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MEMORANDUM

Date: January 18, 2017

To: City of Oxnard

From: David Revell, PhD

Subject: Testimony on the Proposed Puente Power Plant

Executive Summary

- The site is more exposed to existing coastal flooding hazards than represented in the FSA. Using new topography with the same FEMA methodology and storm characteristics, wave run up elevations associated with a 1% annual storm ("100 year event") could overtop the dunes in front of the site.
- Variability in the beaches fronting the site have not been considered in any modeling of coastal hazards, and future exposure to coastal hazards accelerated with sea level rise and exacerbated by likely declines in sediment supply are poorly represented. These shortcomings understates the exposure of the site to future coastal erosion and coastal flooding hazards. The FSA relies almost entirely on draft modeling data that is poorly documented and utilizes questionable assumptions.
- The FSA doesn't consider the latest scientific evidence on tsunamis (which show the site in an existing tsunami hazard zone) and sea level rise which was funded by the CEC for the California 4th Climate Assessment.
- The time frame for evaluating sea level rise and coastal hazard impacts in the future does not follow state agency guidance or the most recent science funded by the CEC. At the very least, the project should examine the same 60-year operational life that the existing MGS plant has experienced.
- Impacts from the demolition of the ocean outfall on beach stability are absent from the FSA and are likely to result in narrowing of the beach fronting the proposed site.
- The cumulative impacts of the project on neighboring community adaptation planning is not addressed in the FSA.
- Alternative locations can avoid all of these existing and future hazards and improve regional resilience to climate change.

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Introduction

> *"Electricity infrastructure is vulnerable to sea level rise along the coast. About 25 coastal power plants may be exposed to high water levels during what is considered a 100-year flood event, which would become more frequent with sea level rise."* – Safeguarding California

Upon review of the Final Staff Assessment for the proposed Puente project on Mandalay Beach in Oxnard, several topics arise that are mispresented or are completely missing in the FSA and deserve consideration by the California Energy Commission as they weigh the pros and cons of the proposed Puente project. These comments relate to the following categories – existing coastal flooding and tsunami hazards, sand supply to the dunes and beaches in front of the site, exposure of the site to coastal hazards exacerbated by sea level rise, shortcomings in the interpretation of existing models (USGS, FEMA, and TNC), and the implications of the proposed project in constraining future climate change adaptation work in adjacent jurisdictions.

Of note, additional details and testimony have been provided during the CPUC process.[1] Comments submitted during the Public Comment period on the PSA were largely unaddressed in the FSA and so many of those comments are restated in this testimony.

Coastal Topographic Changes.

The FSA relies on the dunes fronting the site as the buffer from sea level rise and coastal hazards. The FSA asserts that sea level rise will not pose a significant threat to Puente except in connection with a tsunami toward the end of the life of the facility:

> *"However, the best estimates of sea level rise near the end of the life of the facility, coupled with the maximum estimated tsunami wave height, suggest there may be less than one vertical foot of separation between the minimum site elevation and mapped inundation zone".*
> *- FSA Executive Summary*

The FSA's conclusions regarding the stability of the dunes and their ability to protect the site do not reflect actual beach conditons or reasonably predicted future conditions during the lifetime of the facility. Beaches and dunes change as a result of tides, waves, and sediment supply, as well as the sequence of destructional storm waves and accretional wind events. To date, none of the variability in the beach and dune system has been considered in the FSA or evaluated in any of the coastal hazard modeling. Instead, all of the available hazard modeling has relied on a single 2009 topographic LIDAR data set collected in the fall 2009 when beaches historically were at their widest.[2] This means that all of the hazard models underpredict the existing risk to the site and any modeling that does not allow for erosion or evolution of the shoreline likely paints a rosier (less risky) picture of future conditions.

[1] *See* TN# 204942 and TN# 204943.
[2] The City requested the date of the 2009 data on several occasions, but it was not provided.

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The purpose of this section is to document beach and dune changes at the site since 2009, and to evaluate the variability over time. Ultimately these changes and variability have implications for the hazard modeling results discussed in the FSA.

The 2009 topographic data used in the FSA was collected on November 6 and November 9, 2009. Because this data is over 7 years old and was collected at a time of year when the beach would be at its widest, a topographic survey was collected on 12/20/2016 by drone following all appropriate FAA regulations. The survey consisted of aerial photography collected at <100' altitude with on the ground GPS coordinates visible in the imagery to allow for digital processing of the overlapping imagery to produce a current digital elevation model with a vertical resolution of +/- 3cm (Figure 1).

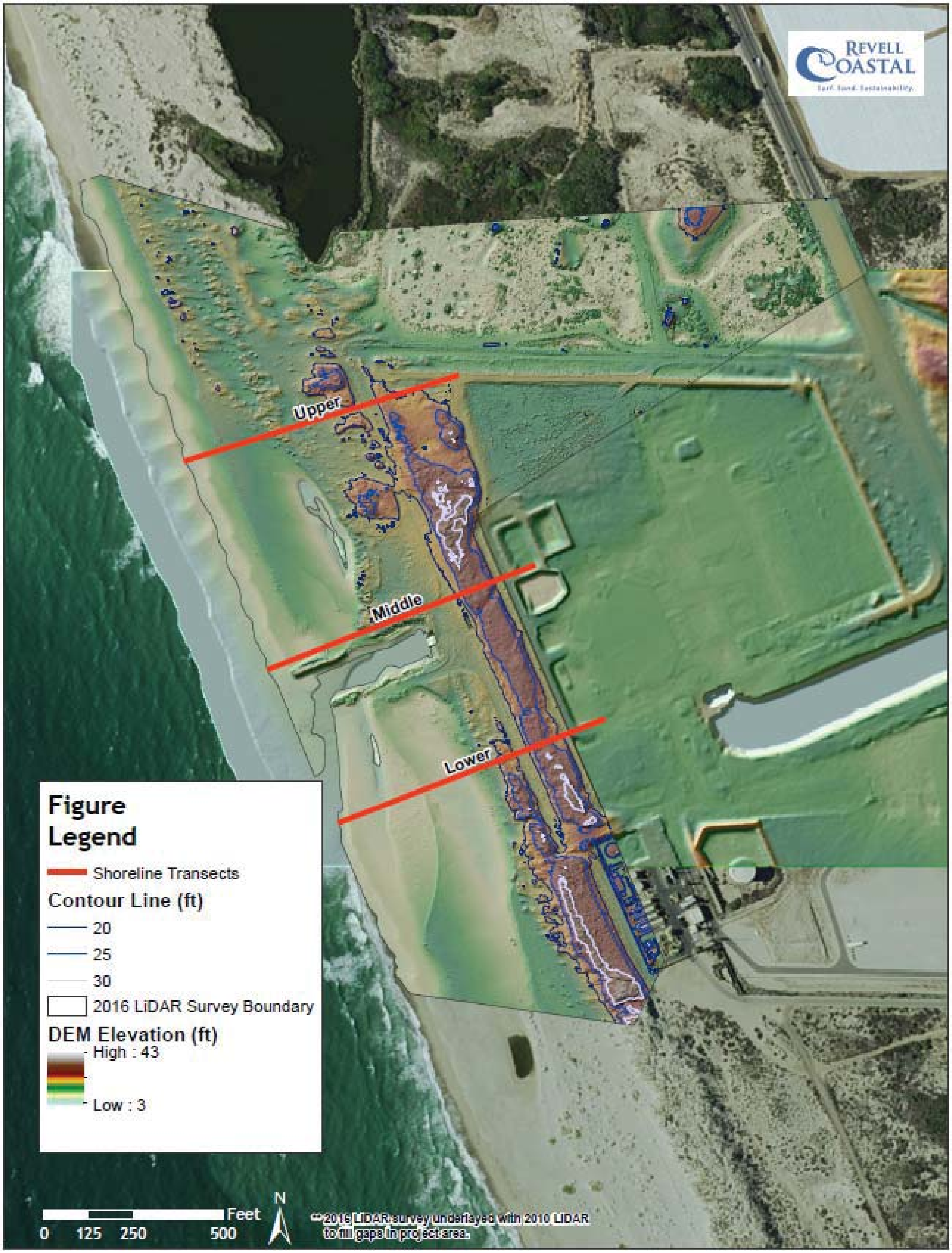

Figure 1. 2016 topographic survey extent with geomorphic analysis transects. Note that the 5' transects between 20 and 30 feet are shown on the map.

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Beach Changes between 2009 and End of 2016

Between 2009 and 2016 several large storms have occurred including the energetic 2015/2016 El Niño. These storms caused several substantive changes to the beaches and dunes in front of the proposed Puente site. Some of these changes can be seen in the cover photo from the FSA (Figure 2), despite artistic renderings to remove the outfall and portray a potential future condition.

Figure 2. Photo from FSA showing view of Puente site with an artistic rendering to show a potential post-construction removal of the existing outfall structure. The black arrow indicates recent dune erosion and the blue arrow shows area of recent wave overtopping to the access road. The green arrow shows part of the area of substantial dune erosion depictedin Figure 3.

To quantify the changes between 2009 and 2016, I generated Figure 3 in which the topographic surfaces were subtracted from each other (2016 – 2009). Areas in hot colors indicate erosion and areas of cool colors indicate accretion (Figure 3).

The most notable changes in topography occur at the dunes directly in front of the proposed location, These dunes were heavily impacted by recent storms--most likely during the energetic El Niño of 2015/2016 and possibly during the December 11, 2015 storm event, which destroyed portions of the Ventura pier and caused extensive flood damages around Ventura and Oxnard. The area of maximum dune erosion resulted in the vertical erosion of 12 feet of sand and reduced the buffering capacity of the dunes fronting the proposed site. The beach during the more recent time periods (2009 and 2016) shows substantial erosion of the dunes at the back of the beach (Upper transect) in the area fronting the proposed site.

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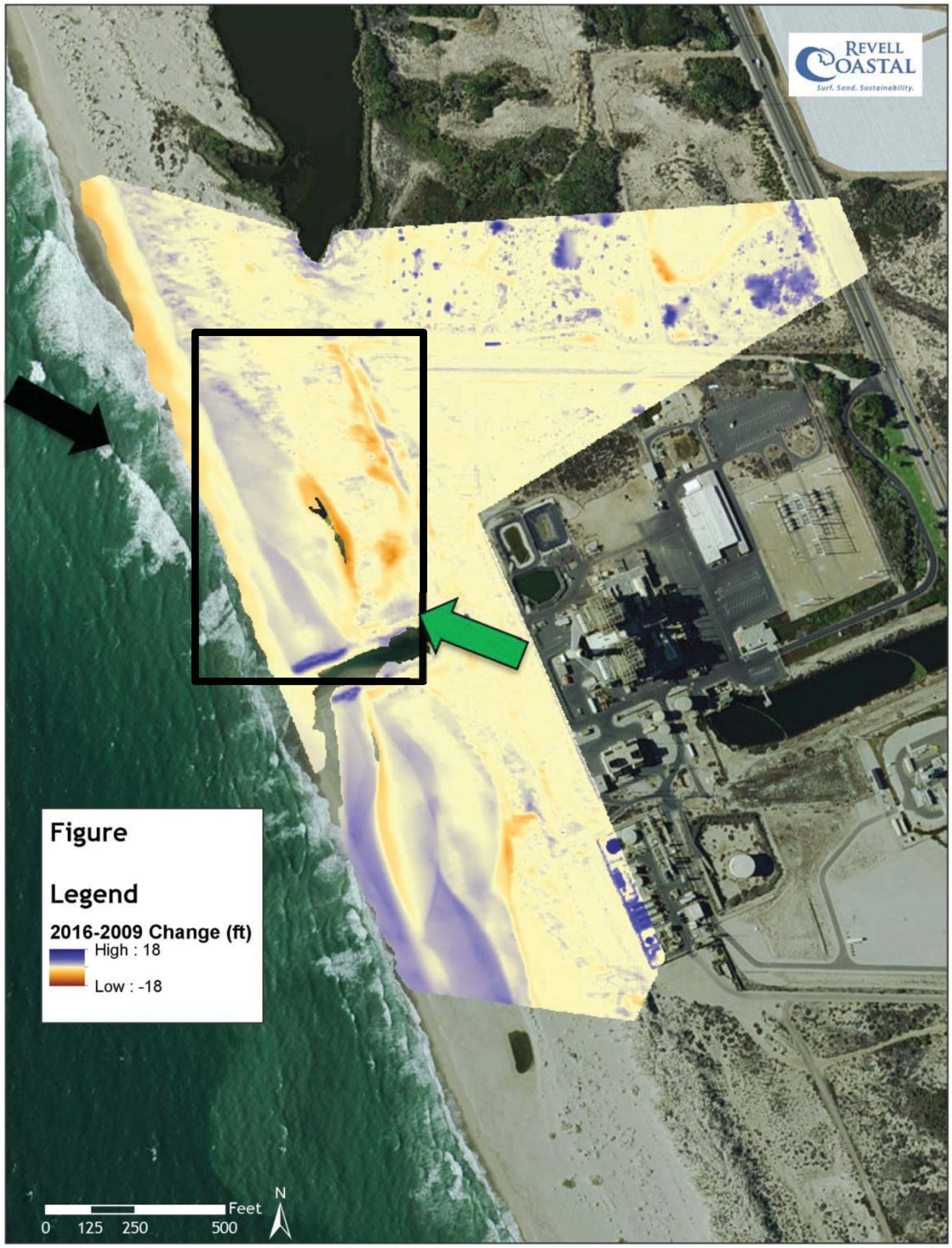

Figure 3. Topographic changes between 2016 and the 2009 LIDAR. The hot colors indicate erosion and the cool colors indicate accretion. The black arrow is the approximate view angle for the FSA cover image and the black box highlights the area of greatest change in front of the proposed Puente project. The green arrow approximates the dune identified with the same arrow in Figure 2.

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The mild accretion of the middle section of the beach is accompanied by erosion of in the lower (seaward) section of the beach.

Figure 4. Ocean waters during December 11,2015 storm event (top) and King tide on December 16, 2015 (bottom). Note the debris line high water markfrom the high tide during the December 11th 2015 storm wave event on the landward side of the beach access road (Black arrow). It is important to note that this December event was not a 100 year event but rather closer to a 25 year event. (Photo courtesy C. Williamson).

The present beach condition has much less protective dunes fronting the proposed Puente Site than assumed in the 2009 data that was relied upon for the hazard modeling in the FSA.

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Historic Beach Variability

Since 1987, BEACON, a joint powers authority representing all of the communities in Santa Barbara and Ventura Counties which focuses on beach erosion issues, has collected beach profiles near the site episodically. More recently as part of a larger regional effort to understand short term seasonal and longer term dynamics, this work has been synthesized (Barnard et al 2009). As part of that research historic and recent beach profiles were collected and synthesized (unpublished data BEACON/USGS). Profile 32 is just north of the proposed site in front of McGrath Lake and show substantial variability, widening and narrowing through time as measured in beach width and beach slopes (Figure 5). The variability of these beach profiles around the approximate MHHW elevation (~2m) show about 450' feet (~150 meters) of changes through time in no particular sequence. While these changes include seasonal and episodic changes without specific causation it illustrates the variability of the beach at this single location near the site. The widest beach shown in October 2007, follows the major 2005-2006 flood event on the Santa Clara River and was reflected in the 2009 LIDAR data used for all of the coastal hazard mapping. This sand that has largely been trapped on the beaches in between front of the site due to the lack of sufficient dredging at the Channel Islands Harbor.

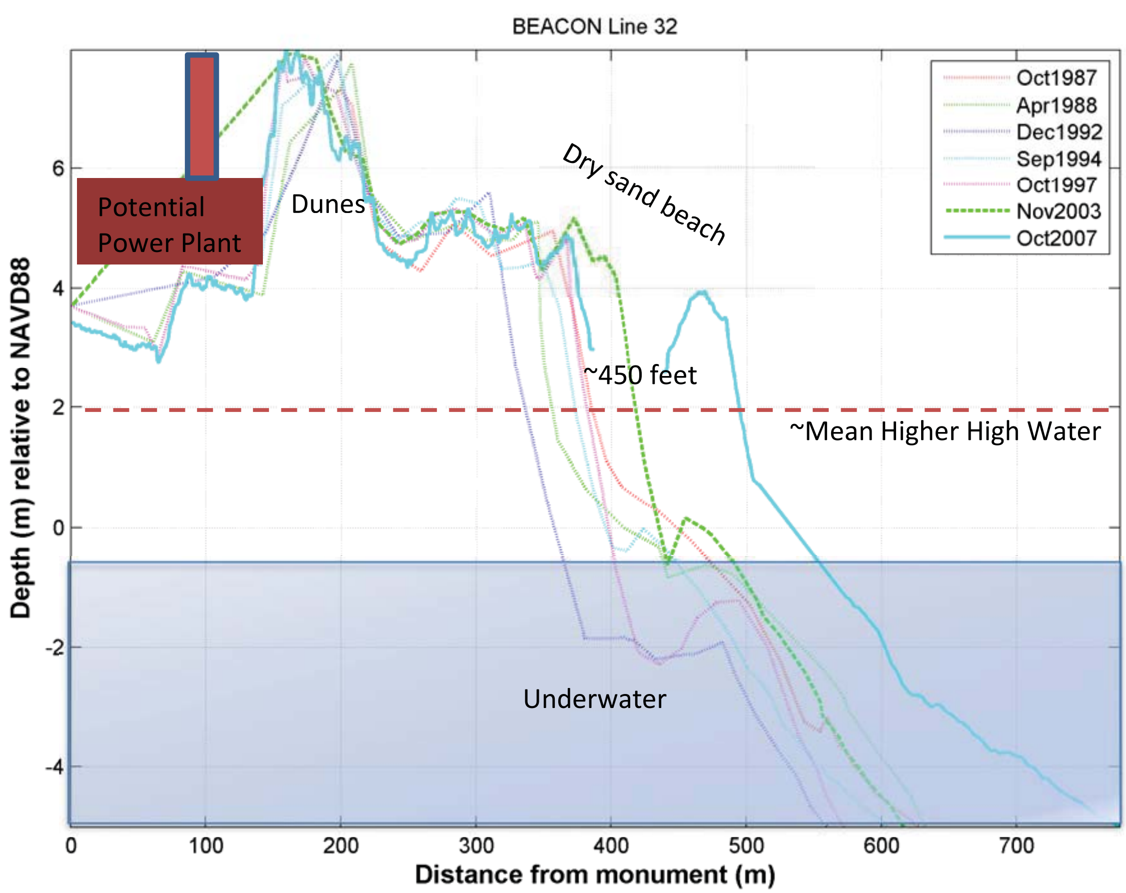

Figure 5. Beach showing elevations and topography through time collected from just north of the

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proposed Puente site between 1987 and 2007. (unpublished data courtesy of USGS/BEACON). The monument near Harbor Boulevard, which is at the landward side of the proposed site.

Topographic variations in front of the Mandalay and Proposed Puente Site

To further examine this beach variability spatially, three topographic data sets, October 1997, April 1998 and November 2009 LIDAR data were obtained from the NOAA Digital Coast website (https://coast.noaa.gov/digitalcoast/) and compared with the December 2016 topographic drone survey. From these 4 topographic data sets, geomorphic elevation and slope analysis and interpretation was completed on 3 transects fronting the proposed Puente Site. (Figure 6: Upper, Middle, Lower).

There are several general findings from the geomorphic analysis of the transects (Figure 6) which are summarized in Table 1.

In general, the beach during the 1997-98 time period was narrower by about 200 feet. The erosion during this El Niño only resulted in about 100 feet of shoreline change, likely as a result of the peak wave heights occuring during low tide. The earlier time period corresponds to a time of reduced dredge bypassing from the Ventura Harbor and below average coarse sediment discharge from the Santa Clara River (Note that while 1997-98 was a large discharge year, the sediment did not show up on the beach until after the topographic LIDAR survey was taken in April). The Lower transect shows up to 9 feet of vertical erosion along much of the beach, and about 7 feet of dune erosion (Middle Transect) (Figure 6 middle). The time period post 2009 which includes the two most recent profiles are indicative of increased sediment from high rain years in 2004 and 2005, normal dredging at Ventura Harbor and a very reduced dredging of Channel Islands Harbor which has completely filled the sand trap upcoast of that harbor and backed up sand along the coast in front of the proposed Puente site (see Sediment Supply discussion below). Please note this same time period has also resulted in substantial erosion downcoast at Hueneme Beach.

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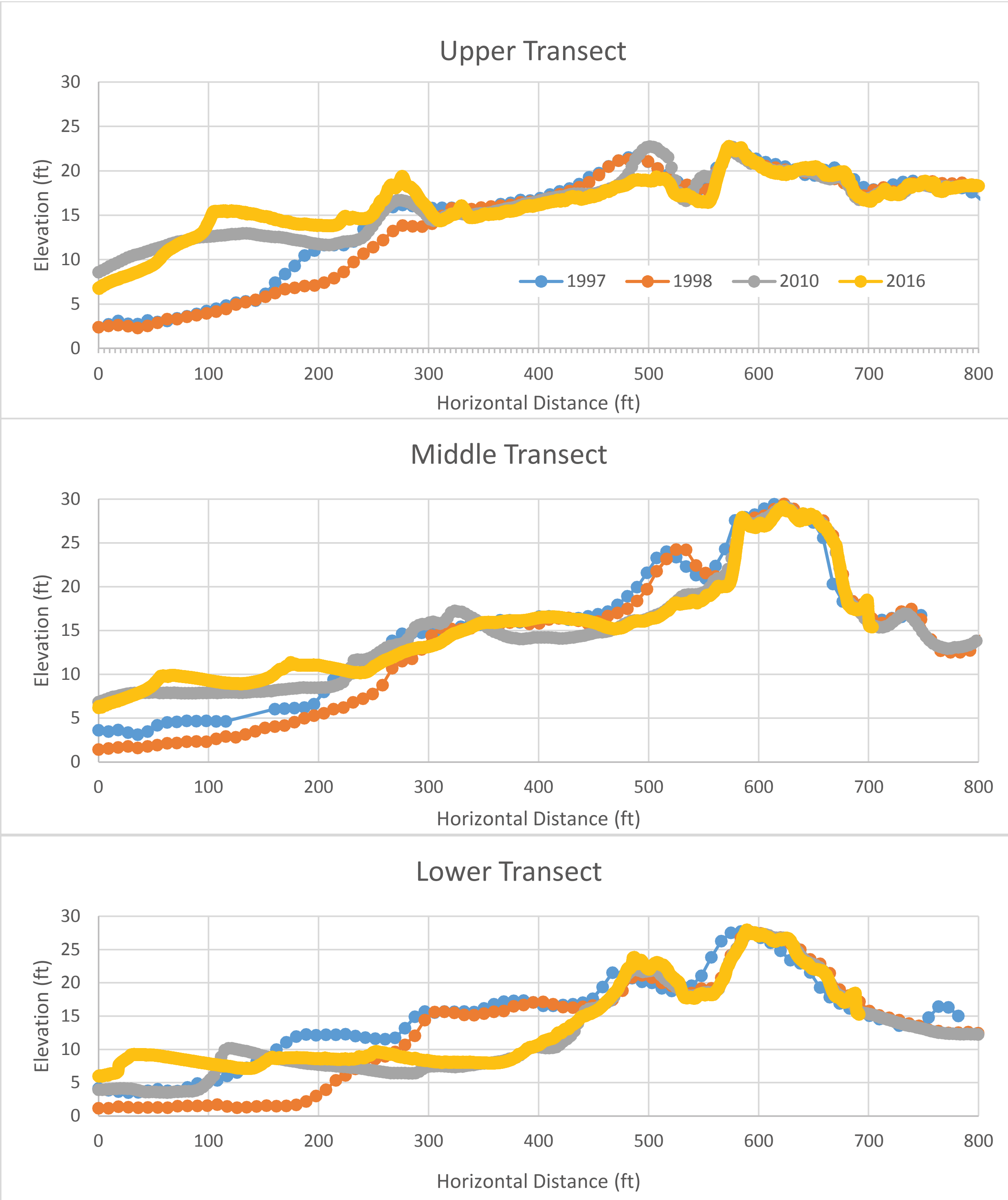

Figure 6. Topographic profiles showing the beach variability across the MGS site from October 1997, April 1998, November 2009, December 2016.

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There is a wide variability in the beach slopes and beach widths between the topographic survey dates (Table 1). The foreshore beach slopes control wave run up. The steeper the beach, the higher the wave run up. In this analysis beach slopes are are measured between 7 and 9 feet elevation NAVD due to data availability. Beach widths were measured from 7 feet elevation NAVD to the back of the access road for consistency.

Table 1. Geomorphic summary of some of the historic beach profiles fronting the Proposed Puente Site.

	Upper			Middle			Lower		
	Beach slope	**Crest**	**Beach width**	**Beach slope**	**Crest**	**Beach width**	**Beach slope**	**Crest**	**Beach width**
1997	0.11	22.3	390	0.16	29.1	345	0.09	27.7	415
1998	0.04	22.2	340	0.09	29.5	310	0.07	27.6	315
2009	0.06	22.7	585	0.05	29.1	550	0.30*	27.6	200
2016	0.05	22.7	535	0.06	29.2	525	0.18	28.0	200

* The 0.30 beach slope measured south of the outfall was likely associated with the outfall channel scouring a near vertical scarp

In summary, the geomorphic analysis demonstrates that the beaches and dunes of this site are quite variable and have widened and narrowed with slopes that steepen and flatten across the beach during the same time periods. This variability has and will always occur. This finding has implications for all of the coastal hazard mapping (FEMA, TNC, and COSMOS) which relied on the same 2009 topographic data set that was collected during a wide beach time. The 2009 elevation data shows one of the widest beach conditions documented in the historic record. The next section, specific to the individual coastal modeling, demonstrates the implications of the more recent topographic data (Figure 1) and the geomorphic variability (Table 1) on the calculations and mapping of existing and future coastal hazards.

It is also important to note that the demolition and removal of the outfall riprap has not been mentioned in the FSA at all. Removal of this structure, which serves as a cross shore sand retention groin structure, will alter the sediment transport dynamics. In upcoast Pierpont Bay, the groins trap substantial amounts of sand which protect the oceanfront properties. Presently the outfall is retaining sediment immediately in front of the site. Removal of this sediment retention may resulting in narrowing of the beach and an increase in the likelihood of dune erosion. This omission requires some additional analysis as it relates specifically to the fragile dunes that according to the FSA protect the site.

Sediment Supply

Sediment supply to the beaches and dunes is critical to maintaining the protective capacity of the system fronting the site. Changes to sediment supply or sediment management may reduce the ability of the beaches and dunes to provide storm protection to the proposed site. The National Research Conservation Service has mapped the soils at the proposed location as “Coastal Beaches”, indicating that this site was formed and is currently forming by coastal processes.

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The FSA discussion of the Santa Barbara littoral cell budget and the sediment contributions to the beach and dune fronting the proposed Puente site is lacking a thorough discussion of the variability of sediment supply. Variability arises from both the Ventura Harbor dredging (and upcoast sources within the Santa Barbara littoral cell), from river discharge on the Santa Clara River, and downcoast dredging at the Channel Islands Harbor which backs up sand to the site.

While the staff assessment notes that there is variability in the sand sources, it focuses on the yearly averages for sediment-supply. PSA Figure 10 (Appendix SW-1) shows the total sediment yield from the Santa Clara River (~1.2MCY/year). It is clear that the sediment flux from the watershed to the coast is extremely variable and in more years than not, remain well below the average sediment yield. For example, during drought years, little coarse sediment (aka sand) is discharged from the Santa Clara River, while during major flood events, such as in 1969, sediment discharges can be up to 27x greater than normal. In fact the 1969 single event contributed ~25% of the total coarse (sand) sediment delivered to to the beaches during the entire 54 year of record shown in PSA Figure 10 (Appendix SW-1).

In addition, the staff assessment relies on a coarse sand sediment fraction of 0.0625 mm, which grain size is too small to be considered as sand remaining on the beach. The littoral cell cut-off diameter or minimum size of sediment making up the beaches in the Santa Barbara littoral cell is ~0.125 mm (Mustain 2007, USGS 2009). By assuming that all sediment over 0.0625 mm will be available for beach and dune replenishment, PSA Figure 10 overstates the volume of sediment supply available to replenish the beach and dunes in front of the site. This area of the Oxnard Plain near the Project site recieves substantial wave energy from both west and south directions (USGS 2009) and the smaller sediments (including small sand) identified in PSA Figure 10 are likely to be pulled from the beach and flushed out to sea. Sediment grains under 0.125 mm in diameter are not likely to replenish the beach in this area.

An average of the sand delivered to the beaches (includes the > 0.0625 mm interpretted from PSA Figure 10) is estimated to be around ~585,000 cubic yards/year (again noting that some of that material is too fine to remain on the beach). If we remove the 1969 coarse sediment yield then the averages used in the FSA, then the average annual sand sized delivery is only ~455,000 cubic yards. If we remove the three highest sand delivery years, the sediment yields only an average of ~315,000. These sand volumes averages show that the role of the annual average Ventura harbor dredging (~600,000 cy/yr) is crucial to maintaining the beaches in front of the proposed site. This is counter to what is stated in the FSA (4.11-41 and 4.11-43).

> *"Moreover, historical climatic data will not suffice to support future management of energy systems and other concerns, as the climate is diverging from its historical "envelope"— in other words, key climate parameters are starting to move outside of historically observed variability—at a rate that makes historical data a poor predictor of future climate."* - Safeguarding California Energy Sector Plan

More fundamentally in considering future site conditions, the staff assessment fails to address whether the ~1.2MCY/year of average sediment discharged from the Santa Clara to the beaches is a sustainable trend. The answer is likely "no." Long term precipitation projections show a decline over the coming

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century (i.e., we will experience longer and more severe droughts) (Cayan et al 2012). By 2050, the sediment yield from the Santa Clara was projected to be similar to present or decrease up to 20% and by 2100 the sediment yield is projected to decrease between 18 and 32% (ESA 2013). When coupled with urbanization of the upper watershed from proposed development projects (Newhall Ranch and others), an increase in impervious surfaces, the sediment discharge trend is more likely to decrease.

In addition to natural variations in sediment supply, dredging in the area also affects the source of sand for the beach and ultimately the beach width. The FSA states, "A comparison of the width of the beach estimated from aerial photographs does not show a direct relationship between the dredging and the beach width." This is a completely unsubstantiated statement with no citation, methods or analysis to allow for any interpretation.

While the FSA focuses primarily on dredging of the Ventura Harbor, it doesn't consider the impact of NOT dredging Channel Islands which backs sand up to the site especially following large river flow years on the Santa Clara River. The substantially less frequent dredging at Channel Islands Harbor in the last decade is likely to partially explain the widening beach widths observed in recent years and also biased the reported USGS COSMOS Coast results (see COSMOS section below). While the lack of dredging at Channel Islands Harbor is evidenced by the observed downcoast erosion at Hueneme Beach (Appendix SW-1, PSA Figure 8), the impact of not dredging this harbor is likely to show the widening of beaches updrift as is seen elsewhere in the Santa Barbara littoral cell (Revell 2007, Revell et al 2008). Specifically, the Channel Islands Harbor has a long term average annual dredge record of ~1.2 million cubic yards per year for the time period between the 2009 and the 2016 topographic surveys. Harbor dredging at downcoast Channel Islands between 2009 and 2013 was in deficit during which substantially more sand was trapped on the beaches in front of the proposed Puente Site (~3.4 million cubic yards).[3] In sum, changes to either harbor dredging practices could impact the stability of the fronting beach and dunes at the Puente site and should be considered when assessing the long-term reliability of the dunes as protection for the Puente project.

Finally, continuing sand supply is necessary to maintain the fronting sand dunes. However, even with continued supply, sea level rise and increasing coastal hazards will likely cause the dune to migrate inland onto the Puente site. Such dune transgression or landward advance will cause more windblown sand onto the site and require additional sand management activities. One can also see the impact of the existing power plant on the dune field. In Figure 1, one can see that the dune field in front of the existing MGS site is in a narrow linear strip, unable to migrate naturally landward. At the north end of the site where the proposed plant would be built, the dunes have been allowed to migrate and they have moved inland. This is a foreshadowing of future conditions if the new plant is built, the dunes will be constrained and the blowing sand will have to be removed slowly narrowing the fragile protective dune habitat (ESHA in City of Oxnard and Coastal Commission language) that protects the site.
If the managed sand is removed from the site, this sand management practice over time could further reduce the sand volume in the dunes and expose them to erosion and the Puente site to elevated coastal flooding. The FSA does not consider anticipated frontal dune migration towards the Puente site that will accompany expected sea level rise and the resulting increase in coastal hazards.

[3] Personal communication USACOE LA District Coastal Studies director Heather Scholosser 1/17/17.

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Implications of Topographic Changes on FEMA Preliminary Coastal Flood Maps

As the FSA notes, FEMA's purpose is to provide rating of *existing* hazards for flood insurance and community floodplain management. There is no consideration of sea level rise in FEMA's regulatory mapping. FEMA has recently (September 30, 2016) released their preliminary revised coastal flood hazard maps which depict the extents of a 1% annual chance storm (aka 100-year event). The FSA relies on the preliminary FEMA map, which shows no limited coastal flooding to the proposed site.

The Preliminary FEMA map is currently undergoing review and does not reflect existing flood threats to the site.[4] First, FEMA maps do not consider coastal erosion or sea level rise. The new Preliminary maps do not follow the 2005 FEMA Pacific Coast flood guidelines (NHC 2005) which recommend using a Most Likely Winter Profile to evaluate potential flood damages. The reason for using the most likely winter profile as part of the guidelines is to directly address multiple storms in sequence during a large storm year. Typically, major erosion occurs in the winter, often during major El Niño events. Rarely does a 1% annual storm impact occur in the summer. The FSA states that the most likely winter profile is utilized in the FEMA analysis, (4.1-130). However, FEMA confirmed at public workshops in April 2016 that the Preliminary FEMA maps use the 2009 topographic data, which reflects one of the most accreted beach conditions in the historic record, not the winter profile.[5]

Actual events also call into question the flood risk shown on the preliminary FEMA maps. On December 11, 2015, a ~25 year storm event hit the California coast and did substantial damage to the Ventura pier just up the coast from the Proposed Puente site (among other places in California). Based on City and personal review of the preliminary maps and photos collected during this December 11, 2015 event, the Preliminary FEMA maps underpredicted flood extents all over Ventura County. Although the 2015 storm event was considered a 25 year storm, none of the flooding and damage that actually occured would have occurred under the FEMA preliminary map of risks from a 100 year storm (Figure 4).

Even with the caveat that the Preliminary FEMA maps under-predicts potential flooding, it is possible to calculate wave run-up elevations using FEMA wave run-up calculations and the 2016 topographic data regarding the beach profile discussed above. FEMA uses wave run-up to determine the Base Flood Elevation in sandy beaches based on the wave run-up equation by Stockdon et al 2006.[6] This wave run-up equation is especially sensitive to beach slopes. Table 2 demonstrates that wave run-up varies significantly with the slope of the beach. Table 2 was calculated using FEMA data and a range of actual beach slopes documented in front of the site (Table 1). This wave run-up analysis utilized still water tide parameters extracted from FEMA's Preliminary Coastal Flood maps and Preliminary database (8 feet) and the run-up elevation (20.1 feet) for the high velocity wave zone (VE zone) defined as the inland

[4] Currently, jurisdictions within Ventura County are supporting a technical review of the FEMA maps as part of the map finalization process. It seems prudent that the area around the plant shown as non hazardous (both onsite and just north of the site) should be carefully reviewed given that the elevations north of the Puente site are below 20' NAVD, and the hydraulic connection to the 14' site is protected by an 18' levee. In addition, the review should examine the sensitivity of the preliminary wave run up elevations based on a wider range of beach profiles.

[5] Personal Communication with Ed Curtis, FEMA, 4/13/16.

[6] Stockdon, H.F., Holman, R.A., Howd, P.A., and Sallenger, Jr., A.H., 2006, Empirical parameterization of setup, swash, and runup, Coastal Engineering, 53, pp. 573-588.

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elevation of wave run up calculated at FEMA Coastal Transect 47 (closest to the site). Using FEMA data including a still water elevation of 8 feet, and 100-year wave characteristics of 20 feet at 20 seconds the Stockdon wave run up equation was used with varying beach slopes measured in front of the proposed site. Results of this FEMA wave run up analysis with varying slopes and NO sea level rise are shown in Table 2.

Table 2. 100 year wave run up using FEMA calculations and wave conditions with different beach slopes and NO sea level rise.

Beach Slope (V:H) (Tanβ)	**1:25 (0.04)**	**1:20 (0.05)**	**1:12.5 (0.08)**	**1:10 (0.10)**	**1:5.6 (0.18)**
Wave Run-Up Elevation (feet NAVD)	**18.9**	**20.1***	**23.9**	**26.7**	**38.6**

** Run up elevation from FEMA Preliminary Coastal Mapping Coastal Transect #47*

This Table demonstrates that under current conditions and based on actual beach slopes measured in front of the site over the past 20 years, wave run-up at the site may be as high as 38.6 feet—much higher than the current height of the dunes.

Moreover, while this FEMA wave run up is a statistical 100 year event, it is worth noting that this 1% event is smaller than the historic buoy observation from January 1983.[7] The January 27, 1983 historic event measured 25 feet at 22 seconds with a still water elevation measured at 7.8 feet. By applying the same FEMA method and beach slope assumption of 0.05 or 1:20 beach slope with wave characteristics from the historic January 1983 event, run-up calculations show an elevation of 23.6 feet NAVD. This elevation is exceeds the dune crest on the north side of the existing dunes. Evidence of this run up elevation can be seen in substantive dune erosion fronting the site in the 1984 event over a year after the event. The storm duration however was not long enough for the dune to disappear entirely (Figure 7).

[7] Seymour, R, 1996. Wave Climate Variability in Southern California. Journal of Waterway, Port, Coastal, and Ocean Engineering, July/August 1996, pp. 182-186.

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Figure 7. 1984 Color infrared air photo. The photo shows dune erosion fronting the entire site associated with the largest historical storm event, erosion appears most severe in the northern portion of the site.

Results of the FEMA wave run-up calculations show that a small change in the assumptions of beach slopes based on observations in front of the site put wave run up elevations in excess of the dune crest today and a risk of coastal flooding to the proposed Puente site. This is not discussed or mentioned as a potential outcome in the FSA and deserves consideration as the fragile dunes fronting the site may not be as resilient as depicted in the FSA.

Sea Level Rise

The science around climate change and most relevant to this project of sea level rise is constantly evolving. The FSA primarily uses a projected sea level rise range of 0.39 feet to 2.0 feet by 2050 considering only a 30-year time horizon for the plant. It is important to note that the Mandalay Generating Station has been operated for roughly 60 years, and many of the state guidance documents recommend that industrial facilities and critical infrastructure be analyzed for 100 year timeframes. All of the state guidance recommends at the very least considering the worst case scenario in the range of scenarios. At the very least, the evaluation should consider a 60-year operational life to 2080, the same as the current MGS plant.

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The most recent science available on sea level rise changes along the coast of California comes from Cayan et al 2016.[8] This recent study, funded by the CEC, identifies probabilities associated with different future sea level rise hazards by decade (50%, 95%, 99%) and examines multiple emissions scenarios called Relative Concentration Pathways (RCP) (RCP 8.5 and RCP 4.5) as part of the 4th California Climate Assessment. This new science suggests that the rate of sea level rise and the ranges may be higher than previously considered. The worst case scenario by 2100 has the 1% chance of sea level rise elevations projected to reach between 4.5 and 9.5 feet above 2000 levels.

On October 10th, 2016, the Climate Action Team Research Working Group released the latest guidance for selecting sea level rise (SLR) scenarios for California's 4th Climate Change Assessment.[9] This guidance, based on the same modeling efforts from Cayan et al., 2016, recommended using the RCP 8.5 50th, 95th, and 99.9th percentile projections for planning horizons before 2060, and RCP 4.5 and 8.5 (50th, 95th, and 99.9th percentile) beyond 2060.

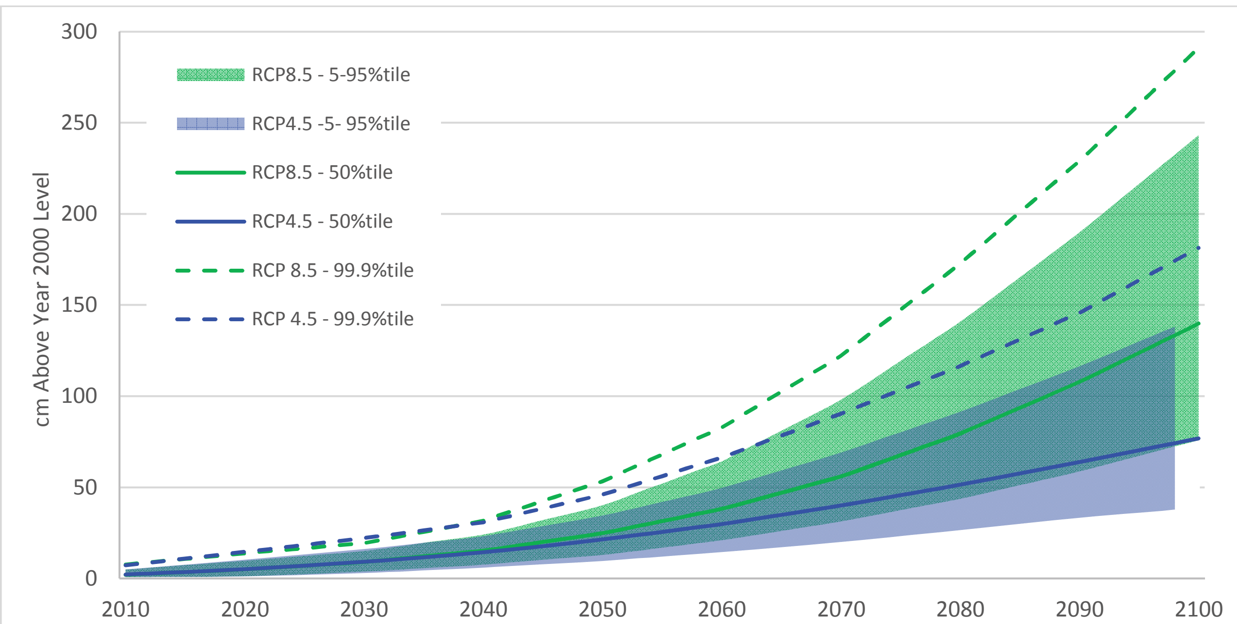

Figure 8. Projections for 5 climate scenarios for mean annual sea-level rise 50th %tile (solid lines), bounded by the 95th and 5th %tile projections (shaded in same color as 50th %tile)

This data and implications have not been included in the assessment of impacts to the proposed project and warrant additional discussion and consideration. The following sections discuss the effect of sea

[8] Cayan, D., Kalansky, J., Iacobellis, S., Pierce, D. (2016). Creating Probabilistic Sea Level Rise Projections. 4th California Climate Assessment for the California Energy Commission.
[9] Franco, G., Anderson, J., Wilhelm, S., Bedsworth, L., Anderson, M. (2016). Sea Level Rise Scenarios for California's Fourth Climate Assessment. California Energy Commission.

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level rise on the FEMA flood maps and the deficiencies in the FSA's approach to analyzing risk from sea level rise at the site.

FEMA and Sea level Rise

FEMA does not currently incorporate sea level rise into the Flood Insurance Rate Maps (FIRMs). However, given that there is a need to improve modeling and have multiple lines of evidence to assess coastal hazards in the face of climate change, the California Department of Water Resources and Ocean Science Trust commissioned a technical manual documenting a preferred method of escalating the FEMA flood maps with sea level rise.[10] Without going into the technical details, the methodology elevates the flood elevation, applies a geomorphic function that shifts the shoreline based on the effect of sea level rise on the total water elevation, and then provides a method to evaluate what implications the change in flood depth over the adjusted profile has to change the inland extent of the high velocity VE zone.[11] The geomorphic function is based on the erodibility of the backshore and for this purpose the dunes were considered erodible.

Following the methods laid out in this technical manual, I calculated the VE zone under current conditions (using the 2016 topographic data) and projected the Preliminary FEMA coastal hazard maps in the future, taking into account sea level rise assumptions for 2050 (1' and 2') and 2100 (4.5 and 9.5 feet.[12] (Table 3 and Figure 9). Results in Table 3 are shown for the Upper transect (which is the transect closest to the proposed site). Figure 9 shows the results of the Composite slope analysis on the 2016 topography for all transects.

Table 3. Results of the sea level rise adjustment to the FEMA VE zone (Feet, Elevation NAVD)

Year	Sea Level Rise	Profile Transgression*	Flood Elevation	2016 Elevation at transgressed profile	Depth of flooding (negative freeboard)	Extension of Vzone from depth of flooding (Composite slope)	Extension of Vzone from depth of flooding (Cox and Machemehl)	Inland shift in Vzone (Composite)	Inland shift in Vzone (Cox and Machemehl)
2016	0	0	20	19.8	0.2	45.0	10.0	45.0	10.0
2050	1	75	21	20.3	0.7	84.2	18.7	159.2	93.7
2050	2	150	22	17.9	4.1	203.7	45.3	353.7	195.3
2100	4.5	337.5	24.5	12.7	11.8	345.7	76.8	683.2	414.3
2100	9.5	712.5	29.5	8.2	21.3	464.4	103.2	1176.9	815.7

* Based on measured shoreface slope of 1:75 using a 40' closure depth

[10] ESA 2016. Relating Future Coastal Conditions to Existing FEMA Flood Hazard Maps: Technical Methods Manual. Prepared for California Department of Water Resources and the California Ocean Science Trust. Pp 114.

[11] ESA 2016. Relating Future Coastal Conditions to Existing FEMA Flood Hazard Maps: Technical Methods Manual. Prepared for California Department of Water Resources and the California Ocean Science Trust. Pp 114.

[12] Cayan, D., Kalansky, J., Iacobellis, S., Pierce, D. (2016). Creating Probabilistic Sea Level Rise Projections. 4th California Climate Assessment for the California Energy Commission.

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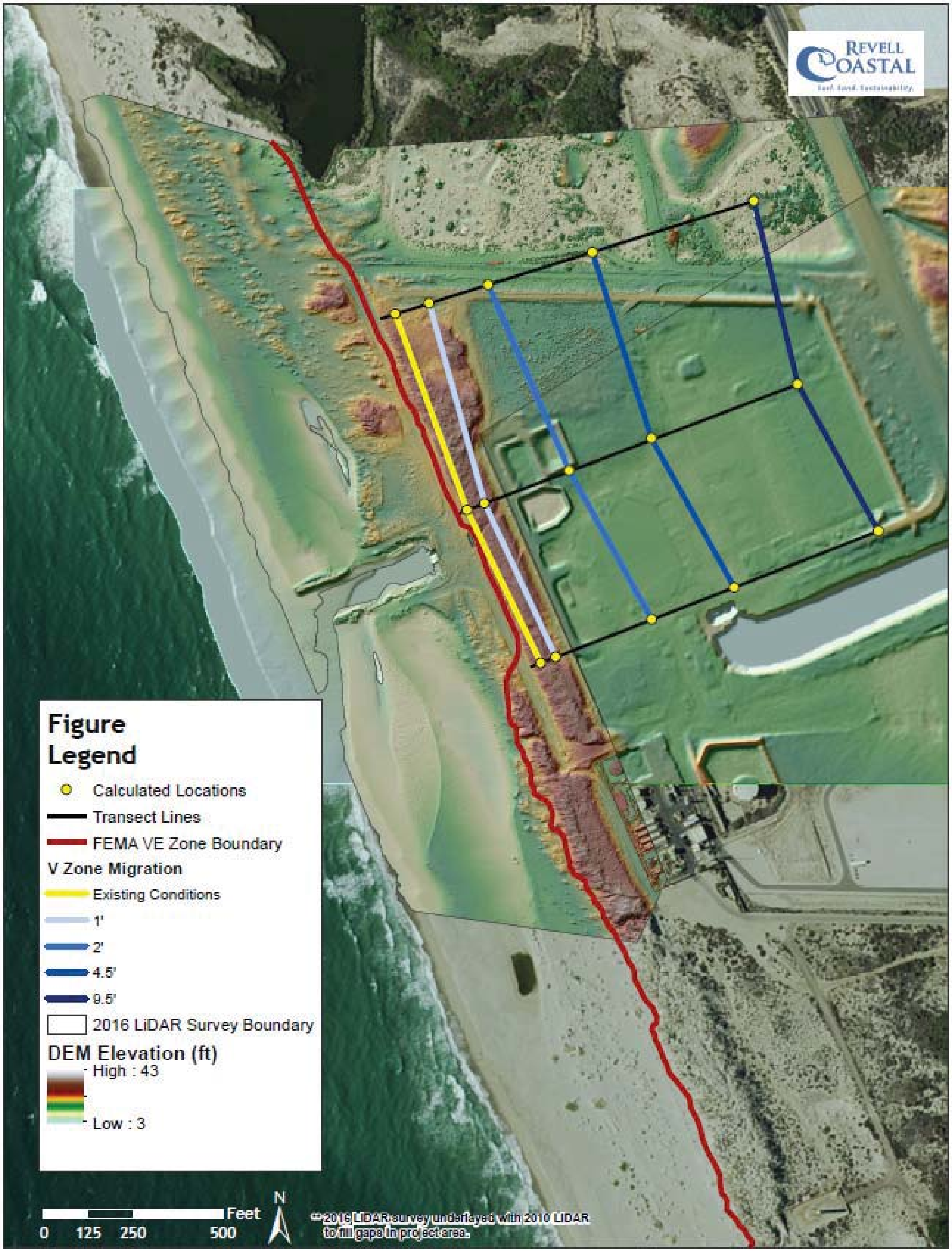

Figure 9. FEMA results with revised topography, showing future VE zones with sea level rise.

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The data show that the VE/Run-up zone intrudes well into the site during the lifetime of the project.

Coastal Hazards and Sea Level Rise Modeling

To interpret sea level rise and coastal hazard model results and make them useful requires an understanding of the methods and assumptions used to develop the projected hazard zones. To date the only model that integrates coastal erosion and coastal flooding with sea level rise is the TNC model. This model is also extensively documented. [13]

The FSA, despite substantial intervenor comments submitted during the PSA, continues to misrepresent the various models. Appendix SW-1- Figure 2, which has not been updated since the PSA, misrepresents the Coastal Resilience, Pacific Institute, and Cal Adapt work with respect the modeling method, and organization/sponsors (e.g. County of Ventura also funded the Coastal Resilience work).[14] For example, the TNC model uses a statistical 100-year storm event to predict erosion, NOT the event of record which is used for the coastal flood calculation. The FSA also asserts, incorrectly, that the COSMOS model it relies on takes into account long term shoreline change. It does not. Specifically, the COSMOS model does not evaluate long term dune erosion.

USGS COSMOS 3.0

The FSA analysis of sea level rise impacts focused primarily on the DRAFT preliminary analysis of COSMOS 3.0. Staff chose to use the Coastal Storm Modeling System (CoSMoS 3.0) because, it claims the model "projects Southern California coastal flooding and erosion due to both sea level rise and storms driven by climate change." (4.11-51). However, the COSMOS 3.0 preliminary data is a largely undocumented model that does NOT integrate coastal storm erosion and coastal flooding, NOR does it account for long term erosion caused by sea level rise.[15]

The FSA reports that the future flood risk based on COSMOS 3.0 PRELIMINARY DATA would be between a low and medium risk (4.11-2). In the staff response to comments (#19, #30, #31) which rely on Appendix SW-1 "Erosion Potential of Dunes" this acknowledgement alone shows a misunderstanding of the modeling done by the USGS in COSMOS 3.0. Presently there is no COSMOS 3.0 module that models the extents of future coastal erosion on dunes and the subsequent impact on coastal flood extents.

In addition to its lack of documentation, there are several problems with COSMOS 3.0. First, the model itself is a downscaled global climate model that does not use any local historic events to verify its results

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13 ESA PWA 2013. Coastal Resilience Ventura – Technical Report for Coastal Hazards Mapping. Prepared for the Nature Conservancy, 7/31/2013, 59 pgs. http://maps.coastalresilience.org/ventura/methods/CRV_Hazards_Mapping_Technical_Report.pdf

14 Appendix SW-1, Table 3.

15 In Appendix SW-1, 4.11-129, there is reference to TWLpx indicating that potentially a beta version or some additional methodological document was made available in advance, yet no citation is given leaving the reader and interpreter of the FSA with no information to evaluate the methods.

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or assumptions. The sea level rise model includes four separate modules: shoreline change, coastal flooding, storm erosion, and cliff erosion, but does not evaluate the combined impact of these processes working together. The technical documentation for this draft model is virtually nonexistent aside from some "fact sheets" and powerpoint presentations.[16] USGS 2016, cited in the FSA, is a powerpoint presentation that contains some general methodological approaches and describes what data would become available in the future once the FINAL data was available. To date, the FINAL data is not available for Ventura County nor is the technical documentation available. As a result, it is impossible to conduct a thorough review of the methods and assumptions of the COSMOS model or to interpret its results.

Second, there is no long-term dune erosion or dune evolution model within COSMOS. This is a noted shortcoming of the existing COSMOS model because it assumes development erodes differently than sand.[17]

The integration of the USGS modeling modules between erosion, shoreline evolution and coastal flood hazards is not expected until February 2017 (NOTE that every COSMOS delivery date has been delayed by months to a year. The only available COSMOS 3.0 final data applicable for the proposed Puente site is the COSMOS COAST model, a Mean High Water shoreline evolution model. This model has serious short-comings, in particular, its reliance on a relatively short timeframe to determine shoreline changes. Specifically, to calibrate the model, COSMOS-COAST used historic shorelines from the time period 1995-2011,[18] a short time period of relatively high sediment discharge from the Santa Clara, average dredging from the Ventura harbor and reduced dredging downdrift at the Channel Islands Harbor (see section on sediment supply). This time period shows accretion at the COSMOS Coast transect of 1.1681 meters/year. In contrast, another published, documented and well cited USGS study on historic shoreline change data for the California coast measured shoreline change rates at the same proposed location. Results from that completed study show a long-term accretion rate (1870s to 1998) of 0.79 meters/year and a short-term accretion rate (1970s to 1998) of 0.34 meters/year (Hapke et al 2006). The lack of a longer time horizon to train the COSMOS COAST model using all available shoreline data biased the results of the COSMOS COAST model toward substantially less erosion in the future and casts doubts on the accuracies of the projections.

The FSA dependence on COSMOS COAST results, DRAFT coastal flooding data without technical documentation, and misunderstanding that COSMOS 3.0 will not account for long term dune erosion raises serious questions on the validity of the projections and the sole reliance on COSMOS 3.0. Therefore this assessment of existing coastal hazards and projected future hazards is deficient and further work is warranted including incorporation of other models and further evaluation and interpretation of COSMOS 3.0 FINAL results along with the FINAL technical documentation when they

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USGS 2016 – U.S. Geological Survey. Santa Barbara and Ventura County CoSMoS Initial Results. Webinar produced by USC Sea Grant on February 9, 2016. 37Thttps://uscseagrant.webex.com/uscseagrant/lsr.php?RCID=656eb6fbeb97c93c7e6b386 6d52e9a4037T accessed March 11, 2016.

[17] Personal communication, USGS 12/15/2016. (With Li Erickson, Andy O'neill, and Patrick Barnard)

[18] Personal communication USGS 12/15/2016.

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become available to determine whether there will be substantive exposure of the Proposed Puente plant to coastal hazards in the future.

In light of only having DRAFT unintegrated data, best practices would require analysis of all available information, including the COSMOS 1.0 results, and any other models (e.g. TNC work, Pacific Institute, FEMA escalated with sea level rise) relevant to assessing coastal hazards in the area. As a result, the section on shoreline change and shortcomings of the modeling (4.10-112 to 4.10-114) is not well documented. The reliance on a draft model and failure to integrate other tested approaches suggests a lack of due diligence in the FSA that likely overlooks some of the potential significant future impacts not to mention the existing coastal hazards.

The Nature Conservancy - Coastal Resilience Ventura

The TNC AND Ventura County (not the City of Oxnard) funded the modeling work to support regional adaptation planning, decision support, site specific conservation acquisitions, and sea level rise planning. This model was completed in final form in 2013 and is publicly available along with a substantive technical documentation report. The model was designed to address exactly the factors stated by the Staff in the FSA to justify COSMOS, "because it projects Southern California coastal flooding and erosion due to both sea level rise and storms driven by climate change." The FSA however disregards the TNC modeling work saying it is a worst case scenario approach and overly conservative.

The staff assessment also mischaracterizes the TNC modelling work and dismisses it based on flawed reasoning. For example, Appendix SW1- Figure 1 incorrectly asserts the TNC modeling work is "a FEMA overtopping model [that] used results projected against topographic surface composite." While the TNC model does use FEMA overtopping methods (NHC 2005), it adds in the long term shoreline change component (which COSMOS 3.0 Preliminary does not) and the impact of what most coastal scientists and engineers use as the 100 year storm of record, the January 1983 storm event. Mapping of ALL of the hazard models (USGS, FEMA, and TNC) use the same 2009 topographic data for mapping.

The rationale set forth in the staff assessment (at page 4.10-108) for ignoring the final TNC modeling results is flawed for the following reasons:

The FSA asserts that the TNC model is "too conservative" because it incorporates "historic event" data. However, the TNC modelling is recognized by the state as an appropriate method for assessing risk from coastal hazards (CCC 2015). Moreover, the draft COSMOS 3.0 model does not analyze *any* storm events based on observed data. COSMOS 3.0 is completely derived from statistical downscaling of global climate models to the Ventura area. By relying solely on COSMOS 3.0, the staff assessment therefore ignores 35+ years of measured data and the well acknowledged storm of record in the project area in favor of Preliminary downscaled modeled data.

The FSA criticizes the TNC model for relying on a "maximum storm wave of unlimited duration." However, this method is consistent with the FEMA Pacific Coast Flood guidelines using the modified

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Komar and Allan approach to evaluating storm induced dune erosion.[19] Presently the COSMOS results utilize a synthetic time series of waves and tides (XBeach) to drive its hypothetical beach and a non erodible shoreline to stop its storm induced dune erosion model. The challenge with the XBeach model approach is that if you alter the time series of waves and tides you get very different results. 100 year storm events (i.e. 1982-83 and 1997-98 and 2015-16 El Niños), were not single events, but rather a sequence of events. Assuming that, with sea level rise, increased water level elevations during storms is longer than current conditions seems a prudent choice when facing so many uncertainties associated with future sea level rise conditions. Instead, the FSA relies on a single 100-year event impacting the wide sandy beach that existed in 2009. This is inconsistent with FEMA guidelines for evaluating potential storm flooding.[20]

The FSA also criticizes the assumption that “areas eroded assumed flooded.” However, this conclusion is completely rational. During any event that causes dune erosion, the entire beach must be underwater at some point and thus flooded. It is physically impossible for a dune to erode from waves and for the beach to remain dry.

Finally the FSA asserts that the TNC model treatment of “flood connectivity” is wrong. However, the TNC method of mapping is consistent with the same method that NOAA uses for mapping of coastal flooding in their SLR viewer with the added improvement of better topographic information and a smaller distance for assuming connection (only 10 feet in the TNC model). The Preliminary COSMOS 3.0 flood data for example doesn’t provide any technical documentation for how they map and clean the resulting model outputs so it is difficult to evaluate what their approach may be. With the TNC model results, one knows what was done and can evaluate the implications in the model interpretation. COSMOS 1.0 data shows that a single 100-year event can cause 206 feet of shoreline change.

To date the TNC modeling and mapping work is the only modeling that incorporates shoreline change from sea level rise with coastal erosion and storm hazards to the proposed project site. The vast differences between the TNC, COSMOS 3.0, and FEMA are largely that the FEMA and USGS work either don’t include sea level rise or coastal erosion (FEMA), or don’t account for long term shoreline evolution with short term coastal flooding hazards (COSMOS 3.0). Given uncertainties associated with each modeling approach, each model should be evaluated and incorporated into the project analysis.

[19] NHC 2005 – Northwest Hydraulic Consultants, prepared for U.S. Federal Emergency Management Agency. Final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States. January 2005.

[20] As another validation of the TNC model is available from aerial photographs of the site that were presented during the PUC hearing. (Figure 7). The TNC model relied on the 1983 wave and water level parameters from the largest storm in the historic record (Seymour 1996) (~100 year erosion event) and calculated dune erosion of 125 feet. (Note that erosion from a statistical 500 year erosion event was projected to cause 150 feet of dune erosion). While there are no direct measurements of dune erosion impacts from the 1983 event, the air photos used by NRG at the CPUC hearing from 1984 showed substantial erosion of the entire dunes fronting the proposed Puente Site (Figure 7).

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Riverine flooding

The FSA document relies on the FEMA FIRM map to determine flood potential to the site. It should be noted that the site previously was flooded during the 1969 flood resulting in the increase of an earthen levee along the northern boundary at an elevation of 18' NAVD. This flood event had regional impacts to the power grid (Figure 10.)

In consideration of potential impacts of climate change on the riverine flooding, the FSA states that the Santa Clara River is two miles away, however in the recent decade, the river has come within 1 mile of the Puente site (Barnard et al 2009), and the Preliminary FEMA map referenced throughout the FSA (Appendix SW-1 Figure 7) shows a Santa Clara River breakout less than ~300 feet north of the Puente site (NOTE: SW Figure 7 has no scale bar).

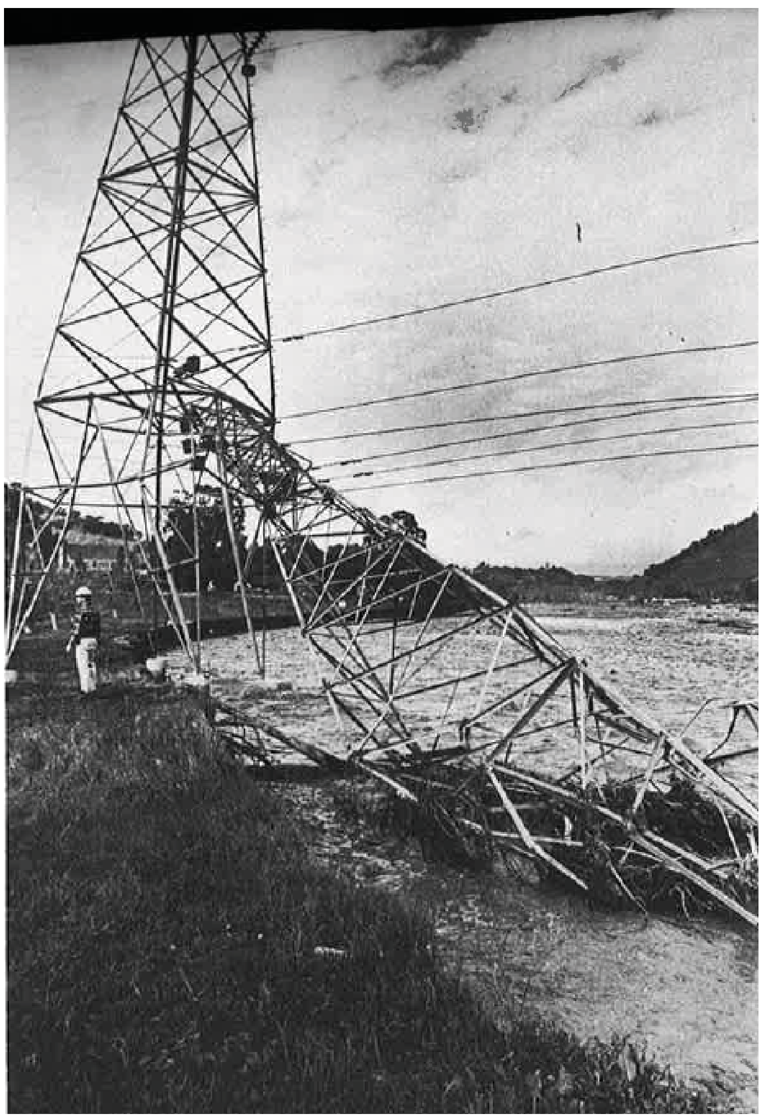

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Figure 10. Flood damages to electric infrastructure during the 1969 Flood in Ventura County.

Tsunamis

Presently the FSA, reports that the proposed location is not subject to existing tsunami inundation hazards. However the executive summary notes that,

> *"the best estimates of sea level rise near the end of the life of the facility, coupled with the maximum estimated tsunami wave height, suggest there maybe less than one vertical foot of separation between the minimum site elevation and mapped inundation zone."*

While it is not clear what the source of the tsunami information used in the FSA includes (no citations are provided), the City has begun emergency planning preparations using the 2014 California Geological Survey maps of tsunami inundation which was based on a nearfield tsunami caused by the Goleta 2 landslide (CGS 2014). Additional work by Everest Coastal on tsunami hazards has been completed in support of the Oxnard LCP update that evaluates the 2011 Japanese tsunami, the Goleta 2 landslide derived tsunami, and a new tsunami source located in the immediate vicinity of the proposed Puente site which would be the triggered by an earthquake on the Pitas Point and Red Mountain Fault.[21] For all of the tsunami work completed to date, none of them consider any erosion of the dunes that would likely occur upon tsunamic impact, so all of these maps likely underpredict the potential damages from a tsunami.

The Goleta 2 landslide scenario would trigger a tsunami 12 feet high with a projected run-up elevation of 14.6 feet. With the various sea level rise scenarios added to this run up elevation, it is possible to see up to 16.4 feet of wave run up by 2050 and 24.1 feet by 2100 under the worst case scenario of sea level rise.[22]

Recent research published in the Journal of Geophysical Research Letters by UC Riverside and U.S. Geological Survey scientists in 2015[23] provided new consideration for local tsunami inundation in the Ventura region (Figure 11). This information is NOT considered in the FSA. The study used a three-dimensional dynamic model to predict the tsunami associated with an earthquake and fault slip along the Pitas Point and Lower Red Mountain Faults offshore of Ventura. Based on the results of the scenario presented in the publication, the tsunami heights along the Oxnard coast were found to be in the range of approximately 13.1 to 23.0 feet leading to a tsunami inundation level of between 17.6 and 27.5 feet. If the high end of this tsunami run up elevation proved true, that would place the proposed Puente Site in a tsunami hazard zone today. If the worst case scenario of sea level was realized,[24] then the potential

[21] Ryan, K. J., E. L. Geist, M. Barall, and D. D. Oglesby (2015), Dynamic models of an earthquake and tsunami offshore Ventura, California, Geophysical Research Letters, 42, oi:10.1002/2015GL064507; Everest 2017, Oxnard LCP Update – Sea Level Rise Vulnerability Assessment Tsunami Analysis, January 16 pages; Figure 11.

[22] Cayan, D., Kalansky, J., Iacobellis, S., Pierce, D. (2016). Creating Probabilistic Sea Level Rise Projections. 4th California Climate Assessment for the California Energy Commission.

[23] Ryan, K. J., E. L. Geist, M. Barall, and D. D. Oglesby (2015), Dynamic models of an earthquake and tsunami offshore Ventura, California, Geophysical Research Letters, 42, oi:10.1002/2015GL064507.

[24] Cayan, D., Kalansky, J., Iacobellis, S., Pierce, D. (2016). Creating Probabilistic Sea Level Rise Projections. 4th California Climate Assessment for the California Energy Commission.

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tsunami run-up elevations could reach between 19.6 and 29.5 feet by 2050, and 27.1 and 37.0 feet by 2100 (Figure 11).[25]

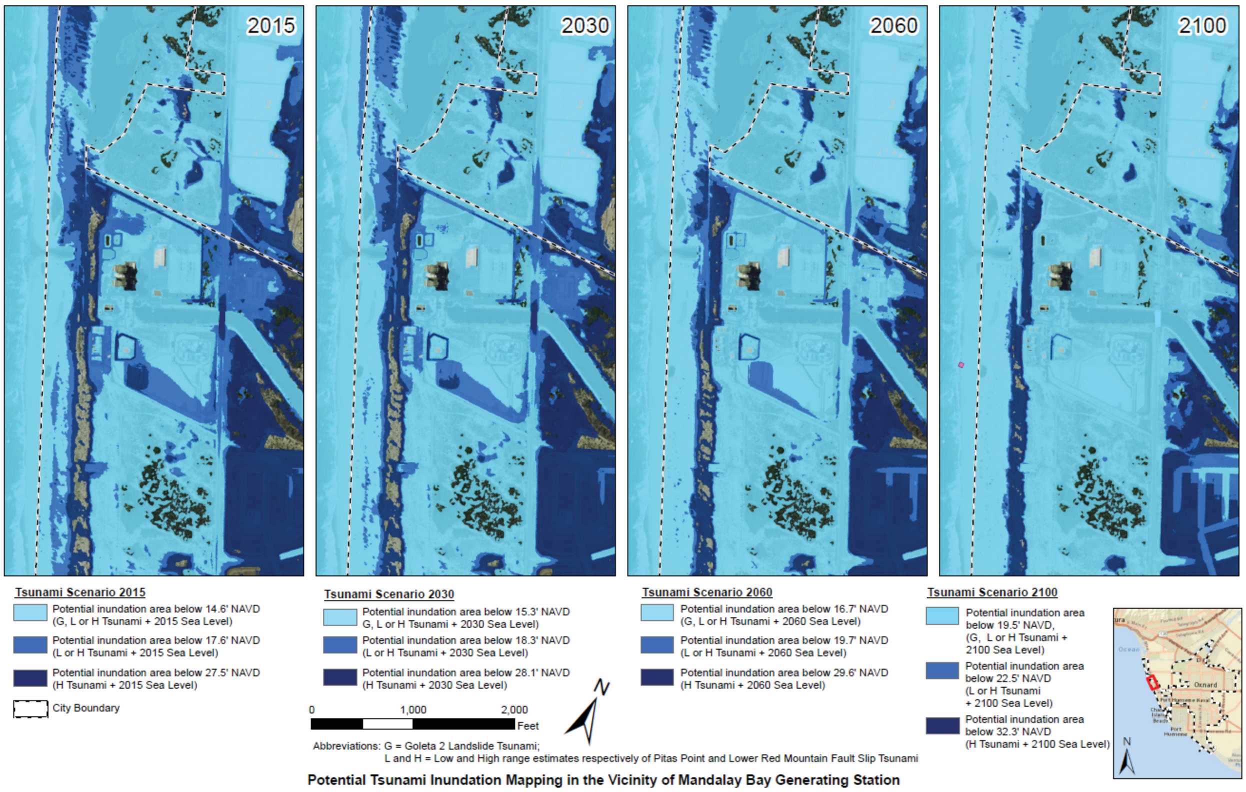

Figure 11. Tsunami inundation associated with an earthquake on the Pitas Point/Red Mountain Fault (Everest 2017).

An earthquake with an epicenter on the Red Mountain Fault could have multiple impacts to the proposed site. The first would be damages to the Puente site from the shaking, potentially causing liquefaction. From the FSA it is not clear what seismic shaking parameters were considered in the structural design. But the site is clearly in a liquefaction zone.[26] Second, the shaking could down transmission lines. The worst case scenario analyzed in the FSA included down transmission lines in one direction. In reality, transmission lines would likely be downed in all directions. If Puente is constructed, then the majority of local generation resources needed for recovery from a major earthquake event (Puente, McGrath, Mandalay 3) are all concentrated in the same small area that is highly vulnerable to a tsunami following that event -- threatening the long term reliability of the region.[27] This was not included in the FSA analysis. Third, the earthquake would likely generate a tsunami capable of reaching

[25] Everest 2017. Oxnard LCP Update – Sea Level Rise Vulnerability Assessment Tsunami Analysis, January 16 pages.
[26] Excerpted Draft Background Report, City of Oxnard General Plan, Figure 6-1.
[27] The downed transmission lines (Figure 10) would also violate Executive Order 11988 FFRMS which specifically affect the site, the local communities and the 3 ports and harbors located immediately adjacent to the site. Executive Order 11988.

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up to 27.5 feet run up (Ryan et al 2015, Everest 2017). This is much larger than the tsunamis analyzed in the CGS mapping which focused on a localized Goleta 2 submarine landslide (CGS 2014).

In summary, an earthquake on the Red Mountain Fault would quite likely down multiple transmission lines, liquefy the saturated sediments on and near the site, and generate a damaging tsunami. All of these are additional hazards beyond those which were analyzed in the FSA and would limit emergency response, economic recovery, and threaten human life.

Regional Climate Adaptation

The failure to evaluate the impacts of the Puente project over a longer time frame also has implications for climate adaption efforts in surrounding communities. Besides the facility itself, all of the communities, infrastructure and utilities that rely on the existing power plant (from Moorpark to Goleta) are forced to make long term community decisions based on these existing utility alignments rather than considering more progressive forms of adaptation, such as management retreat. Community adaptation choices based on current energy utility alignments will narrow the ability to think outside the box and likely lead to climate maladaptation. This interference with the ability of communities to implement climate adaption policies is a significant long term impact throughout the region but particularly to the adjacent communities of Oxnard and Ventura County. Presently the following communities and entities are in various states of planning and preparation for climate change impacts. This may not be an exhaustive list but adaptation planning and policies will be directly influenced by the utility infrastructure.

- County of Ventura – Local Coastal Program update
- City of Oxnard – Local Coastal Program update (jurisdictional City)
- State Parks – Managed retreat at McGrath State Park (adjacent neighbor)
- City of Santa Barbara – Local Coastal Program update and Adaptation
- City of Carpinteria – Local Coastal Program update and Vulnerability Assessment
- County of Santa Barbara – Local Coastal Program update
- City of Goleta – General Plan and Local Coastal Program update and Adaptation Planning

The FSA downplays all of these potential coastal hazards stating that Puente is not a critical facility. Regardless of whether Puente itself is critical, the facility presents a physical impediment to climate adaptation strategies in Oxnard and the surrounding communities. It also commits public resources to the construction of energy infrastructure in an area that will be effected by sea level rise. Although the FSA differs as to whether this impact from sea level rise will occur prior to 2050, all estimates of sea level rise after that time (including the FSA) put this site at risk. Committing public resources to infrastructure in a location that cannot meet long-term energy needs and that physically interferes with adaptation efforts makes no sense. Maladaptation as it is called is frowned upon by all of the State guidance documents.

In accepting that there remains some risk, the FSA conditions a Dune monitoring plan for the site without any future shore protection structure. However, the City of Oxnard and the California Coastal Commission are the regulatory bodies allowed to permit Coastal development Permits for beach nourishment. Typically, adaptation (or mitigation) strategies to coastal hazards require either a structure (seawall or revetment) or beach nourishment (placing of sand. Without seawalls or dune construction,

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there are limited strategies to ensure dune stability without placing sand. However, the most effective strategy is to avoid the hazard in the first place. There are alternative sites to the proposed site that completely avoid existing and future coastal hazards.

Figures

1. Site topography from 2016
2. Cover of the FSA
3. Topographic changes between 2016 and 2009
4. Photo of King tide at dune toe
5. BEACON beach profiles
6. Morphology figures – Beach profiles for three transects
7. 1984 Air Photo
8. Sea level rise curves from Cayan et al 2016
9. FEMA VE Zone migration for various sea level rise elevations with negative freeboard
10. Picture of downed power lines (1969 flood)
11. Tsunami inundation at Proposed Site

Tables

1. Geomorphic variability across the site
2. Beach slopes versus run up elevations
3. VE zone calculations using ESA 2016 methods

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The foregoing report represents my testimony in this matter. My qualifications are attached to this report as an Exhibit.

______________________________ _______1/18/2017____________

Signature Dated

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DAVID L. REVELL, Ph.D.

Principal / Chief Coastal Scientist

Dr. David Revell is a coastal geomorphologist with 20+ years of experience studying marine, coastal and estuarine processes, in particular in the science and management of coastal processes and climate change. He has been involved in a wide variety of contentious community stakeholder processes ranging from evaluating erosion hazard alternatives to climate change vulnerability impacts to lagoon and fisheries management, water quality, and marine spatial planning. Much of his work involves physical process research, and GIS to facilitate communication of science to inform decision making. Dr. Revell has been active in many ground breaking climate change projects including the technical hazards work for the Pacific Institute, The Nature Conservancy's Coastal Resilience projects, and collaborative work in the Monterey Bay region looking at adaptation economics. Dr Revell is currently engaged in many vulnerability and adaptation studies along the California Coast that are in various stages of preparation for the LCP updates. Some of these jurisdictions include: Imperial Beach, Port of San Diego, Carlsbad, Santa Monica, Oxnard, Santa Barbara (city and county), Goleta, Los Osos, Pacific Grove, Monterey (city and county), and Santa Cruz County. He has served as a technical advisor to multiple, state, federal and local jurisdictions related to ocean and coastal management especially at the intersection of how physical processes and human alterations affect hazards, habitats, and human use. David currently advises multiple local jurisdictions on climate change, beach, dune and coastal sediment management, and lagoon processes and inlet management.

Education

Ph.D., Earth Sciences, University of California, Santa Cruz 2007

M.S., Marine Resource Management, Oregon State University 2000

B.A.s, Geography and Environmental Studies, University of California, Santa Barbara 1996

Selected Work Experience

Principal and Chief Scientist, Revell Coastal, LLC *July 2014 - Present*
Founded company to provide scientific and technical consulting services to coastal management agencies, local jurisdictions and non-profit organizations. Communicates the best available science to inform better coastal management decisions. Specific project work includes climate change vulnerability and adaptation planning, regional sediment management, and coastal lagoon management and restoration.

Senior Coastal Geomorphologist, Environmental Science Associates (formerly Philip Williams & Associates), *Jan. 2008 –July 2014*
Managed projects and lead technical analyses on projects related to climate change, coastal lagoons, coastal restoration, sea level rise vulnerabilities, adaptation planning and coastal regional sediment management .

Adjunct Professor, Monterey Institute of International Studies, *Aug. 2013 to May 2014*
Co-instructed graduate level courses on International Marine Science and Policy and Sustainable Coastal Management. Assist with framing the strategic planning for the Center for the Blue Economy with specific emphasis on climate change opportunities.

Project Scientist, Marine Science Institute, UC Santa Barbara – *June 2009 – Present*
Coastal research scientist collaborating on a Seagrant investigation of changes to the sandy beach ecosystems in Southern California. Responsible for physical process field data collection, evaluation of historic trends in shoreline and sand volume changes to integrate with ecological changes. Managed graduate student researcher summer 2009 and 2010.

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Coastal Scientist, CoastalCOMs & Business Development, Coastal Watch USA, ***Jan. 2008 – May 2012***
International business development of coastal monitoring systems for integrated coastal observation. Identification and development of coastal management data products. Applications of video imagery to nearshore processes, coastal engineering, and marine protected areas with an emphasis on integrating ocean and coastal observations. Focus on coastal processes, ports and harbors, socio-economic data collection. Supported USGS data collection efforts for projects in TRNERR, Goleta Beach, and Surfers' Point.

Postdoctoral Scholar/Research Associate – Institute of Marine Sciences, UCSC ***Apr. 2007 – April 2008***
Researched historic shoreline changez along Santa Barbara and Ventura County coasts using a variety of GIS, remote sensing and field collection techniques. Collaborated with USGS, USACE, and BEACON to assess coastal hazards and model sediment transport along the Santa Barbara coast.

Surf 2 Sea Consulting, GIS, Marine and Coastal Processes Consultant – ***Aug. 2002 – Dec. 2007***
Sole proprietor consultant. Contracted with Ecoshore International to develop a beach and groundwater monitoring plan for a passive beach dewatering system in Hillsboro FL (2007). Subconsulted with Moffat and Nichols on Coastal Processes Section of Goleta Beach Environmental Impact Report (2006). Collaborated with PWA on historic shoreline changes to Goleta Beach County Park in Santa Barbara, and helped identify alternative solutions to park protection (2004-05). Worked for oceanfront property owners to assess coastal erosion alternatives and processes affecting property boundaries (2005). Created GIS and planning databases for the City of Bandon in Oregon (2000-03). ---Completed an inventory for the Council for Environmental Cooperation on whale watch operators and guidelines (2002). --- Coordinated the Port Orford Ocean Resources Team GIS project, a community based management effort that interviewed 33 local fishermen and recreational users regarding ocean use, harvest practices, and marine conservation. Digitized interviews into GIS and facilitated socio-economic analyses with Ecotrust (2002-03).

NOAA Coastal Management Fellowship – *Aug. 2000 – Aug. 2002*
Received a NOAA Fellowship through an extended application process working as a technical advisor to the Oregon Coastal Management Program on littoral cell management planning. Developed coastal hazard GIS inventories for five jurisdictions - Coos, Curry, Lincoln, and Tillamook Counties and City of Bandon. Conducted a hazard assessment for the Bandon Littoral cell. Worked on the Oregon Coastal Atlas project as a member of the Project Development Team. This project collects pertinent GIS and database information for ocean areas, rocky shores, sandy shores, and estuaries, and facilitates various spatial analyses such as hazard assessment through a regional Internet Map Server.

Graduate Research Assistant – **Oregon State University -** ***July 1998 – July 2000***
Constructed the Netarts Littoral Cell Coastal Hazard GIS inventory for Oregon Sea Grant, Oregon Parks and Recreation Department, Oregon Coastal Management Program, and Tillamook County. This involved survey fieldwork, data processing, GIS, and project management. Facilitated stakeholder workshops to educate, and receive feedback on GIS design and hazard avoidance strategies. Recommended mitigation alternatives to State Parks regarding the Cape Lookout Dune Restoration Project - Section 227 – Army Corp of Engineers.

Selected Project Experience

City of Imperial Beach California, Coastal Vulnerability and Adaptation Planning. *Project Director*
Revell Coastal is leading a consulting team including USC Seagrant and economists to evaluate future climate change impacts and to develop adaptation strategies for the City of Imperial Beach. As part of this work he has been recently been asked to advise the City on the management of the Tijuana River Estuary which closed this year following the El Niño for the first time in 30 years. This work will include technical

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analysis and review of research being conducted by the National Estuarine Research Reserve, and to collaborate with a variety of regulatory stakeholders.

City of Goleta, Local Coastal Program Climate Change Update. ***Project Director***
Revell Coastal worked for the City of Goleta to incorporate climate change, coastal hazards, and economics into the Local Coastal Program. Technical work involved modeling, fieldwork, model interpretation, and economics. Policy work was focused on the City's Safety and Conservation Elements from their General Plan and included additional technical fieldwork and review of existing scientific literature.

City of Santa Cruz, San Lorenzo Lagoon Outlet Channel. ***Project Director***
During emergency lagoon flooding conditions amidst a regulatory stalemate, Revell Coastal provided on site guidance to construct a temporary outlet channel and reduce lagoon water levels to alleviate flooding while avoiding a rapid dewatering to the lagoon which could have resulted in take of multiple listed species. Revell Coastal continues to advise the City on lagoon mouth management, sand management and lagoon function.

Goleta Slough Management Committee. Goleta Slough Ecosystem Management Plan Update and Sea Level Rise Study, Santa Barbara, California. ***Project Manager.*** Dr. Revell working with ESA PWA conducted a sea level rise vulnerability and adaptation study for the Goleta Slough. This sea level rise study was incorporated into the Ecosystem Management Plan Update. The work consisted of evaluation of climate related impacts including identification of vulnerabilities to both infrastructure and habitats. Following a series of focus groups, a series of appropriate adaptation strategies were identified including proposed revisions to relevant policies. The entire processes included substantial outreach and education of technical information to planners, elected officials and regulatory agencies. This project was recently awarded the American Planning Association – Central Coastal Chapter award for outstanding regional planning.

The Nature Conservancy, Ventura Climate Change Ecological Vulnerability Assessment, Ventura, CA. ***Project Manager.*** Dr. Revell working with ESA PWA conducted climate change modeling that examines changes to coastal hazards of flooding and erosion from sea level rise and increased storminess on the Ventura coast. This included modeling changes to sediment yield and fluvial flooding using HEC-RAS by examining changes to precipitation. The coastal and fluvial changes were used as inputs to drive an ecological vulnerability assessment using SLAMM (Sea Level affecting Marsh Model). The technical modeling supports community adaptation planning as well as The Nature Conservancy conservation acquisition program along the Ventura County coast and Santa Clara River Parkway.

Santa Barbara County Land Trust and UCSB. Ocean Meadows Golf Course – Upper Devereux Slough Restoration, UC Santa Barbara, California. ***Project Manager.*** Dr. Revell working for ESA PWA conducted three phases of conceptual design work to inform the restoration of the Upper Devereux Slough which had been filled in the 1960s to construct a golf course. These first three phases of work improved upon a 2000 Bren School report on the restoration. The first phase evaluated the historic ecology and provided geomorphic interpretation to support restoration of an upland mesa adjacent to the golf course and to ascertain whether the volume of material estimated in the Bren report to be excavated from the golf course could be accommodated on the upland mesa site. The second phase included geomorphic interpretation and initial engineering including conceptual design and cost estimates of an initial grading plan for the upper slough restoration based on the findings that the volume of material required for excavation from the golf course were about half of that calculated in the Bren School report. The third phase focused on hydraulic analyses to specifically examine the potential impacts of the restoration both from the potential to cause scour and damages to the primary access bridge and to also model future water levels and likely functioning of the slough. This work also provided input and guidance on necessary technical studies and recommendations on consideration for future engineering and design.

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Monterey Bay Sanctuary Foundation, Monterey Bay Sea Level Rise Vulnerability Assessment, Monterey and Santa Cruz Counties, CA. ***Project Manager.*** With funding from the California Coastal Conservancy, the Natural Capital Project, and the City of Capitola, Dr. Revell working with ESA PWA modeled projected climate change impacts to the coast of Monterey Bay at a scale suitable for planning purposes. Projected future coastal hazards were mapped which represented an integrated approach of stepping through time eroding the coast and flooding newly eroded areas through hydraulic connectivity. The project was advised by a Monterey Bay region wide technical advisory group comprised of research institutions (UCSC, Naval Postgraduate School, Moss Landing, CSUMB and USGS), local planning agencies (Santa Cruz, Monterey Counties, Cities of Monterey, Santa Cruz, Seaside, Sand City, Capitola), and other technical experts. The is study provided estimates of future erosion rates, flood elevations and depths of flooding at various planning horizons into the future. Uncertainty in the projections was addressed by developing a variety of projected impacts then overlapping them and developing an uncertainty index that shows relative risk of impact.

Mission Creek Lagoon and Laguna Channel Restoration. Santa Barbara, CA. ***Technical Advisor***
Dr. Revell working with ESA PWA summarized the relevant regional and local site conditions to inform the conceptual level restoration design. This work included review and analysis of relevant historic, existing and future coastal processes along the Santa Barbara Waterfront.

Audubon California, the California State Coastal Conservancy and the Department of Fish and Game, Lower Santa Ynez River Estuary Restoration, Santa Barbara, CA. ***Project Manager.*** Dr. Revell working with PWA documented historic changes in land uses, hydrology and lagoon functioning to identify potential restoration opportunities to improve the ecological health of the Lower Santa Ynez River Estuary. This assessment summarized the functioning and evolution of habitats based on existing available information and field data. The goal of this project was to identify restoration opportunities to enhance the ecologic value and ensure sustainability of native habitats in the lower Santa Ynez River corridor and estuary (approx. four river miles). One of these restoration actions was funded for design and permitting to improve southern Steelhead habitat. Funding for preliminary design was acquired from California Dept of Fish and Wildlife and design completed before Vandenberg Air Force Base decided to remove support for the project.

Scott & Waddell Creeks Bridge Realignment, Santa Cruz County, CA. ***Caltrans Project Manager.*** Currently, Highway 1 crosses Scott Creek and Waddell Creek at the interface between the ocean and the creeks' lagoons in Santa Cruz County. Dr. Revell working with ESA PWA evaluated the impact of the existing bridges and various alternative bridge designs and alignments to provide recommendations to Caltrans on design criteria to reduce long term maintenance and impacts to the coastal lagoon habitats of the planned replacement of two bridges located on Highway 1.

Surfrider Foundation, Malibu Lagoon Restoration – Impact Assessment to Surfing Resources, Malibu, CA. ***Project Manager.*** Dr. Revell reviewed technical studies related to the 2012 Malibu Lagoon restoration to assess the potential impacts of the restoration on surfing and beach conditions. Assessment included review of sediment transport, coastal processes and lagoon breaching dynamics and provided recommendations to alter the project slightly to improve benefits to surfing conditions without disrupting the project permitting and schedule.

Santa Barbara County Parks and Recreation, Goleta Beach Erosion Mitigation, Goleta, CA. ***Project Manager.*** Studied coastal processes responsible for erosion hotspot at Goleta Beach County Park. Presented research results to stakeholder groups, and participated in technical discussions evaluating erosion mitigation alternatives. Reviewed and commented on Environmental Impact Report. Developed a reconfiguration alternative to avoid erosion hazards through appropriate setbacks, and reviewed technical modeling.

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The Association of Monterey Bay Area Governments and the Monterey Bay National Marine Sanctuary, Coastal Regional Sediment Management Plan for Southern Monterey Bay, CA. ***Project Manager.*** Development of a coastal regional sediment management (RSM) plan for southern Monterey Bay and evaluation of a range of erosion mitigation strategies. RSM plans take a system wide approach to identifying sources of sediment and implementation of strategies to ensure that sediment delivery to the beaches continues.

Neskowin Shoreline Assessment, Neskowin, OR. Tillamook County, ***Project Manager***. In response to a high rate of erosion that has diminished the beaches and now threatens homes and roads in Neskowin, OR, ESA analyzed the viability of various coastal erosion mitigation strategies to an eroding shore, utilizing existing information from local academics (Oregon State University) and agencies (including the Geology and Mineral Industries Department), as well as applying our experience completing assessments for similar high-energy wave-exposed coastal areas. The community is striving to find a balance of private property protection with maintenance of a sandy beach to support the tourist economy.

Santa Barbara and Ventura County Coastal Processes Study, CA. ***Project Manager*****.** UC Santa Cruz project manager for collaborative USGS study, involving field data collection to determine historic and seasonal changes to beaches in SB and Ventura Counties.

BEACON Regional Sediment Management Plan. Dr. Revell summarized long term trends, erosion hotspots, quantified the sediment budget, recommended changes to the monitoring program and identified opportunistic project locations.

Ocean Protection Council. Coastal Infrastructure and Vulnerability Impacts Assessment. ***Project Manager.*** Mapped coastal erosion hazards resulting from sea level rise scenarios, evaluated geomorphic response of various backshore types by applying a total water level methodology, collaborated with climate change researchers at Scripps, organized and engaged peer review team on methods and results, collaborated with Pacific Institute to vulnerability assessment associated with coastal hazards. Results of this work fed directly into the Pacific Institute work called Sea Level Rise Impacts to the Coast of California.

References

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Selected Publications

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