APPENDIX H

SEA LEVEL RISE AND TSUNAMI RUN-UP ANALYSES

This appendix includes the Coastal Hazard and Wave Runup Study prepared by the Applicant's consultants GeoSoils, Inc. This study assessed the potential impacts of various sea level rise scenarios and tsunami run-up data on the proposed Project. This data, along with other studies and technical data addressing these issues within the City of Hermosa Beach, were used to inform the sea level rise and tsunami impact analysis described in Section 3.7, *Hydrology and Water Quality*.

H1: Coastal Hazard & Wave Runup Study (GeoSoils, Inc. 2016)

March 14, 2016

Mr. Michael Mathews
Bolour Associates, Inc.
8383 Wilshire Blvd., Suite 920
Beverly Hills, CA 90211

SUBJECT: Coastal Hazard & Wave Runup Study, Strand & Pier Hotel, Hermosa Beach.

Dear Mr. Mathews:

At your request, GeoSoils, Inc. (GSI) is pleased to provide the following Coastal Hazard and Wave Runup Study for the proposed Strand & Pier Hotel in Hermosa Beach. This analysis is based upon site elevations, existing published reports concerning the local coastal processes, our site inspection, and knowledge of local coastal conditions. This report constitutes an investigation of the wave and water level conditions expected at the site in consequence of extreme storm and wave action in the next 75 years. It is intended to provide the City of Hermosa Beach and the California Coastal Commission (CCC) the required coastal hazard information, including use of the California Coastal Commission (CCC) Sea-Level Rise Policy Guidance document (adopted in August 2015). Finally, this report also provides conclusions and recommendations regarding the susceptibility of the property and proposed new development to wave attack. The analysis uses design storm conditions typical of the January 18-19, 1988 and the winter of 1982-83 type storm waves and beach conditions (as required by the CCC), and includes future sea level rise consideration.

INTRODUCTION

The subject site, Strand & Pier Hotel in Hermosa Beach, is a combination of several rectangular shaped parcels with approximately 210 feet of beach frontage. The proposed project is to remove the existing older structures (commercial buildings and parking) and construct a new visitor serving hotel and associated commercial uses. The site is fronted by The Stand, a coastal boardwalk, which is adjacent to a wide sandy beach (approximately 450 feet wide), and the Pacific Ocean. Photograph 1 is an aerial photograph downloaded, with permission, from the California Coastal Records Project web site. The photo shows the very wide beach fronting the subject site in September 2013. This shoreline is located in the southern half of the Santa Monica Littoral Cell, just ot the north of the Hermosa Beach Pier. A littoral cell is a coastal compartment that contains a complete cycle of littoral sedimentation including sources, transport pathways, and sediment sinks. The Santa Monica Littoral Cell extends from Point Dume to Palos Verdes Point, a distance of 40 miles. Most of the shoreline in this littoral cell has been essentially stabilized by man. The local beaches were primarily made by man through nourishment as a result of major shoreline civil works projects (Hyperion Treatment Plant, Marina Del Rey, King Harbor, etc.). The up-coast and down-coast movement of sand along the shoreline is generally to the south. A major sink for the beach sands is the Redondo Submarine Canyon, located at the entrance to King Harbor.

Photograph 1. Subject site, Hermosa Pier, The Strand, and wide beach in September 2013.

The USACOE Reconnaissance Report (USACOE, 1994) identified the subject site to be in "Reach 18." Reach 18 is described as being stable. Despite efforts to control the movement of sand along the shoreline, the shoreline is subject to short-term erosion events and possible a small long-term erosion trend. This long-term erosion rate is estimated to be less than 0.5 ft/yr. The wide sandy beach in front of The Strand and this site is normally over 400 feet wide and provides more than adequate protection for the property. Over the vast majority of time, wave runup does not reach The Strand or the site. However, the beach in this area is subject to seasonal erosion due to extreme storm events, which can erode the beach back to near The Strand. This report constitutes an investigation and analysis of wave runup and overtopping of the beach in front of the property under extreme oceanographic conditions that can be anticipated over the next 75 to 100 years, including sea level rise.

DATUM & INFORMATION

The datum used in this report is North American Vertical Datum 1988 (NAVD88), which is about -2.59 feet Mean Sea Level (MSL), and is +0.18 feet Mean Lower Low Water (MLLW). In the open ocean waters of the Santa Monica Bay, Mean High Water (MHW) is 4.48 feet above NAVD88. The units of measurement in this report are feet (ft), pounds force (lbs), and seconds (sec). The offshore slope was taken from Google Earth bathymetry data. Site elevations relative to NAVD88 and the preliminary development plans were provide by HKS Architect, Inc. The project is in FEMA Zone X (outside the 1% annual chance of sheet flow flooding). The National Oceanographic and Atmospheric (NOAA) National Ocean Survey tidal data station closest to the site is the Santa Monica station (NOAA, 2013). The approximate elevations are as follows:

Highest Water November 30, 1982	8.3 feet
Mean Higher High Water	5.23 feet
Mean High Water	4.48 feet
Mean Sea Level (MSL)	2.59 feet
Mean Low Water	0.74 feet
NAVD88	0.0
Mean Lower Low Water	-0.18 feet

WAVE RUNUP AND OVERTOPPING

As waves encounter the beach in front of the site, water rushes up, and sometimes over, the beach berm. Often, wave runup and overtopping strongly influence the design and the cost of coastal projects. Wave runup is defined as the vertical height above the still water level to which a wave will rise on a structure (beach slope) of infinite height. Overtopping is the flow rate of water over the top of a finite height structure (the steep beach berm) as a result of wave runup. Wave runup and overtopping is calculated using the US Army Corps of Engineers Automated Coastal Engineering System (ACES). ACES is an interactive computer based design and analysis system in the field of coastal engineering. The methods to calculate runup and overtopping implemented within this ACES application are discussed in greater detail in Chapter 7 of the Shore Protection Manual (1984) and the Coastal Engineering Manual (2004). The overtopping estimates calculated herein are corrected for the effect of onshore winds which tend to slightly increase overtopping rates. Figure 1 is a diagram showing the analysis terms.

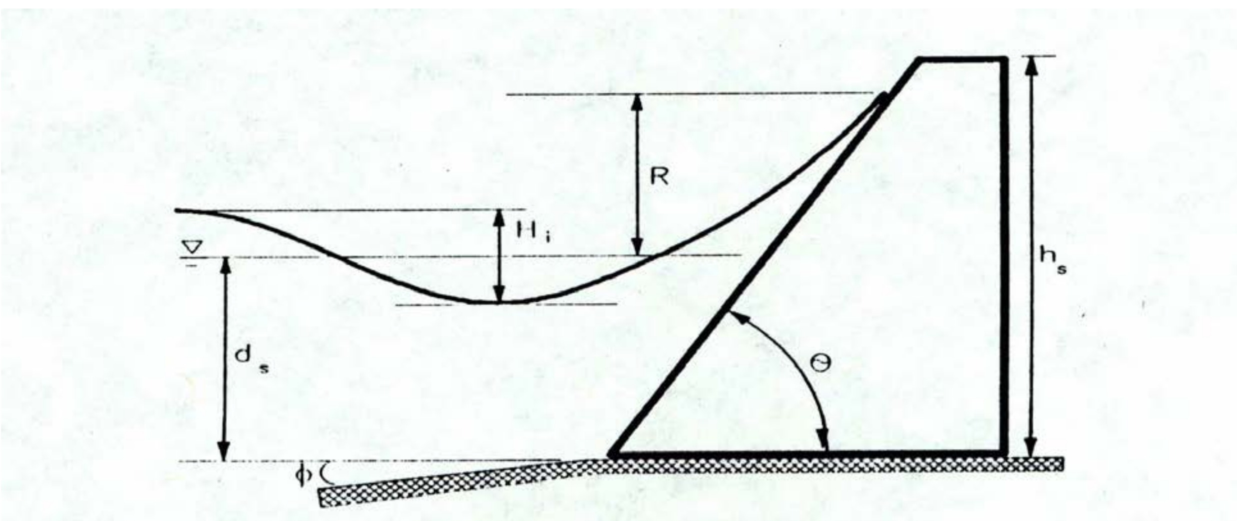

Figure 1. Wave runup terms from ACES manual.

d_s is the depth of the water at the toe of the beach slope.
H_i is the breaking wave height at the at the toe not to be confused with the deep water wave height H_0
R is the height of the wave runup above the still water elevation
h_s is the height of the beach above the toe (elevation to the ~ berm elevation)
Θ is the slope of the beach
ϕ is the nearshore slope or slope from the shoreline to beyond the breakers

The wave, wind, and water level data used as input to the ACES runup and overtopping application was taken from the historical data reported in two USACOE reports on coastal southern California (1986 and 1994). This data has been updated through 2015. The shoreline fronting this property has experienced many storms over the years. These events have impacted coastal property and beaches depending upon the severity of the storm, the direction of wave approach, and the local shoreline orientation. The ACES analysis was performed on an extreme wave condition when the beach is in a severely eroded condition. The El Niño waves during the 1982-83 winter eroded beaches throughout southern California. However, the subject property and adjacent properties were not subject to wave runup attack during that winter. The wave and water level conditions on January 18, 1988 have been described by Dr. Richard Seymour, of the Scripps Institution of Oceanography, as a "400 year recurrence" event. While the property still was not subject to wave overtopping attack during this event, the beach was eroded along this section of shoreline and portions of the King Harbor breakwater/jetty were damaged. The wave runup conditions considered for the analysis use the maximum unbroken wave at the shoreline when the shoreline is in an eroded condition, similar to January 19, 1988.

There have been a number of recent studies that provide some predictions as to the amount of future sea level rise (SLR). The City of Newport Beach contracted Everest International Consultants, Inc. (EICI) to produce an assessment report on the Balboa Island seawall(s) (EICI, 2011). This report provides a comprehensive discussion of future SLR and is applicable to all of southern California. In addition, the U.S. Army Corps of Engineers has provided a guideline for incorporating sea level change in civil works projects (U.S. Army Corps of Engineers, 2009). The 2009 U.S. Army Corps guideline provides a high, an intermediate, and a low SLR estimate. The CCC Sea-Level Rise Policy Guidance document was approved in August 2015. The CCC has adopted the National Research Council 2012 SLR estimates of 16.56 inches to 65.76 inches over the time period from 2000 to 2100. Figure 2 compares many of the current SLR estimates including the US Army Corps of Engineers, the CA Coastal Conservancy, CA Ocean Protection Council, the predictions of leading climate scientists (Vermeer and Rahmstorf) and the NRC/CCC adopted estimates. It should be noted that the CCC maximum SLR (the black line) curve is higher than the other SLR projections plotted at all times until the year about 2090. The CCC minimum SLR line is roughly the same as the USACE/Intermediate dashed red line. It is clear that while there is some agreement over the next 30 years, beyond 30 years from today there is little agreement on SLR projections as evidenced by the large range of SLR in the year 2100.

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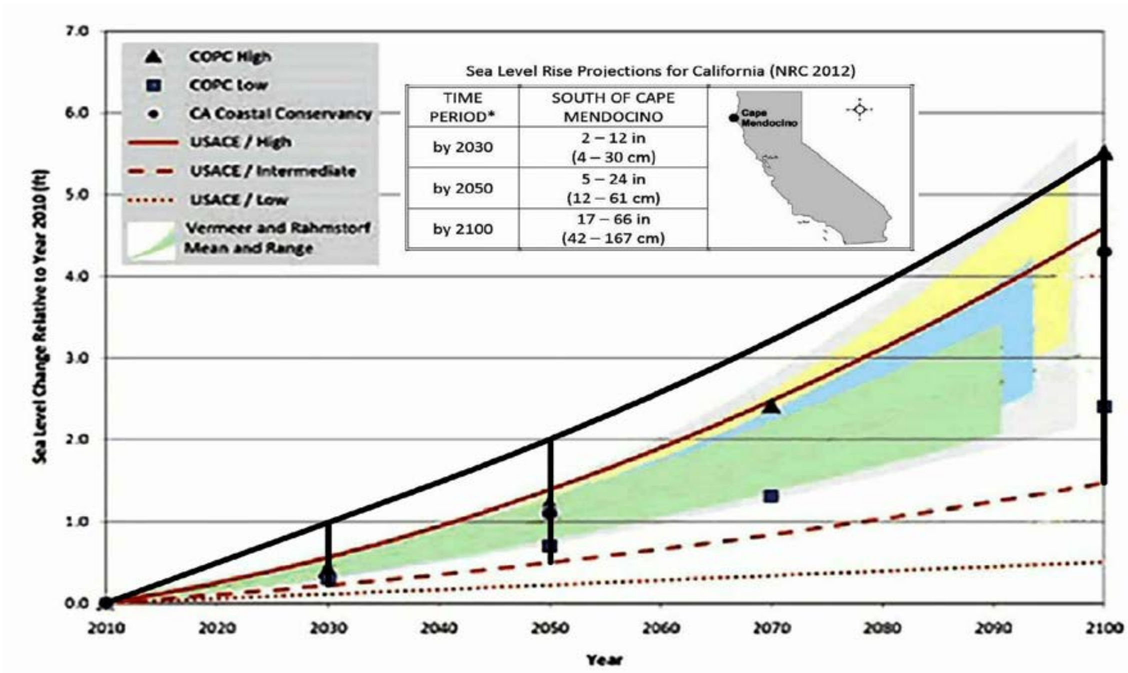

Figure 2. Sea level rise prediction comparison with the CCC range estimates.

The proposed commercial project has a "design life" of 75 years**. Using the CCC SLR estimate from the SLR Guidance document life the range in the year ~2092 (at the end of the project's 75 year design life) is between 1.25 feet and 4.75 feet. This is the sea level rise range that the project could experience**. The highest recorded water elevation on record in the vicinity of the site is 8.3 feet NAVD88. This actual high water record period includes the 1982-83 severe El Niño and the 1997 El Niño events and is consistent with the methodology outlined in the CCC Sea-Level Rise Policy Guidance document. If 1.25 and 4.75 feet are added to this 8.3 feet NAVD88 elevation, then future design maximum water levels of ~9.5 feet NAVD88 and ~13 feet NAVD88 are determined.

The ACES analysis was performed on oceanographic conditions that represent a typical 75- to 100-year recurrence storm with a SLR range. The wave that has the greatest runup is the wave that has not yet broken when it reaches the toe of the beach. The larger waves break offshore of the beach and lose most of their energy before reaching the shoreline. If the total water depth is 8 feet, based upon a maximum scour depth at the toe of the beach slope of 1.5 feet NAVD88 and a water elevation of +9.5 feet NAVD88, then the design wave height will be about 6.2 feet. If the total water depth is 11.5 feet, based upon a maximum scour depth at the toe of the beach slope of 1.5 feet NAVD88 and a water elevation of +13 feet NAVD88, then the design wave height will be about 10 feet. The average height of the beach berm is about +14 feet NAVD88. The slope of the beach is about 1/11 (V to H) and the near-shore slope was measured to be 1/60. **TABLE I** and **TABLE II** are the ACES output for these two SLR design conditions.

TABLE I

ACES	Mode: Single Case	Functional Area: Wave - Structure Interaction	
Application: Wave Runup and Overtopping on Impermeable Structures			
Item	**Unit**	**Value**	Smooth Slope Runup and Overtopping
Incident Wave Height Hi:	ft	6.200	
Wave Period T:	sec	18.000	
COTAN of Nearshore Slope COT(ø):		60.000	
Water Depth at Structure Toe ds:	ft	8.000	Pier & Strand
COTAN of Structure Slope COT(θ):		11.000	
Structure Height Above Toe hs:	ft	12.500	1.25 feet SLR
Wave Runup R:	ft	9.238	
Onshore Wind Velocity U:	ft/sec	16.878	
Deepwater Wave Height H0:	ft	3.631	
Relative Height ds/H0:		2.204	
Wave Steepness H0/(gT^2):		0.000348	
Overtopping Coefficient α:		0.070000	
Overtopping Coefficient Qstar0:		0.070000	
Overtopping Rate Q:	ft^3/s-ft	2.001	

TABLE II

ACES	Mode: Single Case	Functional Area: Wave - Structure Interaction	
Application: Wave Runup and Overtopping on Impermeable Structures			
Item	**Unit**	**Value**	Smooth Slope Runup and Overtopping
Incident Wave Height Hi:	ft	10.000	
Wave Period T:	sec	18.000	
COTAN of Nearshore Slope COT(ø):		60.000	
Water Depth at Structure Toe ds:	ft	11.500	Pier & Strand
COTAN of Structure Slope COT(θ):		11.000	
Structure Height Above Toe hs:	ft	12.500	4.75 feet SLR
Wave Runup R:	ft	11.732	
Onshore Wind Velocity U:	ft/sec	0.000	
Deepwater Wave Height H0:	ft	6.391	
Relative Height ds/H0:		1.800	
Wave Steepness H0/(gT^2):		0.000613	
Overtopping Coefficient α:		0.070000	
Overtopping Coefficient Qstar0:		0.070000	
Overtopping Rate Q:	ft^3/s-ft	18.602	

The calculated overtopping rates for the eroded beach conditions are 2.0 ft^3/s-ft for 1.25 feet SLR and 18.6 ft^3/s-ft for 4.75 feet SLR . For the calculated overtopping rate the height of water and the velocity of this water can be calculated using the following empirical formulas provided by the USACOE (Protection Alternatives for Levees and Floodwalls in Southeast Louisiana, May 2006, equations 3.1 and 3.6) based upon the calculated overtopping rate Q for each SLR case.

$$q = 0.5443\sqrt{g}.h_1^{3/2} \qquad v_c = \sqrt{\frac{2}{3} g h_1}$$

Therefore, for SLR of 1.25 feet with an overtopping rate of 2.0 ft^3/s-ft the water height h_1= 0.75 feet and the velocity, v_c = 4.0 ft/sec. For SLR of 4.75 feet with an overtopping rate of 18.6 ft^3/s-ft the water height h_1= 3.3 feet and the velocity, v_c = 8.4 ft/sec. The US Army Corps of Engineers Coastal Engineering Manual (2002) states that overtopping waters are reduced about 1 foot in elevation for every ~25 feet of horizontal travel across the beach. Currently the site is over 400 feet from the shoreline. The Strand is at about elevation +14.6 feet NAVD88, with a ~36-inch wall on the seaward side of The Strand which is to remain. Therefore, overtopping waters will likely not reach the seaward side of The Strand under the extreme design conditions. Photograph 2, taken on January 19, 1988 the day after the “400-year” wave event, shows the eroded beach in front of the property. However, the beach did not erode back to The Strand and no water reached the site. Photograph 3, taken January 9, 1999, shows what could be described as the normal beach width (about 400 feet).

Photograph 2. Subject site and shoreline one day after the “400 year” wave event.

Photograph 3. Subject site and adjacent shoreline in January 1999 with typical winter beach conditions.

TSUNAMI

Tsunamis are waves generated by submarine earthquakes, landslides, or volcanic action. Lander, et al. (1993) discusses the frequency and magnitude of recorded or observed tsunami in the southern California area. James Houston (1980) predicts a tsunami of less than 5 feet for a 500-year recurrence interval for this area. Legg, et al. (2002) examined the potential tsunami wave runup in southern California. While this study is not specific to The Strand site, it provides a first order analysis for the area. Figure 3 shows the tsunami runup in the southern California bight. The maximum tsunami runup in the Hermosa Beach area is less than 2 meters in height. The Legg, et al. (2002) report determined a maximum open ocean tsunami height of less than 2 meters. The wave runup analysis performed herein is similar to the expected runup due to a tsunami about 2 meters in height. Because of the wide beach and The Strand wall it is unlikely that a 2-meter tsunami will significantly impact the site.

It should be noted that the site is mapped adjacent to the limits of the California Office of Emergency Services (CalOES) tsunami innundation map, Redondo Beach Quadrangle. The tsunami inundation maps are very specific as to their use. Their use is for evacuation planning only. The limitation on the use of the maps is clearly stated in the **PURPOSE OF THIS MAP** on every quadrangle of California coastline. In addition, the following two paragraphs were taken from the CalOES Local Planning Guidance on Tsunami Response concerning the use of the tsunami inundation maps.

> In order to avoid the conflict over tsunami origin, inundation projections are based on worst-case scenarios. Since the inundation projections are intended for emergency and evacuation planning, flooding is based on the highest projection of inundation regardless of the tsunami origin. As such, projections are not an assessment of the probability of reaching the projected height (probabilistic hazard assessment) but <u>only</u> a planning tool.
>
> *Inundation projections and resulting planning maps are to be used for emergency planning purposes only. They are not based on a specific earthquake and tsunami. Areas actually inundated by a specific tsunami can vary from those predicted. The inundation maps are not a prediction of the performance, in an earthquake or tsunami, of any structure within or outside of the projected inundation area.*

The City of Hermosa Beach and the County of Los Angeles have developed a tsunami alert and evacuation plan. This plan recommends that coastal communities within the potential areas of inundation upgrade their tsunami education programs. The City and County have posted signs throughout the community showing tsunami evacuation routes, tsunami evacuation center locations, and the limits of the tsunami hazard zones. The limit of the tsunami inundation zone at the site is at the seaward limit of the proposed development.

GROUNDWATER & SLR

In general, ocean tides impact groundwater elevations when the site is very near the ocean. The further away the site is from the ocean the driving of the groundwater by the tide is typically attenuated. The project site is about 450 feet from the ocean. At this distance the ground water is not significantly impacted by the tides. The referenced Byer Geotechncial report for the development states that the observed groundwater level is at about 8 to 10 feet below grade where grade is about +14 feet NAVD88. Groundwater at the site is about +5 feet NAVD88.

If there is up to 4.75 feet of SLR in 75 years, the future maximum groundwater elevation at the site would be the typical groundwater elevation plus about 4 feet or about elevation +9 feet NAVD88. The lowest finished floor of the basement is at elevation -10 feet NAVD88 with foundation elements down to about elevation -13 feet NAVD88. The Byer Geotechncial report determined that groundwater will impact the basement and foundations. To mitigate groundwater issues Byer Geotechncial recommends that all below grade foundations be properly water proofed. The lowest habitable finished floor is at about +14 feet NAVD88 which is well above the future potential groundwater elevation

(+9 feet NAVD88) with 4.75 feet of SLR. Even with 4.75 feet of SLR in 75 years from today the groundwater will still be 5 feet or more below finished grade at the site..

GSI has reviewed the water proofing recommendations and the preliminary basement and foundation design and determined that a rise in the future groundwater elevation due to SLR will not adversely impact the proposed development.

FUTURE EROSION HAZARD

Analysis of historical aerial photographs contained in the California Coastal Records Project web site and from the Aerial Fotobank, show a very wide beach over the last five decades. There is no photographic evidence of long-term shoreline erosion in front of the site. As stated in the CCC Sea-Level Rise Policy Guidance document (Appendix B, page 237), "predictions of future beach, bluff, and dune erosion are complicated by the uncertainty associated with future waves, storms and sediment supply. As a result, there is no accepted method for predicting future beach erosion." If we assume a very high, long-term, erosion rate (not a seasonal rate) of 1.0 ft/yr, the shoreline may narrow about 75 feet over the 75-year life of the development. This is still over 325 feet (presently over 400 feet) from the project and sufficient beach width to prevent wave attack from reaching the site. The beach can migrate about 200 feet landward/inland in the future and still NOT result in inundation of the site. Because of the beach width, the site is reasonably safe from erosion hazards over the project's 75-year life.

CALIFORNIA COASTAL COMMISSION SLR POLICY GUIDANCE INFORMATION

Step 1. Establish the projected sea level rise range for the proposed project's planning horizon using the best available science, which is currently the 2012 NRC Report.

Using the CCC SLR estimate over the 75-year design life of the proposed project, the sea level rise range for the year ~2092 is estimated to be between 1.25 feet and 4.75 feet. This is the project sea level rise range for the proposed project

Step 2. Determine how physical impacts from sea level rise may constrain the project site, including erosion, structural and geologic stability, flooding, and inundation.

This report provides data demonstrating that the project site is reasonably safe to SLR-related coastal hazards.

Step 3. Determine how the project may impact coastal resources, considering the influence of future sea level rise upon the landscape as well as potential impacts of sea level rise adaptation strategies that may be used over the lifetime of the project.

If the sea level rises as predicted the beach may get narrower; however,, the beach is sufficiently wide that even if a very high, ling-term erosion rate were applied over the next 75 years, the beach width will not likely be less than 200 feet.

Step 4. Identify alternatives to avoid resource impacts and minimize risks throughout the expected life of the development.

Any impact of SLR on the narrowing beach cannot be mitigated at this site alone. With this in mind and recognizing that this is one of the first applications for development where this type of SLR analysis/discussion/planning has been required, it seems reasonable that the applicant agree to participate in whatever County wide plan is developed and approved to mitigate future SLR impacts.

Step 5. Finalize project design and submit CDP application.

The applicant will be responsible fro completing this step.

CONCLUSIONS AND RECOMMENDATIONS

Prediction of runup and overtopping, coupled with sea level rise predictions, on a beach during extreme storm events requires a complex calculation and analysis. The flow rates presented here represent what is defined as flow, which is sustained by continuous volume flow, even though it will actually occur with the cycle of the waves. The calculations made herein use standard of practice methods, yet they are based on several simplifying assumptions (see Coastal Engineering Manual). There are several facts that indicate that wave runup and overtopping should not adversely impact the property over the life of the structure.

- There is a very wide (> 400 feet) sandy beach in front of the property 99.9% of the time. And for the 0.1% of the time where the beach might be narrowed due to seasonal or extreme event conditions, the width of the beach will remain sufficiently wide to avoid wave runup from affecting the project site.

- A review of aerial photographs over the last five decades shows little overall shoreline retreat in general and a wide sand beach even at times when the beach is seasonally at its narrowest.

- The long-term shoreline erosion rate is small, if any long-term erosion occurs at all. If a conservative retreat rate of 1 ft/yr is used, it would account for about 75 feet of retreat over the life of the structure. This conservative retreat rate will not reduce the beach to less than 325 feet in nominal width (200 feet width of beach is recognized by coastal engineers as a sufficiently wide enough beach to provide back-shore protection).

- The property has not been subject to wave runup attack in the past and will likely not be subject to wave runup in the future.

- The presence of the seawall on the western side of The Strand will prevent wave overtopping from reaching the property.

In conclusion, wave runup and overtopping will not significantly impact this site over the life of the proposed improvements. The proposed development will neither create nor contribute significantly to erosion, geologic instability, or destruction of the site, or adjacent area. There are no recommendations necessary for wave runup protection. The proposed project minimizes risks from ocean flooding.

LIMITATIONS

Coastal engineering is characterized by uncertainty. Professional judgements presented herein are based partly on our evaluation of the technical information gathered, partly on our understanding of the proposed construction, and partly on our general experience. Our engineering work and judgements have been prepared in accordance with current accepted standards of engineering practice; we do not guarantee the performance of the project in any respect. This warranty is in lieu of all other warranties express or implied.

Respectfully Submitted,

GeoSoils Inc.
David W. Skelly, MS, RCE #47857

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