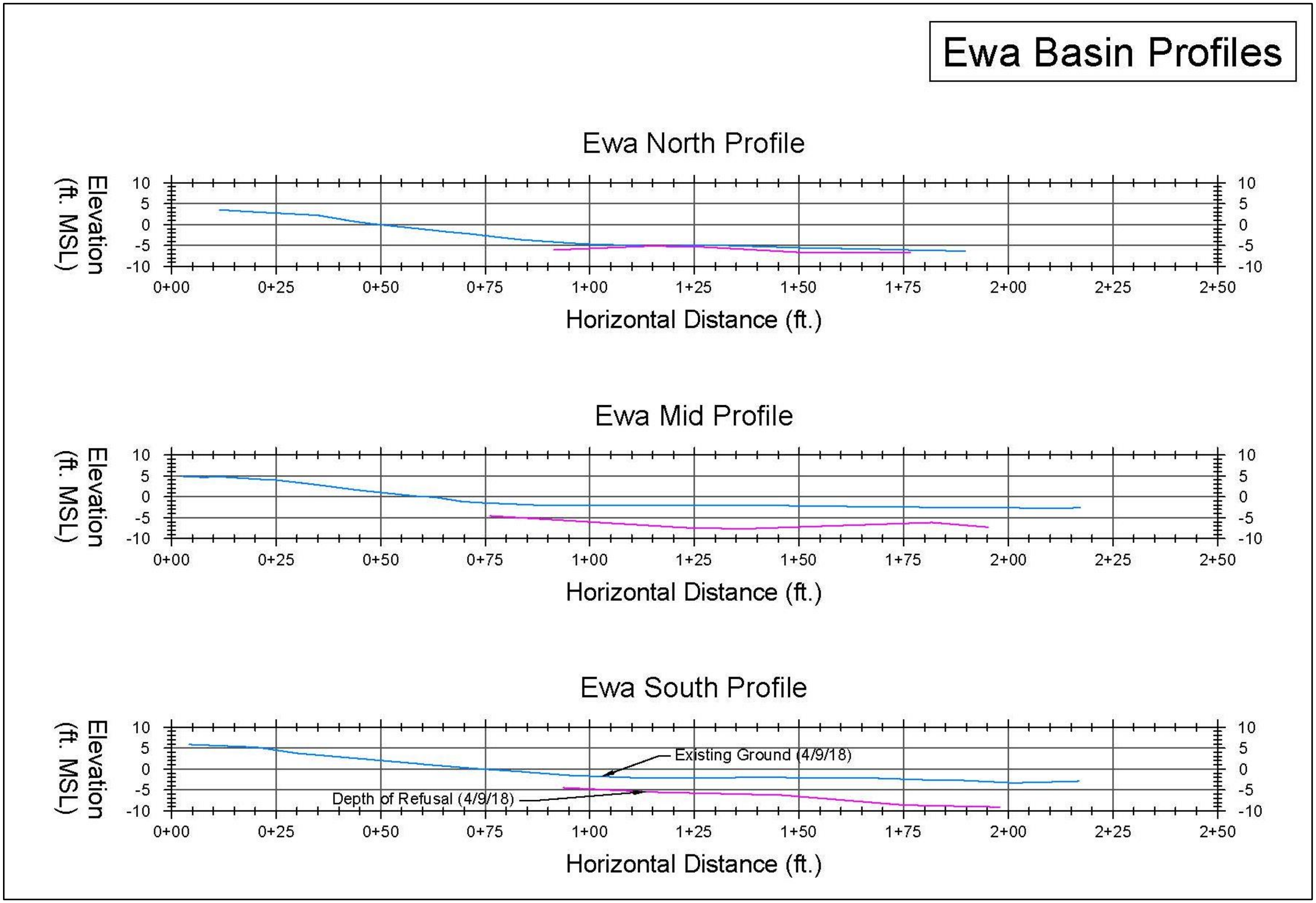

Figure 3-5. Ewa basin transect profiles

Ewa - 1

DH - 5

DH - 4

Figure 3-6. Sand core samples

4. WAVE CONDITIONS

4.1 Waves

Surrounded by the Pacific Ocean, the Hawaiian Islands are subject to wave approach from all directions. The wave climate in Hawaii is typically characterized by five general wave types. These include northeast trade wind waves, southeast trade wind swell, southern swell, North Pacific swell, and Kona wind waves (Figure 4-1). Tropical storms and hurricanes also generate waves that can approach the islands from virtually any direction. Several of these wave conditions may occur at the same time.

Trade wind waves occur throughout the year and are the most persistent in April through September when they usually dominate the local wave climate. They result from the strong and steady trade winds blowing from the northeast quadrant over long fetches of open ocean. Trade wind deepwater waves are typically between 3 to 8 feet in height with periods of 5 to 10 seconds, depending upon the strength of the trade winds and how far the fetch extends east of the Hawaiian Islands. The direction and approach, like the trade winds themselves, varies between north-northeast and east-northeast and is centered on the northeast direction. Although Waikiki Beach is sheltered from the direct approach of trade wind waves by the island of Oahu itself, a portion of the trade wind wave energy reaches the area by refracting and diffracting around the east end of the island and contributes to a generally rough offshore sea state during trade wind conditions.

Waves can also be generated by the southeastern trade winds that blow south of the equator and can occur any time during the year. Southeast trade wind swell has small wave heights on the order of 1 foot and typical periods less than 12 seconds. These waves are not typically used as design criteria but may be important for sediment transport due to their frequency of occurrence. It is suspected that periods of southeast trade wind waves are responsible for moving sand to the west in the Royal Hawaiian beach sector, away from the shoreline fronting the beach concessions, exposing old concrete building foundations that are typically buried.

Southern swell is generated by storms in the southern hemisphere and is most prevalent during the months of April through September. Traveling distances of up to 5,000 miles, these waves arrive with relatively low deepwater wave heights of 1 to 4 feet and long periods of 14 to 20 seconds. Depending on the positions and tracks of the southern hemisphere storms, southern swell approaches from the southeast through southwest directions. Waikiki Beach is directly exposed to south swell, and these waves represent the greatest source of wave energy reaching the project area.

During the winter months in the northern hemisphere, strong storms are frequent in the North Pacific in the mid-latitudes and near the Aleutian Islands. These storms generate large North Pacific swells that range in direction from west-northwest to northeast and arrive at the northern Hawaiian shores with little attenuation of wave energy. Deepwater wave heights often reach 10 feet and in extreme cases can reach 20 feet. Wave periods vary between 12 and 20 seconds, depending on the location of the storm. The island of Oahu shelters Waikiki Beach from northwest swells. However, swells with a more westerly direction can refract and diffract around the west end of the island and provide some energy to the Waikiki shoreline.

Kona storm waves are generated by mid-latitude low-pressure systems moving through the islands and occur at random intervals throughout the year, with higher frequency during the winter months. They approach from the south through west directions. Kona storm waves typically have periods ranging from 6 to 10 seconds; wave heights are dependent upon the storm intensity, but deepwater heights can exceed 15 feet. Deepwater wave heights during the severe Kona storm of January 1980 were approximately 24 feet. Kona storm waves directly affect the Waikiki shoreline and move sand from west to east. During the past few winters, Kona waves have moved sand in the Royal Hawaiian Beach sector toward the east, exposing the normally buried seawall fronting the Royal Hawaiian Hotel.

Severe tropical storms and hurricanes have the potential to generate extremely large waves, which in turn could potentially result in large waves at the project site. Recent hurricanes impacting the Hawaiian Islands include Hurricane Iwa in 1982 and Hurricane Iniki in 1992. Iniki made landfall on the island of Kauai and resulted in large waves along the southern shores of all the Hawaiian Islands. Damage from these hurricanes was extensive. Each caused serious damage to beaches and property on Kauai, as well as at locations on the south and west shores of Oahu. Although not frequent or even likely events, they may be considered for project design conditions, particularly with regard to shoreline structures.

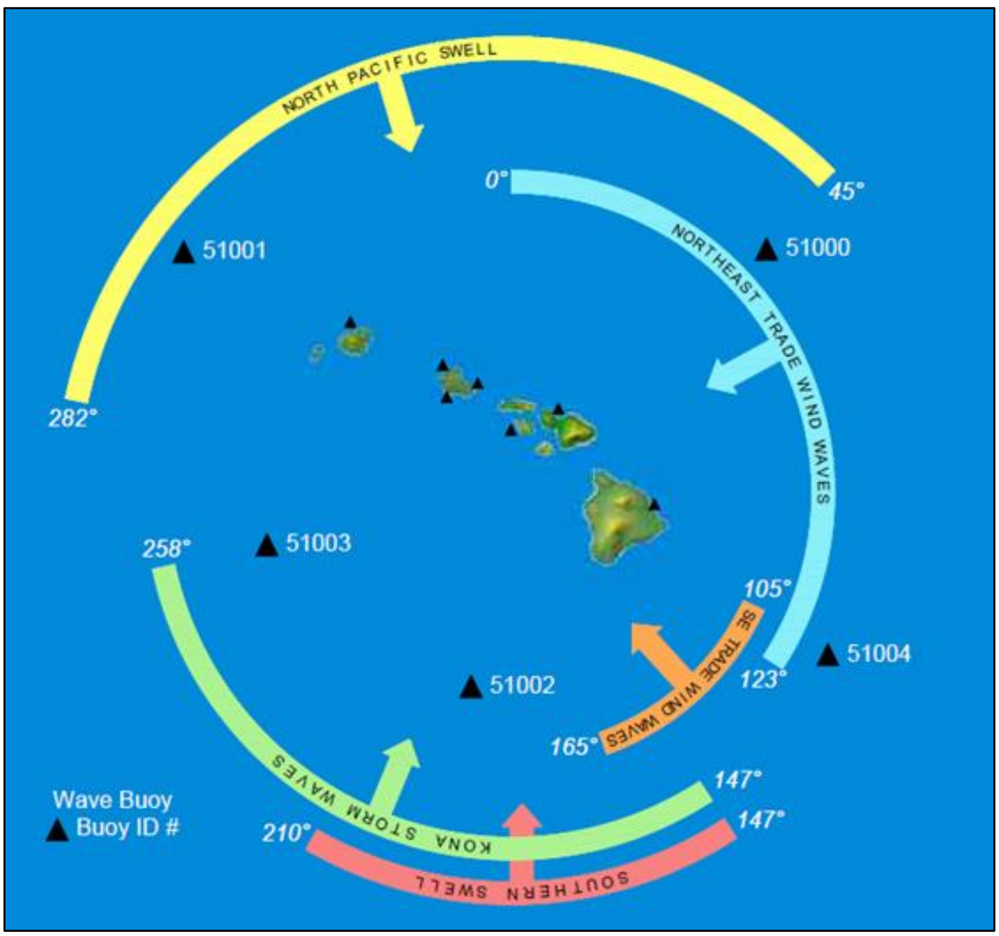

Figure 4-1. Common wave types and approach directions in Hawaii (University of Hawaii SOEST)

4.2 Deepwater Waves

Historical deepwater wave data for this project was obtained from NOAA's WaveWatch III model and from the Scripps Institution of Oceanography Coastal Data Information Program (CDIP). WaveWatch III (WWIII) is a numerical wave model used to forecast and hindcast waves. Hindcast data for a 29-year period (1979-2008) is available for a wide range of locations through NOAA/NCEP. For this study, hindcast data for south swell, southeast waves and Kona waves was obtained from NOAA virtual buoy HNL 11, located 32 miles to the south of Oahu. Wave height and period histograms for virtual buoy HNL 11 are shown in Table 4-1 and Table 4-2, wave roses are shown in Figure 4-1 and Figure 4-2. CDIP buoy 098 is located immediately east-northeast of Oahu, directly exposed to the prevailing tradewind seas. This real-time data buoy has been recording wave data since 2000. A summary histogram of this data is shown in Table 4-3 and Table 4-4, and wave roses are shown in Figure 4-3 and Figure 4-4.

Based on the histograms, representative prevailing deepwater wave characteristics (significant wave height *Hs*, wave period *Tp*, and direction approaching from *Dp*) for the four typical wave types affecting the project area are shown in Table 4-5.

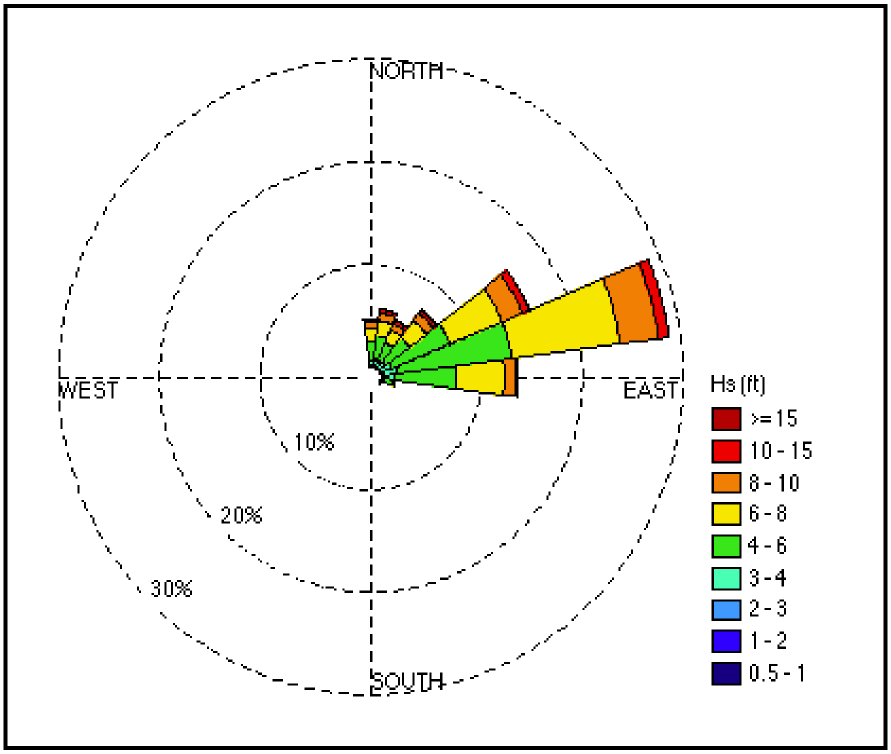

Figure 4-2. Deepwater wave height rose from CDIP 098 *(0° - 105°)*

Table 4-1. Deepwater wave height and histogram from CDIP 098 *(0° - 105°)*

Hs (ft)\Dir	0	15	30	45	60	75	90	105	Total
1-2	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
2-3	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	1.0
3-4	0.5	0.6	0.6	0.7	1.0	1.5	1.1	0.3	6.3
4-6	1.9	2.3	1.9	3.0	6.3	11.4	6.3	0.8	34.0
6-8	1.3	1.5	1.4	2.1	5.6	10.8	4.7	0.2	27.5
8-10	0.6	0.8	0.6	0.9	2.2	3.9	1.2	0.0	10.1
10-12	0.2	0.3	0.3	0.3	0.6	0.9	0.2	0.0	2.7
12-14	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.6
14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1
16-20	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1
20+			0.0	0.0			0.0		0.0
Total	4.6	5.7	5.0	7.2	16.0	28.8	13.6	1.5	

	0	15	30	45	60	75	90	105
Mean	6.2	6.2	6.4	6.2	6.4	6.4	5.9	5.0
StDev	2.2	2.2	2.3	2.1	1.9	1.8	1.6	1.4
Min	1.9	1.8	1.7	1.8	2.0	1.9	2.2	1.9
Max	17.1	18.3	20.5	20.5	18.6	19.8	21.2	12.3

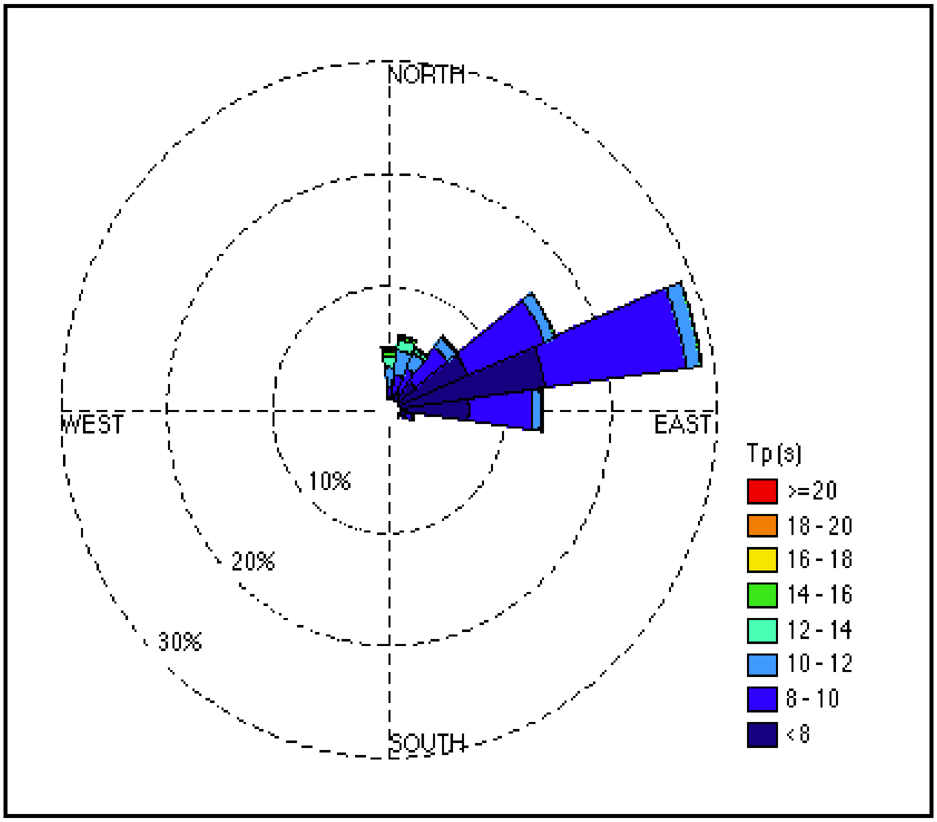

Figure 4-3. Deepwater wave period rose from CDIP 098 *(0° - 105°)*

Table 4-2. Deepwater wave period and histogram from CDIP 098 *(0° - 105°)*

Tp (s)\Dir	0	15	30	45	60	75	90	105	Total
4-6	0.0	0.0	0.1	0.2	0.8	2.7	2.0	0.2	6.0
6-8	0.1	0.3	0.7	2.0	6.2	11.2	4.5	0.4	25.5
8-10	0.9	1.8	2.3	3.8	7.9	13.4	6.1	0.6	36.8
10-12	1.8	2.2	1.5	1.0	1.0	1.4	0.8	0.1	9.8
12-14	1.0	0.9	0.4	0.1	0.1	0.1	0.2	0.1	2.9
14-16	0.4	0.3	0.1	0.0	0.0	0.0	0.1	0.1	1.2
16-18	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
18-20	0.1	0.0	0.0	0.0					0.2
20+	0.1	0.0							0.1
Total	4.6	5.7	5.0	7.2	16.0	28.8	13.6	1.5	

	0	15	30	45	60	75	90	105
Mean	12.0	10.9	9.8	8.8	8.2	8.0	8.0	8.4
StDev	2.6	2.1	1.9	1.6	1.4	1.4	1.8	2.3
Min	4.8	4.8	4.4	4.6	4.2	4.2	4.2	4.2
Max	25.0	25.0	18.2	18.2	16.7	16.7	16.7	16.7

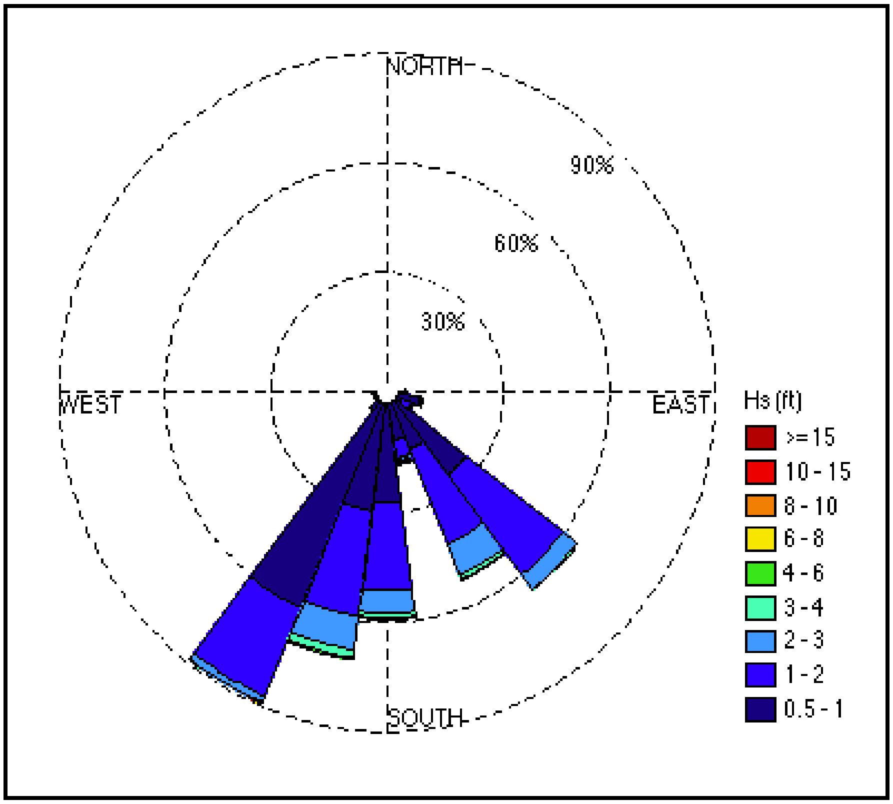

Figure 4-4. Deepwater wave height rose from HNL11 (*90°-270°*)

Table 4-3. Deepwater wave height and direction histogram from HNL11 (*90°-270°*)

Hs (ft)\Dir	90	105	120	135	150	165	180	195	210	225	240	255	270	Total
0.5-1	0.6	6.4	1.1	25.3	13.7	10.1	27.0	29.6	60.7	2.8	0.3	0.2	0.6	178.5
1-2	0.2	0.4	3.3	34.4	28.0	5.0	24.2	29.1	26.4	0.4	0.1	0.1	0.3	151.9
2-3	0.4	0.3	0.6	5.0	9.1	1.0	6.2	9.3	1.9	0.1	0.0	0.1	0.2	34.0
3-4	0.4	0.1	0.0	0.3	1.2	0.5	1.3	2.3	0.1	0.0	0.0	0.1	0.1	6.4
4-6	0.2	0.0	0.0	0.0	0.4	0.3	0.5	0.6	0.0	0.0	0.1	0.1	0.1	2.4
6-8	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
8-10	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
10-12					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12-14						0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-16					0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0
16-20						0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20+							0.0	0.0	0.0		0.0	0.0		0.0
Total	1.9	7.2	5.0	65.1	52.5	17.0	59.2	70.9	89.2	3.4	0.5	0.7	1.3	

	90	105	120	135	150	165	180	195	210	225	240	255	270
Mean	2.3	0.8	1.4	1.2	1.5	1.2	1.3	1.3	0.9	0.9	2.4	3.3	2.1
StDev	1.5	0.6	0.5	0.5	0.7	1.0	0.7	0.8	0.4	1.0	2.8	3.6	2.3
Min	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Max	8.7	6.5	7.8	8.8	14.0	18.9	27.0	26.9	25.9	16.7	20.1	23.7	19.8

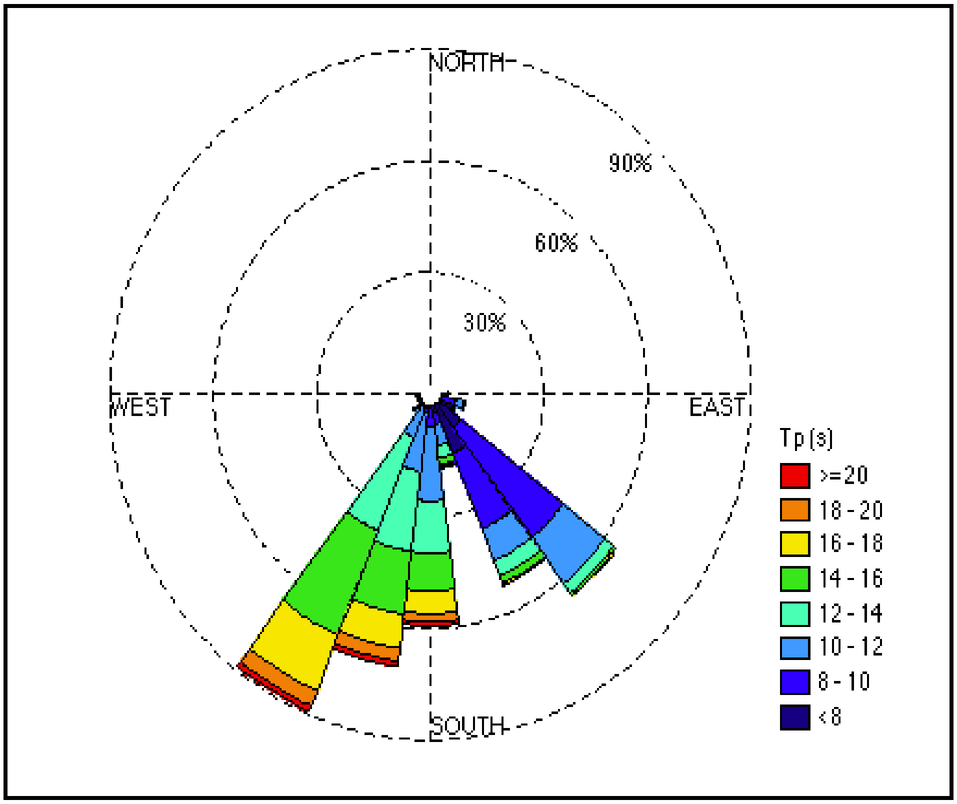

Figure 4-5. Deepwater wave period rose from HNL11 (*90°-270°*)

Table 4-4. Deepwater wave period and direction histogram from HNL11 (*90°-270°*)

Tp (s)\Dir	90	105	120	135	150	165	180	195	210	225	240	255	270	Total
4-6	1.0	0.4	3.7	1.1	4.6	1.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	13.3
6-8	0.2	0.1	0.4	6.8	9.4	0.9	0.3	0.2	0.2	0.2	0.2	0.2	0.1	19.1
8-10	0.2	4.0	0.8	37.4	22.0	2.9	4.9	1.4	0.3	0.1	0.1	0.2	0.2	74.4
10-12	0.3	2.5	0.2	15.5	9.3	5.8	20.1	15.9	8.8	0.7	0.1	0.1	0.5	79.8
12-14	0.1	0.1	0.0	3.2	4.3	3.4	14.0	21.8	27.2	1.2	0.0	0.0	0.2	75.7
14-16	0.2	0.0		0.8	2.1	1.9	10.2	17.0	30.4	0.8	0.0	0.0	0.1	63.6
16-18				0.2	0.6	0.7	6.1	9.3	16.3	0.2			0.0	33.5
18-20				0.0	0.1	0.1	2.3	3.5	4.3	0.0				10.4
20+				0.0	0.0	0.0	1.0	1.5	1.5	0.0			0.0	4.2
Total	1.9	7.2	5.0	65.1	52.5	17.0	59.2	70.9	89.2	3.4	0.5	0.7	1.3	

	90	105	120	135	150	165	180	195	210	225	240	255	270
Mean	7.4	9.6	5.9	9.5	9.3	11.3	13.1	13.9	14.6	12.7	8.0	7.8	10.2
StDev	3.4	1.5	1.8	1.6	2.5	2.9	2.8	2.6	2.2	2.7	2.5	2.4	2.8
Min	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max	15.4	14.7	12.7	20.1	21.5	23.0	25.6	25.1	23.8	21.0	14.5	14.4	24.8

Table 4-5. Selected prevailing wave characteristics (deepwater)

Wave Type	*Hs* (feet)	*Tp* (sec)	*Dp* (degrees true north)
South Swell	3	16	200
Southeast Swell	1	10	145
Tradewind Seas	6	8	075
Kona Seas	8.5	8	25

4.3 Transformation of Deepwater Waves to the Shoreline

As deepwater waves approach the shoreline, they begin to transform due to the effects of shoaling, bottom friction, refraction, and diffraction. As waves shoal, heights increase and the wave crests steepen, to the point that the waves become unstable, leading to breaking and dissipation of wave energy. Wave energy is also attenuated due to bottom friction. The approach direction can change as the wave front refracts or becomes oriented parallel to the existing bathymetric contours. Lateral spreading of energy, known as diffraction, can occur behind natural or man-made barriers. Wave transformation from deep water to the shoreline can be modeled using the numerical computer models SWAN and BOUSS2D. The SWAN (Simulating Waves Nearshore) model is used to transform the waves from deepwater to the nearshore. The SWAN model is a non-stationary (non-steady state) third generation wave model, based on the discrete spectral action balance equation and is fully spectral (over the total range of wave frequencies). Wave propagation is based on linear wave theory, including the effect of wave generated currents. The processes of wind generation, dissipation, and nonlinear wave-wave interactions are represented explicitly with state-of-the-science third-generation formulations. The SWAN model can also be applied as a stationary (steady-state) model. This is considered acceptable for most coastal applications because the travel time of the waves from the seaward boundary to the coast is relatively small compared to the time scale of variations in the incoming wave field, the wind, or the tide. SWAN provides many output quantities including two-dimensional spectra, significant wave height and mean wave period, and average wave direction and directional spreading. The SWAN model has been successfully validated and verified in several laboratory and complex field cases. The SWAN model transformation of the deepwater waves to the nearshore 25-meter depth at Waikiki is shown in Table 4-6. Note that except for south swell, the waves are reduced from their deepwater height and their approach direction altered due to refraction.

Table 4-6. Shallow water wave characteristics

Wave Type	*Hs* (feet)	*Tp* (sec)	*Dp* (degrees TN)
South Swell	3	16	200
Southeast Swell	0.8	10	170
Tradewind Seas	2	8	145
Kona Seas	7	8	245

The nearshore waters of Waikiki include shallow reef, natural and dredged channels, and shore protection structures. Wave and circulation modeling were performed using the Surface-water Model System (SMS) suite of products to identify Waikiki's coastal processes. BOUSS2D, a component of SMS, is a shallow water non-linear wave model developed by the U.S. Army Corps of Engineers that includes the processes of wave shoaling, refraction, diffraction, and breaking. BOUSS2D is best used as a nearshore model, where its offshore boundary is in shallow water and its domain is composed of small grid cells which yield a high resolution. The output of SWAN serves as the input to BOUSS2D at the nearshore water depth of 25 meters, and the waves are transformed the rest of the way to the shoreline. BOUSS2D is a time domain model and is particularly useful in modeling wave/structure interaction. It also can create animations of water surface elevations and can be used to show wave propagation and nearshore wave patterns. The Waikiki nearshore waters contain complex bathymetry resulting in complex wave patterns, and visualization through the model animations provides a greater understanding of the coastal processes and guidance for design.

Figure 4-6 shows a snapshot of the water surface elevation for the south swell wave condition. The bathymetry is underlain and is shown as spectral colors where red is shallow and blue is deep. The water surface is shown as nearly transparent, allowing waves and bathymetry to be seen together. The model results show that the wave patterns are predominately a function of the nearshore reef structure. The wave pattern offshore of Kuhio Beach Park's Ewa groin shows a complex wave pattern resulting from wave interaction with the reef that produces surf at Queens and Baby Queens. The incident waves refract and diffract off the reef, while also diffracting through the larger gaps in the reef, such as between Canoes and Queens surf breaks, presenting a series of curved wave fronts. These waves, which offshore were a continuous wave, are shown in the figure to be separate and interacting with each other. Note the very oblique angle of wave approach near the Kuhio Ewa groin. As the waves propagate to the shoreline, the angle between the wave crest and the shoreline produces alongshore transport potential from the east to the west, away from the Kuhio groin.

Figure 4-6. Water surface snapshot from BOUSS2D for typical south swell waves

5. COASTAL PROCESSES AND SAND TRANSPORT

The Ewa Kuhio Beach groin forms the eastern boundary of the Royal Hawaiian Beach sector of Waikiki Beach, which extends 1,730 feet west to the Royal Hawaiian groin. The Royal Hawaiian groin and the Ewa groin at Kuhio Beach Park effectively prevent longshore sediment transport into and out of this beach sector. There is, however, longshore transport within the sector itself. In the nearshore waters and on the beach, there are wave generated longshore currents that are the major driver of sediment transport direction and magnitude. Sand transport is mostly in the western direction. Hawaii's sandy shorelines, in general, are quite dynamic and change in response to incident wave conditions, such as a change in wave approach direction or height. Sand transport and beach change are highly variable and unpredictable. Recent examples of rapid wave induced sand transport occurred in 2014-15 and in 2017. In December 2014, a period of east and southeast wave approach rapidly moved sand away from the east end of the Royal Hawaiian Beach sector, exposing the old Waikiki Tavern concrete foundation remnants which are typically buried (Figure 5-1). By February 2015, westerly waves had moved all the sand away from the vicinity of the Royal Hawaiian groin, at the west end of the Royal Hawaiian Beach sector and exposed the foundation of the seawall fronting the Royal Hawaiian Hotel (Figure 5-2). The sand had moved east toward Kuhio Beach. In March 2015, the Waikiki Tavern Foundation was reburied in the sand (Figure 5-3). During the winter of 2017, the foundation remained buried. Six months later in August 2017, the sand moved again from the east end of the beach exposing the concrete foundation and damaging the landward end of the Ewa Kuhio groin (Figure 5-4 and Figure 5-5).

Sand can also be transported offshore by rip currents generated by large swells. A rip current has been noted in the vicinity of the Royal Hawaiian groin. Prior to construction of the Ala Wai Canal, the paleo-channel of Apuakehau Stream had flowed into the sea in the Royal Hawaiian Beach sector. The paleo-channel constitutes a low-lying bathymetric feature that may provide a conduit for offshore sand loss. During high surf, the channel becomes the site of rip currents capable of transporting sand away from the beach and depositing them offshore.

Figure 5-1. Project site December 11, 2014

Figure 5-2. Royal Hawaiian Groin, March 11, 2015

Figure 5-3. Project site March 11, 2015

Figure 5-4. Project site February 8, 2017

Figure 5-5. Project site August 21, 2017

Sediment transport from 1985 to 2009 within the Royal Hawaiian Beach sector resulted in shoreline recession at rates up to 2.4 feet per year, and an average rate of 1.5 feet. The highest recession rates in a Waikiki study were found in front of the Moana Surfrider, while the lowest recession rates were adjacent to the Royal Hawaiian groin. The Royal Hawaiian Beach sector reportedly accounts for 93% of the sand loss in Waikiki, with the Royal Hawaiian groin rip current likely representing the largest source of sediment loss for Waikiki Beach. The rip current, coupled with the prevailing longshore sediment transport to the west, help account for prevailing long-term sand loss. Beach surveys following the 2012 beach nourishment project showed that the beach width decreased an average of 2.9 feet over the year following completion of the nourishment project. The width change varied by location within the sector, ranging from +5.7 feet in the central segment to -9.4 feet at the west end near the Royal Hawaiian groin. Continued monitoring of the 2012 beach nourishment project shows that after six years roughly half of the original 2012 width has been lost. The greatest loss of beach width has occurred at the east and west ends, with beach recession of 3 to 5 feet per year recently being experienced at the proposed project site at the east end fronting the beach concessions. The monitoring also confirmed predominant longshore transport to the west and onshore-offshore transport through the deeper paleo stream channel. Shoreline change adjacent to the Kuhio groin between 2012 and 2018 is shown in Figure 5-6.

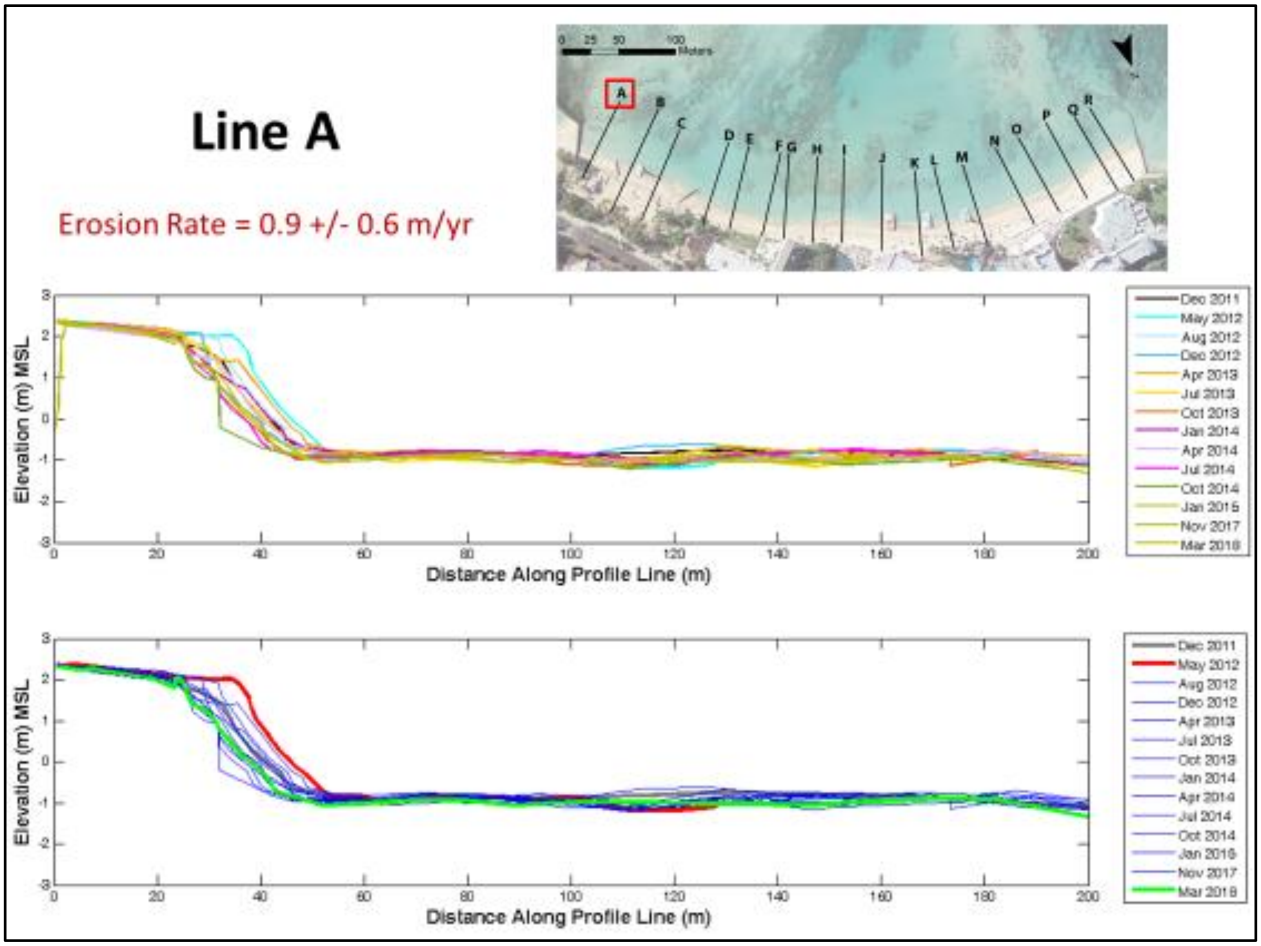

Figure 5-6. Shoreline change adjacent to the Kuhio Beach Ewa groin between 2012 and 2018

6. ALTERNATIVE BEACH STABILIZATION PLANS

Three alternative improvement plans have been considered to stabilize the east end of Royal Hawaiian Beach adjacent to the Kuhio Beach Ewa groin and to help ensure that the Waikiki Tavern concrete foundation remnants remain covered. The proposed project is considered a demonstration project, and ease of installation and removal is a consideration, thus ElcoRock geotextile containers are proposed for the groin construction. ElcoRock is a coastal construction system utilizing robust geotextile containers designed to be filled with sand and then placed to form a stable and durable structure. Large $2.5m^3$ containers are proposed to be used, each weighing approximately 10,000 pounds, which will provide a stable structure for the project site wave conditions. The large bags are also efficient to install and remove. The non-woven geotextile fabric is UV and vandal resistant, has excellent abrasion resistance, and its soft finish is attractive and non-abrasive.

The design beach position would maintain a two-foot (2') vertical buffer of sand over the makai edge of the foundation. Each alternative presented would fulfill this design guideline. Fill volumes for each alternative is based on topographic survey data collected in March 2018. Actual fill volumes on the date of construction could be less or greater than the volumes listed.

The proposed project would use calcareous sand from an inland source (Pacific Aggregate, Waianae) to fill the ElcoRock containers. Sand would be borrowed from the Kuhio Beach Diamond Head basin to provide the necessary beach fill.

6.1 Plan 1 – Straight Groin

In Plan 1, a single 95-foot-long groin would be placed 140 feet west of the existing Kuhio Beach west groin. The 95-foot groin length is the minimum length necessary to ensure adequate beach width to keep the concrete rubble covered. The groin would have a crest elevation of +3.5 feet msl and would have a toe elevation of -2.8 feet. The groin would require 68 ElcoRock containers to construct, and 225 cy of sand to fill the containers. Approximately 750 cy of sand would be required to cover the concrete rubble and fill the cell between groins to its design shape. Plan and section views of the groin and beach fill are shown in Figure 6-1.

6.2 Plan 2 – Straight Groin with Kuhio Groin Stub

As previously discussed, waves approaching the project area shoreline at an oblique angle generate a west setting longshore current that moves sand from the east to the west. The westerly movement of sand is exacerbated during periods of easterly waves such as tradewind seas and southeast swell waves. A short, 55-foot-long, stub groin at the bend of the west Kuhio Beach groin would diffract the approaching waves and result in a more shore-parallel wave approach to the beach, reducing the longshore current and sand movement potential significantly. This would help ensure stable sand cover over the concrete rubble and reduce erosion and flanking of the Kuhio Beach west groin root. The stub would be constructed of 36 ElcoRock containers in a similar manner to the Plan 1 groin and would require 115 cy of sand to fill them. Approximately 900 cy of sand would be required to achieve the design beach configuration. A plan view of this alternative is shown in Figure 6-2.

6.3 Plan 3 – Second Straight Groin

Monitoring of the beach shows continuing and rapid erosion and beach width loss along the entire beach fronting the beach concession area. A second groin placed 200 feet west of the first groin would help further stabilize the east end of the beach fronting the beach concession area. The second groin could be in addition to either plans 1 or 2. This groin would be constructed identically to the single straight groin. No sand fill is proposed between the first and second groins. A plan view of this alternative is shown in Figure 6-3.

6.4 Summary of Alternative Plan Features

A summary of the plan features is shown in Table 6-1.

Table 6-1. Summary of alternative plan features

Plan	Length	No. of Sandbags	Sand in Bags (cy)	Beach Fill (cy)	Total Sand (cy)
1	Straight Groin – 95 ft	68	225	750	975
2	Straight Groin – 95 ft Kuhio Stub – 55 ft	68 36	225 115	900	1,240
3	Straight Groin – 95 ft Second Groin – 95 ft	68 68	225 225	750	1,200

6.5 Selected Groin Plan

Plan 1, a single straight 95-foot long groin would meet the project objectives and result in the least change to existing beach conditions and is the selected plan for the proposed project. Plan 2 would add a measure of additional beach stability; however, it would be located in an area sometimes used for beginner surfing lessons and would require more sand fill to be borrowed from the Diamond Head Kuhio Beach basin. Plan 3 would help stabilize more of the east end of Royal Hawaiian Beach, but is not necessary to meet the primary project objective of stabilizing the sand cover over the Waikiki Tavern concrete foundation. In addition, there is considerable seasonable variation in beach width at the east end of this beach sector, and a second groin would transfer this variability to the west side of the second groin, where the beach is narrower directly fronting the Moana Surfrider Hotel.

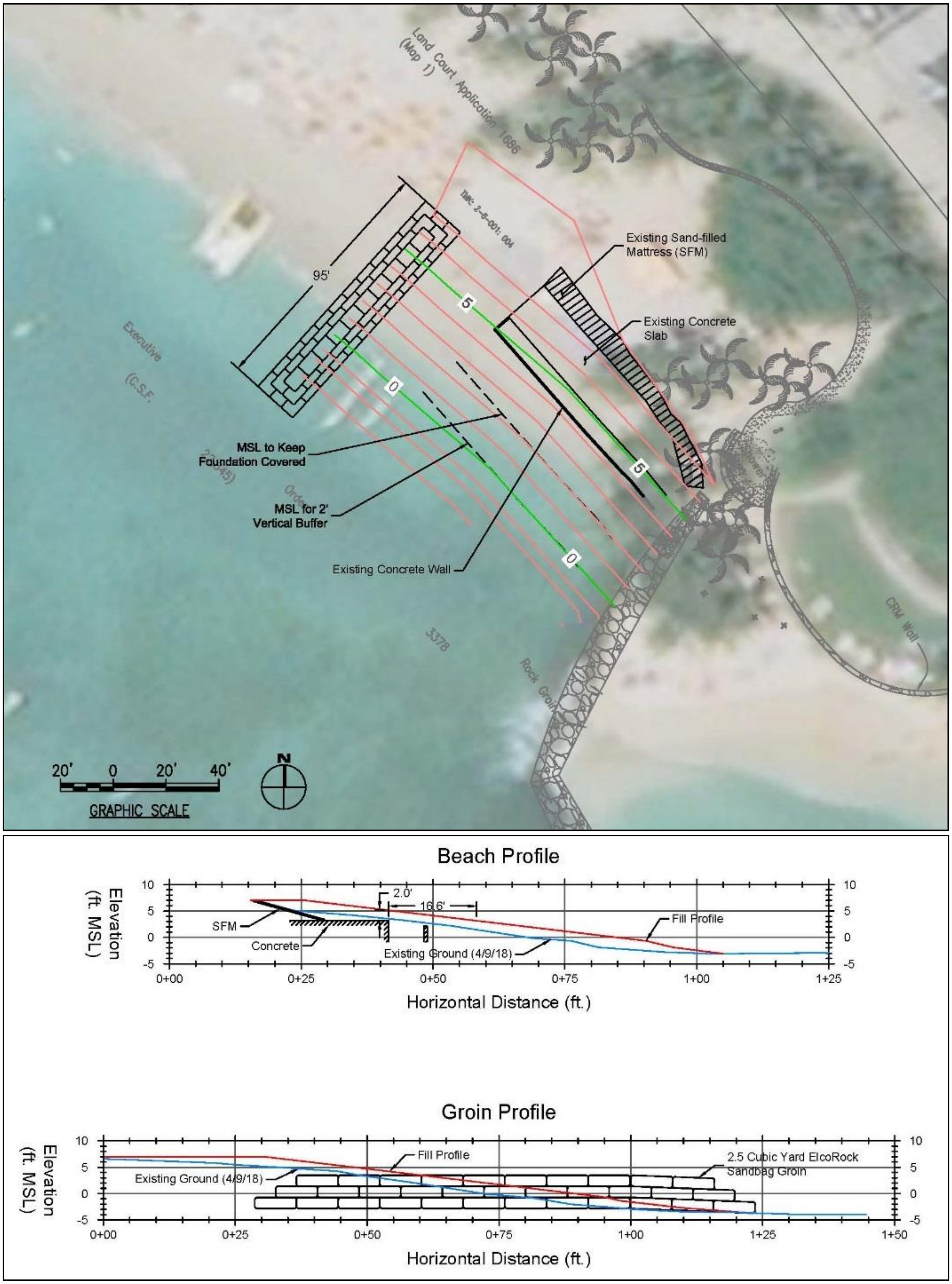

Figure 6-1. ***Plan 1*****: Straight groin**

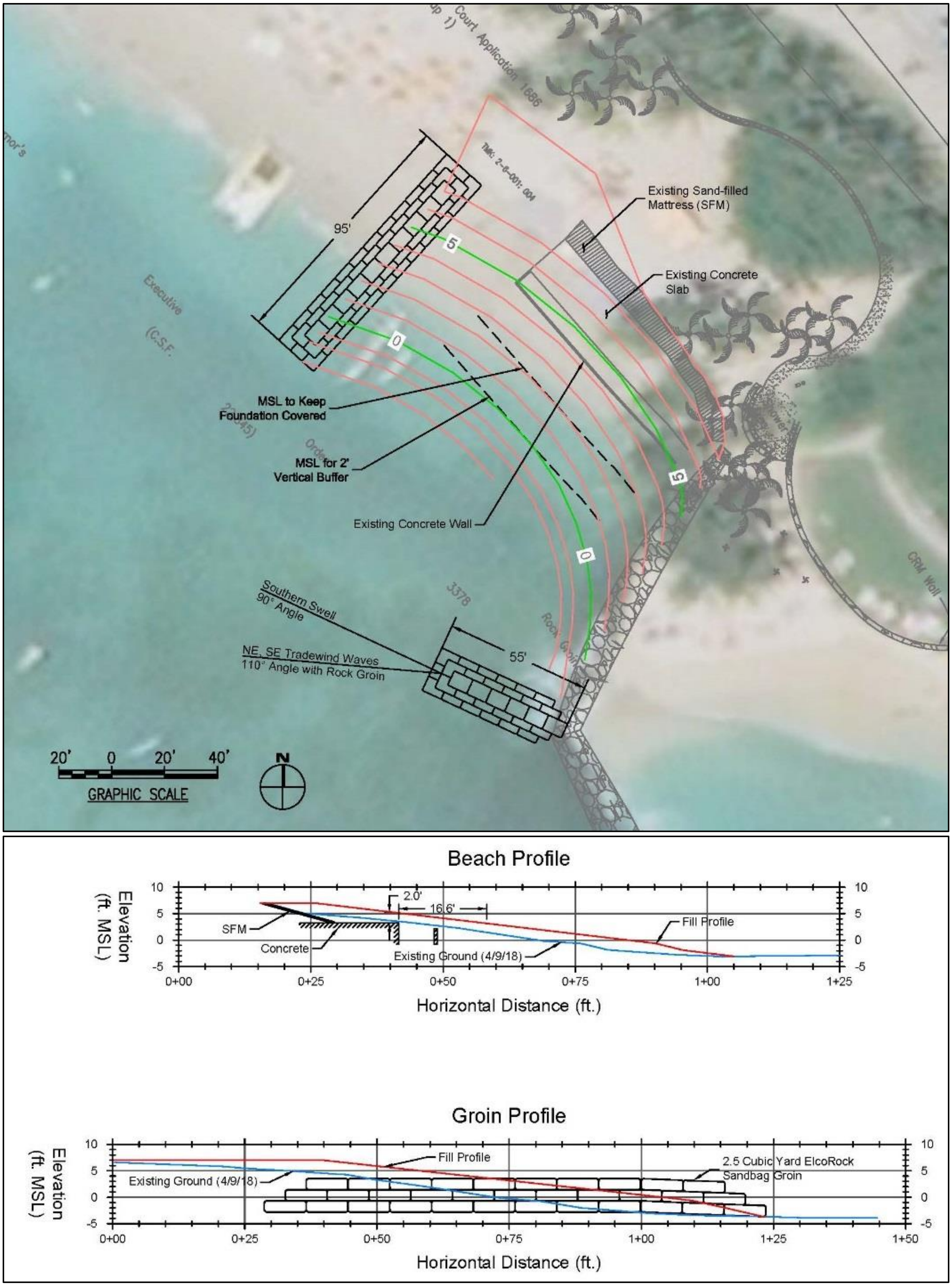

Figure 6-2. *Plan 2:* Straight groin with Kuhio stub groin

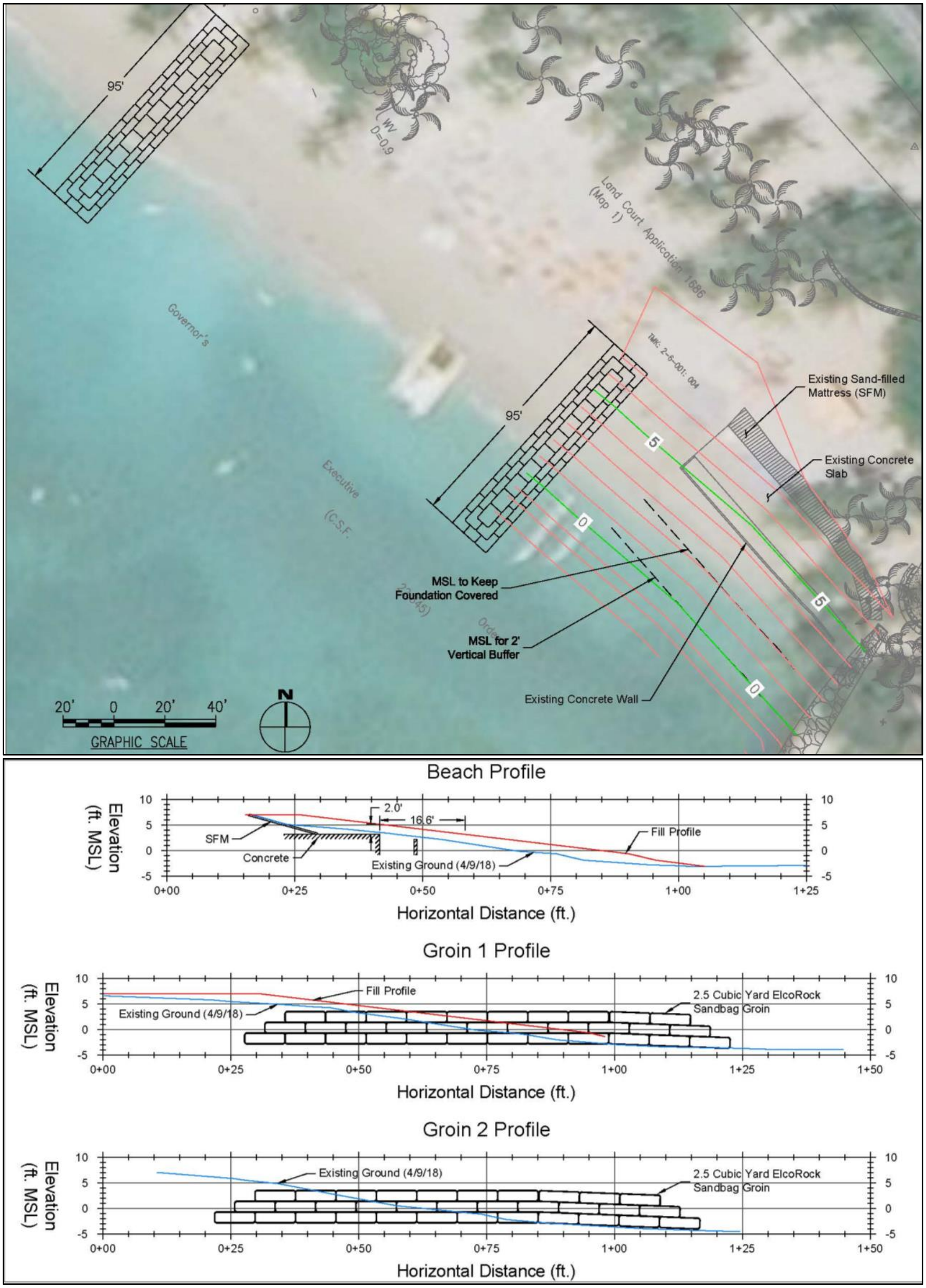

Figure 6-3. *Plan* 3: Two straight groins

6.6 Kuhio Beach Sand Borrow Plan

An approximate 2-foot thickness of sand would be removed from the beach face between the +5-foot crest and the - 1-foot toe, for a distance of 300 feet along the shore. This would result in an approximate 12-foot landward recession of the beach crest. The plan layout and typical section are shown in Figure 6-4 and Figure 6-5.

6.7 Construction Methodology, Sequence, and Schedule

Construction will require the closure of much of the beach in the vicinity of the ElcoRock groin installation and a portion of the Kuhio Beach Diamond Head basin for approximately two weeks to ensure the safety and welfare of the public. The work specifications will specify that the construction is to be completed in the most time effective manner as possible so as to minimize the inconvenience of beach closure.

Filling and placing the ElcoRock containers would involve a small excavator for placing sand in the hopper of the filling stand, and a medium size excavator (40 ton) to transport and place the containers. Based on installation guidance from the ElcoRock manufacturer, an estimated 3 to 4 containers can be filled and placed per hour. Construction would proceed from the shore seaward. The beach within the groin footprint would be excavated down to the -2-foot elevation for placement of the first layer of ElcoRock containers, with excavated sand being side cast to the east. The first course of bags would be placed all the way to the end and will provide a stable platform for the placement equipment (excavator) to traverse. Groin construction would then proceed from the seaward end and work landward placing the second and third layers of ElcoRock to complete the groin. Turbidity containment devices (silt curtains) would be placed around the area of groin construction and sand placement. Once the groin is in place, the fill sand would be trucked from the nearby Kuhio Beach basin and pushed into place using a small bulldozer.

The estimated construction sequence and schedule is as follows:

Day 1-3: Mobilize equipment and materials on site. Site preparation, including the installation of safety fence around the entire work area, installation of environmental protection and turbidity containment in the DH basin. Truck in and stockpile ElcoRock fill sand in the vicinity of groin installation.

Day 4-7: DH basin work, remove sand from the beach face and stockpile it in the backshore.

Day 4-7: Fill and place the ElcoRock containers to construct the groin.

Day 8-9: Truck fill sand from Kuhio Beach to the fill site and shape beach to design configuration.

Day 10: De-mobilize and clean-up work area.

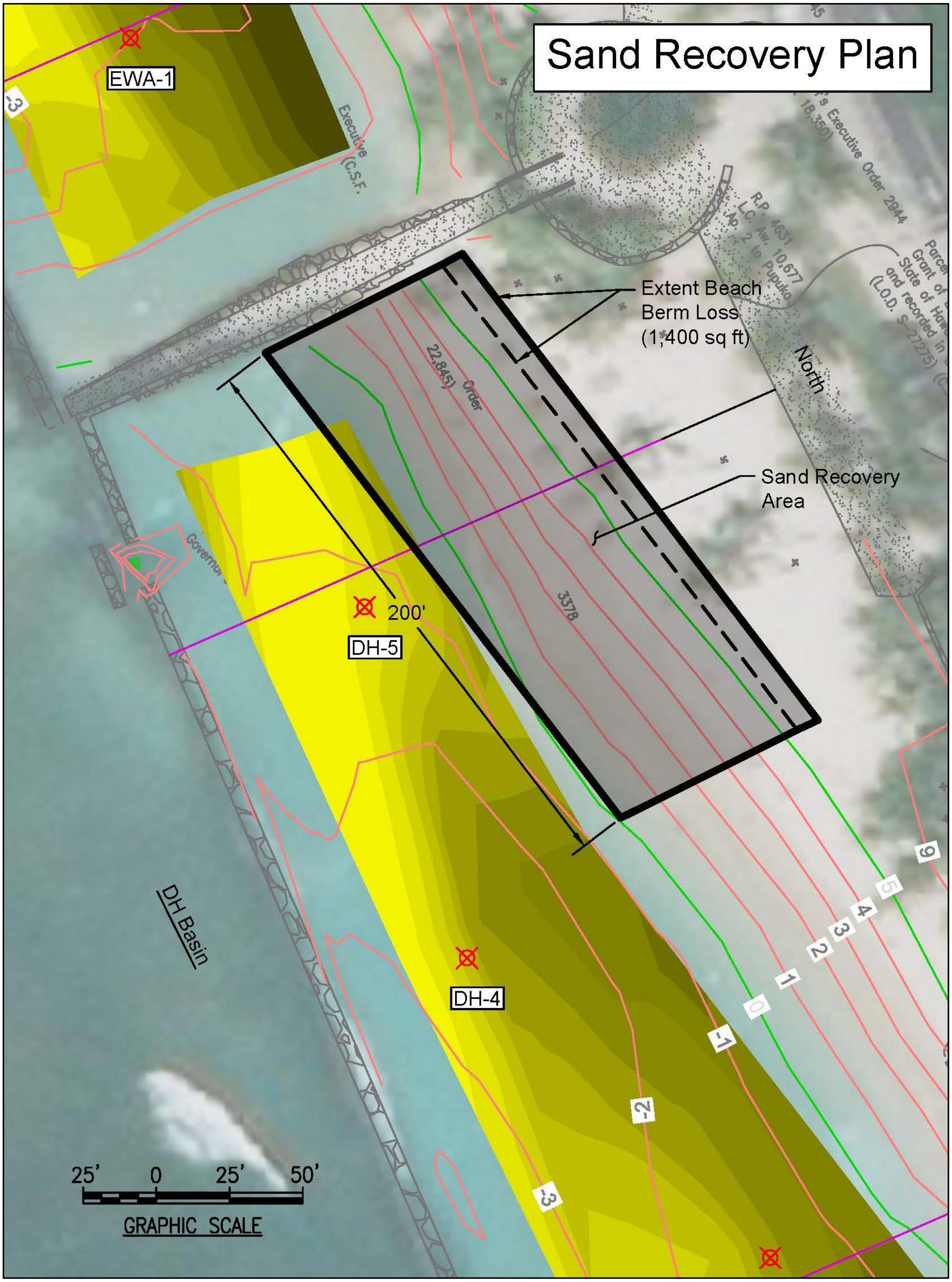

Figure 6-4. Kuhio Beach Diamond Head basin sand borrow plan

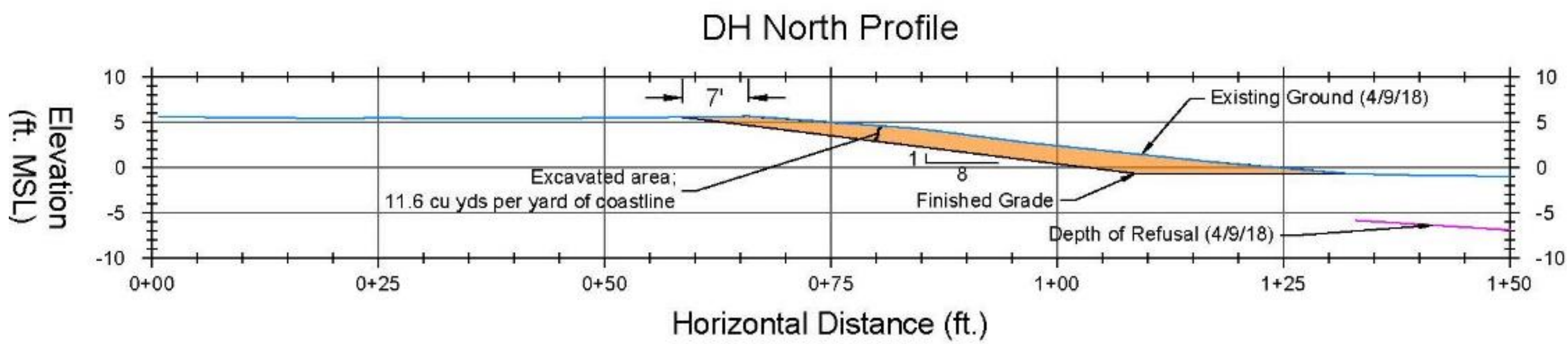

Figure 6-5. Sand borrow typical section

7. PROJECT ASSESSMENT

7.1 Seafloor and Shoreline Processes

7.1.1 *Existing Condition*

The seafloor in the vicinity of the groin placement is all sand. Further seaward there are fossil limestone reef outcrops, which show significant evidence of sand scour and have little or no benthic biota on them. The Royal Hawaiian Beach is very dynamic, particularly at the east and west ends. Longshore sand transport is predominately to the west, however, during periods of westerly wind and waves, sand can be rapidly transported to the east into the project site.

7.1.2 *Potential Effects*

The proposed groin will have no effect on the prevailing coastal processes and sand transport; however, it will effectively create a new east end of the Royal Hawaiian Beach sector. This will transfer the present beach width variability currently experienced adjacent to the Ewa Kuhio Beach groin to the west side of the new ElcoRock groin. The sand fill placed between the Ewa Kuhio Beach groin and the new groin will be stable; however, there will be a relatively short period of equilibration immediately following placement, and the beach slope and toe location may change. The ElcoRock containers will be placed on an unconsolidated sand foundation, and there may be some scour at the head and around the edges of the groin, and some settlement of the groin may occur. During high tides and high waves, overtopping of the beach may result in flanking of the groin, and some sand movement around the landward end of the groin.

The analyses and designs in this report have been done in accordance with industry standards contained in publications produced by the U.S. federal government and/or other industry experts, as referenced in the report. However, the prediction and assessment of natural hazards and their effects have an element of uncertainty that cannot be eliminated. Oceanographic conditions such as winds, waves, storms, and currents are highly variable, and the corresponding response of coastal systems and structures cannot always be predicted with absolute accuracy. Unforeseen changes to the seafloor or water depths resulting from the natural processes of sand transport and shoreline erosion may occur and may be attributed to coastal projects. Other temporary or permanent changes may also occur to the natural environment that are not foreseen in this report

7.2 Water Quality

7.2.1 *Existing Condition*

The waters offshore of Waikiki Beach are classified in the Hawaii Water Quality Standards as (a) marine waters, (b) open coastal, (c) reef flat, (d) Class A, and (e) Class II marine bottom ecosystem. It is the objective of Class A waters that their use for recreational purposes and aesthetic enjoyment be protected. Investigations for the 2012 beach maintenance project showed that in General Waikiki water quality is consistent with that typically found in Hawaii's coastal waters, with temperature, salinity, dissolved oxygen, and pH within normal limits. Total nitrogen and total phosphorus are typically slightly high, and turbidity levels generally exceed State water quality criteria. The high turbidity levels are attributed to wave action stirring up and suspending fine bottom sediment. The State Department of Health, Clean Water Branch, monitors nearshore water quality in Waikiki, including Waikiki Beach Center and Kuhio Beach.

These two areas have been listed as impaired water bodies, meaning they do not meet Hawaii Water Quality Standards, particularly during the wet season.

7.2.2 *Potential Effects*

Turbidity containment devices (silt curtains) will surround the groin installation and sand fill placement work areas, and the Kuhio Beach Diamond Head basin sand borrow area. These will remain in place until construction has been completed and turbidity within the containment area has dissipated. Even with containment, however, some turbidity increase in the project vicinity during construction may occur. Standard Best Management Practices (BMPs) for work near or in coastal waters will be employed to prevent adverse impacts to coastal waters. No long-term effects on water quality resulting from the project are expected.

7.3 Marine Biota

7.3.1 *Existing Condition*

The project site nearshore seafloor is entirely mobile sand, which does not provide a suitable habitat for marine biota. Seaward of the project site the seafloor is a highly bio-eroded fossil limestone reef platform with sand-filled pockets and channels. Corals are generally absent from the reef platform offshore of Waikiki. Coral colonies typically account for less than one percent of the bottom area and are composed almost entirely of two species, *Porites lobata* and *Pocillopora meandrina*. Wave-induced scour from suspended sand is likely responsible for the observed limited coral abundance. The dominant species of benthic organisms on the reef platform are marine algae, which cover virtually all exposed reef surfaces. The invasive algae species *Acanthophora spicifera* and *Gracilaria salicornia* dominate the benthic flora in Waikiki. The most common macroinvertebrates on the reef platform are the rock-boring urchin *Echinometra mathaei* and the black sea cucumber *Holothuria atra*. The predominate biotic attributes of the reef platform are a result of sand suspension and sand scour due to wave action. Reef fish are also relatively sparse throughout the area.

7.3.2 *Potential Effects*

Given the nature of the seafloor within the project area and the footprint of the proposed groin, and the relative paucity of marine biota in the Waikiki nearshore area, no effects on marine biota are expected either during construction or over the long-term.

7.4 Protected Species

7.4.1 *Existing Condition*

Listed protected species, sea turtles, Hawaiian monk seal, and humpback whales occur in the project vicinity. State protected hermatypic corals occur in Waikiki in very low numbers. Of the sea turtles found in the Hawaiian Islands, only the green sea turtle is common in the project vicinity. Turtles can frequently be seen foraging on the abundant benthic macroalgae in nearshore waters. However, turtles are not known to nest on Waikiki Beach. Turtles are often found in the vicinity of swimmers and waders and do not appear to be deterred or bothered by human activities. The beaches and coastline of Oahu are used by the endangered Hawaiian monk seal for hauling out (resting) and for pupping and nursing. Seals are known to occur in the waters off Waikiki, and a seal recently gave birth to a pup on Kaimana beach, a little bit east of the project site. Endangered Humpback whales can regularly be seen in Hawaiian waters during the winter; however, the shallow Waikiki nearshore waters prevent them from coming close to shore. All nearshore waters in Hawaii are designated as Essential Fish Habitat (EFH), thus the proposed project is located within waters designated as EFH.

7.4.2 *Potential Effects*

As discussed above, sea turtles and monk seals are regularly observed in nearshore waters in the project area. No obvious congregation or resting areas have been seen, but the turtles clearly forage on the algae that grow abundantly in the nearshore area. Turtle surveys in the general area indicate that turtle abundance is not negatively affected by the number of people in the water or all the water recreation activities which occur in Waikiki. Turtles would be expected to move away from the construction activities, and as the impact area is relatively small and primarily on sandy bottom construction would not affect turtle foraging area. Construction of the groin will not involve in-water work, such as pile driving, which could be expected to result in significant underwater sound that would adversely affect marine creatures.

The following Best Management Practices (BMPs) as typically recommended by the National Marine Fisheries Service (NMFS) will be adhered to during construction of the project to avoid impacts to the turtles or other marine protected species:

1. Conduct a survey for marine protected species before any work in the water starts, and if a marine protected species is in the area, a 150-foot buffer must be observed between the protected species and the work zone.
2. Establish a safety zone around the project area whereby observers will visually monitor this zone for marine protected species 30 minutes prior to, during, and 30 minutes post project in-water activity. Record information on the species, numbers, behavior, time of observation, location, start and end times of project activity, sex, or age class (when possible) and any other disturbances (visual or acoustic).
3. Conduct activities only if the safety zone is clear of all marine protected species.
4. Upon sighting of a marine protected species within the safety zone during project activity, immediately halt the activity until the animal has left the zone. In the event that a marine protected species enters the safety zone and the project activity cannot be halted, conduct observations and immediately contact National Marine Fisheries Service staff in Honolulu to facilitate agency assessment of collected data.
5. For on-site project personnel that may interact with a marine protected species potentially present in the project area, provide education on the status of any listed species and the protections afforded to those species under Federal laws.

By using the above BMPs, noise/physical disturbance to green sea turtles and Hawaiian monk seals is expected to be temporary and insignificant and not result in adverse behavioral changes. Based on the in-water work being conducted in very shallow water with turbidity containment barriers surrounding the work area, any exposure of marine protected species to turbidity is expected to be temporary and not significant. There would be no loss of turtle foraging area.

7.5 Historic, Cultural and Archaeological Resources

7.5.1 *Existing Condition*

In prehistoric and early historic periods, Waikiki was a place of great cultural significance for Hawaiians. It was important as an agricultural center, a site of royal residences and heiau, as well as being a center for traditional Hawaiian cultural practices including human sacrifice, surfing, gathering of limu, and the traditional healing ablutions in the waters of Kawehewehe. Waikiki was also the site of at least two important battles, the 1793 invasion of Oahu by the forces of the Moi of Maui, Kahekili and the 1795 invasion of Oahu by Kamehameha the Great which led up to the unification of the Hawaiian Islands under his rule. Waikiki was a center of population and political power on Oahu beginning long before the Europeans arrived in the Hawaiian Islands during the late eighteenth century. Waikiki's ancient chiefs had located residences there for hundreds of years. Beginning in the fifteenth century, an extensive system of irrigated taro fields (lo'i kalo) was constructed across the littoral plain from Waikiki to lower Manoa and Palolo Valleys. This field system – thought to have been designed by the chief Kalamakua – took advantage of streams descending from Makiki, Manoa, and Palolo valleys, which also provided ample fresh water for the people living in the ahupuaa. Water was also available from springs in nearby Moiliili and Punahou. Closer to the Waikiki shoreline, coconut groves and fishponds dotted the landscape. A sizeable population developed amidst this Hawaiian-engineered abundance.

Beginning in the 1880s, the Waikiki shoreline has been extensively modified; and today it is the primary tourism center for Hawaii. In 1881 Long Branch Baths bathhouse was built on the beach at the water's edge, near the present-day Moana Surfrider Hotel. They serviced visitors by providing changing rooms, towels, swimsuits, and access to the beach, all for a fee, which caught the attention of Waikiki businessmen. In the early 1900s much of the beach at Waikiki disappeared under structures and landscaping, and reportedly significant volumes of sand were removed from the beach. In later years sand was brought into Waikiki to replace that which had been lost to encroachment and removal. Numerous shore perpendicular and shore parallel channels have been dredged in the reef for fill material, navigation/access channels, and swimming. The Moana Hotel (today Moana Surfrider) opened in 1901, with a restaurant on piles over the beach and water. In 1922 construction of the Ala Wai Canal commenced to drain the wetlands and divert streams away from Waikiki. With the completion of the canal in 1926 urban development of Waikiki began in earnest. Construction of the Royal Hawaiian Hotel was completed in 1927, including a new seawall and a 170-foot long groin at the site of the still existing Royal Hawaiian groin. The groin was lengthened to about 370 feet in 1930, and to this day it stabilizes about 1,730 linear feet of beach in the middle of Waikiki, the "Royal Hawaiian Beach" sector, which extends from the western Kuhio Beach crib wall west to the Royal Hawaiian groin. Other early Waikiki structures include the Waikiki Tavern (ca 1930), built on the beach at the proposed project site, Waikiki War Memorial/Natatorium salt water swimming pool (1927), construction of the Kapahulu storm drain (1951), the beginning of what is today the Kuhio Beach crib walls (1939), and construction of the first Ft. DeRussy storm drain (1917). Today Waikiki Beach is a highly-modified urban shoreline, with no natural shoreline between Honolulu Harbor and Diamond Head.

7.5.2 *Potential Effects*

Although Waikiki has a rich historical and cultural legacy, the proposed project would be unlikely to have a significant effect on historic or archaeological sites. Implementation of the proposed project does not involve construction on or excavation of land areas that might contain archaeological materials or burials. Work would take place in areas already highly transformed by Waikiki development and substantially altered over more than a century. Work would be along an existing shoreline that experiences episodic shoreline change due to sand erosion and accretion. There also do not appear to be any known traditional Hawaiian cultural practices that would be affected by the proposed project. Implementation of the project would protect the remnants of the old Waikiki Tavern foundation.

7.6 Recreation

7.6.1 *Existing Condition*

The project vicinity, including the waters offshore, is the most heavily used section of Waikiki Beach and is used for many different ocean recreation activities. These activities include sunbathing, swimming, surfing, standup paddling, canoe surfing, bodyboarding, sand skimming, snorkeling, spear fishing, pole fishing, walking, wading and metal detecting. Annual recreation events such as canoe regattas and surf contests are held in the project area. Two beach concessions are located landward of the project site, providing beach umbrella and surfboard rentals, surfing lessons, and canoe rides. The Mana Kai sailing catamaran beaches in the vicinity of the proposed groin. “Canoes” and “Queen’s” surf sites are located seaward of the project area shoreline.

Canoes is the most highly used surf spot in Hawaii for commercial surfing activities, including surfboard rentals, surfing lessons, and outrigger canoe rides. Beginning surfers and surf instructors with beginners receiving lessons are concentrated on the smaller inside waves, which is known as “Baby Canoes”, while intermediate and advanced surfers ride the bigger waves outside. Queen’s is the name of the surf spot located directly off the Duke Kahanamoku Statue. The waves at Queen’s are steeper than those at Canoes and are concentrated in a much smaller area, so beginning surfers and surf instructors with beginners receiving lessons generally do not surf there. Waves at Queen’s, however, reform near shore on the shallow reef near the Kuhio Beach Ewa groin. This surf spot is known as “Baby Queen’s” and attracts beginning surfers and surf instructors with lessons.

7.6.2 *Potential Effects*

Groin construction would disrupt existing shoreline activities for about two weeks. An approximate quarter acre (100 ft x 100 ft) contractor work and storage area would be located at the landward end of the groin, and the beach would be closed between the Kuhio Beach Ewa groin and the ElcoRock groin to ensure the safety and welfare of the public. Some relocation of beach concession activities would be required. Sand borrow operations would also require the closure of the Ewa end of the Kuhio Beach Diamond Head Basin for 3 to 4 days.

Once completed, the proposed groin would have little impact on normal beach recreation. The stable beach area between the Kuhio Beach groin and the proposed groin would provide a good entry point for swimmers and surfers. The new groin would only extend about 50 feet seaward of the mean sea level shoreline, well landward of even the beginner surfing area. The sailing catamaran would be able to beach where it customarily does, on the west side of the new groin. The proposed groin would be an obstacle for beach users and swimmers moving laterally to avoid; however, its heavy geotextile material has a soft finish with no sharp edges. The groin itself would likely over time grow algae on its surface, which would be slippery if walked on. Possible scour around the groin could result in depressions or holes in the immediate vicinity of the groin. Signage could be used to caution people about both the slipperiness and the possible uneven sea floor.

Coastal structures tend to be highly visible and are frequently placed in public venues with easy access. They are often not designed for public access, may have hard, slippery surfaces, voids, and sharp edges, and may be subject to significant wave exposure. Despite all reasonable precautions, accidents may occur on or around these structures.

7.7 Noise

7.7.1 *Existing Condition*

Existing ambient noise levels vary considerably within the project area both spatially (i.e., from place to place) and temporally (i.e., from one time to another). In general, existing background sound levels along Waikiki Beach are relatively high, 55 to 60 dBA, due to surf, traffic, aircraft, and on-going maintenance and construction equipment. In the vicinity of significant construction activity, noise levels can intermittently reach 80 dBA.

7.7.2 *Potential Effects*

It is not feasible to mitigate construction noise to the extent that it does not at times exceed existing background noise levels or is inaudible to beach users, hotel guests, etc. Some reduction is practical, however, and the following measures would be implemented.

- Equipment operation on the shoreline will be limited to the hours between 7 a.m. and 10 p.m.
- Broadband noise backup alarms in lieu of higher frequency beepers will be required for construction vehicles and equipment. Broadband noise alarms tend to be less audible and intrusive with distance as they blend in with other background noise sources.
- The project will specify the use of the quietest locally available equipment, e.g., high insertion loss mufflers, fully-enclosed engines, and rubber-tired equipment when possible.
- The use of horns for signaling will be prohibited.
- Worker training on ways to minimize impact noise and banging will be required.
- A noise complaint hotline will be provided at the job site to allow for feedback from the hotel operators, which can be used to help develop modifications to construction operations whenever feasible.
- Construction operations will cease in the vicinity of scheduled performances, such as the nightly hula show at the west end of Kuhio Beach.

7.8 Natural Hazards

7.8.1 *Existing Condition*

Flood hazards for the portion of Waikiki in which the project is located are shown on Flood Insurance Rate Map Flood Sheet 15003C0370F, which indicates that the shoreline is exposed to flooding caused by storm waves and tsunami. The area immediately inland of the shoreline is in Zone AE with a base flood elevation of 7 feet above mean sea level. The wave regime along the Waikiki shoreline is discussed in Section 4. The threat from high waves is moderate to high because this shoreline regularly experiences nearshore breaking wave heights on the order of 6 feet.

7.8.2 *Potential Effect*

Given the very small scale of the proposed groin, it is not expected to have a measurable effect on existing natural hazards.

7.9 Scenic and Aesthetic Resources

7.9.1 *Existing Condition*

The gentle curve of the Waikiki shoreline, the wide expanse of water with multiple surf breaks, the changing colors resulting from the varying water depths and bottom types, and the backdrop of Diamond Head make the seaward and long-shore views from the shoreline spectacular. The appearance of the beach is extremely important to the overall attractiveness of Waikiki. During periods when the sand is eroded from the east end of Royal Hawaiian Beach, exposing the remnant concrete foundation and rusting reinforcing steel, the beach in the project area is very unattractive and poses a hazard to beach users.

7.9.2 *Potential Effects*

While the proposed groin is relatively small in scale, it would be visually obvious on the beach. However, the geotextile container fabric is tan in color, very similar to the sand color, and sand clings to the coarse fabric surface. Thus, to a large extent, the groin will blend into the surroundings. The groin will stabilize the beach east of it and prevent the episodic exposure of the hazardous old concrete foundation material.

8. MITIGATION

8.1 Mitigation During Construction

8.1.1 Protection of Endangered Species

The following endangered species BMPs as recommended by the National Marine Fisheries Service (NMFS) shall be adhered to during construction of the project.

1. Establish a safety zone around the project area whereby observers shall visually monitor this zone for marine protected species 30 minutes prior to, during, and 30 minutes post daily project activity. Record information on the species, numbers, behavior, time of observation, location, start and end times of project activity, sex, or age class (when possible), and any other disturbances (visual or acoustic).
2. If a marine protected species are in the area, either hauled out onshore or in the nearshore waters, a 150-foot buffer must be observed with no humans approaching it. If a monk seal/pup pair is seen, a minimum 300-foot buffer must be observed.
3. In the event that a marine protected species enters the safety zone and the project activity cannot be halted, conduct observations and immediately contact NMFS staff in Honolulu to facilitate agency assessment of collected data. For monk seals contact the Marine Mammal Response Coordinator, David Schofield, at (808) 944-2269, as well as the monk seal hotline at (808) 220-7802. For turtles, contact the turtle hotline at (808) 983-5730.
4. For on-site project personnel that may interact with a listed species potentially present in the action area, provide education on the status of any listed species and the protections afforded to those species under Federal laws. NMFS may be contacted for scheduling educational briefings to convey information on marine mammal behavior and explain why and when to call NMFS and other resource agencies.

8.1.2 Best Management Practices During Construction

Best Management Practices (BMPs) for construction operations will be developed to help minimize adverse impacts to coastal water quality and the marine ecosystem. The project specifications will require the Construction Contractor to adhere to environmental protection measures, including, but not limited to, the following:

- The Contractor shall perform the work in a manner that minimizes environmental pollution and damage as a result of construction operations. The environmental resources within the project boundaries and those affected outside the limits of permanent work shall be protected during the entire duration of the construction period.
- Any construction related debris that may pose an entanglement hazard to marine protected species must be removed from the project site if not actively being used and/or at the conclusion of the construction work.
- The Contractor shall submit a Best Management/Environmental Protection Plan for approval prior to initiation of construction. The plan shall include, but not be limited to:
    1. Protection of Land Resources
    2. Protection of Water Resources
    3. Disposal of Solid Waste
    4. Disposal of Sanitary Waste
    5. Disposal of Hazardous Waste

6. Dust Control
7. Noise Control

- The construction contractor shall be required to employ standard BMPs for construction in coastal waters, such as daily inspection of equipment for conditions that could cause spills or leaks; cleaning of equipment prior to operation near the water; proper location of storage, refueling, and servicing sites; and implementation of adequate spill response procedures, stormy weather preparation plans, and the use of silt curtains and other containment devices.
- Designated project personnel will be responsible for daily inspections and maintenance of all project BMPs. Inspections and observations will be noted upon Daily Production Reports and, combined with Water Quality Monitoring Reports, will be submitted to the contracting officer daily.
- No contamination (trash or debris disposal, alien species introductions, etc.) of marine (reef flats, lagoons, open oceans, etc.) environments adjacent to the project site shall result from project related activities.
- The Contractor shall confine all construction activities to areas defined by the drawings and specifications. No construction materials shall be stockpiled in the marine environment outside of the immediate area of construction.
- The Contractor shall keep construction activities under surveillance, management and control to avoid pollution of surface or marine waters. Construction related turbidity at the project site shall be controlled to meet water quality standards. All water areas affected by construction activities shall be monitored by the Contractor. If monitoring indicates that the turbidity standards are being exceeded due to construction activities, the Contractor shall suspend the operations causing excessive turbidity levels until the condition is corrected. Effective silt containment devices shall be deployed where practicable to isolate the construction activity, and to avoid degradation of marine water quality and impacts to the marine ecosystem. In-water construction shall be curtailed during sea conditions that are sufficiently adverse to render the silt containment devices ineffective.
- Underlayer fill shall be protected from erosion with armor units as soon after placement as practicable.
- Waste materials and waste waters directly derived from construction activities shall not be allowed to leak, leach, or otherwise enter marine waters.
- The presence of heavy equipment on the shoreline creates a potential for pollutants, such as fuel and petroleum products, to enter the water. To prevent such discharges from occurring, heavy equipment will be visually inspected at the beginning and end of each workday to ensure early detection of potential leaks or line breaks. Equipment will be kept clean to ensure that grease or dirt does not enter the water. Fuel will be delivered to the site at sufficiently frequent intervals such that the volume of fuel stored on site is minimal. Spill kits will be kept at the site and workers will be trained on spill response.
- Fueling of project related vehicles and equipment should take place away from the water. A contingency plan to control the accidental spills of petroleum products at the construction site should be developed. Absorbent pads, containment booms, and skimmers will be stored on site to facilitate the cleanup of petroleum spills.
- In the event of a spill, the following actions shall be taken:
  1. STOP FUELING / OILING IMMEDIATELY!

2. Reduce the amount of the spill by shutting down the equipment, shutting off the valve, shutting off the pump, uprighting the container, etc. Place a pan or bucket under the leak to catch as much of the spill as possible.
3. Confine fuel to containment areas as much as possible.
4. Notify the Company Spill Response Safety Officer by radio or telephone. He will take over coordination of operations and further notifications. Whether assistance is required or not, all supervisors and personnel shall follow these notification steps.
5. If the spill is too large to handle with on-site resources, then an emergency spill clean-up contractor will be notified and mobilized.
6. Notify the Contracting Officer immediately.
7. The spill clean-up contractor will take over containment, clean-up, and disposal of the spill and any contaminated material in accordance with their established procedures. The contractor will provide whatever aid the spill clean-up contractor requires.

- Any spills or other contaminations shall be immediately reported to the DOH Clean Water Branch (808-586-4309).
- The project shall be completed in accordance with all applicable State and County health and safety regulations.
- All construction material shall be free of contaminants of any kind including: excessive silt, sludge, anoxic or decaying organic matter, turbidity, temperature or abnormal water chemistry, clay, dirt, organic material, oil, floating debris, grease or foam or any other pollutant that would produce an undesirable condition to the beach or water quality.
- Best management practices shall be utilized to minimize adverse effects to air quality and noise levels, including the use of emission control devices and noise attenuating devices.
- The contractor, at his own expense, shall keep the project area and surrounding area free from dust nuisance. A dust control program shall be implemented, and wind-blown sand and dust shall be prevented from blowing offsite by watering when necessary. The work shall be in conformance with applicable federal and local laws and regulations regarding air pollution control.
- Public safety best practices shall be implemented, possibly including posted signs, areas cordoned off, and on-site safety personnel.
- Areas of operation upon the shoreline will be clearly marked with fencing, barricades, or other approved devices, to protect the public from the hazards of construction. All work areas will have posted signs advising the public of current construction activities and related hazard warnings.
- Public access along the shoreline during construction shall be maintained so far as practicable and within the limitations necessary to ensure safety.
- The Contractor shall review all best management practices with the project applicant/representative prior to the commencement of beach nourishment activities.
- Work will not be performed until a pre-construction survey is conducted, where necessary, to identify structures, significant environmental features, etc. This survey will determine baseline conditions to which the area will be returned, following the completion of construction. Resources landward of construction areas will be protected from construction activities as necessary.
- The project staging area will be used as the primary point of collection of all waste derived from project construction. Rubbish and construction debris will be collected and

confined to waste bins. The containers will be serviced as needed to prevent the build-up of large amounts of waste stored on-site.

- Portable chemical toilets will be located on-site and will be serviced weekly, at a minimum.
- All storage containers will be free of leaks to prevent solid/sanitary waste from entering the environment. If leaks are detected at any time, repairs will be made immediately, or the deficient container will be replaced.
- No wash down of project equipment, or runoff from such activities, will be permitted on this project.
- Hazardous waste will not be generated during the performance of the contract. Typical petroleum products used during the normal course of construction activities may potentially be sources of hazardous waste. Only the minimum amounts required to perform the work activities will be stored on-site.
- The contractor shall coordinate his haul route, staging area, and all associated requirements, such as land use permit, with the contracting officer and the affected landowners.
- The contractor shall be responsible for the clearing and removal of all silt and debris generated by his construction work and deposited and accumulated on roadways and other areas.
- All existing utilities, concrete walkways, steps, and walls, whether or not shown on the drawings, except those designated to be removed, shall be protected from damage at all times during construction and grading work. Any damages to them shall be repaired by the contractor at his expense.
- The contractor shall verify dimensions, locations, elevations, etc., that are indicated for verification and inform the contracting officer in writing of any differences prior to installation of new facilities.
- The contractor shall tone the area to be excavated to ascertain the location of uncharted utilities. The contractor shall be responsible and shall pay for all damages to existing utilities. The contractor shall also contact the necessary utility companies to properly locate the underground utilities and cables that lie in and adjacent to the roadway.
- Work shall be done between 7:00 AM and 5:00 PM HST. No work shall be done on Saturdays, Sundays, holidays, or after normal work hours at any time, without special arrangement and prior approval by the contracting officer. Project work shall be in conformance with applicable federal and local laws and regulations regarding community noise control.
- No blasting will be allowed on this project.
- Waste material will be disposed of at an approved off-site disposal area. The contractor shall be responsible for locating the disposal area.
- The contractor shall take extreme care in performing work near existing concrete electrical/communication ducts. Appropriate protection shall be implemented as required to prevent damage to those lines.
- If the contractor uncovers any cultural remains, such as artifacts or burials, during excavation work, the contractor shall stop work in the area of the find and notify the contracting officer.
- No contractor shall perform any demolition, grubbing, stockpiling, and grading operation so as to cause falling rocks, soil, or debris in any form to fall, slide, or flow onto adjoining properties, streets, or natural watercourses. Should such violation occur, the

contractor may be cited, and the contractor shall immediately make all remedial actions necessary.

- The contractor shall provide for access to and from all existing driveways and walkways at all times.

8.2 Compensatory Mitigation

The project is very small in scale, and the groin and sand fill will be placed on a constantly shifting sand sea floor, thus there will be no loss of marine bottom habitat or impact to marine biota. Therefore, no compensatory mitigation should be required for the proposed project.