appendix

technical memorandum 01 : coastal engineering

Prepared by:

ESA PWA

Cobble Berms: A Brief Summary in Support of the Ocean Beach Master Plan

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ESA PWA
January 20, 2012

The Ocean Beach Master Plan has identified an array of actions to mitigate coastal hazards and improve the public space. One of the elements in the Master Plan is a cobble berm to be installed in South Ocean Beach, from the vicinity of Sloat Boulevard southward to the limit of development at Fort Funston. The cobble berm is an innovative approach to allow erosion while protecting a sewer tunnel and providing public access. The report provides background information on cobble berms in support of the Master Plan report and other documents.

This report is not exhaustive in terms of identifying and considering all available knowledge. Nor is this work adequate to conclude the appropriateness of construction of a cobble berm at Ocean Beach. Additional work is needed prior to implementation.

Background:

The purpose of the cobble berm (dynamic revetment) at Ocean Beach is to "soften" the protrusion of the Lake Merced Transport Pipe that will result from shore recession. Under the Hybrid Scenario, the Lake Merced Pipe will be protected in place until it is replaced or no longer needed. Since the pipe crown is about even with the back beach elevation, it is likely that erosion will remove most of the overburden covering the pipe. The San Francisco PUC and DPW have indicated that this could allow vertical or lateral movement of the pipe, or otherwise change the loadings such that the pipe could rupture. Hence, the Hybrid plan includes a Taraval-type seawall (Figure 1) or a structural modification of the pipe itself (e.g. reinforcing the pipe internally or reducing its section and elevation).

Figure 1: Taraval Seawall. The picture shows the north end, near Santiago Street, during an extreme, eroded condition during the 1998 El Nino. Photograph © Bob Battalio, taken 1998.

Since the feasibility of these "protect-in-place" approaches have not been fully evaluated, the most intrusive to beach use is assumed, which is the Taraval-type Seawall, as depicted in the Master Plan graphics for South Ocean Beach (Figure 2).

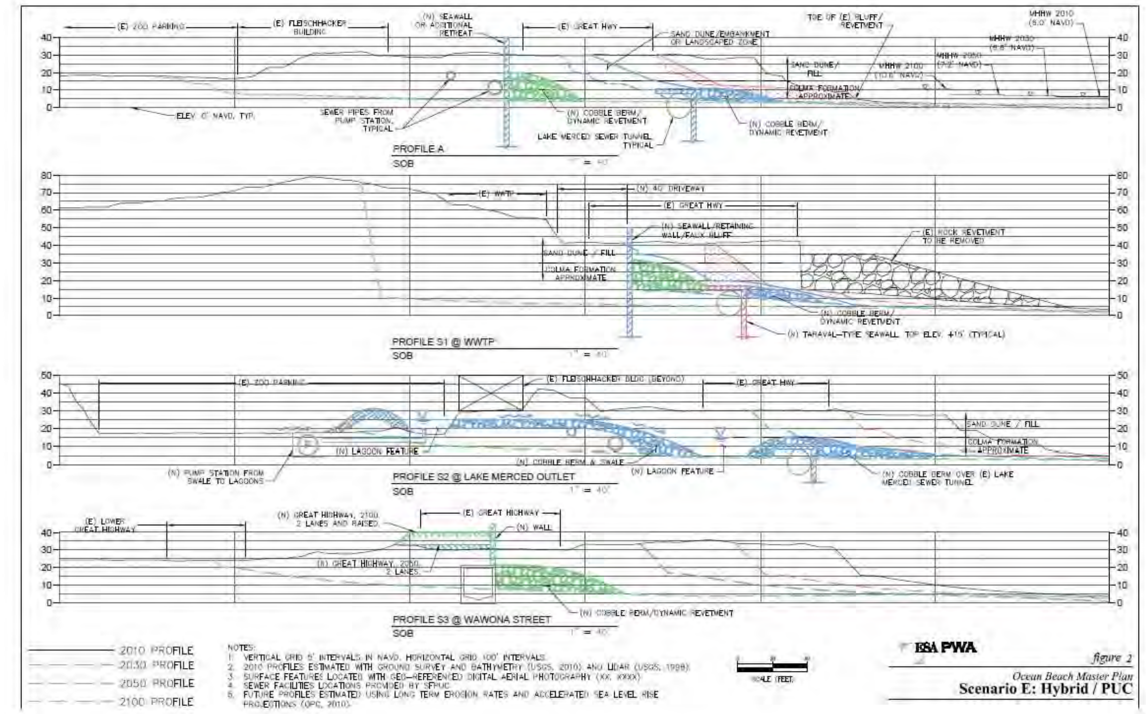

Figure 2: SOB Sections of Hybrid Scenario, Ocean Beach Master Plan.

The Lake Merced Pipe and protective structure(s) are likely to be exposed, and result in a vertical offset with the beach (similar to the condition shown in Figure 1). To mitigate this impact somewhat, a cobble berm is proposed in front of the wall. It is intended that the cobble berm would mitigate wave reflection and scour, provide a more accessible surface for people, and have a tolerable appearance. Also, the cobble berm is intended to provide a stable sill for a new outlet from Lake Merced to the beach (Figure 2, Profile S2).

In this application, the cobble berm is therefore a shore protection and hydraulic structure that is intended to provide a better balance with recreational and ecological objectives than more traditional quarry stone revetments and reinforced concrete seawalls. The cobble berm is not required to protect facilities, however, as the proposed Taraval-type seawall or structural modification of the pipe would be "stand-alone." Therefore, the proposed cobble berm could also be considered a landscaping element.

Finally, the cobble would replace the existing rubble and revetments at the site (Figure 3). The proposed extent of the cobble berm is in South Ocean Beach, generally from Sloat Boulevard southward to Fort Funston (Figure 4).

Figure 3: Picture(s) of existing rubble, SOB. Photograph © Bob Battalio, taken February 1, 2010.

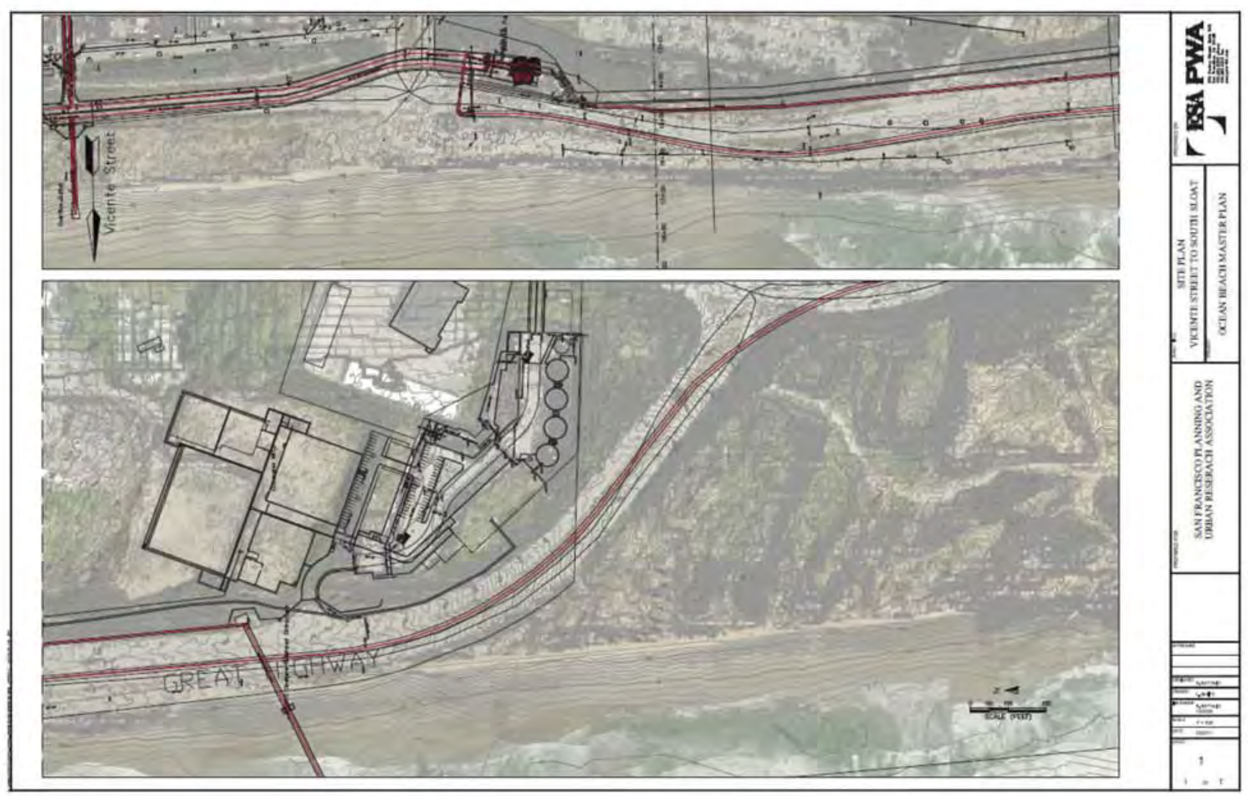

Figure 4: Plan extents of the proposed cobble berm are generally from Sloat Boulevard to the south end of the Southwest Sewer Treatment Plant, in the Master Plan region called South Ocean Beach (SOB).

Definition of a Cobble Berm, aka Dynamic Revetment

Cobble berms are mounds of rounded rock sorted and shaped by waves (Allen et al, 2005; Everts et al, 2002; Lorang, 1997; Bauer, 1974). These features are naturally occurring at locations where rock exists, such as the toe of coastal cliffs and at the mouths of creeks and rivers, and are often covered by sand some or most of the time. These features have been installed by man as a component of restoring beach morphology and ecology, and also for erosion and flood mitigation. When installed as a erosion control structure where they wouldn't otherwise exist, cobble berms are often called dynamic revetments. The term "dynamic revetment" is intended to hearken to a traditional revetment of rough, angular quarry stone that has the appearance of an engineered rock slope, like a breakwater. The term "dynamic" is intended to contrast with traditional quarry stone revetments and convey that the smaller, rounded rock (cobble) is expected to move in response to wave action. At Ocean Beach, San Francisco, the term dynamic revetment is probably more applicable. This is because the cobble berm would be introduced – cobble deposits are not known to exist at Ocean Beach.

Examples

Cobble berms and dynamic revetments have been constructed in several locations.

- Cape Lookout Oregon: A dynamic revetment was installed at Cape Lookout State Park (CLSP), Oregon, in 2000 (Allan and Komar, 2004; Allan et al., 2005; Allan et al., 2006; Allan and Hart, 2007). Allen and Komar (2004) described the design of the cobble berm, backed by artificial sand dunes, and report success in accomplishing the goal to minimize overtopping events and erosion problems at the park. The cobble berm was placed in the back of the beach with a seaward slope of 5:1 (H:V) with artificial dunes located directly behind the berm (Figure 5). Monitoring efforts have demonstrated that seasonal variations in the level of sand significantly affect the activity and transport of cobble and gravel. In the summer, when moderately gentle surf deposits sand on the beach face, the gravel-sand intercept increases and covers the larger size sediment, inhibiting the movement of cobble and gravel. In contrast, during winter months when large waves remove sand from the beach and expose underlying cobble and gravel, significant cross-shore and along-shore transport of gravel and cobble is evident. We have heard but not verified that some damage may have occurred recently (winter 2011-12).

Figure 5: Cape Lookout Cobble Berm. Source: Allan et al, 2005.

- Pacifica state beach: Pacifica State Beach is located in Pacifica, CA, just south of San Francisco. The project is an often-referenced example of managed shore retreat and realignment (NOAA, 2007a). Cobble berm and beach nourishment (cobble and sand placement) were proposed as part of a design for the Pacifica State Beach Enhancement (PWA, 2005). Funding was not sufficient to import cobble to "recharge" the degraded cobble berm (Figure 6). There was some grading of cobble after removal of fill and structures, in particular at the mouth of the restored San Pedro Creek. Figure 7 shows the cobble sill at the restored mouth of San Pedro Creek.

Figure 6: Pacifica State Beach. Photograph April 15, 2005, Courtesy, City of Pacifica.

Figure 7: Picture of Cobble berms at Pacifica State Beach before the restoration project. Note the "double berm" which implies landward motion of the lower cobble berm. The house in the background was purchased by the State and demolished. San Pedro Creek mouth is on the far side of the next house, which was also demolished. Photograph © Bob Battalio, taken March 9 2002.

Figure 8: Picture of San Pedro Creek Mouth with cobble sill. Photograph © Bob Battalio, taken December 20, 2011.

- Surfers point: Surfers Point is project with erosion mitigation and managed retreat objectives at the mouth of the Ventura River, California (NOAA, 2007b). The project entails removal of fill and pavement, and placement of cobble and sand to restore the back beach for public recreation, ecology, and storm damage reduction. Cobble underlays the entire area owing to its location at the mouth of the Ventura River. Therefore, cobble placement was considered restoration of the disturbed backshore. The project was designed using a reference site from a less disturbed shore on the other side of the river mouth at Emma Wood State Beach, as well as consideration of the available design guidance and analysis of water levels, waves and runup (PWA, 2005). Figure 9 is a picture of the reference site, showing the cobble berm and the dunes and wetlands behind it. The water side (beach restoration, cobble and sand placement) was designed by PWA and Phase 1 was constructed in 2010-2011. PWA is presently monitoring the project. Figure 10 is a picture of the constructed portion (Phase 1).

Figure 9 Emma Wood reference site for Surfers Point. This reference site is on the west side of the Ventura River Mouth, and the Surfers Point site is on the east side. The dead trees are casualties of coastal erosion, as the shore, with cobble berm, migrates landward. Source: PWA, 2005.

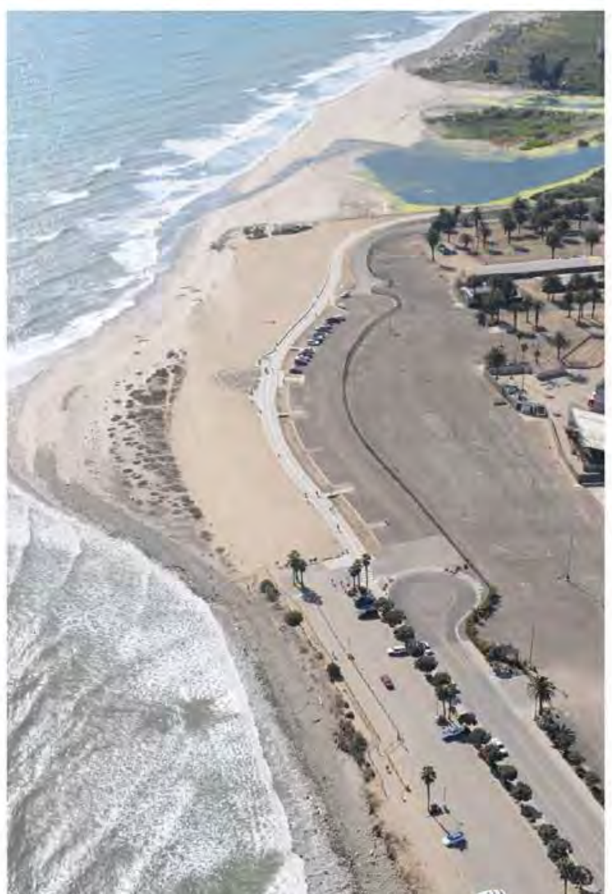

Figure 10 Surfer s Beach post construction phase 1. The new cobble berm is buried beneath the sand. Cobble is exposed along the shore. Phase 2 will include the renovation of the shore in the forefront of the photograph. Photograph courtesy of the City of San Buenaventura and Rasmussen (construction contractor), taken fall, 2011.

- Puget Sound: There are many gravel and some cobble beaches along the shore of Puget Sound. Several projects have been pursued, resulting in several documents addressing the overall concept and design of shore form enhancements (ESA, 2010), and cobble – gravel berms in particular (ESA PWA, 2010). An example of a constructed gravel-cobble system is at Birch Bay, Whatcom County (CGS, 2004). This project entailed a shore section as a demonstration project, to test the concept developed by Bauer (1974) for the remainder of the shore. The project was constructed in 1986 and has been re-nourished with sediments ten times since then. Figure 11 shows the site from a monitoring report (CGS, 2004). Figure 12 shows a proposed enhancement for the adjacent shore (PWA, 2002; 2007)

Figure 1. Oblique aerial photo mosaic of the study site, located immediately left (north) of the mouth of Terrill Creek (at right). Photos taken May 24, 2001 for WA Dept. of Ecology.

Figure 11: Birch Bay Demonstration Project: Source: CGS, 2004.

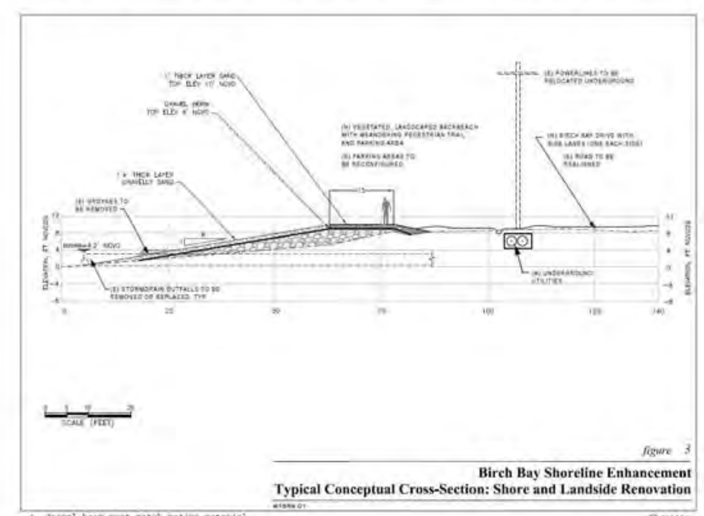

Figure 12: Birch Bay Typical Section, showing conceptual design cross-section of new gravel-cobble berm with sand cover. Source: PWA, 2007.

Description of Behavior and Design Considerations:

Cobble berms (aka Dynamic Revetments) respond differently to waves than shores comprised of smaller sediments and engineering structures composed of large quarry stone boulders.

Function – Berm morphology and processes

Cobble berms exist because of the natural sorting of wave runup processes. The momentum of breaking waves results in wave runup and rundown on a beach. The runup will entrain and transport sediment landward and the following rundown carries sediment seaward. The extent that sediment is moved depends also on the sediment size, density and distribution of sediment, among other factors. Sand tends to have a net movement landward during gentle surge induced by low-steepness waves (typical of summer conditions in California), and move offshore in storm waves which are steep and very energetic. Large sediments such as gravels and cobbles react differently than sand because of their size. Larger particles settle more rapidly and can stand on a steeper slope, but also respond disproportionately to acceleration versus drag. Hence, cobble tends to move onshore under the abrupt wave runup but tends to not move as far offshore under the longer duration but slower wave rundown. Therefore, relative to sand, cobble tends to move onshore during large wave events while sand tends to move offshore more often. This results in a typical winter-time sorting and exposure of cobble and gravel underlying beaches that are sandy in the summer time.

Cobble and gravel berms tend to have a larger voids and hence dissipate the extent of wave runup and rundown. However, the morphology of coarse sediment beaches results in overtopping that can be extensive during extreme conditions. Hence, cobble berms in their natural configuration are not complete barriers to wave runup and erosion. In fact, most natural cobble shores include driftwood and other wrack on the crest of the berm.

Gravel and cobble also move along shore under oblique wave action but the transport is also different than sand. In generally, the along shore transport is less rapid than sand and not as uniform.

Cobble and gravel berms processes are not manifested unless the deposits are large enough to interact and respond to wave runup as a mass. Therefore, designs typically include a minimum thickness, extent and volume. Also, if the voids are filled with sand, the cobble will tend to react to storm wave similar to sand until the sand is sorted out and the high porosity of a cobble deposit can interact with the waves and affect cobble movement.

Function – public access

A dynamic revetment / gravel -cobble berm can be traversed on foot more easily than a quarry stone revetment or a vertical seawall. The mass of rock will also reduce and adjust to scour that occurs when wave action reaches a wall or cliff.

Function – Lake Merced Outlet and Lagoon Sill

Cobble deposits are often found at river and creek mouths. The discharge from the rivers and creeks degrades the elevation of the cobble berm that forms under wave action alone, resulting in a lowering of the berm elevation in the vicinity of the mouth and specifically in the channel(s). However, the cobble tends to reduce down-cutting, thereby acting as a weir or sill. Therefore, the low point in the channel and the elevation of the water upstream are typically higher where a cobble deposit exists in comparison to a stream mouths on sandy shores without cobble. This function of a cobble sill will be beneficial for a restored mouth of Lake Merced, in order to inhibit wave overtopping and salt water intrusion, and provide a hydraulic control for a lagoon-like feature. This feature would be ephemeral, and filled with sand during low rainfall conditions. Profile 2 in Figure 2 is a schematic of the Lake Merced discharge and coastal lagoon feature. This type of managed system will not provide full ecological benefits and is not sustainable over the long term without intervention. Future restoration, if it occurs, that removes development from the flood plain and allows higher water levels in Lake Merced would not require a cobble sill to inhibit salt water intrusion and pumping would not be needed.

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date January 20, 2012

to Ben Grant (SPUR)

from Louis White, PE

subject Ocean Beach Master Plan: Extreme Wave Runup Results

Introduction

ESA PWA is assisting the San Francisco Planning and Urban Research group (SPUR) to develop the Ocean Beach Master Plan (OBMP). The OBMP is intended to recommend strategies for managing the coastal resources in the face of sea level rise and effects of climate change. ESA PWA estimated the limits of extreme wave runup for existing and future conditions as part of the analysis of the coastal physical dynamics. This memorandum is intended to summarize the results and document the methodology used in estimates of the extreme wave runup limits as part of the OBMP. The work described in this memorandum was accomplished by Louis White and To van Dang with oversight by Bob Battalio.

Wave Runup Model

Wave runup was modeled using a program developed by PWA. The program uses several published methods to assess the extent of wave runup on beaches and shores with irregular topography and surface conditions. Wave runup is computed using the method of Hunt (1959) which is based on the Irrabarren number (also called the Surf Similarity Parameter), a non-dimensional ratio of shore steepness relative to wave steepness. The program also uses the Direct Integration Method (DIM) to estimate the static and dynamic wave setup and resulting water surface profile (FEMA 2005; Dean and Bender 2006; Stockdon 2006). The methodology is consistent with the FEMA Guidelines for Pacific Coastal Flood Studies for barrier shores, where wave setup from larger waves breaking farther offshore, and wave runup directly on barriers combine to form the highest total water level and define the flood risk (FEMA 2005). This program also incorporates surface roughness which acts as friction on the uprush of the waves and uses a composite slope technique as outlined in the Shore Protection Manual (USACE 1984) and Coastal Engineering Manual (USACE 2002).

Four cross-shore profiles were used to estimate the wave runup along Ocean Beach: Profile A was located south of Sloat Boulevard; Profile B was located near Rivera Street; Profile C was located near Moraga Street; and Profile D was located at the western end of Golden Gate Park. The existing profiles were based on nearshore bathymetry and beach surveys collected by the USGS in January 2010, and LIDAR flown in 1998 that was collected by NOAA. Profiles for future scenarios in year 2100 were modified based on assumptions of the rate of sea level rise, shore erosion and accretion due to sand budget, and other management treatments as determined by the SPUR working group. This resulted in future profiles differing substantially from existing profiles. First, continuation of erosion in the southern profiles (A, B and C) and accretion in the northern profile (D) was projected. Second, the transgression of the shore in response to sea level rise was modeled as an upward and inward transgression. Third, the effects of management actions were added in terms of widening from sand placement and armoring to prevent erosion.

The still water level (SWL) elevation for existing conditions was assumed to be 9 feet NAVD[1], which is about 2 feet above an astronomic high tide with an annual recurrence, and about 3 feet above the mean higher high water tidal elevation. For future conditions with sea level rise, the SWL was assumed to be 13 feet NAVD. These water levels are rounded to the nearest whole foot in elevation relative to NAVD for simplicity and in recognition of the large uncertainty in wave runup and future conditions.

Four offshore wave conditions representative of an event with a 100-year recurrence interval were selected based on other studies and professional judgment (Table 1). The four wave scenarios used as input to wave runup calculations were characterized by offshore significant wave height in feet and the wave period in seconds. The wave conditions for existing and future conditions were assumed to be the same.

Table 1. Offshore wave conditions representative of a 100-year event.

Wave height, H (feet)	Wave Period, T (s)
36	13
32	17
28	21
24	25

Results

Maximum values of wave runup heights typically exceeded the height of the fronting dune or seawall at the 100-year recurrence, which indicates that overtopping will occur. The wave runup analysis was accomplished to ascertain both the potential elevation of wave runup on the Great Highway embankment and the landward extent of wave runup that overtops the embankment. The primary difference in runup with the scenarios was seen in the elevations at the roadway barrier: The retreat scenarios resulted in lower elevations at the barrier because it was located farther landward (retreat), while the "hold the line" scenarios (Max Infrastructure and Max Recreation) resulted in much higher runup elevations over time as the shore seaward of the armoring erodes and recedes. There was not much difference in the inland extent of runup predicted for the different scenarios. These results follow from the fundamental physics of wave runup: The momentum of wave runup is dissipated by friction and turbulence with inland travel and by gravitational acceleration with vertical travel. Therefore, barriers that impede inland travel will result in the highest potential runup elevation and low, overtopped profiles will result in the farthest inland propagation.

Maximum Runup Elevation at Great Highway: Existing elevations of the dunes and seawalls for the four locations along Ocean Beach generally range between 25 and 30 feet NAVD. Maximum wave runup elevations for existing conditions were typically estimated to be between 24 and 42 feet NAVD, up to approximately 10 feet above the existing elevation at the Great Highway at some locations. The potential wave runup elevations are much higher for future conditions, where the elevation was estimated to range between 30 feet NAVD and over 60 feet NAVD for some cases. Typically, the future wave runup exceeded the existing wave runup on the order of 10 to 50 feet. These high values are theoretical projections above the high point (e.g. the top of a seawall), and provide an estimate of the potential energy rather than the height that would actually occur: In reality, runup above a barrier becomes a mass of water flowing inland and dissipates via turbulence and surface friction rather than elevation. The main point is that the wave runup during an extreme event exceeds the elevation of the existing dunes and seawall , and by 2100 will exceed elevations of structures or barriers that might be considered

[1] NAVD refers to the North American Vertical Datum of 1988.

for future conditions. Difficulties in increasing the elevations of the Great Highway and / or other barriers along the beach is expected for several reasons, including concerns related to high cost of maintaining infrastructure, habitat impacts, decrease in recreational value, and visual impacts on existing properties. In other words, the increased wave runup elevations are substantially higher than the Great Highway and it probably isn't publically acceptable to raise the roadway to an elevation necessary to prevent increased flood and damage risk.

Maximum Inland Extent of Wave Runup: Allowance of some amount of overtopping behind the Great Highway shifts the solution to the problem from one of height at the existing "barrier," to one of planning for extreme overtopping and flooding referred to here as the "inland extent" of runup. The inland extent of the wave runup was measured for each profile relative to the location of the existing 0 feet NAVD contour. Table 2 presents the inland extents and ground elevations and the inland extent of the wave runup for existing and future conditions at each profile.

Table 2. Inland extent of wave runup for existing and future conditions.

Profile	Existing Conditions		Future Conditions		Difference	
	Inland Extent from 0 feet NAVD Contour (feet)	Ground Elevation at Inland Extent (feet NAVD)	Inland Extent from 0 feet NAVD Contour (feet)	Ground Elevation at Inland Extent (feet NAVD)	Inland Extent from 0 feet NAVD Contour (feet)	Ground Elevation at Inland Extent (feet NAVD)
A	475	16.9	780	18.2	305	1.3
B	494	31.2	872	26.9	378	-4.3
C	422	35.4	883	26.7	461	-8.7
D	746	26.0	912	27.0	166	1.0

Figure 1 presents a graphical map of the approximate wave runup limits from extreme coastal flooding events for existing and future conditions. The limits of the wave runup shown in the figure are similar to the limits of coastal erosion presented by the Pacific Institute (2009) in a study of potential impacts of sea level rise on the California Coast (Heberger et al. 2011; Revell et al. 2011): See Figures 2 and 3. However, the flood mapping developed in the Pacific Institute study did not account for dissipation by inland propagation, and over-predicts the coastal flood extents (Figure 3). The results shown by the Pacific Institute (2009) is based on work performed by PWA (2009) in a supporting study to determine erosion and flood hazard zones due to sea-level rise along the coast of California from California to Santa Barbara. Furthermore, the flood mapping shown in Figure 3 was also used in recent FEMA preliminary coastal flood mapping (see Figure 4). We consider the wave runup limits presented here to be superior to previous estimates of coastal flooding and erosion including those available via the Pacific Institute and FEMA.

While these maps are the best available mapping of coastal flood hazards, they are still approximate and not intended to assess property values, insurance rates or development potential. Any use of the information presented here except for the Ocean Beach Master Plan is at the user's sole risk and is not authorized by ESA PWA.

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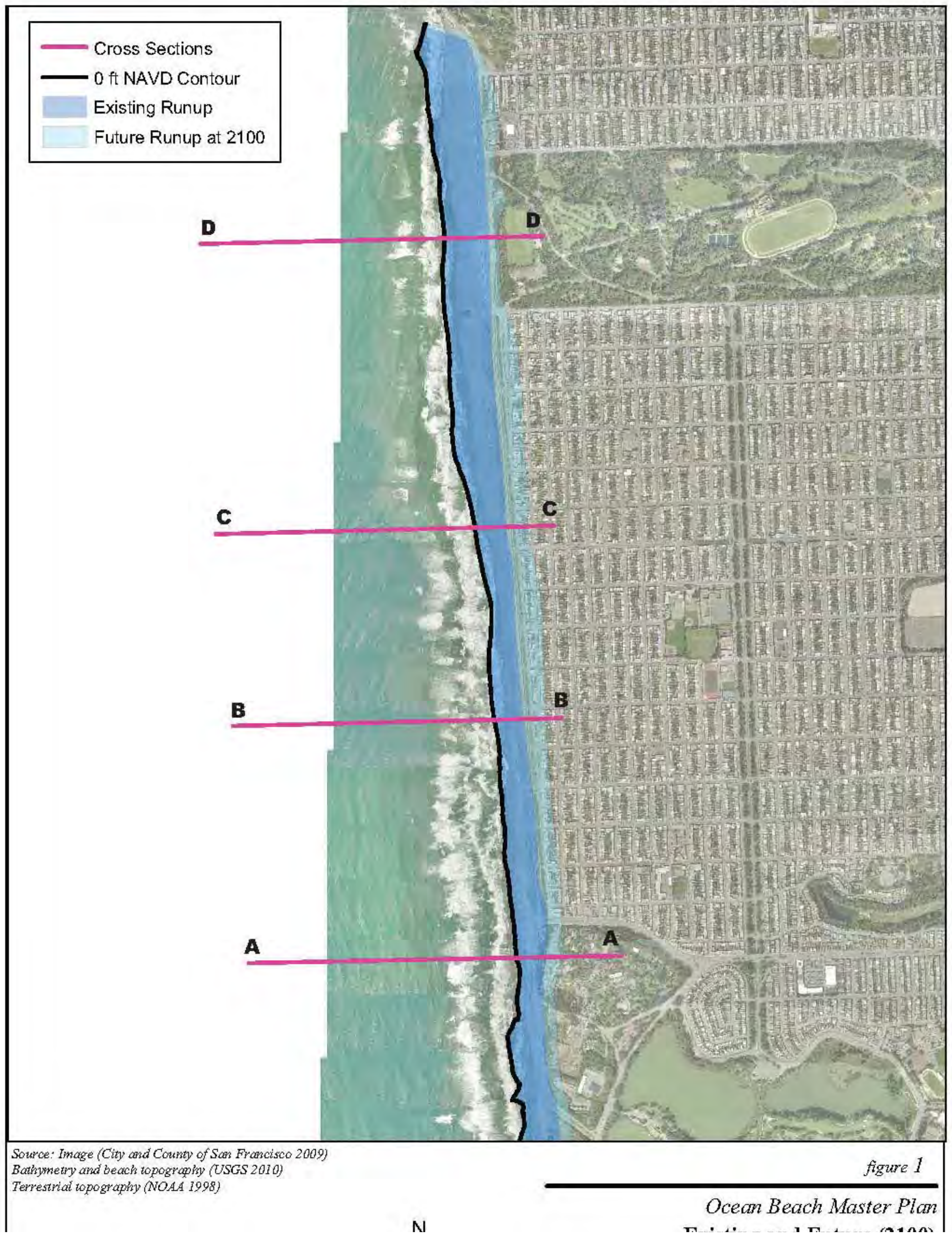

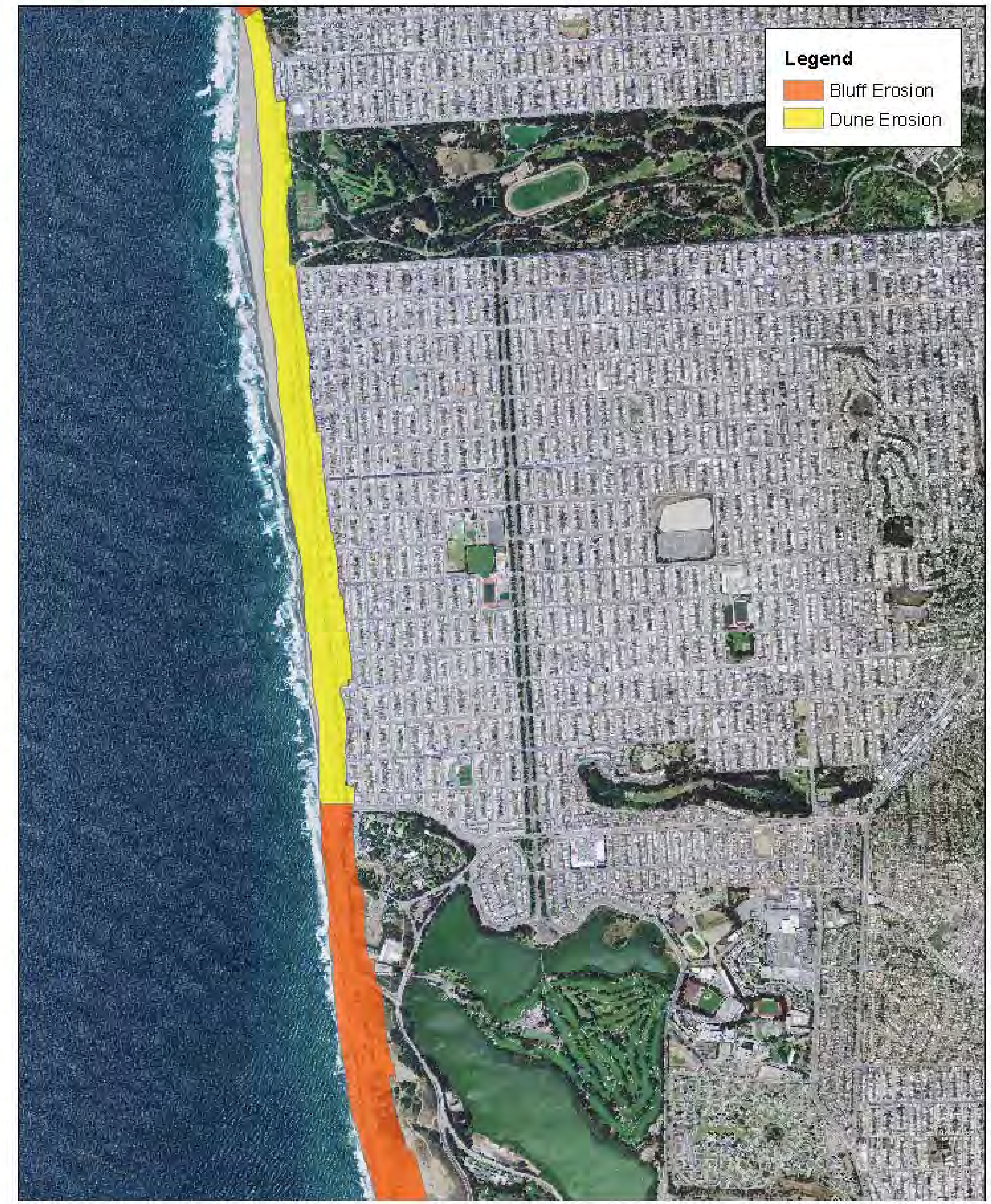

Figure 2. Bluff and dune erosion hazard zones predicted with 4.6 feet of sea level rise (after Pacific Institute 2009).

Figure 3. Areas of coastal flooding with 4.6 feet of sea level rise (after Pacific Institute 2009).

Figure 4. Preliminary FEMA flood map (source: Baker-AECOM).

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to Phil King, Ph.D, VooDoo Economist

from Bob Battalio, PE, Defier of the Edifice

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Alma Du Patricia EDAW

subject UPDATE FOR SCENARIO E – HYBRID PUC SCENARIO
Scenario Analysis – Coastal Costs
Ocean Beach Master Plan
ESA PWA #2054

UPDATE October 2011: This memorandum was updated to include a new, hybrid scenario herein called SCENARIO E – HYBRID PUC. This scenario includes elements from the other scenarios, but maintains PUC infrastructure in place at least through 2040, while keeping options open for subsequent changes to carry through 2100. The overall concept is managed retreat, with retreat for sewage infrastructure delayed until 2040 or beyond owing to the PUC's need to have time to plan for future conditions, and to get more years of service from their existing facilities.

Per discussions with you and Ben, here is an explanation of the revised beach and dune widths, and descriptions of coastal actions.

Revisions to Scenarios: I revised the scenario modeling to better represent the intent of the scenario descriptions. This was done based on a discussion with Ben. Basically, we revised scenario modeling:

1. Middle Ocean Beach: Beach nourishment is included with B. Max Recreation and D. Max Infrastructure, but not with the others.
2. Middle Ocean Beach: The sewer box is either relocated (A. Max Habitat) or left in place and modified to be a seawall (all the others, ***including E. Hybrid PUC***). ***The Sewer Box Sewall Modification includes reconstructing the UGH to about elevation +40' NAVD which is about 10' higher than it is now.***
3. South Ocean Beach: I modified the beach nourishment as follows:
   A. Max Habitat: 50' beach and 50' barrier dune every 20 years
   B. Max Rec: 50' beach and 50' barrier dune every 20 years
   C. Green Infrastructure: 50' beach and 50' barrier dune every 20 years
   D. Max Infrastructure: 50' beach and 50' barrier dune every 20 years, plus additional 300,000 cyy to maintain some beach in winter seaward of existing bluff.
   E. Hybrid PUC: 50' beach and 50' barrier dune every 20 years .

Erosion Management for Scenarios: Here are descriptions of the erosion management for each scenario over time:

A. Max Habitat: Shore retreat and realignment are emphasized. In SOB, sand placement is accomplished to widen the beach and sacrificial sand berm, and armor and fill removal are accomplished to provide room for a more natural shore. Dune construction is accomplished in MOB and NOB.

South Ocean Beach (SOB)

- Year 2020: Remove about 260,000 cubic yards (cy) of rubble and dispose for about $35/cy or about $9M. Add sand to widen the beach and barrier dune 50' each (100' total) using about 560,000 cy @ $20/cy totaling about $11m. These two items cost about $20M.
- Year 2040: Remove more rubble and earth fill totaling about $2M. Place another $11M worth of sand.
- Years 2060, 2080, 2100: Each another $11M for sand.

Middle Ocean Beach (MOB)

- No sand placement for beach – retreat.
- Remove box culvert year 2070.
- Build dunes: Assume an average dune field depth of about 370', over a length of 10,300', which amounts to about 3.8M square feet. Based on a sand thickness of about 15' and a total cost of about $30/cy, I suggest using about $26/sf. For 3.8M sf, you get about $100M. This should cover purchase, transport, placement, planting, etc. This is very rough, so lets look at it as an allowance or budget for building a dune field that is several hundred feet wide along MOB.
- Relocate road, buy property, etc. form others.

B. Max Recreation: A mix of retreat, nourishment and armoring. In SOB, retreat is limited in order to maintain a public corridor in front of the sewer plant, initially with sand placement and ultimately with an offshore surfing reef system. In MOB, there is some retreat and reconfiguration but beach nourishment is emphasized.

South Ocean Beach (SOB)

- Year 2020: Same as A Max Habitat.
- Year 2040: Same as A Max Habitat
- Years 2060, 2080, 2090: Same as A Max Habitat (three placements of $11M). Also, add offshore rock reefs as sand retention structures (low crested breakwaters): Estimate about $40M for the one kilometer reach.

Middle Ocean Beach (MOB)

- Sand placement to maintain beach. Assume 50' beach and 50' dune widening every 20 years amounting to about to about 1.5M cy. Assume $20/cy for a cost of $30M every 20 years.
- Year 2070 the box culvert is modified to be a seawall.
- Year 2070 the road is setback an additional 50' and converted to dunes (behind the seawall).
- Other costs by others.

C. Green Infrastructure: Retreat until the shore reaches "immoveable" infrastructure, while losing beach and dunes in SOB and MOB. Sand placement and retreat in SOB until need to armor sewer treatment plant.

South Ocean Beach (SOB)

Middle Ocean Beach (MOB)

- ***Sand placement to maintain beach. Assume 50' beach and 50' dune widening every 20 years amounting to about to about 1.5M cy. Assume $20/cy for a cost of $30M every 20 years.***
- ***Year 2070 the box culvert is modified to be a seawall.***
- ***Year 2070 the road is setback an additional 50' and converted to dunes (behind the seawall).***
- ***Other costs by others.***

END

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Memorandum – draft

date May 13 2011, revised January 20, 2012

to Ben Grant, SPUR

from Bob Battalio, PE
Phil King, Ph.D,

subject Scenario Analysis – Coastal
Ocean Beach Master Plan
ESA PWA #2054

The Spur team has developed scenarios to inform the Ocean Beach Master Plan. ESA PWA (PWA) and Phil King (King) will analyze the coastal conditions for each scenario. This memorandum describes the analysis methodology.

Analysis Methodology Overview

PWA will estimate the change in beach and dune widths over time, and the width where key triggers occur (triggers are thresholds of damage or action). King will translate this input to costs (e.g., infrastructure loss, nourishment costs) and benefits (e.g., recreational benefits) over time. The estimated costs and benefits will be used by SPUR and team in the evaluation of the scenarios.

PWA will estimate coastal change by translating representative shore profiles based on estimated shore change rates, and transgressing shore profiles landward and up in response to sea level rise. Where profiles intersect shore protection and other substantial structures, the landward migration will be halted and the profile modified to include the exposed structure. When other less substantial structures are encroached upon, damages will be triggered. Beach nourishment will be accommodated as a seaward translation of the profile.

PWA will extract the beach and dune widths from the profiles, and tabulate as output to King's analysis of ecological and recreational benefits. King will identify the time frames at which damage and action triggers are achieved, based on when the profiles encroach upon particular features and locations.

The PWA output will be profiles, beach and dune widths, encroachment into developed areas, and the estimated width for triggers. King output will be tabulated costs and benefits and time of trigger. In general, infrastructure triggers and responses have been developed with the SF PUC and DPW: At the time of this memorandum, we anticipate further attention will be required to attain or estimate all the infrastructure related parameters. Ecological criteria have been discussed with the National Park Service, GGNRA. The ecological criteria are less well defined and the methodology for valuing ecological conditions requires further attention. The recreational valuations will be developed using methods previously used by King, with local data.

In addition to the profile analysis discussed above, PWA will also calculate the landward extent of wave runup during an extreme event approximating a recurrence frequency of 1% per year (i.e. the 100-year runup event). The limits of runup will provide a sense of coastal flooding potential landward of the coastal dunes and bluffs. These data may be used to estimate potential flood damages or used as a qualitative estimate of damage hazard.

Scenarios

Scenarios have been developed by the SPUR Team with input from the Management and Advisory Committees. These are described in documents produced by AECOM, attached (110506-Scenarios Board-PAC mtg.pdf and 110509-Evaluation Criteria - revisions mtg.pdf). The scenarios have different responses at different triggers, which will result in different outcomes. There are four scenarios:

A. Maximum Habitat;
B. Maximum Recreation;
C. Maximum Green Infrastructure;
D. Maximum Infrastructure.

The scenarios include treatments at four time periods:

+ 0 Years (2010);
+ 20 years (2030);
+ 40 years (2050);
+ 90 years (2100).

The scenarios are divided into three shore reaches (Figure 1):

A. North Ocean Beach (NOB) from Point Lobos-Cliff House south to Lincoln Boulevard;
B. Middle Ocean Beach (MOB) from Lincoln Boulevard to Sloat Boulevard;
C. South Ocean Beach (SOB) from Sloat Boulevard to Fort Funston.

The above results in approximately 48 permutations (four scenarios x four time periods x three reaches).

Profiles

Profiles are constructed from survey data collected in January 2010 and provided by the USGS, and lidar collected by NOAA in April, 1998, and downloaded and converted to topographic contours. The profiles were therefore constructed from three data sets with different collection methods:

A. Offshore bathymetry (fathometer and kinematic GPS surveys from jet skis);
B. Beach topography (kinematic GPS from ATVs);
C. Airborne lidar remote sensing.

PWA compiled the data into one digital file. The lidar and beach survey data diverged due to the different dates (2010 and 1998), requiring interpolation between the end of the USGS beach survey and a selected point on the lidar.

Profiles were selected to represent each of the three reaches:

A. Golden Gate Park – NOB;
B. Moraga – MOB, with dune backshore;
C. Rivera – MOB, with seawall backshore;
D. North Parking Lot, south end – SOB.

Beach widths will be calculated from the Mean Higher High Water (MHHW) elevation (i.e., "dry beach"), rounded to +6' NAVD, to the back beach. The back beach is defined as the junction with the toe of a dune, bluff or structure. These profiles are considered to represent winter beach conditions, and useful to indentify when the receding shore will impact landside development. However, the recreational and ecological values are better attributed to yearly average beach conditions, which are wider than typical in the winter. The average beach width is approximated as the beach width indicated in the profiles plus an average seasonal change as follows:

A. NOB - 150' (Reaches 9A and 9B);
B. MOB Moraga – 100' (Dune-backed Reaches 3,4,5,7 and 8);
C. MOB Rivera – 100' (Seawall-backed Reach 6);
D. SOB – 50' (Reaches 1 and 2).

The above were derived from Table 3.1-3 Summary of Analysis for Shoreline Change (M&N, 1995) by averaging the seasonal width changes for the shore reaches indicated. The averages were rounded to the nearest 50'.

Dune widths will be calculated as the distance between the beach and development. For each profile, an average value will be used for the shore reach it represents.

Profile Translation

Profiles will be translated using a shore movement rate (accretion is seaward and erosion is landward), and a response to sea level rise as follows:

Shore horizontal translation = (Shore Movement Rate) * (time) - Seal Level Rise recession;
Shore vertical translation = Sea Level Rise.

Shore movement rate

The shore movement rate is estimated using judgment, consistent with limited funding available for our analysis as well as the author's extensive experience with the topic. Table 1 summarizes the basis for the estimates.

The data used are based on careful analysis of maps and aerial photographs from 1929 to 1995 produced under the author's supervision (M&N, 1995; 1994; Battalio and Trivedi, 1996). The rates for the ten shore reaches (1-9B) are tabulated and averaged for the four profile and three shore reaches used in this study. These averaged rates are listed in Table 1 in the column labeled "averages." These averages are not the selected values because we anticipate different conditions going forward resulting in future rates that are different than historic rates. The recent more eroded conditions and trends discussed in the Ocean Beach Littoral Congress indicates that Ocean Beach will likely be more erosional in the future (ESA PWA, 2011 in press). The implication is that Ocean Beach is expected to become more "erosional" due to reduced sediment supply and geomorphic changes. The selected more erosional rates for application in this study are in Table 1, and described below.

Table 1: Selection of Shore Movement Rates

Reaches, Master Plan	Reaches, Analysis[1]	Linear Trend (feet / year)[1]	Averages (feet / year)[2]		Selected (feet / year)	Comment
	9A	-3				
A. NOB	9B	+5	+2		+1	Expect accretion rate to slow due to saturation of fillet and reduction of sand supply
	8	+2				
B. MOB Moraga	7	0	+1.6	+1.2	-1	Expect change to erosion due to reduction in sand supply
C. MOB Rivera	6	-1	-1	+1.2	-1	Expect change to erosion due to reduction in sand supply and shore rotation associated with bar shrinkage
	5	+3				
	4	+2				
	3	+1				
D. SOB North Lot	2	+1	0		-1	Use Fort Funston bluff recession rate as long term control.
	1	-1				

1. Source: M&N, 1995.
2. Average by reach (not length).

The Littoral Congress participants noted the more eroded shore conditions that have existing since the 1997-1998 El Nino winter. Battalio and Bromirski noted the possibility that these eroded conditions may have some relationship to the Pacific Decadal Oscillation (Figure 2). Figure 2 indicates that OB may be in an erosional phase and an accretionary period may occur in the near term. However, this possibility is not emphasized given the high level of uncertainty in climate at the present time. Moreover, recent analysis indicates that sea level rise may accelerate in the very near term on the Pacific Coast as it "catches up" with global trends (Bromirski et al, 2011). In summary, it is difficult to predict the effect of climate on erosion rates, with the exception of sea level rise (discussed later).

The USGS have postulated that the radial "shrinking" of the SF Bar planform is resulting in a counter-clockwise rotation of the shore, with accretion at the north end transitioning to erosion south of Noriega Street and increasing southward, indicating increased erosion rates in MOB and SOB. Battalio and Trivedi postulate that the reduction in dredged sand discharge onto the SF Bar would diminish onshore transport and sand supply, thereby reducing the supply to MOB and NOB. Battalio concludes that a reduction in dredged sand supply is likely due to:

(1) reduction in dredging rate is demonstrated in the dredging records, primarily due to the lack of channel deepening and widening since the 1970s and reduced sedimentation rates as the side slopes of the channel reach equilibrium and deposition becomes dominated by only ebb tidal currents;
(2) the sand placement has not been on the bar for about 5 years (Barnard, et. al, 2009), and rather has been placed offshore of SOB, and hence not available to MOB and NOB; the effect of changed dredging practice will eventually result in decreasing onshore sand transport if it hasn't already; and,
(3) Sea level rise will reduce the required dredge depth.

In addition, the USGS notes that the grain size of dredged sands is significantly smaller than the native beach sands, and hence the effectiveness of beach nourishment is expected to diminish. The above discussion leads to a more erosional condition at all shore reaches.

While NOB has accreted, this accretion has been attributed to dredging practice between the early 1970s to 2005, which increased sand supply to the MOB and NOB (M&N, 1995; Battalio and Trivedi, 1996). While other explanations have been provided (i.e.bar rotation (Hansen and Barnard, 2010), climatic fluctuations (Battalio)), the evidence of linkage between the SF Bar and OB via onshore sand transport and dredging is too strong to dismiss (Hanes, et. al, 2011). This indicates that reduced dredging will eventually translate into reduced accretion and possibly erosion. Secondly, the widening of NOB is attributed partly to the groin-effect of Point Lobos. Therefore, there is a maximum amount of accretion that can be anticipated in this fillet plan form, indicating that the rate of accretion should slow.

Hansen and Barnard (2010) measured changes from 2004-2009 and found MOB to be eroding (except from Lincoln to Noriega which was relatively stable) at a rate of over 2 m/yr +/- 2m yr

Battalio notes that the Funston Bluffs form a control on shore position south of the SF Bar (generally south of Sloat Blvd.), and hence the historic rate of erosion at Reach 1 is considered more indicative of the future natural rate of erosion in the SOB area. Therefore, and erosion rate of -1 fpy is estimated for SOB. For comparison, the stretch of coastline immediately surrounding the Daly City Outfall site, to the south of SOB in Fort Funston, appears to exhibit a long-term erosion rate on the order of 1.3-1.6 ft/yr (Hapke et. al, 2006), although much of this erosion presumably occurs in the form of episodic slumps and landslides. In addition, for those scenarios where armor is removed, the northern part of SOB will likely adjust with a limited but rapid recession before taking a more uniform rate: An initial recession of 40 feet is estimated based on the geometry of the existing planform and specifically the location of the bluffs and dunes to the north and south.

With the erosion rate in SOB estimated to be -1fpy, the historic rates in MOB of between -1 to +1.6 fpy (se averages in Table 1) are too accretionary, and an erosion rate of -1 fpy is selected for this study. Similarly, the historic average rate of accretion in NOB of +2 fpy is reduced to +1 fpy for this study. While somewhat arbitrary (obviously different rates could be "selected"), these are the only estimates of future erosion available for Ocean Beach. For comparison, the rates selected here are generally consistent with the "short term" erosion rates of Hapke et al (2006), except for SOB where greater erosion rates were documented. The pattern (accretion / stability in the north and erosion in the south) is also generally consistent with Hansen and Barnard (2010) but their short term rates (2004-2009) are higher.

Response to Sea Level Rise

Sea level rise estimates will follow the interim state guidance (OPC, 2010):

- 14" 2050 (+40 years);
- 55" 2100 (+90 years).

Shore response is presumed to be transgression, which is the "rollover" of the shore face to the higher sea level and higher elevation of wave action. The response is estimated generally following the "Bruun Rule" with the shore recession estimated to be the sea level rise divided by the overall slope of the profile. The overall slope of the profile is calculated as the shore face height divided by the shore face width. A slope of 1:60 (horizontal:vertical) is selected based on historic profiles (Figure 2). This results in the following changes:

- 40 years, 70 feet of recession and 1.2 feet (14") of shore rise;
- 90 years, 275 feet of recession and 4.6 feet of shore rise.

Nourishment

Beach nourishment is the act of placing sand to widen the beach. Beach nourishment has occurred frequently at Ocean beach. In the scenarios, beach nourishment is included in SOB and MOB.

Beach nourishment in SOB will be included consistent with the intentions of the USACE and CCSF to beneficially reuse sand dredged from the Bar Channel to widen the beach. The dimensions and performance of this sand placement will be developed from information provided by the USACE and or CCSF, or will be estimated by ESA PWA if no information is provided (a report exists but has not been provided).

Beach nourishment in MOB will be estimated by ESA PWA based on a review of prior studies, as discussed in the Littoral Congress (ESA PWA 2011). It is assumed that the conversion between volume and area is about 2.0 cy/sf of beach and dune. This is based on 1.3 cy/sf for the beach (35' profile height) and 0.7 cy/sf for dunes (20' dune height). Also, an "overfill" factor of about 1.3 due to finer sand source (about 0.15 mm instead of 0.3 mm d_{50}) is assumed. Assume 20% losses due to increased transport away from nourishment area. The total conversion is therefore 2.0 x 1.3x1.2 = 3.1 cy / sf of shore profile. Assume 2.5 mile length of nourishment (Lincoln to Sloat). This amounts to about 2 M cy to rebuild the linear barrier dune and beach. This is assumed to be required once every 10-30 years.

This amounts to about 5 M cy in 50 years. San Francisco Bar Channel maintenance dredging has averaged about 300,000 cubic yards per year over last few years (Peter Mull, USACE; referred to DMMO records). Therefore, the proposed beach nourishment of 5 M cy in 50 years is generally within the range of the rate of sand maintenance dredging of the SF Bar Channel by the USACE, indicating that the existing dredging operation can be considered as a sand source. However the desired placement period is shorter (2 Mcy in 1 – 2 years) vs the navigation-based dredging frequency (about 0.6 Mcy in 1-2 years) and hence there will be a cost premium associated with advance maintenance dredging or sand borrow from outside the navigation channel. To the extent that the USACE places sand in SOB, it will not be available to MOB and NOB.

Wave Runup

Wave runup will be calculated for the profiles in order to estimate the landward extent of velocity coastal flooding. Special methods are required to estimate the limit of runup over the coastal barrier formed by the linear dunes, walls and roadways at Ocean Beach. The overall methodology follows that in the Guidelines for Pacific Coastal Flood Studies (FEMA, 2005). Runup is calculated using the surf similarity parameter which is essentially the ratio of beach slope to wave steepness, or relative shore steepness. The average slope is used, following the composite slope method described in the USACE coastal engineering manuals. Wave setup is calculated based on the largest waves, and the maximum runup is selected from sampling a range of breaker heights through the surf zone. Setup is calculated using the parameterized "DIM" (Direct Integration Method). The runup limits provide an indication of coastal flooding potential that is expected to extend inland of the erosion limits, and vary somewhat by scenario.

Coastal Hazard Zone

The coastal hazard zone is defined as the inland from the ocean to the limit of coastal flooding and erosion possible during the planning horizon. Figure 4 is an approximate estimate derived from a State-wide study of sea level rise effects on erosion and flooding (PWA, 2008). The figure shows the estimated extent of the coastal hazard zone in year 2100 using a the same sea level rise scenario listed above, with a 100-year coastal runup event.

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Attachments:
Scenario Descriptions: 110506-Scenarios Board-PAC mtg.pdf
Scenario Evaluation Criteria: 110509-Evaluation Criteria - revisions mtg.pdf

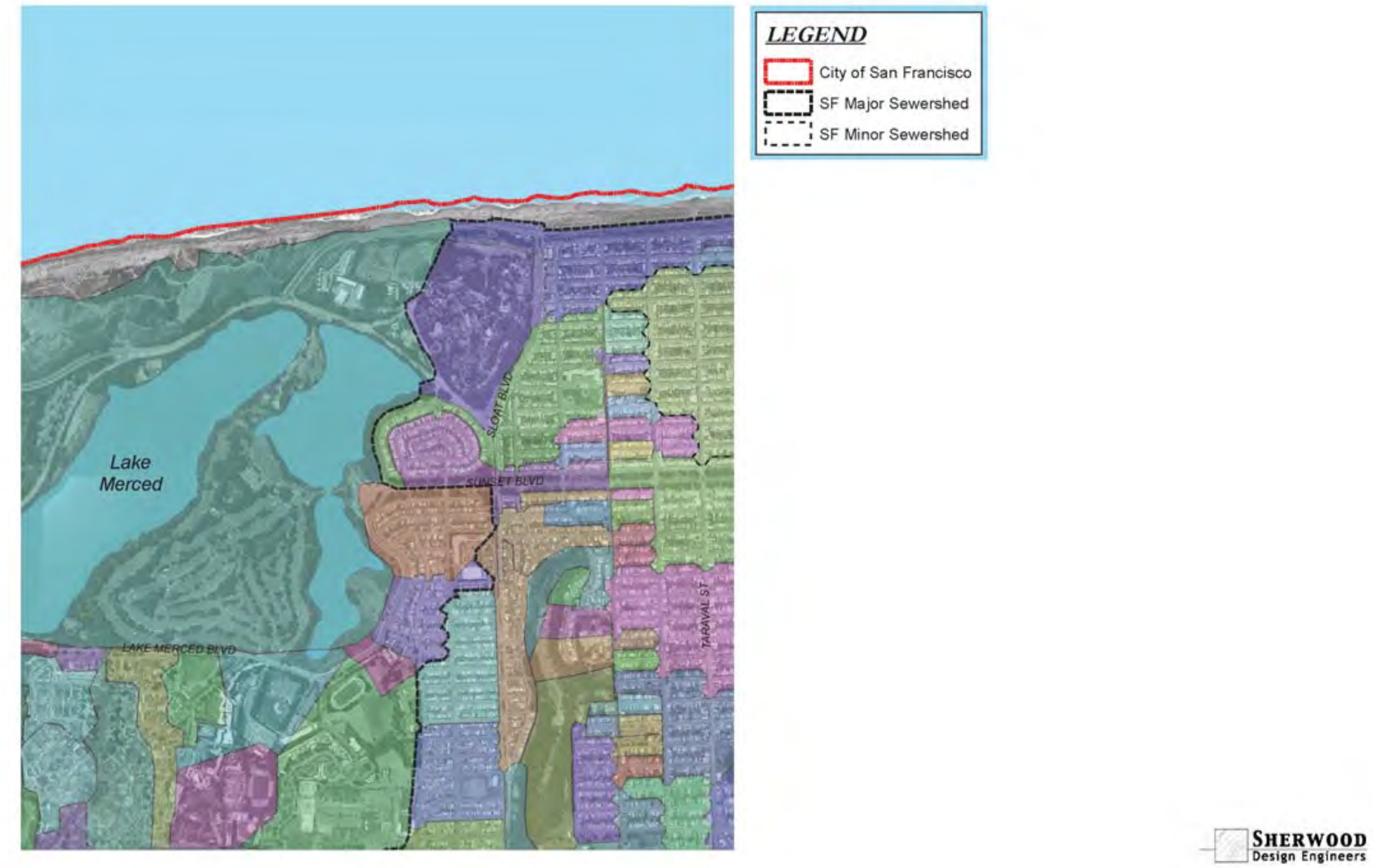
Figures:

1. Ocean Beach – Map with reaches and profile locations.
2. SOB historic shore line positions showing multi-decade oscillations and long term erosion trend.
3. Ocean Beach Profile showing shore face geometry and slope.
4. Approximate coastal hazard zones from prior study, year 2100.

technical memorandum 01 : civil engineering

Prepared by:

Sherwood Design Engineers



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From: "Bry Sarte" <bsarte@sherwoodengineers.com>
Date: January 20, 2012 8:30:14 AM PST
To: "Ben Grant" <bgrant@spur.org>
Subject: Re: OB

Ben,
I assume the pieces to desribe the zoo intvention are mutifaceted. I am happy to fill in / review other descriptive language where there are any holes. Just ket me know. Below is the romantic and the technical text you requested. Our exhibit that shows the watersheds described will follow.

Intro, why?
Building off of San Francisco citywide momentum to reduce stormwater flows to the bay and ocean and to simultaneously improve public spaces and ecological amenities, we have advanced a concept that provides all of these functions in a simple and powerful gesture at the zoo parking lot and along Sloat Boulevard. This intervention is composed of a living system for moving storm water flows and directing the water to seep into the ground to recharge groundwater and combat saltwater intrusion into San Francisco's freshwater aquifer. (ben, thats the quick summary. Let me know if you have room for more here about the city's system, ecological storm water management, the role of green streets on Sloat and the side streets, the possible connection from Lake Merced, or other details)

Wetland Treatment System

Description: The system will treat and store stormwater in a shallow wet pond with vegetation planted throughout in order to provide the ecological and biological function, and enhanced habitat of a natural wetland. Runoff will pond up within the wetland allowing the water to settle and infiltrate into the soils. Water quality improvements are achieved through particle settling, nutrient uptake and filtration as water soaks into the ground. Stormwater quantity control is achieved through ponding, infiltration and void storage within drain rock layers. The wetlands have sloped sides (a max of 3:1) and a minimum depression depth of 6 inches. The bottoms gently slope to allow for infiltration across the entire surface area.

Contributing Areas: Runoff from areas within the San Francisco Zoo, along Sloat Boulevard, and near and within Lake Merced will be re-directed to the newly constructed wetland via sheet flow from a proposed riparian stream, structural conveyance mechanisms, and retrofitted low impact development conveyance structures. These areas are currently directed to the wastewater treatment plant.

Sloat Boulevard Area	= 1,525,600 sf (35 ac)
San Francisco Zoo	= 1,864,034 sf (43 ac)
Zoo Parking Lot	= 183,155 sf (4.2 ac)
Lake Merced	= 2,322,350 sf (53 ac)
Riparian Area	= 330,850 sf (7.6 ac)
Wetlands (minimum area)	= 43,612 sf (1.1 ac)
Wetlands (maximum area)	= 145,375 sf (3.3 ac)

2yr 24 hr Design Storm Quantities (Minimum Wetland Area):
Total 24-hr Storm Volume = 842,088 cf
Weighted C-Value for Entire Area = 0.75
Total Annual Volume = 8,973,588 cf
Total Peak Runoff = 190 cfs

2yr 24 hr Design Storm Quantities (Maximum Wetland Area):
Total 24-hr Storm Volume = 848,481 cf
Weighted C-Value for Entire Area = 0.74
Total Annual Volume = 9,039,786 cf
Total Peak Runoff = 191 cfs

Wetland Capture (Minimum)
24-hr volume = 126,475 cf (infiltrates into native soils)
Annual volume = 1,349,490 cf (infiltrates into native soils)
Peak Runoff = 161 cfs (reduces current peak runoff by approximately 16%)

Wetland Capture (Maximum)
24-hr volume = 421,588 cf (infiltrates into native soils)
Annual volume = 4,498,345 cf (infiltrates into native soils)
Peak Runoff = 96.3 cfs (reduces the peak runoff by approximately 50%)

Conclusions: The proposed constructed wetland and vegetated swales will reduce the overall 2-yr 24hr design storm peak runoff rate and the annual storm volume by a maximum of 50%. Intercepting the runoff from the above areas and directing it to the wetlands, reduces the amount of water entering the wastewater treatment by a maximum of approximately 4.5 million cf (33,750,000 gallons).

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technical memorandum 01 : cost/benefit analysis

Prepared by:

Phil G. King PhD

January 3, 2012

Memo

To: Ben Grant, SPUR

From: Philip King, Ph.D.

Re: Assumptions used for Benefit/Cost Analysis applied to Ocean Beach San Francisco

A benefit/cost analysis is only as good as the assumptions that lie behind it. This analysis was performed on a very limited budget and involves a large number of variables, many not well known. The analysis also involves forecasting future costs and benefits—the farther any benefit or cost is projected into the future, the more speculative the analysis. Despite these difficulties, it is useful to see which variables are critical in the analysis and which are less so and to see which alternatives yield the best benefit/cost ratio, particularly if these differences are very large. The economic analysis for this project is best classified a pre-feasibility; in other words, the purpose of the analysis is to eliminate options that are clearly not feasible or which are dominated by other options which are significantly cheaper or which convey much higher benefits.

The discussion below groups assumption into various categories and discuss how the estimates were made, what sources were used, and the degree of confidence in these sources.

Recreational Value: The recreational value of Ocean Beach was determined by estimating the attendance, type of recreational activity, and the value of these activities per person per day (day use value).

- **Attendance** was estimated from detailed survey data conducted by the San Francisco Public Utilities Commission (SFPUC) from 1998-2000 (SFPUC, 2002) and confirmed by a number of independent observations of Ocean Beach and conversations with people familiar with recreational use patterns. Although this data is over a decade old, attendance at Ocean Beach has remained relatively stable over time, as has San Francisco's population. The one area that was adjusted was surfing, particularly south of Sloat Blvd., which has increased significantly since the survey was taken.

  The SFPUC survey was conducted at a number of specific sites at Ocean Beach and these site estimates were translated into the three reaches--North Ocean Beach (NOB), Middle Ocean Beach (MOB) and South Ocean Beach (SOB) used throughout the analysis. Overall we estimated that 334,748 people visit Ocean Beach (on the sand or in the water) every year; 48% in NOB, 42% in MOB, 11% in SOB (by far the shortest reach—attendance is fairly evenly distributed). 70% recreate on the sand only, 11% are surfers, 15% go into the water but are not surfers; 3% are fishermen. More detail is contained in the Excel tables.

  The SFPUC survey was well thought out and detailed, so we are confident in these estimates. The main area of uncertainty concerns potential increases in recreational activity as well as yearly differences. Beach attendance varies depending upon the weather, though the weather at Ocean Beach is reasonably consistent from year to year.

- **Recreational Value per Day** was estimated using the CSBAT model developed for the State of California and the USACE (e.g., see King, McGregor and Whittet 2011). The recreational value per day depends upon the type of recreation (in particular surfing is considered to be higher value) and the amenity value. Changes in beach width influence amenity value—wider beaches are preferred up to a point (about 250-300 ft).

- **Economic Impact** estimates used spending per visitor per day from King and Symes (2004) with attendance data.

Water/Sewage/Highway Infrastructure Values were estimated from various sources. Wherever possible, official sources from government agencies were used, in particular from the SFPUC. Previous studies of Ocean Beach, such as one conducted by Moffatt and Nichol for the USACE, were also incorporated.

- **SFPUC water/sewage infrastructure costs** of replacement/repair were obtained directly from the SFPUC. Insert table
- The costs of **removing/rerouting the Great Highway** were estimated from a study conducted by Moffatt and Nichol for the SFPUC (cite). They used an estimate of $770 per foot per lane for highway removal/replacement.
- Several smaller but by no means insignificant infrastructure issues were ignored due to lack of insufficient data.

The costs of **shoreline protection** and periodic **beach nourishment** were estimated by PWA and incorporated into the analysis. The costs of non-native plant removal and placement of native vegetation were derived from a study conducted by California State Parks (2007) at Little River State Beach. These figures imply a cost of approximately $6000 to $7000 per acre. Given that construction/demolition costs are higher in San Francisco and to be conservative, this figure was increased to $10,000 per acre.

The costs of **Low Impact Development** (LID) were derived from a detailed analysis conducted by the SFPUC (2010) and modified by Ben Grant, coordinator for the project and Bry Sarte (affiliation, title). Benefits…$2 gallon (cite?)

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