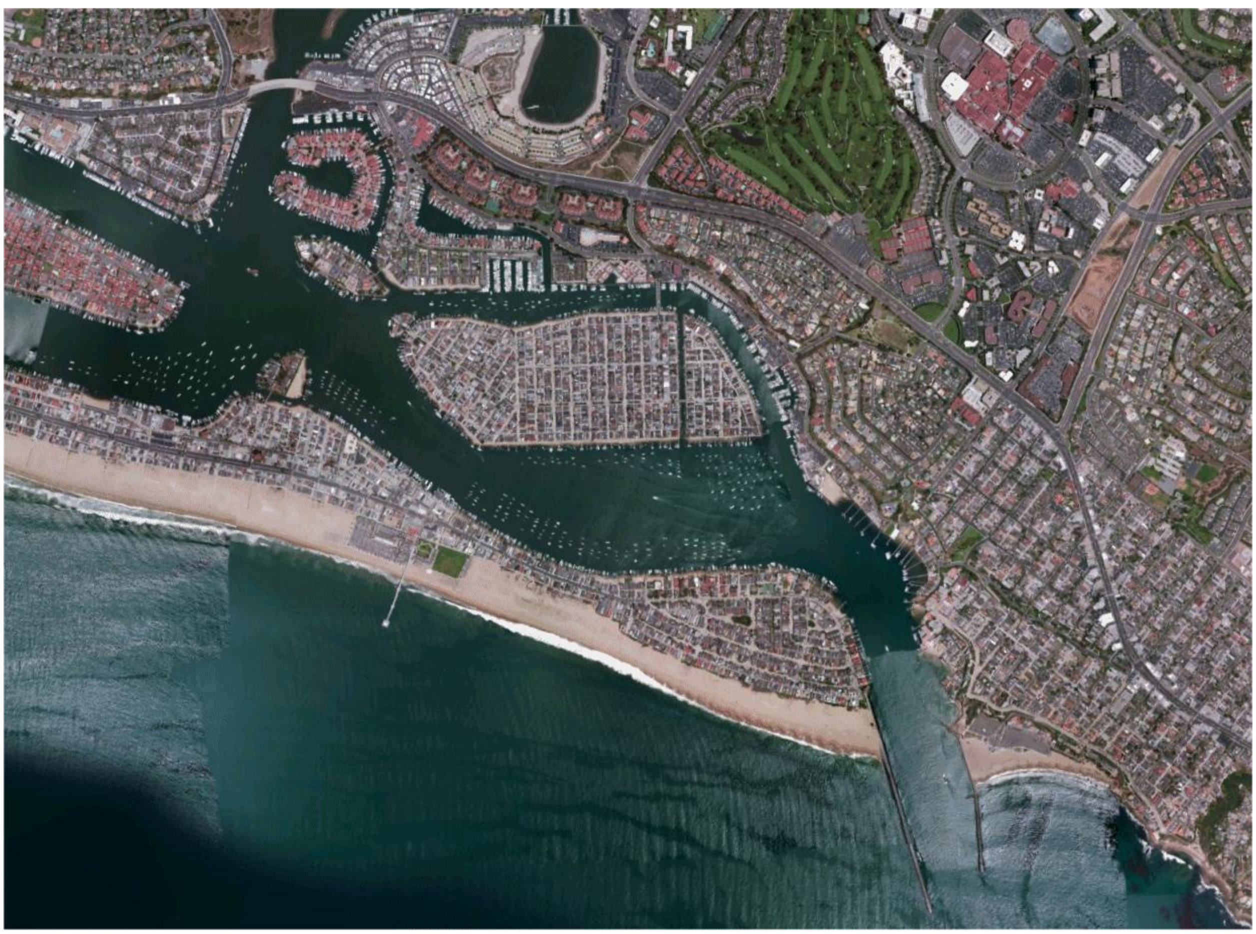
Determination of Sheltered Water Coastal Flood Levels

Balboa Island – Newport Bay

City of Newport Beach, CA



The expert in **WATER ENVIRONMENTS**

Final Report
December 2013

Determination of Sheltered Water Coastal Flood Levels

Balboa Island – Newport Bay

City of Newport Beach, CA

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Project Number	41801873
Revision	0.0

CONTENTS

1 Executive Summary

This report summarizes the analyses carried out by DHI Water & Environment, Inc. ('DHI') to study coastal flood levels for Balboa Island in Newport Bay, for the City of Newport Beach ('the City').

The entire Balboa Island is currently designated to be in a Special Flood Hazard Zone AE, so DHI investigated this flood zone designation and what would be needed to get the island removed from this designation, at the request of the City.

The following items were included in DHI's scope of work for the study reported here:

1) Verify the existing Flood Insurance Study (FIS) that the City of Newport Beach is operating under. Verify that the Base Flood Elevation (BFE) is accurate at 9.0 feet NAVD88. This BFE level puts the entire Balboa Island in a special flood hazard zone.

2) Estimate the BFE using newer data and FEMA-approved methodologies that would be used today.

3) Estimate the minimum seawall height required to apply for a Letter of Map Revision (LOMR) to move Balboa Island out of the floodplain.

Referring to the three scope items listed above, the results and conclusions of the study are as follows.

1) <u>Existing BFE based on Previous FIS Studies</u>

The current BFE is based on the analysis of water levels from studies performed in 1978 and 1983 but with some conversions applied during the FEMA MAPMOD (Map Modification) program. During the MAPMOD program, paper maps were converted to digital maps (DFIRM conversion), and often vertical datums were converted from NGVD29 to NAVD88 during this process. During the conversion process, the flood levels have been converted, translated and rounded using various conservative assumptions. The accumulation of these conservative assumptions has likely added about 1-foot of additional height to the initially determined BFE. Note, neither the previous studies nor the DFIRM Conversion included the effect of waves or internally generated storm surge within Newport Bay on the flood levels.

2) <u>Estimate of New BFE</u>

Based on DHI's analysis of tide gage data from Port of Los Angeles and the Newport Harbor Entrance, it was determined that the 1% (100-year) Still Water Elevation (SWEL) should be between 7.6 and 7.7 feet NAVD88, giving an 8.0-foot BFE contour, not accounting for waves.

Under the present scope of work, the evaluation of wave impacts on flood levels took a two path approach. The first path would be if it could be determined conclusively that wave effects were negligible, for example by applying worst possible boundary conditions in a wave model, and seeing no appreciable waves in the Bay, in which case we would be able to neglect waves, and the still water level would essentially describe the final BFE. But this was not the situation with all waves. One test case did show waves contributing to the total flood level, for a condition where local wind generated waves in the Bay led to more than 1-foot of wave run-up. However, a more rigorous joint probability analysis of waves and water level would be required to quantify the full impact of waves.

3) Determination of Minimum Seawall Height

First of all, it is proposed that the Balboa Island seawall be considered as a coastal levee since the 1% SWEL is generally higher than the ground elevation on the landward side of the seawall. This means that freeboard (vertical distance from water level to crest of seawall) requirements must be met for the seawall to be certified/considered as a flood protection levee.

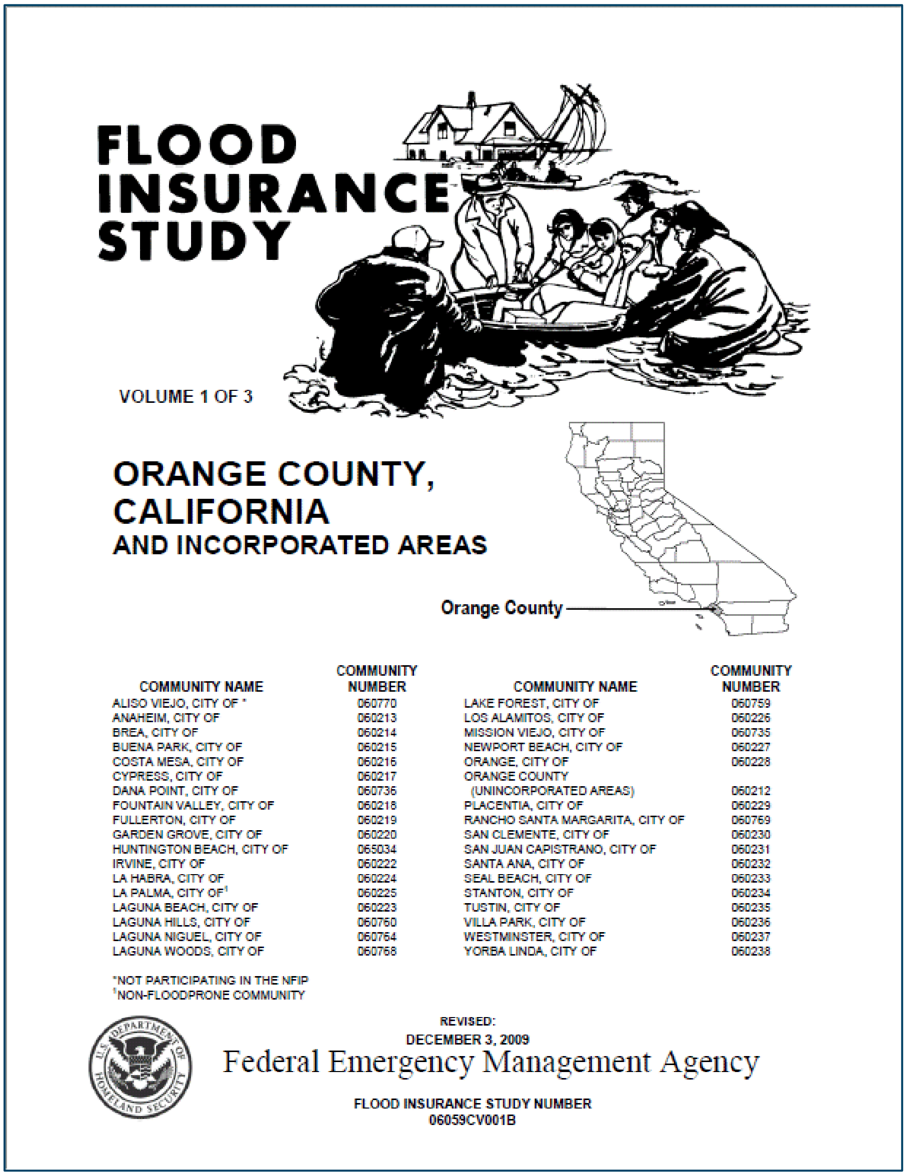
A 2-foot freeboard requirement applies to the 1% SWEL. This requirement cannot be met with the existing seawall, which would need to be extended minimally to about 7.7 + 2.0 = 9.7 feet NAVD88, not considering waves, sea level rise or wind induced storm setup generated within Newport Bay. If the seawall height was not extended, the seawall would have to be removed from the flood analysis, and the 7.7 foot (or 8-foot BFE contour level) would have to be horizontally projected across the island topography. In this situation, it is likely that FEMA would allow the seawall to stay intact for the wave analysis (if performed), meaning the waves would only impact a narrow zone near the seawall, creating a very narrow VE special hazard zone.

For the 1-foot freeboard requirement to the total water level (which includes waves), a quantitative conclusion cannot be reached at this time. DHI believes that wave effects could contribute to coastal flooding, but it is generally believed that this additional contribution to the total water level would be in the order of 1 to 2 feet. A joint probability analysis of high waves combined with high water levels must be considered, and a response based hindcast of the wave run-up would need to be performed to fully quantify this.

The full analyses completed by DHI to address these three main tasks are presented in the following sections of this draft report.

2 Review of Existing BFE

DHI and Lyle Engineering requested available backup data from the FEMA Library to help determine the basis of how the present BFE of 9.0 feet NAVD88 at Balboa Island was determined. The documentation received from FEMA is incomplete, but there exists enough information and evidence to deduce how it was determined.



FLOOD INSURANCE STUDY

VOLUME 1 OF 3

ORANGE COUNTY, CALIFORNIA
AND INCORPORATED AREAS

Orange County

COMMUNITY NAME	COMMUNITY NUMBER	COMMUNITY NAME	COMMUNITY NUMBER
ALISO VIEJO, CITY OF *	060770	LAKE FOREST, CITY OF	060759
ANAHEIM, CITY OF	060213	LOS ALAMITOS, CITY OF	060226
BREA, CITY OF	060214	MISSION VIEJO, CITY OF	060735
BUENA PARK, CITY OF	060215	NEWPORT BEACH, CITY OF	060227
COSTA MESA, CITY OF	060216	ORANGE, CITY OF	060228
CYPRESS, CITY OF	060217	ORANGE COUNTY	
DANA POINT, CITY OF	060736	(UNINCORPORATED AREAS)	060212
FOUNTAIN VALLEY, CITY OF	060218	PLACENTIA, CITY OF	060229
FULLERTON, CITY OF	060219	RANCHO SANTA MARGARITA, CITY OF	060769
GARDEN GROVE, CITY OF	060220	SAN CLEMENTE, CITY OF	060230
HUNTINGTON BEACH, CITY OF	065034	SAN JUAN CAPISTRANO, CITY OF	060231
IRVINE, CITY OF	060222	SANTA ANA, CITY OF	060232
LA HABRA, CITY OF	060224	SEAL BEACH, CITY OF	060233
LA PALMA, CITY OF[1]	060225	STANTON, CITY OF	060234
LAGUNA BEACH, CITY OF	060223	TUSTIN, CITY OF	060235
LAGUNA HILLS, CITY OF	060760	VILLA PARK, CITY OF	060236
LAGUNA NIGUEL, CITY OF	060764	WESTMINSTER, CITY OF	060237
LAGUNA WOODS, CITY OF	060768	YORBA LINDA, CITY OF	060238

*NOT PARTICIPATING IN THE NFIP
[1]NON-FLOODPRONE COMMUNITY

REVISED:
DECEMBER 3, 2009

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
06059CV001B

Figure 2.1 FEMA FIS Report for Orange County, December 2009. /Ref 3/

Investigation indicates that the BFE at Newport Harbor Entrance was originally mapped to a 6 foot elevation, but the 6 foot contour was referenced to the NGVD 1929 vertical datum. NGVD29 was in use when the original study was performed back in, 1978 and updated in 1983. DHI has an old flood map from 1978 that shows the 6 foot BFE in Newport Harbor. A portion of that map is shown in Figure 2.2.

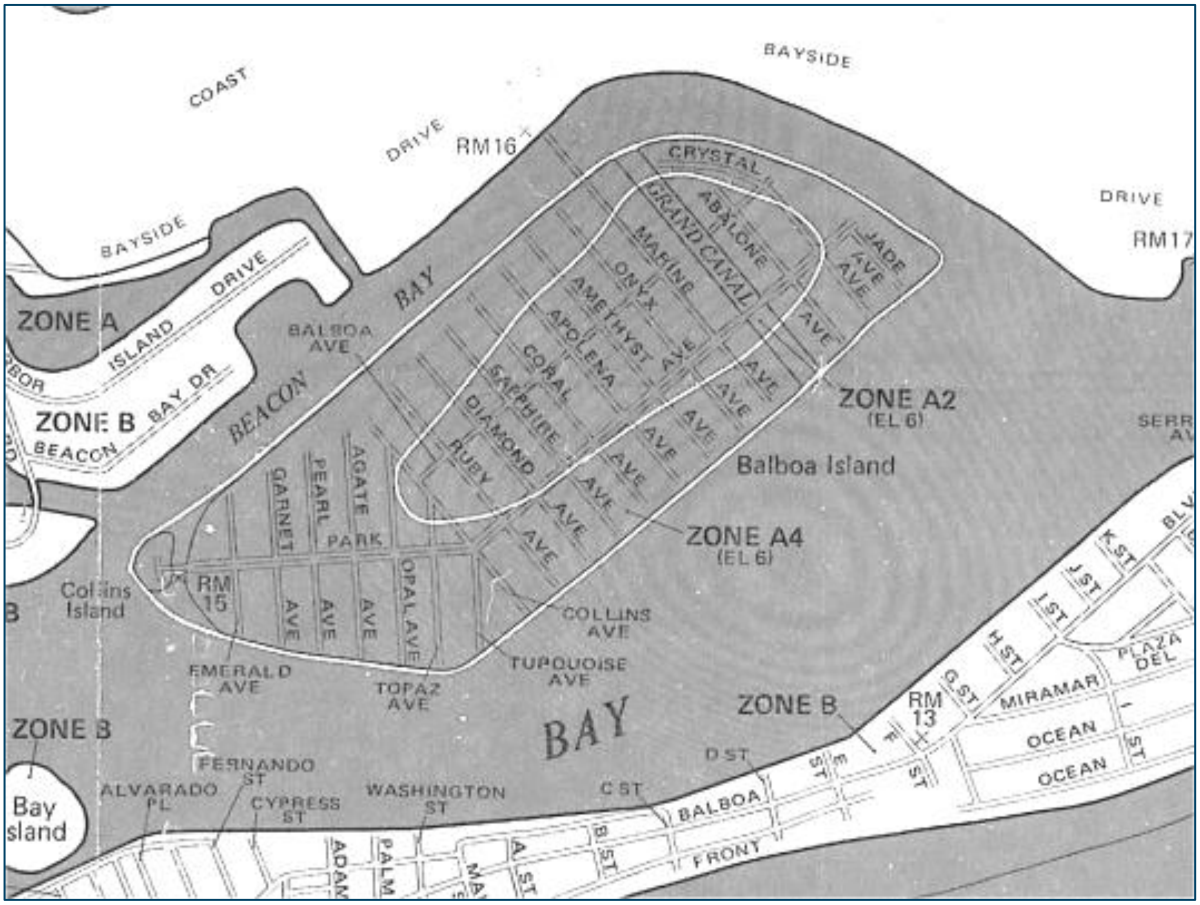


Figure 2.2 FIS FIRM map from 1978 showing 6 foot (NGVD29) BFE at Balboa Island.

During FEMA's MAPMOD program, most existing flood maps were digitized (DFIRM conversion) and most of these maps were converted to NAVD88 vertical datum if they previously existed in NGVD29 vertical datum. The conversion of vertical datum was an approximate method which did not include new model analysis. Using National Geodetic Survey (NGS) VERTCON software or the Army Corps of Engineers CORPSCON software, it can be determined that the conversion between the two datums, NAVD88 and NGVD29, at Newport Harbor is 2.3 feet. So it appears that during the DFIRM conversion process the 2.3 feet conversion was simply added to the existing 6 foot BFE contour on the maps. This would add up to 8.3 feet, which is reported in the current FIS report. It is apparent that FEMA decided to round this up to 9 feet BFE on the maps to be conservative. DHI were not able to confirm this rounding procedure, but there is enough evidence to strongly point in this direction. But technically, if the flood level was 8.3 feet, a case could be made for rounding it down to an 8 foot BFE.

DHI was not able to find the original calculations that determined the 6 foot contour. But literature suggests it is a combination of analysis of tide gage records and computer models developed by Tetra Tech back in the late 1970's and early 1980's. It is important to know what the actual BFE elevation to the tenth of a foot was that made up the 6 foot BFE contour. Since FEMA rounds to the nearest half foot, it could be anywhere between 5.5 and 6.4 feet NGVD29, which would translate to a range of 7.8 to 8.7 feet, NAVD88. There doesn't seem to be any backup data that can clarify what the true base value was in NGVD29. Perhaps, given this range of uncertainty is why FEMA chose to round up to the 9.0 feet contour even though the central estimate value of 8.3 feet is reported in the recent FIS report.

It is also important to note that previous studies did not consider the effects of internal wind setup, waves or riverine influences inside the harbor, and the BFE, or 1% Still Water Elevation (SWEL) from the channel entrance was simply projected into the harbor without the effect of waves.

3 Determination of New BFE

DHI, as a member of the Technical Advisory Panel reviewing the California Coastal Analysis and Mapping Project (CCAMP, Ref /2/), has gained insight into the methodology that FEMA's study contractor, BakerAECOM, will be using in their comprehensive re-study of the Southern California coastline. DHI have attempted to follow or consider their methodology as much as possible in this study. It should be noted that CCAMP methodologies could change by the time their study reaches Newport. But DHI believes the analysis used here will be very close to their method even if they were to change.

3.1 Analysis of Water Levels

Essentially the methodology for determination of 1% SWEL relies on measurements from a long record tide gage for which extreme value analysis is performed for determination of return period water levels. Long term measurement gages along the California coastline are sparsely available, so some spatial adjustments are made due to the long term gage being located far away from the point of interest.

For Newport Beach, there are two NOAA gages of particular interest and importance.

The NOAA gage at the Port of Los Angeles Outer Harbor (NOAA Gage 9410660) has recorded about 85 years (from June 1928 to present) of hourly observations (with some gaps) making it very useful to analyze and determine long return period statistics. Figure 3.1 shows the time series of the Los Angeles tide gage water level. The figure shows the total water level, the residual tide level (total minus predicted tide) and the trend line of sea level rise. Note that the sea level rise is about 0.21 feet over the ~85 year period, or about 0.03 inches per year.

The Los Angeles Outer Harbor gage is located some distance away from Newport Harbor. To account for the spatial variability between Los Angeles and Newport Channel, a second NOAA gage of interest has been identified: it is located at the Newport Harbor Channel Entrance (NOAA Gage 9410580). This gage only collected data for a short period of time and is no longer in service. But it did collect measurements for a sufficiently long period that NOAA was able to analyze and determine the astronomical tidal constituents at the channel entrance. Existence of tidal constituents makes it possible to compare tidal amplitudes between Los Angeles and Newport Channel Entrance. Additionally, DHI procured NOAA's FORTRAN tide calculation software, NTP4, so that 85 years of tide could be predicted locally at Newport Channel using these constituents. To illustrate the difference in tidal amplitudes between Los Angeles and Newport, Table 3.1 compares the main tidal constituent amplitudes. Although very similar, it is evident that tidal amplitudes at Newport Channel Entrance are slightly smaller than at Los Angeles, and these differences are considered in the overall analysis as a slight reduction to the predicted 1% SWEL, see Table 3.2.

It is recognized that local winds inside of Newport Bay could potentially generate storm surge setup locally and could add to the gage measurements. DHI believes this component is negligible in Newport Bay. DHI performed one numerical model test with a strong wind applied to confirm that internal storm setup is on the order of two to three hundredths of a foot. This numerical model is based on the application of the MIKE 21 HD (Hydrodynamic) model on the mesh described in Section 3.2 below.

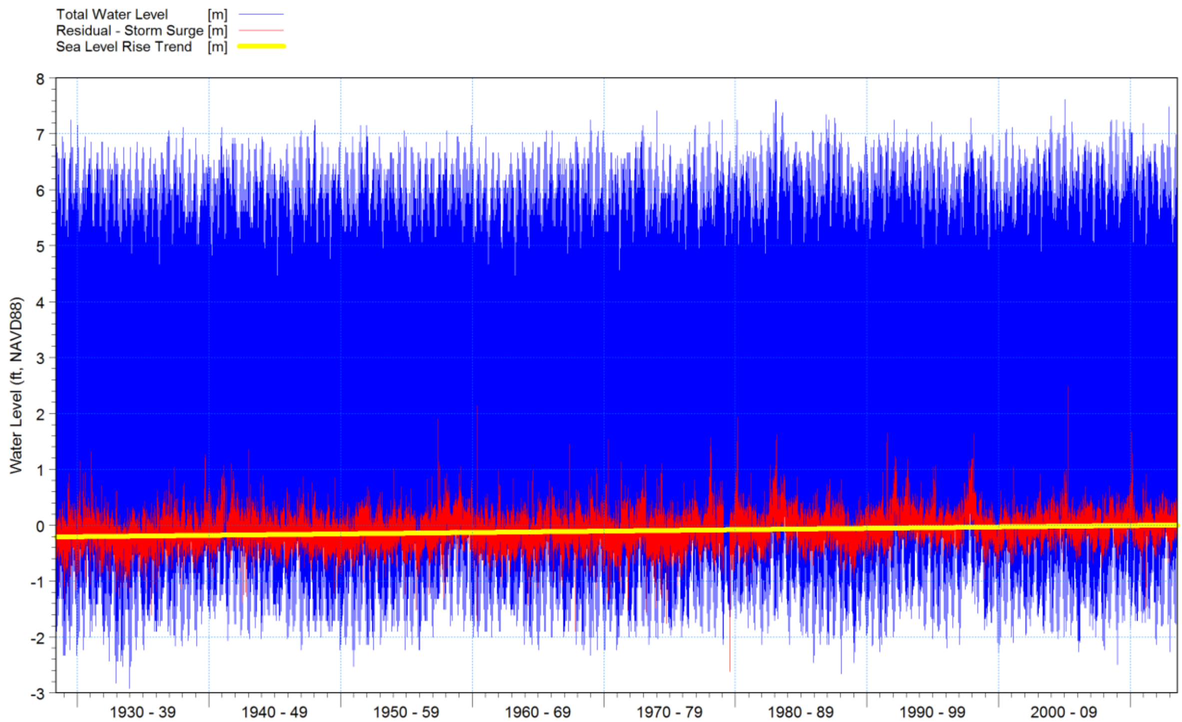


Figure 3.1 Time series of total tide (blue), residual tide (red), and sea level rise trend (yellow) at NOAA's Los Angeles Outer Harbor tide gage 9410660.

Table 3.1 Comparison of tidal constituent amplitudes between Los Angeles and Newport Channel gages

Tidal Constituent Name	Los Angeles Outer Harbor Amplitude (feet)	Newport Channel Amplitude (feet)	Difference NC-LA (feet)
M2	1.69	1.66	-0.03
K1	1.12	1.10	-0.02
O1	0.71	0.71	-0.01
S2	0.67	0.67	0.00
N2	0.40	0.39	-0.01
P1	0.35	0.35	0.00
SA	0.22	0.21	-0.01
K2	0.20	0.20	0.00

The main steps in the procedure to compute the 1% SWEL are as follows:

1) Acquire hourly water levels from NOAA Los Angeles Outer Harbor Gage 9410660 from 1928 to 2013, including total water level and predicted tide.

2) Compute tidal residual (storm surge) from Los Angeles data (Total minus Predicted tide).

3) Compute Sea Level Rise (SLR) trend from the Total Water Level at Los Angeles gage.

4) Generate predicted tide at Newport Channel Entrance using NOAA's NTP4 software, from 1928 to 2013.

5) Add the residual computed in Step 2) to the predicted tide at Newport Channel Entrance, to compute the total water level at Newport.

6) De-trend the Total Water level for the Sea Level Rise trend computed in Step 3), or in other words, raise historical sea level to current sea level. Note, FEMA does not consider SLR for future conditions, but is normal to de-trend historic measurements.

7) Perform Extreme Value Analysis (EVA) on Newport Channel total water level using annual maxima Generalized Extreme Value (GEV) Maximum Likelihood (ML) and Peak-over-threshold Weibull probability fit.

The analysis in Step 7) is performed using two different extreme value approaches. One is using the Annual Maximum Series (AMS) peaks in a Generalized Extreme Value probability distribution, and the other using a Peak-over-Threshold (POT) Weibull distribution. We applied both because BakerAECOM have used both methods in their CCAMP study, depending on which county is being studied and by which study team. They have justified using both distributions. To perform the analysis, DHI's EVA (Extreme Value Analysis) software was used.

Figure 3.2 shows the annual maximum peaks from the generated Newport Channel Entrance water level. Note the peak of 7.59 feet, NAVD88 in January 1983. Figure 3.3 shows an example probability distribution fit of these data using the GEV/ML method. Also notice that the highest peaks appear to occur in more recent years, starting around 1974. This could be important if BakerAECOM decided to apply their full response-based approach for waves, which is based on the latest 50-years of data only. If they did this, this could bias the results a little higher. This is not likely to happen, but it is worth considering.

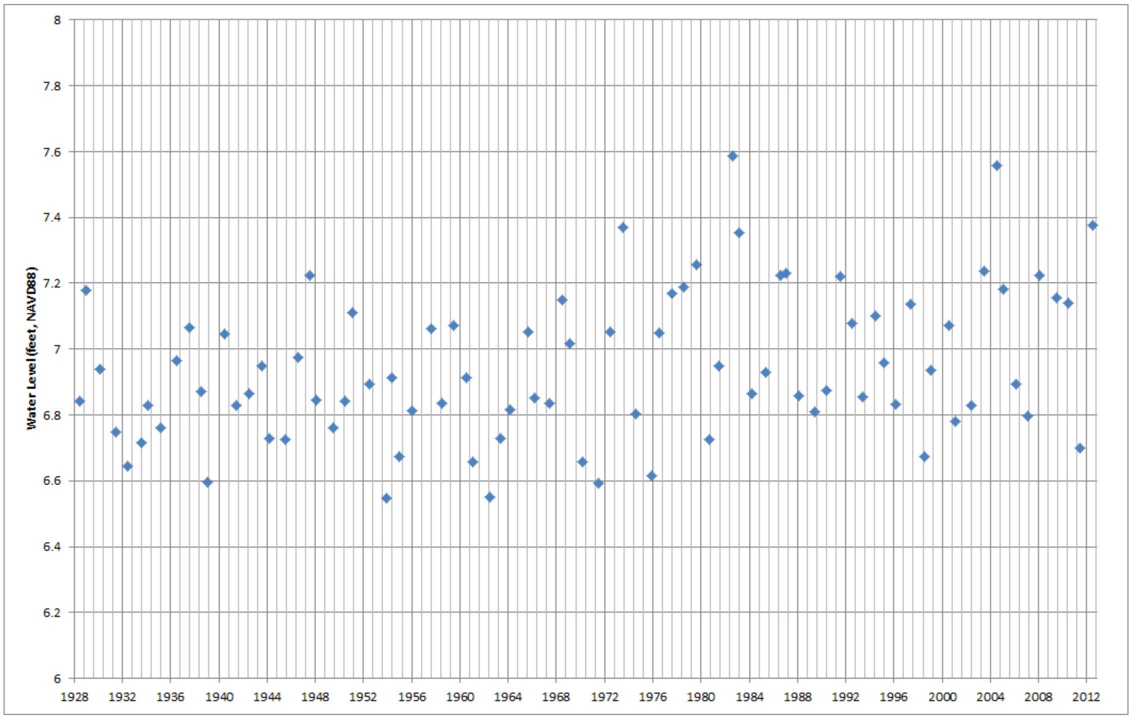


Figure 3.2 Annual maximum peaks at Newport Channel Entrance.

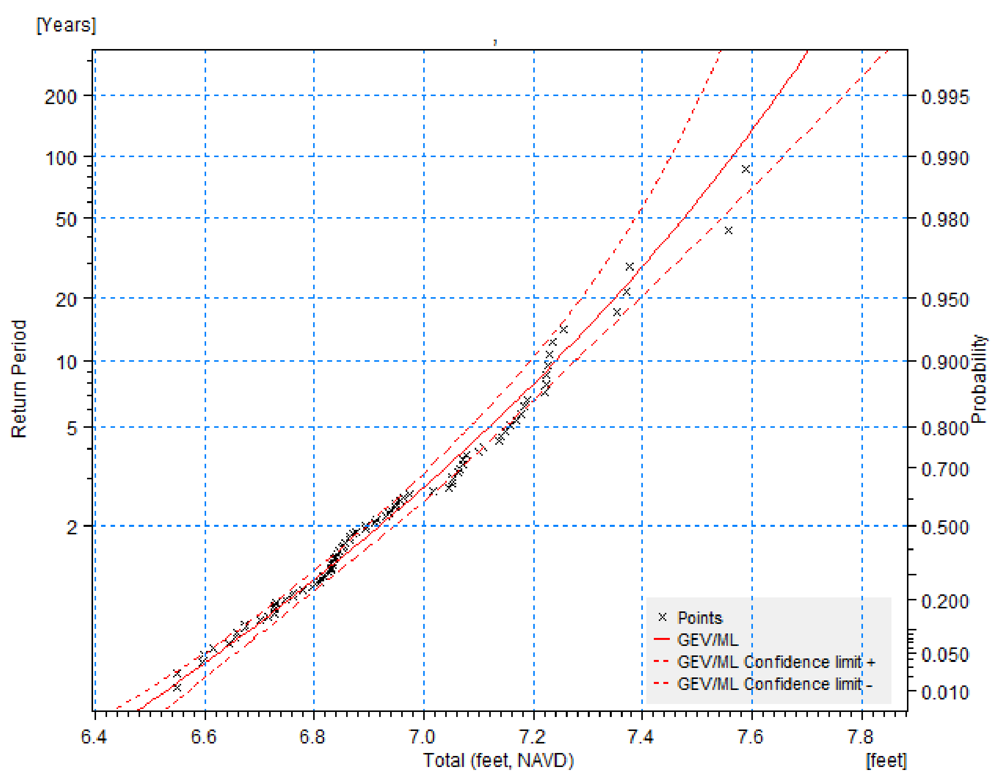


Figure 3.3 Example probability plot using GEV/ML method at Newport Channel Entrance

The 1% SWEL results of the Newport Channel tide and the Los Angeles Outer Harbor tide are shown in Table 3.2. These values seem reasonable considering the peak value of 7.59 feet shown in Figure 3.2, the highest water level in 85 years. At this time it is probably safest to assume the values at Los Angeles given that BakerAECOM may not choose to take the spatial consideration into their analysis. The 7.69 feet value would round up to an 8-foot BFE contour, however, the 7.7 foot level (rounded to the tenth of a foot) could be used as the starting point for freeboard evaluation and wave run-up computations. Note, these values compare closely to the 7.71 feet, NAVD88 that Everest (Ref /6/) determined and reported using measured data up to year 2010.

Table 3.2 Computed 1% SWEL at Newport and Los Angeles based on

GAGE LOCATION	*1% SWEL (feet, NAVD88)*	
	GEV (Maximum Likelihood)	*POT (Weibull)*
Newport Channel Entrance	*7.56*	*7.56*
Los Angeles Outer Harbor	*7.65*	*7.69*

3.2 Analysis of Wave Related Flood Levels

Although waves were seemingly not considered in the determination of the current BFE, or perhaps were determined (assumed) to have a negligible contribution to flood levels in earlier FIS studies, a more detailed assessment of the potential contribution of waves to flood levels was carried out as part of the present analyses. Note, this wave analysis is meant to determine if inclusion of waves into the determination of total water level is important to consider or not, but does not include the full rigorous treatment that would be performed by BakerAECOM if they later determined waves were important to the FEMA analysis.

DHI set up and tested a 2D spectral wave model of the harbor entrance and bay, and simulated a number of typical extreme wave conditions that would likely occur during high water events to see if there is any likelihood that waves would propagate into the harbor and significantly contribute to the total water level. The potential contribution to flood levels of wind waves generated within the bay was also investigated through a few tests.

The MIKE 21 Spectral Wave (SW) model was used for all the wave conditions listed above. The MIKE 21 SW model is approved for use in FEMA studies (Ref/ 4/).

An unstructured model mesh consisting of triangular elements of variable size and shape was used to resolve the bathymetry of the area of interest in MIKE 21 SW. Figure 3.4 below shows the extent of the model bathymetry. Figure 3.5 shows a detailed view of the model bathymetry around the entrance to Balboa Harbor and Balboa Island. Figure 3.6 presents the unstructured mesh elements.

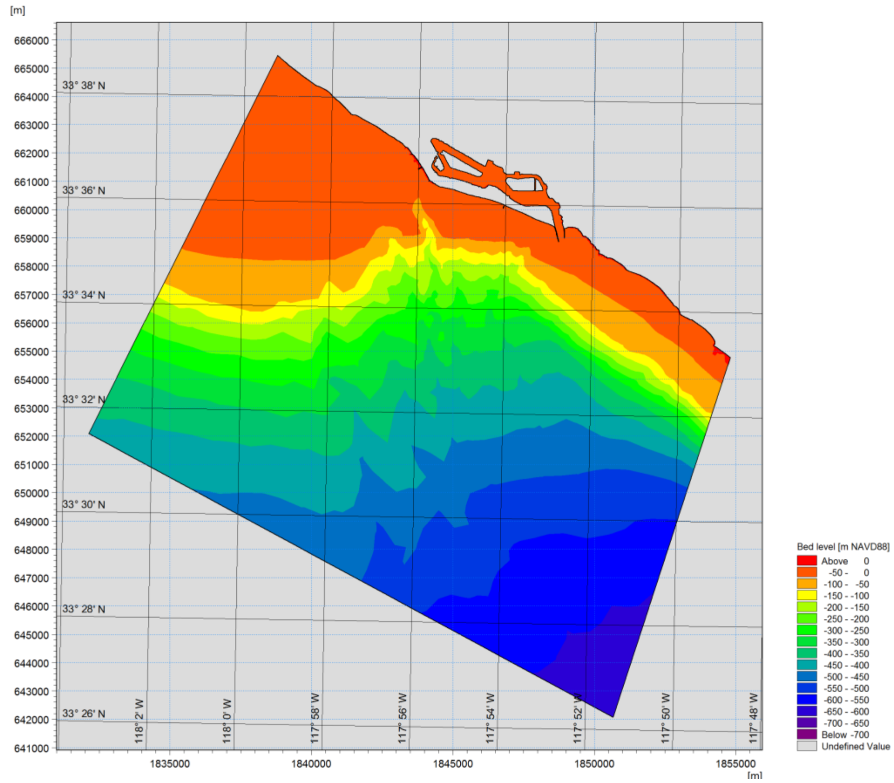


Figure 3.4 Horizontal extent of MIKE 21 SW model bathymetry. Horizontal coordinates are in meters and relative to the State Plane, California VI NAD83 system

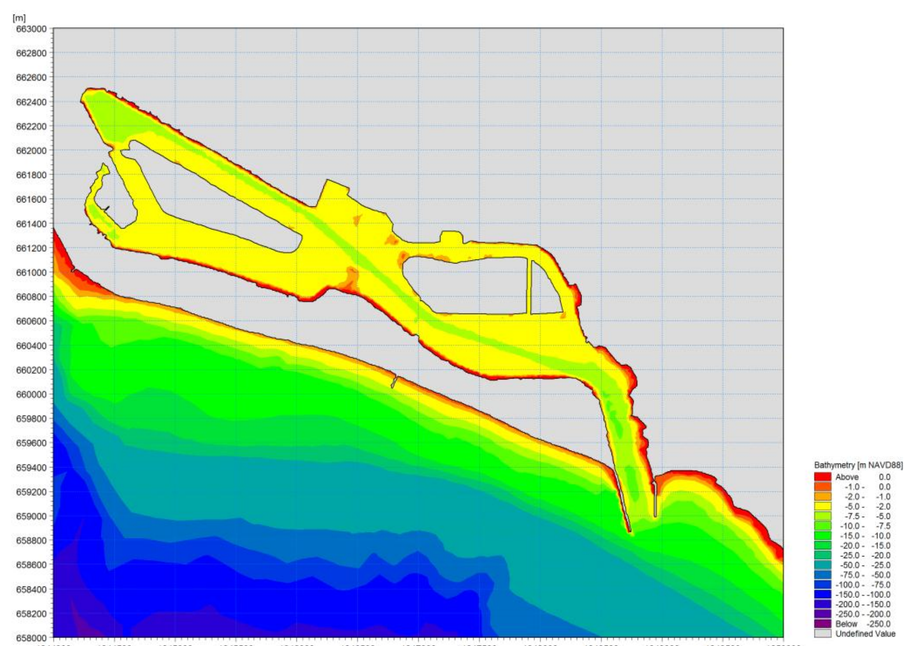


Figure 3.5 Detailed view of the MIKE 21 SW model bathymetry around the entrance to Balboa Harbor and Balboa Island. Horizontal coordinates are in meters and relative to the State Plane, California VI NAD83 system

The offshore/south boundary of the MIKE 21 SW model bathymetry was made coincident with the location of Wave Information Study (WIS) Station 83102 (33.500°N, 118.000°W), as boundary wave conditions for the analysis of ocean wave propagation into Newport Bay were taken from this station of the WIS dataset developed by USACE (Ref /5/). Note BakerAECOM will be using an alternative wave hindcast dataset developed for the CCAMP study, which is not publicly available at this time.

Use of an unstructured mesh to resolve the model bathymetry combines the advantage of increased mesh resolution in areas of interest, which is achieved through smaller mesh elements, while at the same time allowing to keep the total number of mesh elements (and runtimes) within reasonable limits by reducing resolution in e.g. offshore areas, as illustrated by Figure 3.6. In the present study, the highest mesh resolution was used for areas around Balboa Island and the entrance to the bay.

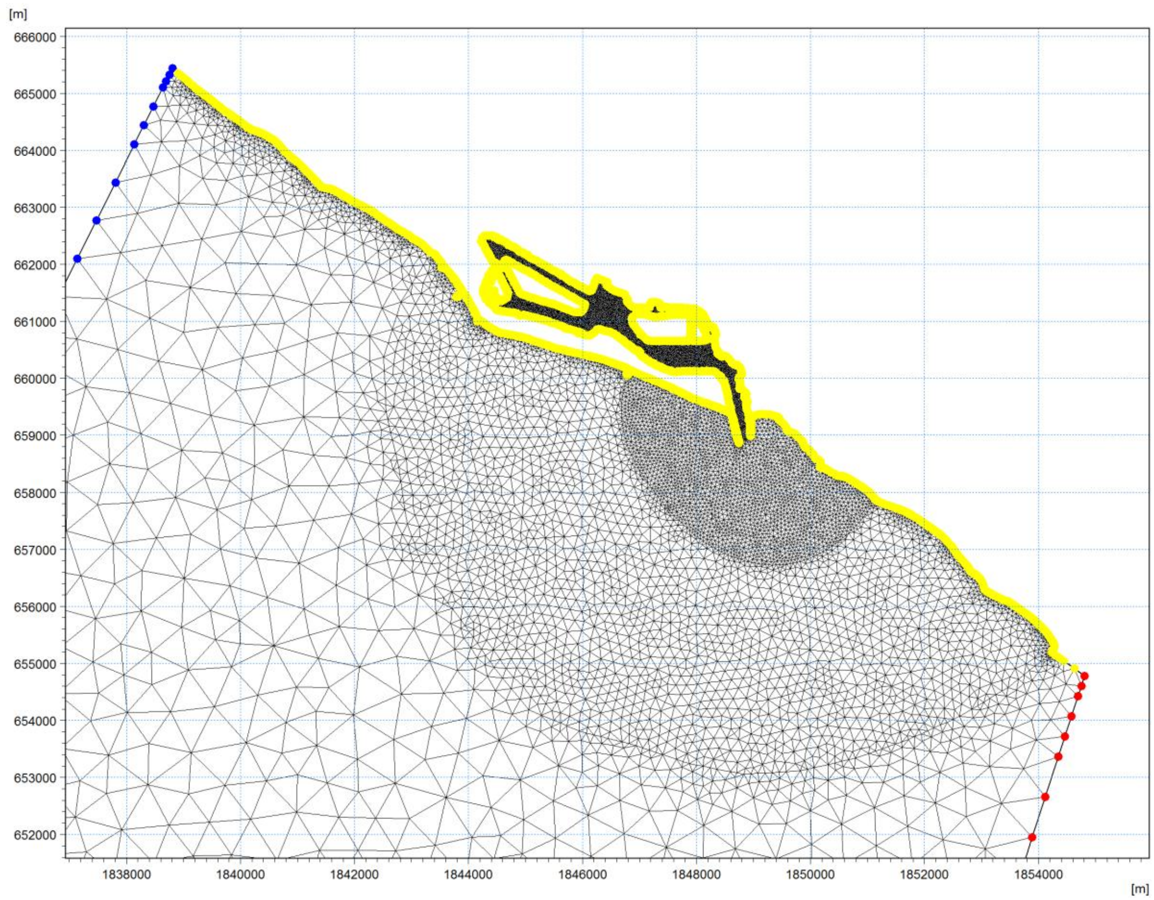


Figure 3.6 Partial view of the unstructured mesh used to resolve the bathymetry of the study area in MIKE 21 SW. Horizontal coordinates are in meters and relative to the State Plane, California VI NAD83 system

A number of exploratory runs were initially carried out with MIKE 21 SW in order to assess the sensitivity of model results to input parameters such as mesh resolution, water level, bottom friction, wave breaking, and directional spreading of the waves, to name a few. In these analyses, wave heights calculated by the MIKE 21 SW model were extracted at the 11 points shown in Figure 3.7 below in order to ease the analysis and comparison of results. Some of the main findings are summarized below:

- the largest wave heights occur in all cases at or around Point 11 in Figure 3.7, which can be reasonably expected since this location is the most exposed to waves penetrating from the Pacific Ocean through the harbor entrance and potentially reaching Balboa Island
- waves approaching the entrance from an offshore direction of 155° (measured clockwise from North) yield the largest wave heights at the extraction points in Figure 3.7, all other conditions kept unchanged
- offshore waves with shorter periods (all other conditions kept unchanged) result in larger wave heights in front of Balboa Island compared to longer waves, as shorter waves are less affected by refraction towards the sides of the access channel as they propagate into the bay than longer waves are
- use of a model mesh with increased resolution at the entrance and/or increasing the still water level and/or reducing bed friction and/or reducing directional spreading of the waves in the MIKE 21 SW model results in larger wave heights at the extraction points than adopting the opposite alternative

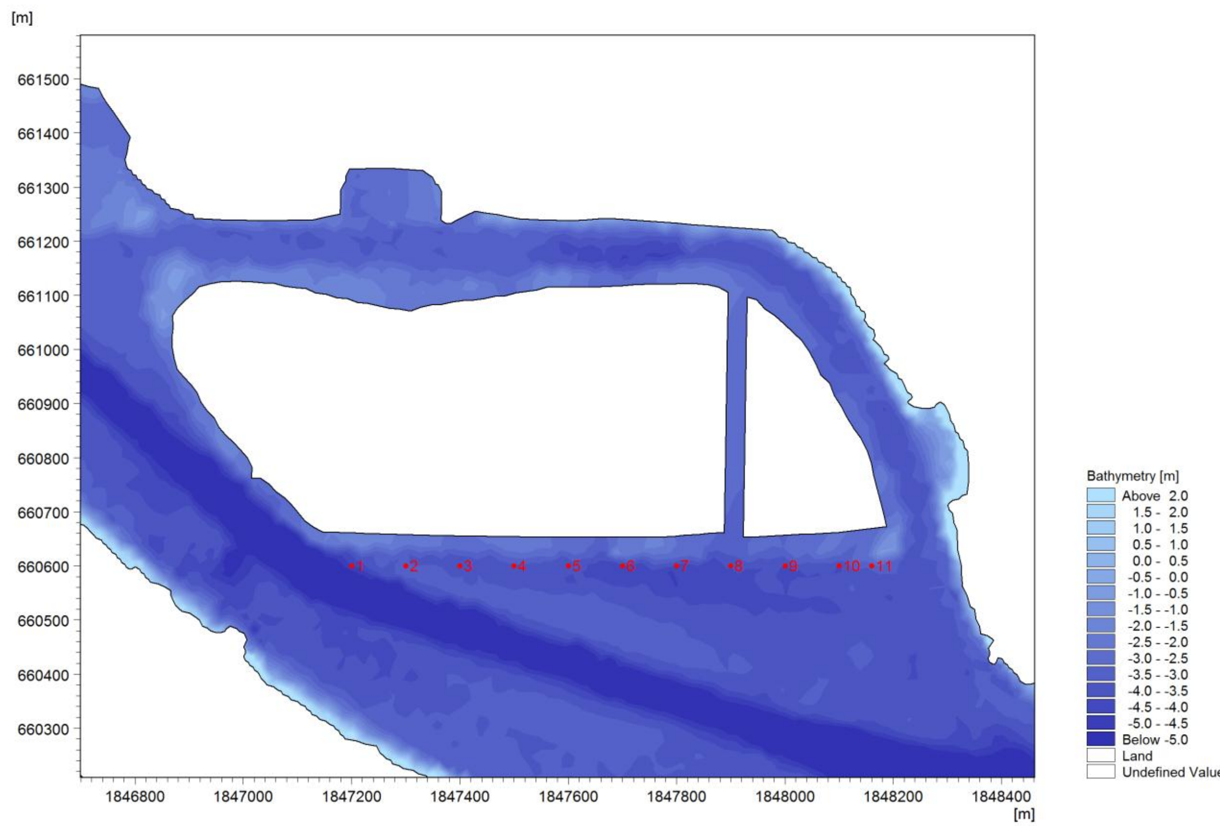


Figure 3.7 Position of extraction points for MIKE 21 SW results. Horizontal coordinates are in meters and relative to the State Plane, California VI NAD83 system.

Following the sensitivity analyses described above, two additional runs were carried out with the spectral wave model MIKE 21 SW in order to assess:

1. Which are the largest wave heights that can be reasonably expected to occur in front of Balboa and Little Balboa islands as a result of Pacific Ocean waves propagating through the entrance for historical wave conditions?

2. Which hypothetical offshore wave condition and water level would be required for a 1-foot high wave to reach the south coast of the islands?

In order to respond to the first question, the WIS wave hindcast data for Station 83102 was scanned to identify periods of time during which large ocean waves approached the entrance to Balboa Harbor from directions around 155°N. A storm in December 1987 was found to fulfill both requirements.

Figure 3.8 shows time series of WIS hindcast wave parameters (significant wave height, peak wave period and mean direction of wave propagation), together with water levels recorded by NOAA at Port of Los Angeles for an event in December 1987. As Figure 3.8 shows, as the wave direction changes from approximately WSW to SE-SSE, the wave height increases and the wave period drops. As discussed in the bullet points above, all of these three factors should lead to relatively higher waves in front to the island than their alternatives.

The offshore waves in Figure 3.8 were propagated on the water level shown in the same figure using the MIKE 21 SW model described above. Whenever possible, model parameters such as e.g. bed friction were selected in such a way as to obtain the largest possible wave heights at the extraction points, by selecting model parameters in agreement with the findings discussed in the bullet point list above.

Even under these assumptions, the largest significant wave height calculated during the course of the storm in December 1987 was less than 0.1 feet at extraction points 9 and 10, and less than 0.16 feet at extraction point 11.

The same model setup used to simulate the storm of December 1987 was applied in the determination of the offshore wave conditions that would hypothetically result in a 1 feet high wave at extraction point 11. A constant water level of +8 feet NAVD88 was adopted together with a significant wave height H_{m0} = 8.2 feet, a peak wave period T_p = 6s and an offshore direction of wave propagation MWD = 155°N. A narrow directional wave distribution and low bottom friction were adopted in order to achieve the largest possible waves in front of Balboa Island.

Even under these rather extreme assumptions (the statistics for the hindcasted waves at WIS station 83102 do not show waves higher than ~4 ft. from direction 155°N), the calculated wave height at extraction point 11 equaled 0.86 ft.

It was therefore concluded that ocean waves propagating through the entrance to Balboa Harbor are rather small in front of Balboa Island and Little Balboa Island and therefore have a negligible contribution to flood levels in the Bay.

The same conclusion cannot be necessarily reached for wind waves locally generated in the bay. According to the information and photographic records presented in Ref. /6/, waves overtopped the seawall at Turquoise and South Bay Front (more or less in front of extraction point 1) during the storm of December 2010, causing significant flooding in the area.

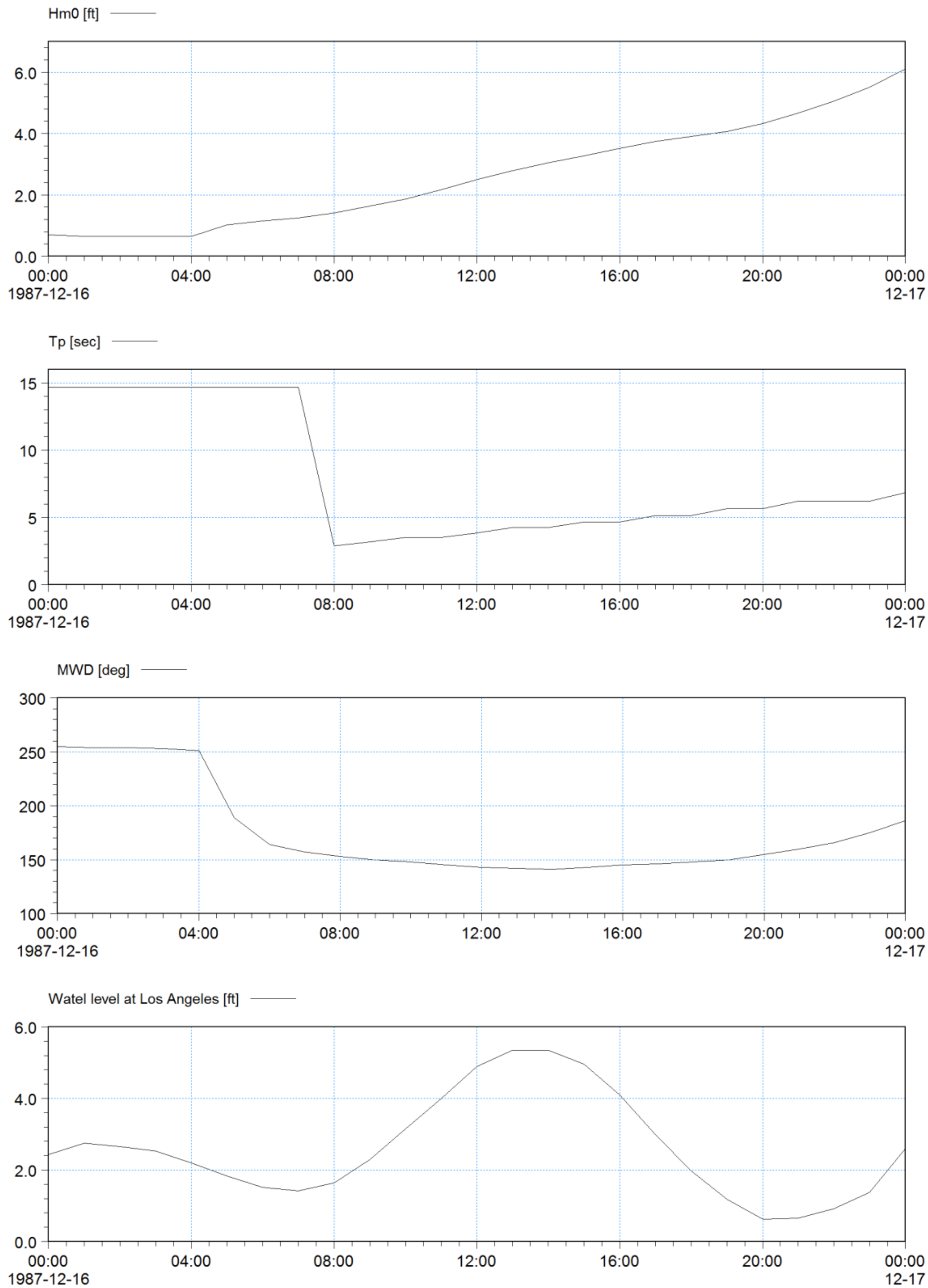


Fig. 3.8 Time series of significant wave height Hm0 (ft.), peak wave period Tp (s), direction of wave propagation MWD (°N) at WIS hindcast station 83102 and water level at Port of Los Angeles (ft. NAVD88) during the storm event in December 1987

The MIKE 21 SW spectral wave model was therefore used to hindcast local wind generated waves in Newport Bay for this storm event. The adopted simulation period was December 18-24, 2010, and wind records from NOAA Station 9410665 Los Angeles Pier J were applied as forcing to the model. Waves were propagated over the water levels recorded at Los Angeles. The time series of wind parameters and water levels over the simulation period are shown in Figure 3.9.

The time series of calculated wave heights at the extraction points in Figure 3.7 were subsequently used to compute wave run-up on the Balboa Island seawall using the TAW method in FEMA Guidelines & Specifications for the Pacific Coast of the US. Extraction point 8 was left out of this analysis since there is no seawall in front of it, as shown in Figure 3.7.

According to the TAW method, the wave run-up can be computed as:

$$R = H_{m0}\begin{cases} 1.77\gamma_r\gamma_b\gamma_\beta\gamma_p\xi_{0m} & 0.5 \le \gamma_b\xi_{0m} < 1.8 \\ \gamma_r\gamma_b\gamma_\beta\gamma_p\left(4.3 - \dfrac{2.6}{\sqrt{\xi_{0m}}}\right) & 1.8 \le \gamma_b\xi_{0m} \end{cases}$$

Where:

R is the 2% run-up

H_{m0} is the spectral significant wave height at the structure toe

γ_r is the reduction factor for influence of surface roughness

γ_b is the reduction factor for influence of berm

γ_β is the reduction factor for influence of angled wave attack

γ_p is the reduction factor for influence of structure permeability

ξ_{0m} is defined as:

$$\xi_{0m} = \frac{m}{\sqrt{\dfrac{H_{m0}}{L_{m-1.0}}}}$$

Where H_{m0} is the wave height at the toe, $L_{m-1.0}$ is the deepwater wave length computed from $T_{m-1.0} = T_p/1.1$.

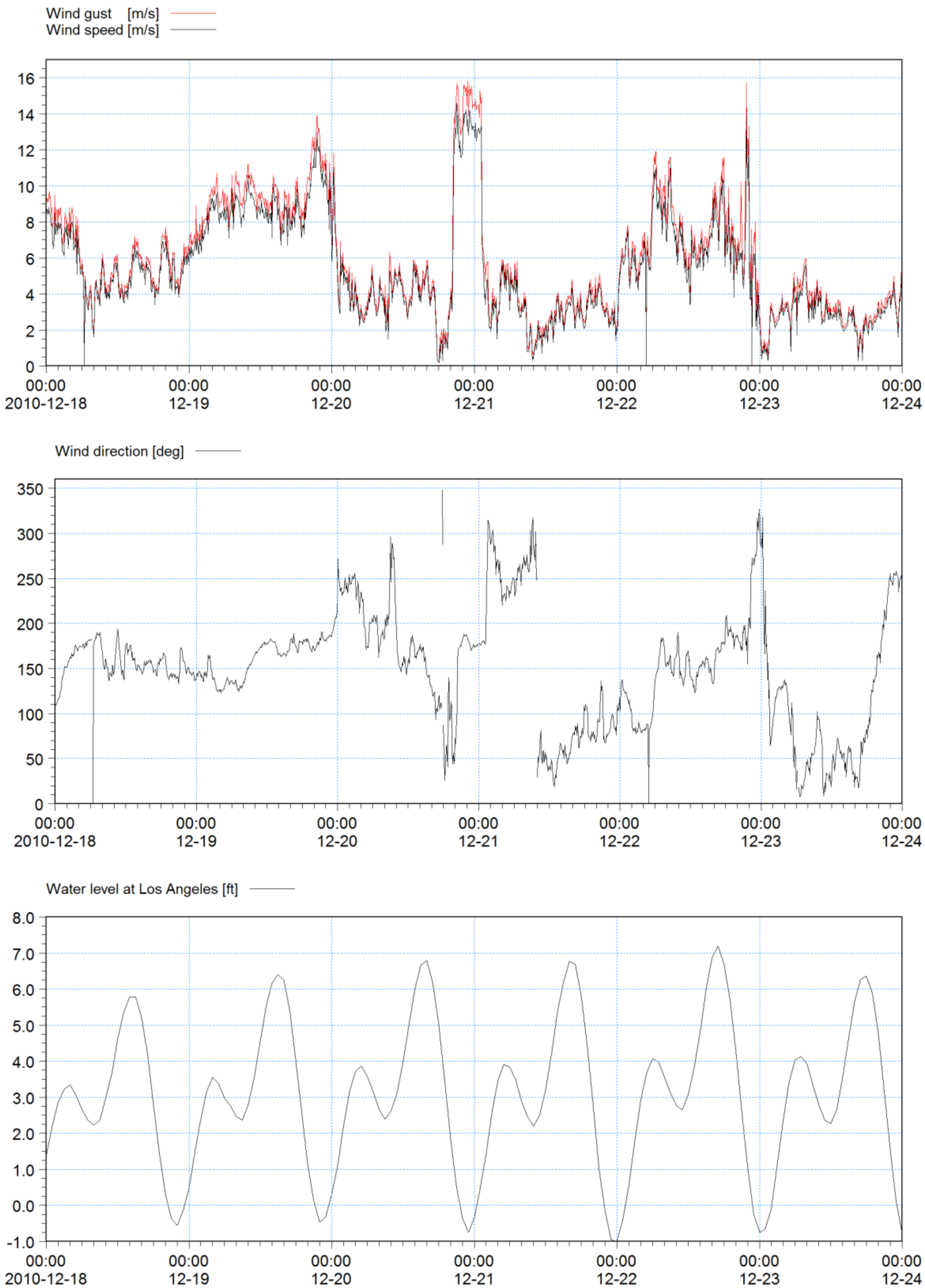


Fig. 3.9 Time series of wind speed (m/s) and direction (°N) as recorded at NOAA station 9410665 Los Angeles Pier J and water level measured at Port of Los Angeles (ft. NAVD88) during the storm event in December 1987.

For a vertical seawall, m → infinity, and so does ξ_{0m}.The second line in the equation for wave runup R applies in this case, and can be simplified to

$$R = 4.3\ H_{m0}\gamma_r\gamma_b\gamma_\beta\gamma_p\gamma_v$$

Where:

γ_v is the reduction for steep or vertical walls, and equals 0.65 for a vertical seawall.

Furthermore, for a smooth impervious seawall, $\gamma_r = \gamma_p = 1.0$. The Balboa Island seawall is not fronted by a berm, so $\gamma_b = 1.0$ too. Finally, assuming normal wave incidence on the seawall $\gamma_\beta = 1.0$ and the equation for wave run-up simplifies to

$$R = 2.795\ H_{m0}$$

H_{m0} is the spectral significant wave height at the structure toe, and was calculated as the minimum of the wave height at the extraction point and 0.8 times the local water depth at the toe, i.e. the depth-limited breaking wave height at the toe of the seawall. The depth at the toe was calculated as the difference between the instantaneous tide level at Los Angeles gage and the beach elevation at the toe of the seawall, which was obtained from the 2006 LiDAR data.

The time series of wave heights at the extraction points calculated by the MIKE 21 SW spectral wave model and the corresponding time series of run-up elevations are shown in Figure 3.10.

It can be seen that the wave run-up R exceeds 1 foot at several locations along the south front of both islands. According to FEMA's Guidelines and Specifications, the run-up elevation is directly added to the still water elevation in sheltered waters like Newport Bay. Therefore, it can be reasonably expected that the wave run-up will add at least 1 foot to the 1% flood level.

Based on the results presented above, it is clear that wind waves contribute to flood levels in Balboa Bay. Therefore, it is our recommendation that a more detailed analysis of wind waves in Balboa Bay and associated run-up elevations be carried to accurately determine the flood levels.

It should be mentioned that the run-up analyses presented above assume that level of the beach fronting the seawall is well below the top of the structure. For situations in which the beach extends high up along the seawall, the nature of wave run-up and overtopping will change and will most likely resemble sheet flow over the crest of the seawall. The detailed analyses mentioned in the previous paragraph would also address such a situation.

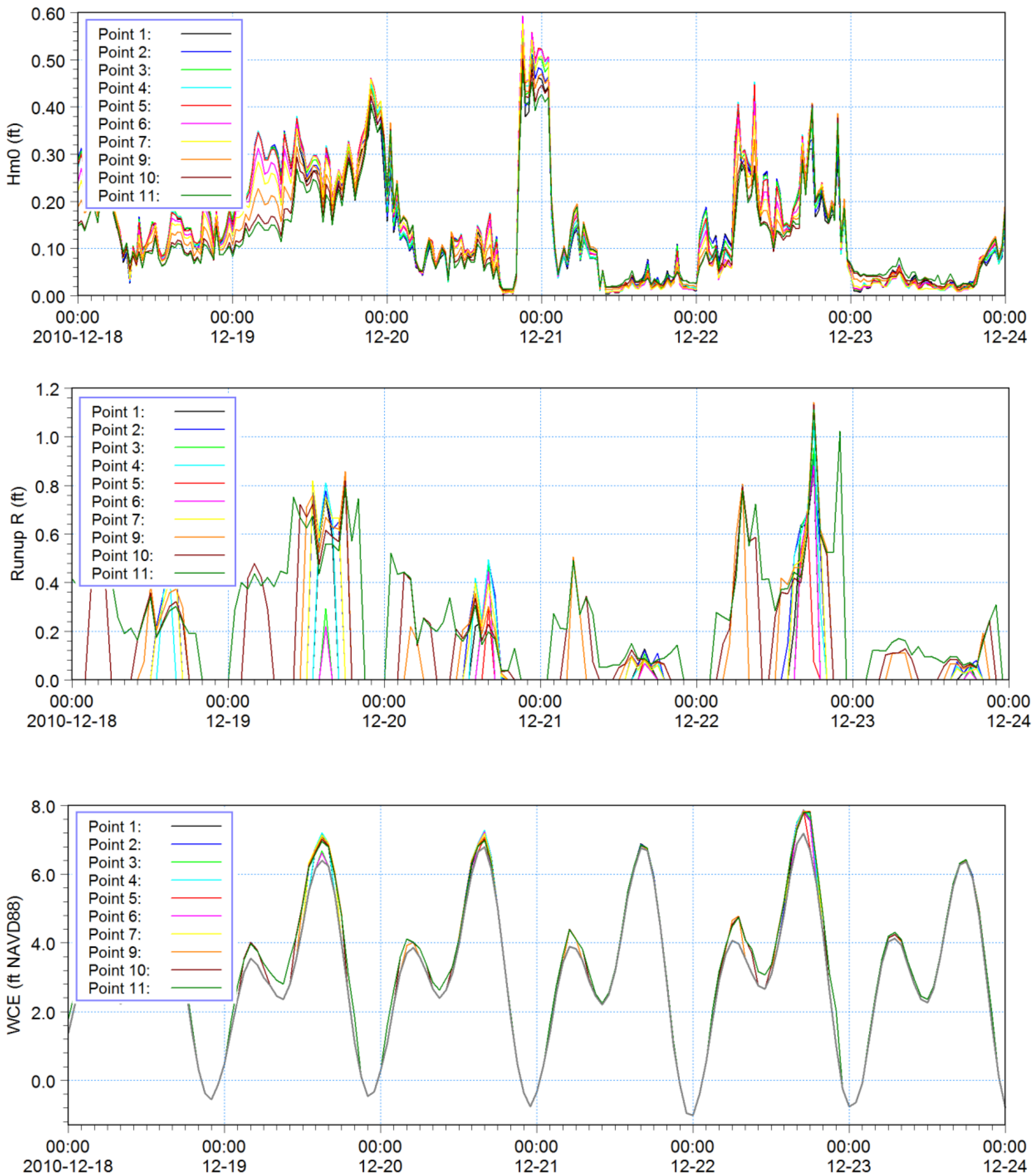


Fig. 3.10 Time series of calculated significant wave height Hm0 at the extraction points in Figure 3.7, associated run-up height R in front of the South Bay Front seawall, and total water level including wave run-up (WCE).

4 Minimum Seawall Height

The determination of the minimum sea wall height has to be considered carefully. The main factors to consider are:

- is the seawall a levee, a coastal structure, or both?
- crest height and integrity of the seawall
- the 1% SWEL
- are waves important, and if so, what is the associated wave run-up

Regarding the first bullet above, the Balboa Island seawall likely needs to be considered as a flood control levee as well as a coastal structure (wave break). Figure 4.1 is provided for reference. In the case of Balboa Island, typical seawall crest heights could be about +8.5 feet NAVD88, and 1% SWEL is around 7.7 feet NAVD88. The seawall is higher than the 1% SWEL, but the land on the backside of the seawall is below the 1% SWEL level, and holds back the tidal flood. For this reason, the seawall almost certainly has to be considered as a levee. For a coastal levee, FEMA requirements are that the levee meet certain structural integrity requirements, but also that the levee crest is 2 feet above the 1% SWEL, and 1 foot above the WCE (or total water level including wave run-up), as illustrated by Figure 4.1.

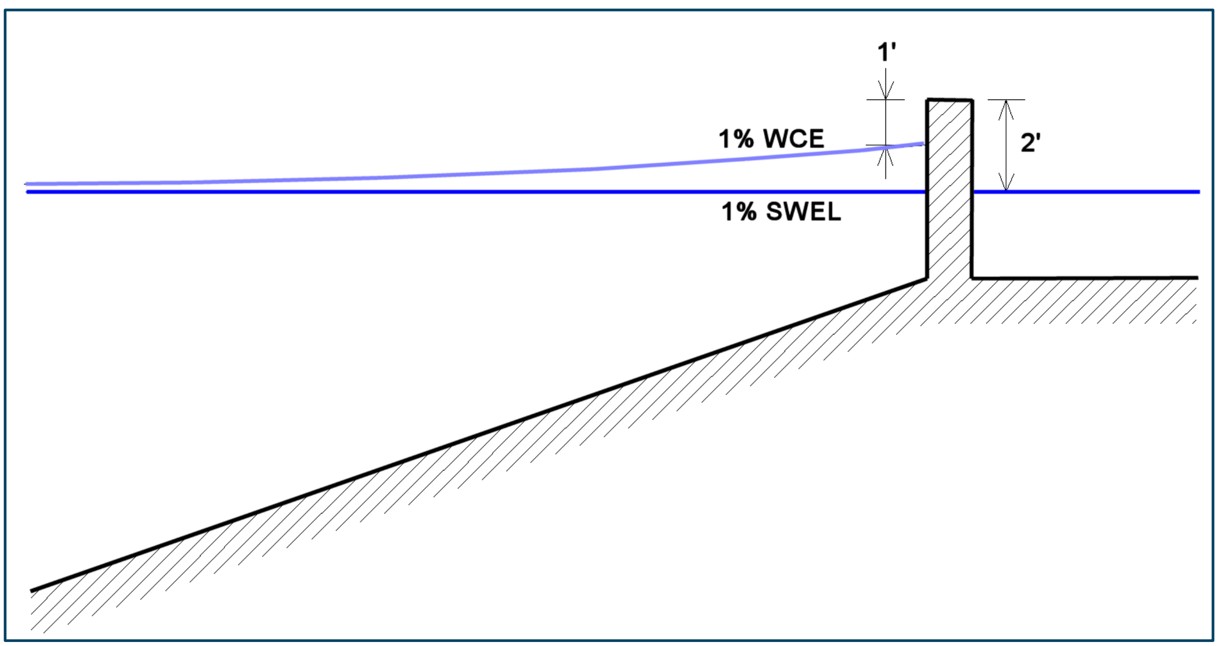


Figure 4.1 Definition sketch of freeboard requirements for a coastal levee.

This report does not address the structural integrity aspects of the seawall, but simply the height requirements.

If waves are not considered, then the crest elevation would need to be minimally equal to the 1% SWEL level plus 2 feet of freeboard.

Freeboard Based on SWEL

1% SWEL + 2-foot freeboard requirement

7.7 + 2.0 = 9.7 feet, NAVD88

Freeboard Based on Wave Runup

Once the 1% WCE is determined, then the freeboard requirement is 1 foot above the 1% WCE.

The analysis performed in Section 3.2 only gives some indication that waves could be important, regardless of whether BakerAECOM decides to consider them in the future study. For the one local wind wave storm condition that DHI looked at (December 2010), the wave run-up was computed to be around 1.14 feet at extraction point 9 from Figure 3.7. However, from Figure 3.10, if the highest water level is consdiered, which occurs at Point 4, when the highest tide level is 7.19 feet, the run-up is only 0.69 feet, resulting in a total level of 7.88 feet, NAVD88. Conversely, when the run-up is a maximum at Point 4, or 0.95 feet, the tide level is only 6.70 feet leading to a WCE of 8.65 feet, NAVD88. The joint occurence of these parameters must be considered. To determine the actual 1% WCE, the total WCE level would have to be computed at each hour of the full 85-year hindcast length, and then perform EVA statistics on the time series of WCE. This is what is referred to as a response-based approach.

It must be stressed however, that the wave analysis performed here was not a rigorous FEMA treatment, but only to give an indication of whether waves are important or not. There could be conditions that would lead to higher a WCE if the full 85-year period was analysed including waves. Since the waves could be important, a quantitative conclusion cannot be made at this time. The full treatment would require performing a full hindcast and response-based analysis similar to the methodology of BakerAECOM for the CCAMP study. BakerAECOM is basing their analysis on a 50-year hindcast length. However, it seems that the wave model testing performed by DHI in this study indicates that wave run-up resulting from open ocean swell is negligible, and only internally generated wind waves are important. If this is the case, then perhaps the wave analysis could be performed using simpler methods confined to the area within Newport Bay. DHI could provide a scope, budget and cost to perform this analysis.

If the analysis was performed today with the current seawall configuration, FEMA would require that the seawall be removed from the analysis because it would not meet the 2-foot freeboard requirement. The effect of this is that the 7.7 foot SWEL (8-foot BFE contour) would be projected over the island (as shown to the right of the seawall on Figure 4.1), similarly to how the 9-foot BFE is currently mapped in Newport Bay. A case could be made to leave the seawall intact for the wave analysis, as it is unlikely it would be destroyed under current conditions. So in this case wave run-up at the seawall could create a local elevated VE zone in a narrow zone near the seawall, then the 8-foot BFE would project inland without further inland wave propagation or re-growth. Ponding from wave overtopping could also be calculated, but is probably insignificant to the analysis if the seawall is already removed from the analysis for the SWEL component.

5 Conclusions

Existing BFE

Based on an investigation of the FEMA FIS backup data, other supporting data, and a knowledge of FEMA procedures, it is concluded that the 9-foot BFE was determined as a result of a number of conversions from the original study in 1978, updated in 1983, including conversion of the original BFE related to NGVD29 vertical datum to NAVD88, which resulted in transforming the old 6-foot BFE to 8.3 feet in NAVD88. Normally the 8.3 value would round down to an 8-foot BFE, but since the old 6-foot contour could be a product of rounding of half-foot increments, then it could have been based on a range of levels between +5.5 to +6.4 feet NGVD29, which translates to a range of +7.8 to +8.7 feet NAVD88. Due to this range of uncertainty, it is likely that the value was rounded up to the upper limit, 8.8 feet, or a BFE contour of 9 feet NAVD88. Conclusion: the existing 9-foot BFE is based on a number of conservative rounding assumptions, and appears to be high by at least one foot. However, waves were not considered in the previous studies, and any wave effects could add to this BFE in a future study.

Determination of New BFE

Based on the analysis of long-term tide gage measurements, the 1% SWEL (without waves), based on a number of alternative computations, should be between +7.6 to +7.7 feet NAVD88, rounding up to an 8-foot BFE contour. This is also consistent with the 1% value determined by Everest (ref. /6/) of 7.71 feet NAVD88.

Based on a limited number of wave model simulations, and the subsequent analysis of wave run-up at the Balboa Island seawall, although generally small waves were found, waves generated by local winds inside Newport Bay could produce run-up elevations that could be important to consider for sheltered waters coastal flooding. Wave run-up elevations for one condition (December 2010) could add an additional ~1.15 foot to a storm tide elevation. However, this is only a single wave event. A more rigorous wave modeling effort, including joint probabilities of waves and water levels, would be needed to the expected 1% total water level. However, the one local wind/wave event in December 2010 indicates that it could be important to consider. The full treatment would have to be done under an extended scope of work effort. DHI can provide scope, budget and schedule upon request.

Determination of Minimum Seawall Height

Given that the importance of waves on the total water level cannot be completely dismissed based on our preliminary analysis, a conclusive seawall height cannot be provided at this time. A more rigorous analysis of the waves would be required to provide further confidence. However, the following conclusions can be made.

The 2-foot freeboard requirement to the 1% SWEL cannot be met with the existing seawall, which would need to be raised minimally to about 7.7 + 2.0 = 9.7 feet NAVD88, not considering waves, sea level rise and wind induced setup generated within Newport Bay. If the seawall height was not extended, the seawall would have to be removed from the flood analysis, and the 8-foot BFE contour level would be projected over the island topography. In this situation, it is likely that FEMA would allow the seawall to stay intact for wave analysis (if performed), meaning the waves would only impact the narrow zone near the seawall, creating a very narrow VE special hazard zone.

For the 1-foot freeboard requirement to the total water level (with waves), or WCE in this case, a quantitative conclusion cannot be made at this time since DHI believes that wave effects could contribute to coastal flooding. This study could not quantify the absolute magnitude of the wave effect from a probabilistic sense. We found one case where the wave run-up would add about 1.14 feet in December 2010. However, the joint probability of high wave combined with high water levels must be considered, and a response based hindcast of the wave run-up would need to be performed to fully quantify this. Given that open ocean swell do not seem to contribute to the total water level, but instead only local wind generated waves, this could simplify the full response based wave analysis approach. DHI could provide a scope, budget and schedule to perform this analysis.

6 References

/1/ Tetra Tech. 1982. Methodology for Computing Coastal Flood Statistics in Southern California. (Tetra Tech Report TC-3205.) Prepared for Federal Emergency Management Agency, Washington, DC.

/2/ CCAMP project website. http://www.r9map.org/Pages/CCamp-Main.aspx

/3/ FEMA. Orange County California Flood Insurance Study, December 3, 2009. Volume 1 of 3. Flood Insurance Study Number 06059CV001B

/4/ List of numerical models approved for use in FEMA Studies website. http://www.fema.gov/national-flood-insurance-program-flood-hazard-mapping/numerical-models-meeting-minimum-requirement

/5/ WIS project website http://wis.usace.army.mil/WIS_Documentation.shtml#po

/6/ Everest International Consultants, Inc. 2011. Assessment of Seawall Structural Integrity and Potential for Seawall Overtopping for Balboa Island and Little Balboa Island. Prepared for City of Newport Beach.