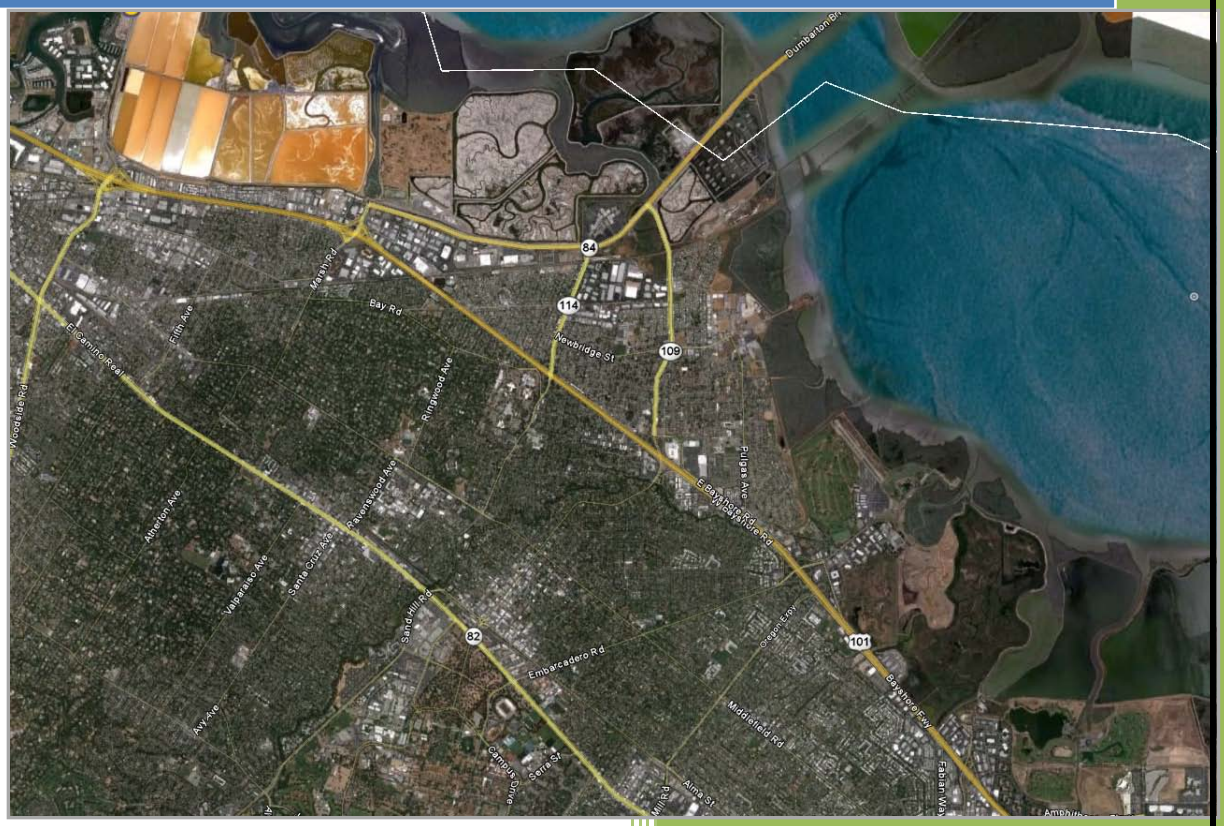
US Army Corps of Engineers

2011

San Francisquito Creek – Preliminary Flood Damage Analysis



USACE, San Francisco District

11/18/2011

Table of Contents

Executive Summary iv
1. Introduction 1
1.1. Purpose 1
1.2. Flood Damage Analysis Overview 1
1.3. Brief Description of the Flood Modeling 3
2. Structures, Contents, and Infrastructure at Risk from Fluvial Flooding 5
2.1. Delineation of Economic Impact Areas 5
2.2. Structure Types and Flooding Characteristics by EIA 6
2.2.1. San Mateo EIAs 7
2.2.2. Santa Clara EIAs 7
3. Structures, Contents, and Infrastructure at Risk from Coastal Flooding 8
3.1. Delineation of Economic Impact Areas 8
4. Combined Risk – Areas With Both Fluvial and Coastal Flood Risk 10
5. Structure, Content & Vehicle Valuation 12
5.1. Structure Inventory 12
5.2. Structure Valuation 12
5.3. Content Valuation 13
5.4. Structure Inventory and Valuation Results – Fluvial Floodplain 15
5.5. Structure Inventory and Valuation Results – Coastal Floodplain 17
5.6. Elevation and Flood Damage Relationships 18
5.7. Structure and Content Depth-Damage Relationships 20
5.8. Automobile Depth Damage Relationship 21
5.9. Residential Displacement Costs Depth Damage Relationship 23
6. Expected Annual Damage (EAD) 25
6.1. EAD – Structures, Contents, Vehicles, and Residential Displacement 25
6.2. Other Damage Categories Not Yet Quantified 28
6.2.1. Emergency Costs 28
6.2.2. Insurance Policy Administration 29
6.2.3. Income Loss to Businesses 29
6.2.4. Travel Delay and Detour Impacts 30
6.2.5. Impacts to Palo Alto Airport 33
6.2.6. Impacts to the Palo Alto Water Quality Control Plant 34
7. Summary & Discussion of the Without-Project NED Flood Damages 38
8. Preliminary Project Options Proposed by the JPA 39
8.1. Fluvial Options 39
8.2. Coastal Options 45
9. Discussion of Potential Federal Interest 48
10. Regional Economic Development and Other Social Effects 49
10.1. Regional Economic Development (RED) 49
10.2. Other Social Effects (OSE) 49
11. Recreation Analysis 52

12. Addendum 53
12.1. Flood Maps 53
12.2. Structure and Content Depth-Damage Curves 54
12.3. Fluvial Analysis HEC-FDA Screen Captures* 58

List of Tables

Table 1: Description of Fluvial Economic Impact Areas 6
Table 2: Description of Coastal Economic Impact Areas 9
Table 3: CSVRs per Structure Type 14
Table 4: Structures in .2% Floodplain 15
Table 5: Value of Structures and Contents in .2% Floodplain ($1,000s) 16
Table 6: Depreciated Replacement Value 16
Table 7: Structures in .2% Coastal Floodplain 17
Table 8: Value of Structures and Contents in .2% Coastal Floodplain ($1,000s) 17
Table 9: Depreciated Replacement Value and Square Footage of Structures 18
Table 10: Equivalent Annual Damages ($1,000s), Coastal Flooding 27
Table 11: Equivalent Annual Traffic Delay Costs, Highway 101 33
Table 12: Example of Height at Which Treatment Plant 36
Table 13: Repair and Replacement Damage to Palo Alto WQCP ($M) 37
Table 14: OSE Structure Counts 50

List of Figures

Figure 1: Fluvial Impact Areas 5
Figure 2: Coastal Impact Areas 8
Figure 3: Map Showing Areas of Combined Flood Risk 10
Figure 4: Example of Parcel Centroid Location 18
Figure 5: SFR1 Structure Depth-Damage Curve 21
Figure 6: Depth-Damage Function for Vehicles 22
Figure 7: Displacement Cost and Days Displaced 24
Figure 8: Displacement Depth Damage Curve 24
Figure 9: Fluvial EAD by Major Category and Impact Area ($1,000s) 26
Figure 10: Coastal EAD by Impact Area and Structure Category 27
Figure 11: Coastal Flooding at Highway 101 31
Figure 12: Distribution of Travel Delay Cost, Highway 101, 1 Day Closure 32
Figure 13: Aerial Showing Location of Palo Alto Airport and WQCP 34
Figure 14: Reach 1, Option 1 (Source: JPA) 39
Figure 15: Reach 1, Option 2 (Source: JPA) 40
Figure 16: Reach 1, Option 3 (Source: JPA) 41
Figure 17: Reach 2, Option 1 (Source: JPA) 42

Figure 18: Reach 2, Option 2 (Source: JPA) 43
Figure 19: Reach 2, Option 3 (Source: JPA) 44
Figure 20: Reach 1, Options 1 & 2 (Source: JPA) 45
Figure 21: Reach 2, Option 1 (Source: JPA) 46
Figure 22: Reach 2, Option 2 (Source: JPA) 47
Figure 23: Draft .2% Coastal Floodplain 53
Figure 24: SFR1 Content Depth-Damage Curve 54
Figure 25: SFR2 Structure Depth-Damage Curve 54
Figure 26: SFR2 Content Depth-Damage Curve 55
Figure 27: Commercial Structure Depth-Damage Curve 55
Figure 28: Commercial Content Depth-Damage Curves 56
Figure 29: Industrial Structure Depth-Damage Curve 56
Figure 30: Industrial Contents Depth-Damage Curve 57

Executive Summary

This report describes the data, methodology, and policy requirements for documenting the results of the without-project fluvial and coastal flood damage analysis for the San Francisquito study area. The damages were computed separately for eight different fluvial EIAs, and four different coastal EIAs, incorporating the effect on the creek and the coastal floodplain resulting from the Curve III sea-level rise scenario.

As is generally the case in USACE flood damage analyses, physical damages to structures and contents comprise the vast majority of damages expected from flooding. Residential structures are expected to sustain over 90% the total damages from flooding. Emergency Costs, NED Income Loss to businesses, Travel Delay and Detour Costs, and Insurance Policy Administration costs are all categories that will also get further treatment at the next phase of the feasibility analysis and report. It is not anticipated that these damage categories will significantly change the total expected annual damage estimates, but it is important to thoroughly describe the full range of impacts from flooding as well as the potential benefits from projects that reduce flood risk.

As currently estimated, a 1% fluvial flood event is anticipated to cause $225 million in overall damage. Future sea-level rise did not factor significantly in the fluvial flood modeling. All else equal, further sea-level rise scenario analysis would not be expected to change the results enough to affect plan formulation.

While the risk-based coastal modeling has not yet been completed for the area north of San Francisquito Creek, the preliminary results for a 1% coastal flood event in “Year 0” is estimated to cause $131 million in overall damage. Factoring in sea-level rise impacts, the damage from the 1% event grows to approximately $767 million by the end of the period of analysis – Year 2066

A comprehensive flood risk management solution comprised of various options thus far developed by the non-Federal sponsor are estimated by the sponsor cost between $144 million and $243 million (these are preliminary estimates that don’t include several important cost elements such as real estate valuation, interest during construction, and other economic costs).

At the current FY12 water resources discount rate of 4% and amortized over fifty years, these comprehensive project costs equate to annualized costs between $6.7 million and $11.3 million. Effectively reducing the flood risk in the area to all but the most extreme events (beyond the 1% annual exceedence probability event) is preliminarily estimated to result in $30 million in average annual flood damage reduction benefits.

Annual benefits of $30 million would support total project costs up to $644.5 million, while maintaining a benefit-cost ratio of unity (i.e. 1.0). Given the preliminary estimates, in order to have a B-C ratio of 2.0 or greater the project would need to cost less than $323 million. Finally, to achieve a B-C ratio of 2.5 the total project costs could not exceed $258 million. While these scenarios all seem to support the economic feasibility of the preliminary project options (which the sponsor has estimated will cost between $144 million and $243million), the data and model results completed thus far (both hydraulic engineering and economics) are not yet sufficient to claim any plan or plans as economically viable (i.e. b-c ratio >= 1) at the feasibility study level.

Moreover, USACE Planning Guidance requires that separable elements of a project must be economically justified based upon their own benefits. In other words, measures that protect from riverine flooding but not coastal flooding would have to be justified solely upon fluvial benefits. Likewise, coastal solutions that did not help reduce riverine damages would have to rely only upon coastal benefits. There could be plans that protect against both types of flooding, and the appropriate accounting of benefits would need to be conducted based upon coincidental floodplain depths that have yet to be developed for this study.

Another concern for USACE regarding Federal Interest would be the consideration of non-structural alternatives to lower flood damage risk. USACE's Planning Guidance Notebook requires that planning studies properly consider alternatives such as temporary or permanent relocations, raising structures in place, and/or developing comprehensive flood warning systems to achieve economic benefits. Since the preliminary Year 50 coastal floodplains show substantial flooding at the 50% and 20% annual exceedance probability events (2 and 5-yr return periods, respectively), significant changes in future land use for the area would have to be considered and analyzed.

Still, all of these preliminary numbers leads to a reasonable conclusion that there do exist potential solutions—either proposed by the Federal Government or the non-Federal Sponsors or a combination of the two—that justify continuing this feasibility study. Although there are inevitably many hurdles during a planning feasibility study—engineering as well as environmental concerns involving people, animals, and fauna—there seem to be sufficient without-project damages that could be prevented and count towards flood risk reduction benefits to support substantial cost figures, as just described. At this point in the analysis, the numbers seem to indicate that the criterion of economic feasibility would likely be met in order to justify continuing Federal Interest in the San Francisquito Creek feasibility study.

1. Introduction

1.1. Purpose

The purpose of this report is to document the methodology and results of the Economic Analysis conducted to assess the without-project condition as it relates to damages from potential future fluvial and coastal flooding in the area known as the San Francisquito Creek study area.

The analysis focuses on without-project conditions related to flood damages to structures and contents. Other damage categories such as autos, utilities & infrastructure, and foregone costs related to flood fighting, evacuation, and cleanup will be added in the next Planning Milestone economics analysis. The primary focus of this analysis is to estimate the economic damages associated with potential future flood events in the study area assuming no Federal project is constructed/implemented. At the non-Federal sponsor's request, there is also a discussion of the potential economic justification of the preliminary conceptual project options that have been developed by the sponsor. In order to address this issue at this point – since the full without-project coastal modeling has not yet been completed, nor have with-project modeling or full cost estimates been developed – several simplifying assumptions were made. These are described in detail throughout the report, and in particular Sections 8 and 9 describe the preliminary assessment of economically justified projects.

At subsequent study phases, the difference between the without-project damages and with-project damages (the net of those two being the project benefits) will be compared to the costs of various alternatives. The net economic benefits to the Nation resulting from each of the alternatives will then be compared in order to identify the National Economic Development (NED) alternative (per the *"Planning Guidance Notebook"*)

1.2. Flood Damage Analysis Overview

The principal guidance referenced for this analysis comes from the U. S. Army Corps of Engineers (USACE) "*Planning Guidance Notebook*", ER 1105-2-100, with specific guidance from Appendix D – Economic and Social Considerations. Additional guidance on risk-based analysis has been obtained from USACE ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*, dated January 3, 2006. Benefits and costs are expressed in average annual terms at FY 2011 (Oct 2010) price levels using the mandated federal discount rate of 4%. The period of analysis is 50 years. The study/project Base Year, defined as the year when the project is expected to be operational and benefits begin to be realized, is 2017. Within the floodplain there is little or no vacant, developable land, and for this reason the analysis assumes that the future without-project floodplain inventory of structures and land use is equivalent to the current without-project condition.

By policy, USACE Flood Risk Management feasibility reports must evaluate the flooding problem (and potential measures to reduce the risk of flooding) against four "accounts." These are National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). While all four accounts will ultimately be considered in the evaluation of potential federal investments, this without-project flood damage analysis focuses primarily on the NED account. The OSE account is of increasing importance from an agency perspective, and a preliminary description of the effects is included at the end of this report.

The USACE Planning Guidance Notebook (PGN) describes the NED account as such:

> *Contributions to national economic development (NED) are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the Nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed.*

The NED account is exclusively concerned with national net economic benefits, and thus does not include local or regional economic transfers. For example, according to the PGN, the prevention of income loss results in a contribution to national economic development only to the extent that such loss cannot be compensated for by postponement of an activity or transfer of the activity to other establishments.

The primary NED damage categories evaluated for this study phase is as follows:

- Structure and content damages to residences, business & industry, and public buildings

The following list represents typical benefits categories that will be included during the Alternatives Analysis phase of this feasibility study:

- Cost to temporarily displaced residents
- Automobile damages
- Traffic delay and detour costs
- Emergency and cleanup costs

The damage to structures, contents, automobiles, and the cost of residential displacement are all estimated within the computer program HEC-FDA v.1.2.5a, while damages related to the other categories will be estimated outside of the HEC-FDA program. Traffic delay costs are typically estimated via a simple spreadsheet model that is based on the methodology and value of time recommended by IWR Report 91-R-12 "*Value of Time Saved for Use in Corps Planning Studies*." For those damage categories calculated in HEC-FDA, the value of these assets was estimated outside of the program, and then imported into the program along with probability-stage data for each particular structure. The base structure elevation data (not including a first floor adjustment) was provided to the USACE San Francisco Economics Section by the Geographic Information System (GIS) Section.

The HEC-FDA models were built with data for each structure for each exceedance probability – 4%, 2%, 1%, .4% and .2% events. This report uses exceedance probabilities to describe flood events. The exceedance probability is the reciprocal of what is often referred to as the "return period." The return period (or recurrence interval) of an annual maximum flood event has a return period of X years if its magnitude is equaled or exceeded once, on the average, every X years. As an example, a 1% return period (1/100) means that there is a 1% probability of an occurrence in any one year. HEC-FDA uses Monte Carlo simulation to calculate a stage-damage relationship with uncertainty, and the program then annualizes the probability-weighted damages to calculate an equivalent annual damage value for each scenario considered.

This report addresses the fluvial and coastal flood risk in the study area. While the overall approach is similar, there are differences in how the fluvial and coastal risk is evaluated. The models used to produce the floodplain data, the depth-damage relationships assumed, and the need to consider sea level rise scenarios all differ between the fluvial and the coastal analysis. Thus, the two analyses will be presented separately, while the coastal analysis will refer to the methods described in the fluvial analysis when they are equivalent – for example, both use the same method for structure valuation.

This analysis used the procedures of directly inputting the set of water depths for each of the economic impact areas (EIAs) into HEC-FDA as a water surface profile, then calculating the exceedance-probability stage data within HEC-FDA, and including the ground elevations of the structures (with first floor elevation (FFE) adjustments) in the inventory import file. As such, HEC-FDA calculates the depth of flooding at each structure for each event and develops an aggregated stage-damage curve. Finally, the program calculates an Expected Annual Damage figure by linking the exceedance probabilities to stage-damages, incorporating risk and uncertainty based upon the Period of Record assigned to the probability-stage curve and the standard deviations resulting from the aggregated stage-damage curves.

1.3. Brief Description of the Flood Modeling

This without-project flood damage analysis considers damages from San Francisquito Creek fluvial flooding as well as coastal flooding. The extent to which the flooding from these two sources is coincidental is not known at this point. It is expected, however, that flooding from these two sources will be somewhat correlated, and proper procedures to avoid double-counting will need to be incorporated during the next phase of this study. In order to accurately understand the benefits of a project, and in order to understand the residual risk associated with either a fluvial or coastal project, it is important to understand the relationship between the two flooding sources. It is likely that adjustments to the analysis will need to be made as more is learned about the likelihood of coincidental flooding in some areas.

With respect to fluvial flooding, according to the Without-Project H&H analysis, flooding in the EIAs is primarily caused by a lack of capacity for conveying water volumes under several bridges that cross San Francisquito within the study area. Moreover, there are existing levees at the downstream end of the study area that would be overtopped during the 4% event and greater. Geotechnical investigations completed for this study indicates that the levees have fragility curves (i.e., there is a probability of some type of engineering failure before being overtopped), but due to the volume of water escaping into the upstream floodplains because of the too-small bridge underpasses, the geotechnical fragility curves were not used for the Without Project damages calculation. These levee fragility curves will be incorporated in the subsequent Alternatives Analysis phase of this feasibility study.

The coastal modeling for the area north of the San Francisquito Creek is only partially complete

With respect to the coastal flooding, flooding from storm events is the result of storm surge, wave run-up, low and relatively fragile coastal levees, and expected future sea-level rise. For practical reasons, the coastal flood modeling was performed using two different methods. The coastal area south of San Francisquito Creek was modeled as part of the effort to assess the existing and future conditions in the South San Francisco Bay Shoreline Feasibility Study. The coastal area north of the creek was modeled as part of the San Francisquito Creek Feasibility Study.

For the area north of the creek, the only future condition fully modeled to date assumes the National Research Council's (NRC) Curve 3 sea-level rise scenario[1]. The Curve 3 projections are most similar to the State of California's requirements for the consideration of sea-level rise in project planning. The area south of the creek has data for multiple future sea-level rise scenarios, but for consistency's sake the results for the Curve 3 scenario will be the primary focus of the report. Importantly, the coastal modeling in this area is preliminary, and has not been completed to a level of detail that is commensurate with either the fluvial

[1]Corresponds to 2.13 feet of sea level rise at project year 50 (year 2067)

floodplain or the area south of the creek. For this reason, it should be expected that the results for this area shown in this report will change.

While Corps guidance on sea-level rise analysis (EC 1165-2-211) recommends *"a multiple scenario approach to deal with key uncertainties for which no reliable or credible probabilities can be obtained"*, this report is simply an interim, preliminary product and does not include a full analysis of multiple future scenarios.

2. Structures, Contents, and Infrastructure at Risk from Fluvial Flooding

The sections below briefly describe the structures classifications and contents values of each of the 8 economic impact areas within the fluvial floodplain. These areas have been analyzed separately in order to aid in an incremental approach to plan formulation and the economic analysis.

2.1. Delineation of Economic Impact Areas

The Economic Impact Areas (EIAs) were generally constructed based upon the following main criteria:

1. visual examination of the floodplain maps showing several flooded areas within the overall study area,
2. consideration of major streets and roads within the floodplains that obviously serve as de facto borders between residential and commercial/industrial neighborhoods, and
3. ensuring that no EIA straddled San Francisquito Creek due to its role as the natural borderline between San Mateo and Santa Clara counties; five (5) EIAs in San Mateo and three (3) are in Santa Clara counties. Figure 4 and Table 1 describe and show the general location of each of the EIAs.

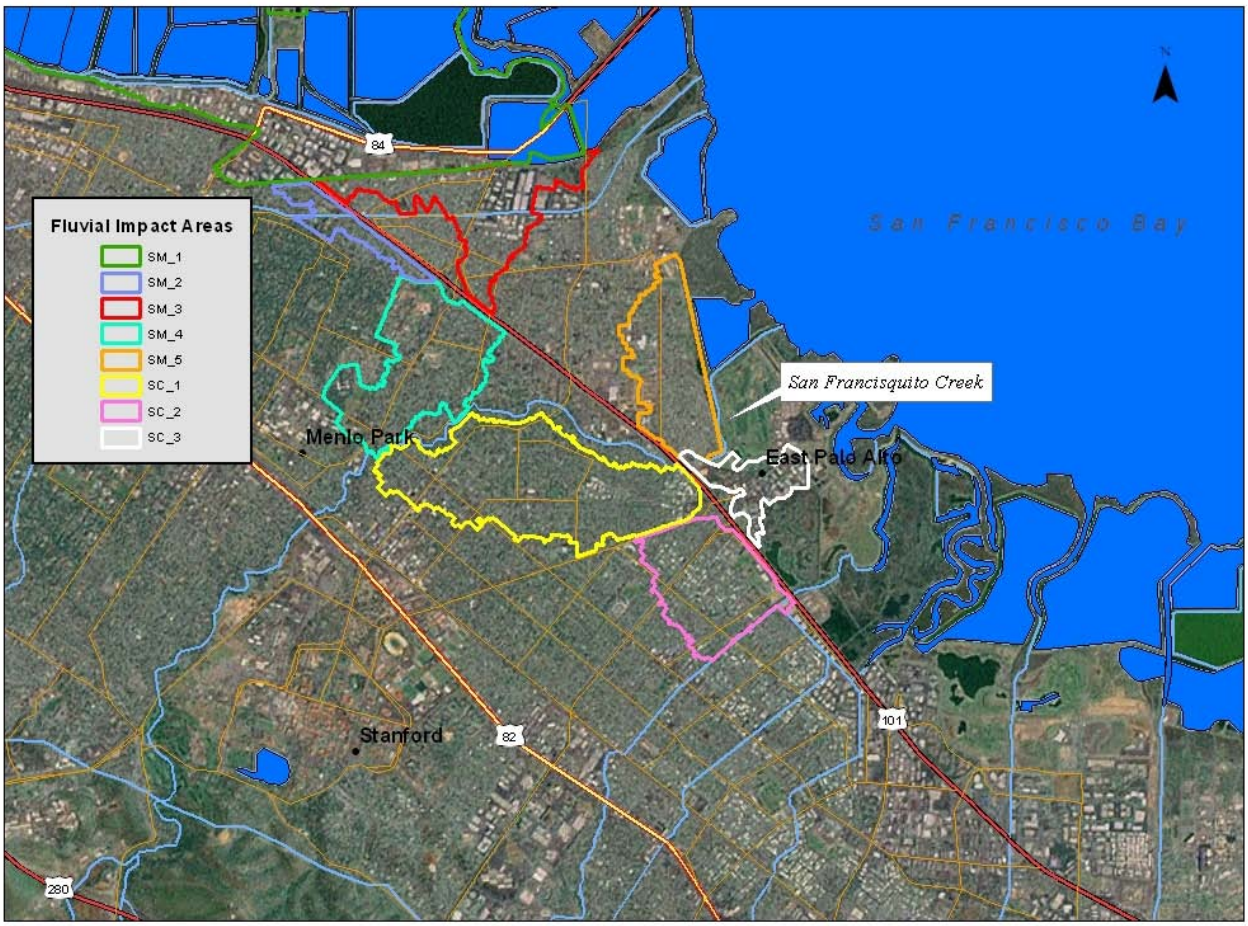


Figure 1: Fluvial Impact Areas

Figure 1 above shows the fluvial EIAs in the study area. In the figure, EIAs San Mateo County are called SM_1 through SM_5, while those in Santa Clara County are called SC_1 through SC_3. Table 1 and the sections that follow further describe the location of each of the impact areas and the land use within each area.

Table 1: Description of Fluvial Economic Impact Areas

EIA	Description
San Mateo 1	BAYFRONT EXPRESSWAY (mostly industrial/commercial area north of Bohannon Dr/RR tracks between Marsh and Willow Rds.)
San Mateo 2	FLOOD PARK TRIANGLE (mostly residential generally bound by Bohannon, Van Buren, and Bay Rd. -- west of US 101)
San Mateo 3	BELLE HAVEN (mostly residential with some industrial located south of Bohannon/RR tracks, east of US 101 and west of Ralmar Ave)
San Mateo 4	WILLOWS/VINTAGE OAKS (mostly residential west of US 101, east of Middlefield Rd, between the north bank of San Francisquito Creek and Willow Rd)
San Mateo 5	PULGAS AVENUE (mostly residential straddling Pulgas Ave east and west by several blocks, bounded between Bay Rd to the north and US 101 to the south)
Santa Clara 1	CRESCENT PARK/DUVENECK-ST FRANCIS (mostly residential with commercial; south of San Francisquito Crk. across University, north of Embarcadero Rd between Waverly St and US 101)
Santa Clara 2	OREGON EXPRESSWAY (residential south of Embarcadero Rd. and north of Clara Dr. between Ross Rd. and US 101)
Santa Clara 3	EMBARCADERO/EAST BAYSHORE (mostly commercial with industrial located west of US 101 straddling Embarcadero Rd eastward to Embarcadero Way

2.2. Structure Types and Flooding Characteristics by EIA

This section describes the types of structures and flooding characteristics in each of the eight EIAs. The land use maps were created based on the structure inventory work performed by the Corps between during February and March 2011. The source of the raw data (particularly square footage) was county assessor parcel data obtained directly from San Mateo and Santa Clara counties, with field investigations done by Corps economists. The construction characteristics of the homes and businesses in the study area are consistent with other regions of California.

The structure inventory database and the flood damage analysis contain 16 structure types. A description of these structure types is contained in Section 3. The extent of the inventory was based on an estimate of the .2% floodplain extent of the Curve III sea-level rise scenario. Due to FFE adjustments, in reality the number of structures susceptible to flood damage is somewhat fewer than is reflected in the inventory maps.

For the Base Year 2017, each EIA was assigned a water surface elevation profile which was created by overlaying floodplain depths generated by FLO2D and overlaid onto GIS maps of the study area. All of the EIAs floodplains were then attached to an H&H (hydrology and hydraulics) index point at the upper end of the creek. This adjustment was necessary due to the relatively "flat" probability-stage relationship within the overbank floodplains. Since HEC-FDA is largely dependent upon change-in-depth flooding (as opposed to sheet-flow flooding where subsequent larger events tend to have similar depths but larger geographical extents), the FLO2D floodplains depths were attached to an in-channel HEC-RAS probability-stage curve. This methodology has been used in other San Francisco and Sacramento District studies as an appropriate way to accurately model damages while using the USACE-approved HEC-FDA model. Flood maps are displayed showing the depths of flooding for the 5 modeled events previously noted. The actual depths in and around the structures generally averages no more than a few feet, due to the sheet-flow nature of the overbank flooding.

2.2.1. San Mateo EIAs

Bayfront Expressway (San Mateo 1) is primarily a commercial and industrial area located between the San Francisco Bay and US 101. There is one small pocket of residential structures at the most eastern extent of this EIA called Harbor Village Mobile Home Park. This EIA contains the Carlsen Porsche dealership as well as several industrial and commercial park areas with a wide variety of companies: mailing & shipping, medical technology, banking, and machining to name a few.

San Mateo 2 – 5 contain the neighborhoods of Belle Haven and the Pulgas Avenue area on the east side of US 101 (generally, East Palo Alto). West of US 101 the neighborhoods of Flood Park Triangle and Vintage Oaks (Menlo Park) lie within the study area. All are almost completely residential, with only a few commercial structures susceptible to flood damage. In addition to residences, these neighborhood EIAs have several schools, parks, libraries, hospitals, and churches. In Base Year 2017, the first significant floodplain damage occurs at approximately the 4% event.

2.2.2. Santa Clara EIAs

Santa Clara 1 (Crescent Park/Duveneck-St Francis) is the largest geographic EIA within the study area (Palo Alto). It covers several older and more established neighborhoods and the accompanying shops, restaurants, and grocery stores typical near residential areas. The Edgewood Plaza Shopping Center is located within this EIA. It also has several schools and medical facilities, as well as a community center and library branches. This EIA is directly adjacent to San Francisquito Creek. The Oregon Expressway EIA (Santa Clara 2) shares Embarcadero Road as a border; EIA 2 is similar in structure type and land use to Santa Clara 1.

Santa Clara 3 is also within the city limits of Palo Alto, although it is located across US 101 from both Santa Clara 1 & 2. This EIA contains mostly commercial structures (restaurants, office parks, and car dealerships) as well as several public buildings including the Palo Alto Post Office. Nearby, there is the Palo Alto commercial airport and the Palo Alto Municipal Golf course; neither of these land parcels were shown to incur flooding at the .2% event however and do not factor into this economic damage analysis.

3. Structures, Contents, and Infrastructure at Risk from Coastal Flooding

The sections below briefly describe the structures classifications and contents values of each of the 4 economic impact areas within the study area's coastal floodplain. These areas have been analyzed separately in order to aid in an incremental approach to plan formulation and the economic analysis.

3.1. Delineation of Economic Impact Areas

The EIAs for the coastal analysis were developed following discussions with the coastal engineers that performed the floodplain modeling. The floodplain south of San Francisquito Creek (in Santa Clara County) is divided into three areas that are defined various creeks. Santa Clara Coastal 1 is the area south of San Francisquito Creek and north of Matadero Creek. Santa Clara Coastal 2 is the area south of Matadero Creek but north of Barron Creek. Santa Clara Coastal 3 is the area south of Barron Creek and north of Adobe Creek. Figure 2 below shows these areas.

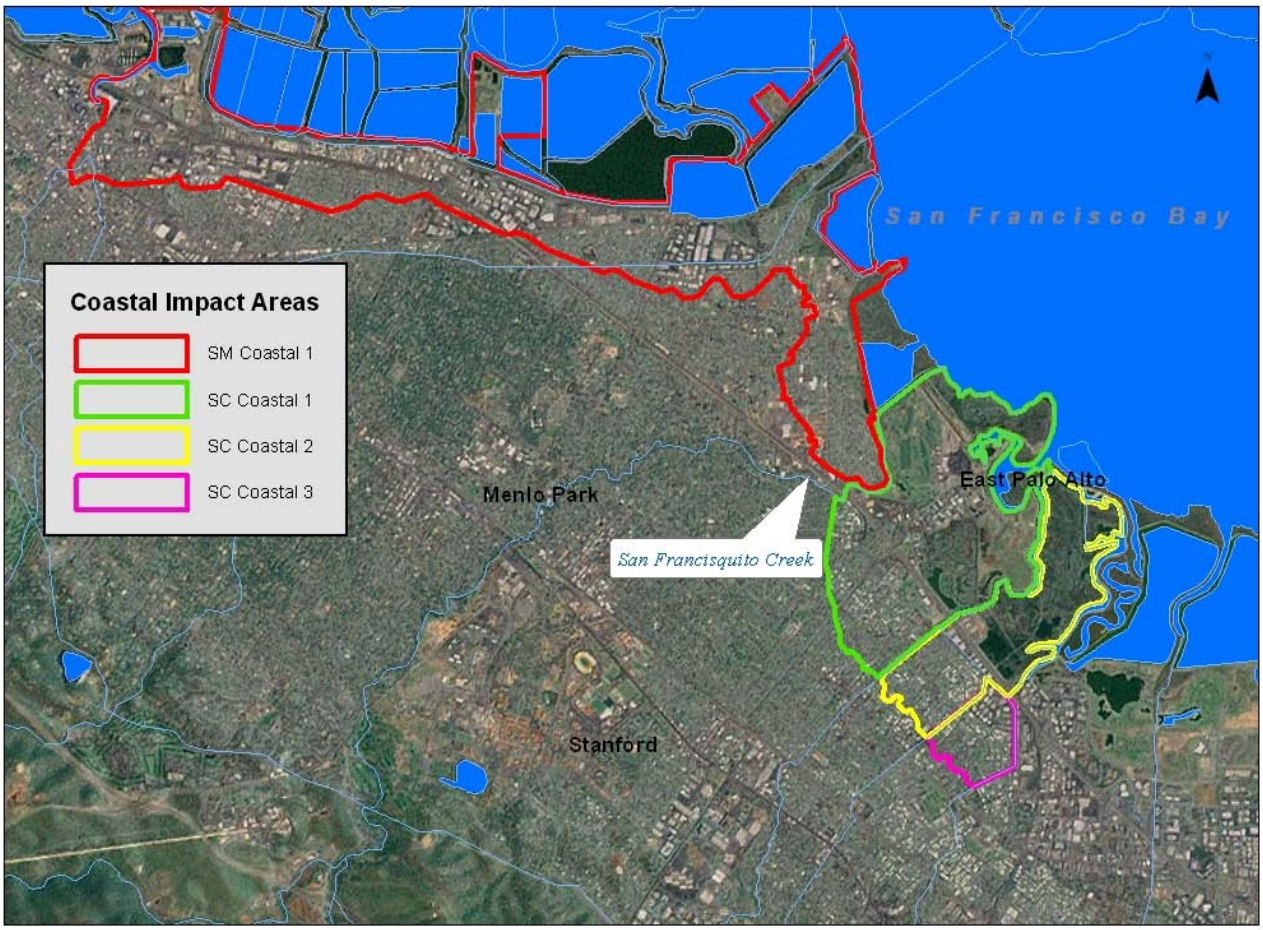


Figure 2: Coastal Impact Areas

Table 2: Description of Coastal Economic Impact Areas

EIA	Description
San Mateo Coastal 1	SAN MATEO COASTAL Mix of commercial, industrial, and residential structures between San Francisquito Creek and the Port of Redwood City
Santa Clara Coastal 1	SFQ-MATADERO Mostly residential area south of San Francisquito Creek between the creek and Matadero Creek
Santa Clara Coastal 2	MATADERO-BARRON Mostly residential area south of San Francisquito Creek between Matadero Creek and Baron Creek
Santa Clara Coastal 3	BARRON-ADOBE Mostly residential area south of San Francisquito Creek between Barron Creek and Adobe Creek

San Mateo Coastal 1 is a mix of commercial, industrial, and residential structures. At the northwest end are the Port of Redwood City and a large business park. At the south end of the area is the city of East Palo Alto, a large part of which is in the coastal floodplain under the Curve 3 sea-level rise scenario. East Palo Alto is a low-income area whose residents are primarily from minority groups.

Santa Clara Coastal 1 is primarily a residential area, and over 95% of the structures at risk from flooding are single-family and multi-family residences. Importantly, the Palo Alto Airport and the Palo Alto Water Quality Control Plant are also located in this impact area. Highway 101 runs through this and the adjacent EIAs, and is one of the most trafficked stretches of highway in the region, with more than 400,000 trips per day. Below a WSEL of approximately 9 ft, flooding is limited to the commercial and industrial structures on the bay side (east) of the freeway. The area between the highway and the bay is relatively low in elevation and structures are expected to sustain damage at a WSEL of around 6.5 ft. Floodwaters higher than 9 ft will overtop the freeway, causing traffic impacts and damaging the primarily residential structures west of the freeway.

Santa Clara Coastal 2 and 3 are almost completely residential, with a handful of commercial and industrial structures located near Highway 101. Nearly all of the structures that are at risk from flooding are on the inland side of Highway 101, and water is not expected to overtop the freeway until approximately WSEL 8ft. In Year 2017, the first significant damage occurs at approximately the 4% event.

4. Combined Risk – Areas With Both Fluvial and Coastal Flood Risk

The figure below shows that combined flood risk from both fluvial and coastal sources is an important factor in the study area and for this damage analysis. There is a combined risk of both fluvial and coastal flooding where the polygons overlap the grey area. This is an important factor because a project that reduces the damage from just fluvial or just coastal flooding would have a potentially high degree of residual risk, and thus the benefits associated with the project would be lessened.

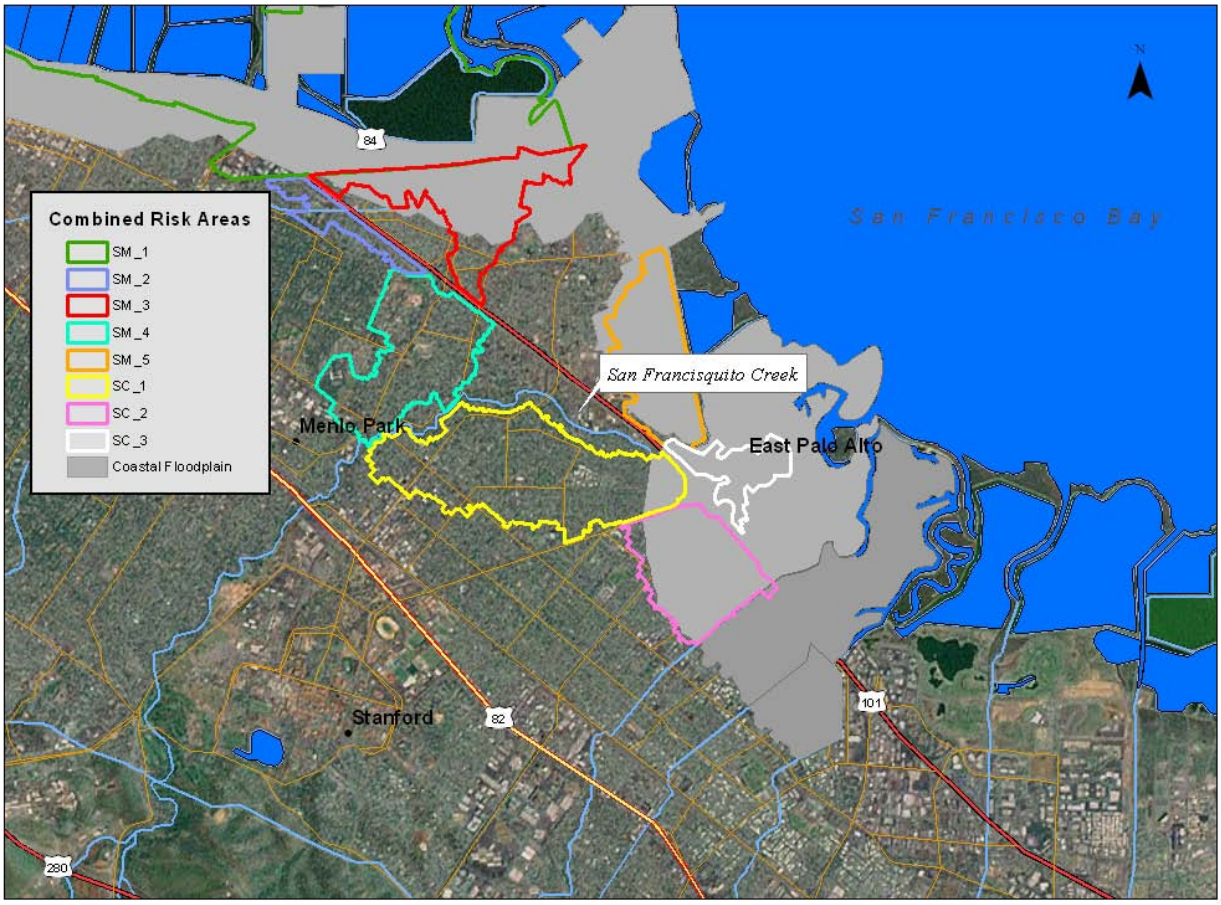


Figure 3: Map Showing Areas of Combined Flood Risk

There are approximately 7,500 structures in the fluvial floodplain and 3,000 structures in the coastal floodplain. Approximately 1,650 structures are in both the coastal and fluvial floodplains. About one-fifth of the fluvial structures and one-half of the coastal structures are in the combined risk area. Thus, it is clear that combined flood risk is a significant issue for much of the study area.

Unfortunately, at this point not enough coastal modeling has been completed to describe the extent to which the coastal and fluvial flooding are correlated. The understanding of this issue is necessary for a complete analysis and project planning.

5. Structure, Content & Vehicle Valuation

In order to estimate the value of damages to property as a result of flood events within the study's floodplains, it is first necessary to inventory the structures and other assets within the floodplain. This section describes how the inventory and valuation of structures were accomplished. The next section will describe how this data was used to develop an estimate of the value of the damages expected to occur from flooding.

5.1. Structure Inventory

An initial inventory of the parcels in each .2% floodplain was compiled in ArcGIS (ArcMap) software by linking the raster flooding depth file with a point shapefile containing the parcel information, and then exporting those parcels in the modeled floodplains to a spreadsheet. For each parcel, the data was linked to the geographic center of mass of the particular parcel by creating a data centroid within the ArcMap program. Because only those parcels whose centroid overlaps the floodplain are considered as impacted, only those parcels that are at least bisected by the floodplain are included in the inventory. This is done in an attempt to improve the accuracy of the structure inventory – eliminating the inclusion (and ultimate valuation) of those parcels that are least likely to have structures that are actually impacted by the flooding, even while a portion of the parcels receive some non-zero level of flooding. However, there are cases where the centroid of the parcel shape does not accurately enough reflect the location of the structure – for instance, some commercial, industrial, or public parcels contain more than one structure. In order to manage this eventuality, and to make sure the damage model includes all of the structures at risk of flooding, spot checking of the parcels and structures along the outer edge of each floodplain was conducted during the economic fieldwork. When it was the case that aerial photography showed a structure to be located in the floodplain when the ArcMap centroid method did not, this structure was added to the database with the appropriate depth of flooding referenced.

5.2. Structure Valuation

The parcels identified as within the .2% floodplain via the procedure described above were then matched to data obtained from the San Mateo and Santa Clara assessor offices. These real property databases include parcel-specific information on structure type, square footage, construction date, information on improvements, etc. The vast majority of the residential structures inventoried fit into the Class D category. Class D buildings are characterized by combustible construction. The exterior walls may be made up of closely spaced wood or steel studs, as in the case of a typical frame house, with an exterior covering of wood siding, shingles, stucco, brick, stone veneer, or other materials. They may also consist of an open-skeleton wood frame on which some form of a curtain wall is applied including the pre-engineered pole or post-frame buildings.

For the valuation of the structures in the floodplain, structures were classified as one of the following 16 categories listed below:

- Single Family Residential (SFR) 1-Story
- SFR 2-Story
- Multi-Family Residential (MFR) 1-Story
- MFR 2-Story
- Manufactured Housing (MH)
- Commercial
- Grocery & Gasoline
- Office C (Marshall & Swift)
- Office D (Marshall & Swift)
- Restaurants
- Retail
- Public - Wood Frame
- Public – Masonry
- Industrial (Generic)
- Ind. R&D
- Ind. Warehouse

The calculation of structure value in a floodplain can be done several different ways, each having their advantages and disadvantages. One method, estimating the Depreciated Replacement Cost of the structures in the floodplain, involves integrating the following: size of the structure, the unit cost of construction as measured in cost per square foot, and an allowance for deterioration as measured as a percent of total value. An alternative way of calculating the total structure value in the floodplain would be to use tax assessment records on each parcel's improvement value. While this assessment information is readily available, California's Proposition 13, which limits increased assessments until a home is sold, results in unequal valuations of one home relative to another. It is primarily for this reason that this study uses the Depreciated Replacement Cost method. More information on the different structure valuation methods can be found in IWR Report 95-R-9, *Procedural Guidelines for Estimating Residential and Business Structure Value for Use in Flood Damage Estimations*. The Depreciated Replacement Cost method requires visits to the structures themselves in order to attain the necessary information, which includes foundation height, structure type, and structure condition. This process is explained below.

The valuation of the structures in the floodplain requires information on structure type, construction quality, current condition, and number of stories[2]. Once collected, this information was used to calculate the structure depreciated replacement values. Base per square foot construction cost estimates for each structure type were determined by utilizing the Marshall and Swift Real Estate Valuation Service method according to the following procedure:

- Construction quality and current condition of the structures were noted from field surveys.
- For a given structure type, the per square foot construction cost (replacement cost) was determined using the most current Marshall & Swift Valuation Service data. This per square foot cost estimate reflects the construction quality of the structure.
- The per square foot costs, which are based on a national average, were modified to reflect local cost conditions using Marshall & Swift local cost multipliers.
- This current, locally adjusted cost per square foot was then adjusted additionally for the condition of the structure, which determines the appropriate depreciation factor to apply. In order to correlate the current condition of the structure to a percent depreciation, the study used Tables 7 through 9 of IWR Report 95-R-9, '*Procedural Guidelines for Estimating Residential and Business Structure Value for Use in Flood Damage Estimations*'.
- The depreciated replacement cost per square foot values were multiplied by square footage to arrive at the total depreciated replacement value for the different types of structures.
- If the square footage was not available within the real estate records for a particular property, square footage estimates were made from aerial photography measurements using the Google Earth application.

5.3. Content Valuation

As described above, under this study's methodology, the value of the contents within each structure is assumed to be a function of the value of the structure. The value of the contents of each structure was estimated by multiplying the Content Structure Value Ratio (CSVR) for the particular structure type by the estimated structure value (as calculated per the method described in the previous section).

Table 3 shows the ratios assumed for the content-to-structure values of the different classifications of residential and non-residential buildings in the floodplain. The primary source of CSVR estimates used for this analysis is a report produced for the USACE New Orleans District. The report is the product of a very thorough and extremely detailed expert panel elicitation.

[2] Structure first floor elevation was also recorded for each structure visited as part of the field inventory work. While this data is not relevant for the structure valuation, it is a critical variable in the estimate of flooding damage.

Table 3: CSVRs per Structure Type

Structure Type		CSVR	Standard Deviation
Residential	SFR	0.5	0.12
	MFR	0.5	0.12
	MH	0.5	0.12
Commercial	Eating and Recreation	0.4	0.7
	Groceries & Gas Stations	1.4	0.7
	Professional Businesses	0.9	0.9
	Retail and Personal Services	1.7	1.45
Other	Industrial	0.7	1.0
	Public	0.4	0.5

5.4. Structure Inventory and Valuation Results – Fluvial Floodplain

Table 4 shows the numbers of structures by type that was inventoried for the .2% floodplain. Not all of these buildings ultimately end up contributing to damage estimates. Based upon the depth of water for the .2% flood event and the data gathered during the economic fieldwork—specifically the building foundation height--, many of these structures' first floor were in fact elevated well above the floodplain.

Table 4: Structures in .2% Floodplain

EIA	Residential	Commercial	Industrial	Public
SM 1	5	31	89	0
SM 2	356	3	0	1
SM 3	791	6	56	16
SM 4	1,123	25	1	6
SM 5	1,263	8	4	10
SC 1	2,646	61	0	9
SC 2	1,266	1	0	4
SC 3	0	26	4	2
Total	7,450	161	154	48

The following tables display the total claimable value of structures and contents, by structure type, in the .2% floodplain for Year 2017. It is important to note that the values are estimates of the depreciated replacement value of structures and contents only, and do not represent expected damages. Instead, the estimates can be seen as the total estimated value of the structures and contents that are within the extent of the .2% floodplain. The values only include structures and contents, and do not include automobiles or the value of infrastructure in the floodplain such as the three water pollution control plants. As is generally the case with USACE flood damage analysis, the value of land is not included in the damage analysis.

As can be seen in the tables and figures below, residential structures far outnumber commercial and industrial structures in the study area. Commercial and industrial buildings represent the majority of value in the Bayfront Expressway EIA (SM 1) and in the East Bayshore EIA (SC 3). Even in EIAs where residential structures are predominant, there are concentrated areas along both sides of US 101 within the study area that contain commercial and industrial parks that also include important warehouse/distribution facilities.

Table 5: Value of Structures and Contents in .2% Floodplain ($1,000s)

	Residential		Commercial		Industrial		Public		Total
	Structure	Content	Structure	Content	Structure	Content	Structure	Content	
SM 1	15,700	7,900	154,700	138,100	128,700	87,600	-	-	532,700
SM 2	38,200	19,100	1,100	960	-	-	124	46	59,500
SM 3	63,00	31,600	4,300	4,300	93,000	63,300	8,500	3,150	271,200
SM 4	128,600	64,300	24,700	22,000	57	39	13,000	4,800	257,500
SM 5	113,500	56,800	750	680	2,200	1,500	11,200	4,200	190,800
SC 1	599,900	300,000	36,800	33,100	-	-	8,800	3,300	981,800
SC 2	178,400	89,200	2,900	2,600	-	-	1,700	611	275,400
SC 3	-	-	90,740	81,700	3,200	2,200	1,600	580	180,000
Total	1,137,300	568,900	315,990	283,440	227,157	154,639	44,924	16,687	2,750,000

Table 6 shows the median depreciated replacement value, as well as square footage statistics for the four broad structure categories included in this study. The residential value is consistent with those calculated for other recent Corps studies in the area, while the commercial and industrial are somewhat higher than usual because of the large size of the structures of these types.

Table 6: Depreciated Replacement Value And Square Footage of Structures

County	Structure Type	Mean DRV (1,000s)	Mean Sq. Footage	Median Sq Footage
SAN MATEO	Commercial	$2,612	24,850	8,900
	Industrial	$1,555	31,600	20,289
	Public	$1,023	8,560	5,616
	Residential	$102	1,435	1,225
SANTA CLARA	Commercial	$1,535	13,200	5,000
	Industrial	$722	15,230	14,640
	Public	$828	7,700	4,850
	Residential	$199	2185	1800

5.5. Structure Inventory and Valuation Results – Coastal Floodplain

Table 7 shows the numbers of structures by type that was inventoried for the .2% floodplain. As with the structures in the fluvial floodplain, not all of these buildings ultimately end up contributing to damage estimates. Based upon the depth of water for the .2% flood event and the data gathered during the economic fieldwork—specifically the building foundation height-- many of these structures' first floors were found to be elevated well above the floodplain.

Table 7: Structures in .2% Coastal Floodplain

EIA	Residential	Commercial	Industrial	Public
San Mateo Coastal 1	587	129	127	20
Santa Clara Coastal 1	1098	18	2	6
Santa Clara Coastal 2	817	4	2	2
Santa Clara Coastal 3	504	16	1	1
Total	3,006	167	131	29

Table 8 displays the total depreciated replacement value (DRV) of structures and contents, by structure type, in the .2% 50-year coastal floodplain. Table 9 contains the mean DRV by structure type and damage area, in addition to statistics about building square footage. It is important to note that the values are estimates of depreciated replacement value of structures and contents only, and do not represent expected damages. The estimates do not include the value automobiles or infrastructure in the floodplain. As is generally the case with USACE flood damage analysis, the value of land is not included in the damage analysis.

Table 8: Value of Structures and Contents in .2% Coastal Floodplain ($1,000s)

	Residential		Commercial		Industrial		Public		Total
	Structure	Content	Structure	Content	Structure	Content	Structure	Content	
San Mateo Coastal	93,006	46,503	564,116	507,704	142,788	97,082	20,099	7,437	1,478,735
Santa Clara Coastal 1	168,344	84,195	35,550	30,643	2,646	1,799	7,934	2,935	334,046
Santa Clara Coastal 2	108,430	54,202	11,288	10,272	4,130	2,808	3,592	1,329	196,051
Santa Clara Coastal 3	85,954	42,947	34,643	31,525	2,646	1,799	227	84	199,825
Total	455,734	227,847	645,597	580,144	152,210	103,488	31,852	11,785	2,208,657

Table 9: Depreciated Replacement Value and Square Footage of Structures

County	Structure Type	Mean DRV (1,000s)	Mean Sq. Footage	Median Sq Footage
SAN MATEO COASTAL	Commercial	$4,148	35,047	7,845
	Industrial	$1,133	21,991	15,794
	Public	$1,340	12,748	5,760
	Residential	$144	2,341	1,150
SANTA CLARA COASTAL	Commercial	$3,291	31,158	19,823
	Industrial	$1,800	36,608	42,722
	Public	$1,711	17,411	6,950
	Residential	$152	1,831	1,612

As with the fluvial floodplain, residential structures far outnumber commercial and industrial structures in the coastal study area. Commercial and industrial buildings represent the majority of value in the San Mateo Coastal EIA; in the other EIAs, residential structures represent the majority of value.

5.6. Elevation and Flood Damage Relationships

For structure and content damages, depth of flooding relative to the structure's first floor is the primary factor in the magnitude of the damage. The GIS database, provided by San Mateo and Santa Clara County, contained spatially-referenced polygons for each parcel in the study area. Each parcel was then assigned a centroid in order to determine the ground elevation at the parcel, which was taken from the latest Digital Elevation Model available. Figure 4 shows an example of the location of the parcel centroid relative to the structure in a residential area of the floodplain.

The USACE San Francisco GIS Section ran statistics on the elevation of each of the parcel centroids, and provided the Economics Section with data tables containing depths at each centroid for each probability event modeled.

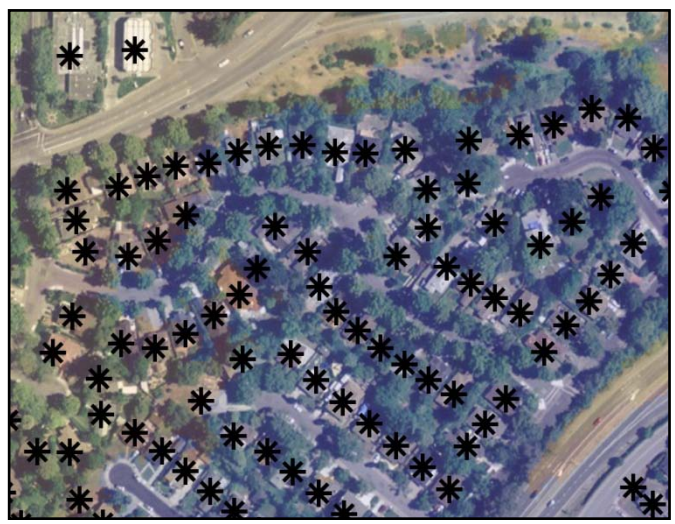


Figure 4: Example of Parcel Centroid Location

The centroid elevation method described above reasonably describes the elevation at a structure only to the extent that the structure is located approximately at the center of the parcel. Using this method to determine flooding depth and damage, it is possible that structures located on large parcels could be left out of the analysis and assumed to not be impacted for a particular event or events. It could also be the case that the elevation varies across the large parcel, and that the depth of flooding at the centroid does not reasonably represent the depth of flooding at the structure. This error would be expected to occur most often for non-residential parcels, especially some commercial and public parcels. In order to minimize the chance of this error, the study area parcels, centroids, and floodplains were reviewed in combination with aerial photography. In several cases the elevation assigned to a structure was changed to more accurately reflect the observed floodplain characteristics.

The elevation of each structure in the study area - along with an adjustment for the first floor elevation (FFE) - was combined with economic data (structure and content value, uncertainty of value expressed as a standard deviation percentage, etc.) and imported into the HEC-FDA model. For residential structures, a representative sample of first floor heights was observed in the field and applied with uncertainty to the population of structures in that EIA. For the non-residential structures, the complete inventory was observed in the field. Table 6 shows the average FFE adjustment for each of the major structure categories in each of the EIAs.

Table 6: Average FFE Adjustments by EIA and Structure Type

	Structure Type			
EIA	**Residential**	**Commercial**	**Industrial**	**Public**
SM 1	2.5	0.5	0.5	N.A.
SM 2	0.5	0.7	N.A.	1.0
SM 3	0.5	0.7	0.2	0.6
SM 4	1	0.5	0.5	0.6
SM 5	0.8	0.5	0.8	0.6
SC 1	0.7	0.5	N.A.	0.6
SC 2	0.5	1.0	N.A.	0.3
SC 3	N.A.	0.3	0.3	0.4

The table below shows some of the descriptive statistics of the flooding in the study area as calculated at the parcel centroid. The depths were calculated in the HEC-FDA models using WSEL data, structure value data, and FFEs. Three exceedance probabilities are shown for each of the floodplain scenarios. The decrease in mean depth for less frequent events at Year Zero can be explained by a greater number of structures getting shallow flooding as the outer edge of the floodplain expands.

Table 7: Selected Depth of Flooding Statistics (ft), Base Year Curve III)

Scenario		Year Zero		
Return Period		**1%**	**2%**	**4%**
Depth (ft)	Mean	1.4	1.1	0.6
	Median	0.9	0.8	0.4
	Maximum	7.6	6.0	3.8

5.7. Structure and Content Depth-Damage Relationships

Flooding can cause significant damage to structures of all types. Water can cause a structure's structural components to shift or warp – including the studs and foundation. Water can also damage the wiring, gas lines, and septic system. For high water, ceilings may sag under the weight of trapped water or soggy drywall, wet floorboards can bend and buckle, and the roof may leak or break altogether. Flooding in a basement can be especially dangerous; if the water is removed too quickly, pressure from the soaked earth outside can push inward and crack the foundation walls. In all types of residential housing flooding will most likely destroy the interior walls. Soaked wallboard becomes so weak that it must be replaced, as do most kinds of wall insulation, and any plywood in the walls is likely to swell and peel apart. Water can also dissolve the mortar in a chimney, which creates leaks and thus a risk of carbon monoxide poisoning once the heat comes back on.

Also, floods often deposit dirt and microorganisms throughout the house. Silt and sediment can create short circuits in the electrical system as residue collects in walls and in the spaces behind each switch box and outlet. Appliances, furnaces, and lighting fixtures also fill with mud, making them dangerous to use. Anything that gets soaked through with water may contain sewage contaminants or provide a substrate for mold. Most upholstered items must be thrown away, as well as carpets and bedding.

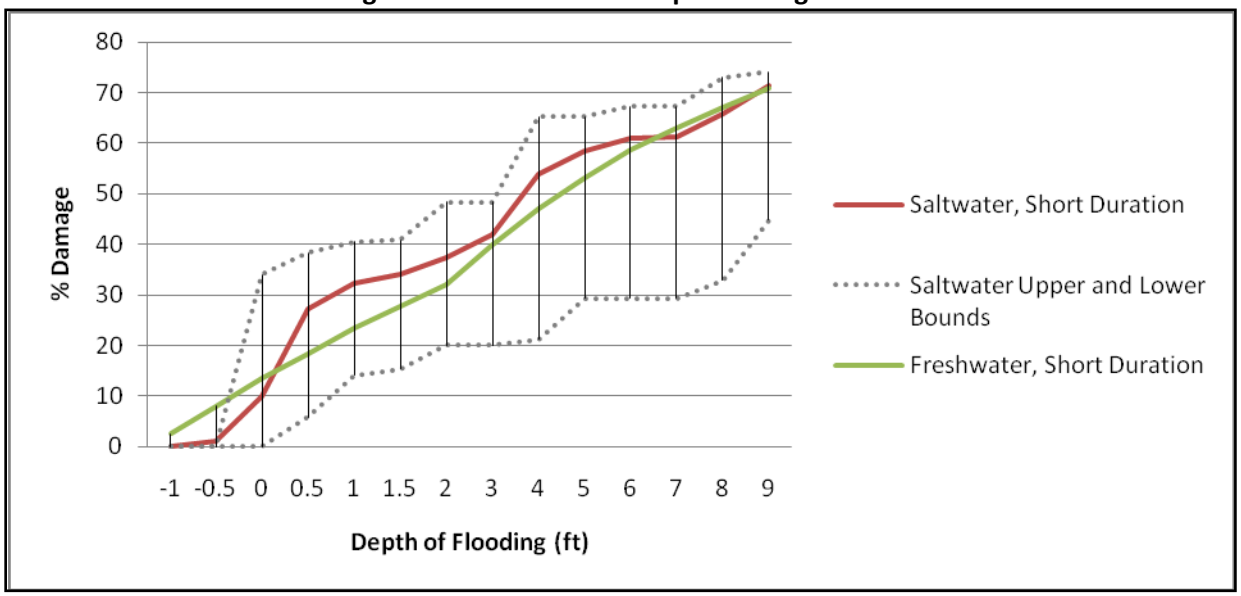
Damages to structures, contents, and vehicles were determined based on depth of flooding relative to the structure's first floor elevation. To compute these damages, depth damage curves were used. These curves assign loss as a percentage of value for each parcel or structure. The deeper the relative depth, the greater the percentage of value damaged. The sources of the relationships were different depending on structure type.

The depth-damage relationships for the primary structure types, contents, and vehicles are shown in the following figures below. SFR1 and SFR2 stand for Single Family Residential 1-Story and 2-Story, respectively. The curves for these are taken from USACE Economic Guidance Memorandum (EGM) 04-01, and are shown for comparison's sake.

The freshwater curves are used for the fluvial flood damage analysis, and the saltwater curves were used for the coastal damage analysis. Because of the corrosive nature of salt, for any given depth of flooding, damage should be greater for saltwater than for freshwater. The figures below show that the saltwater damage is generally greater than the freshwater damage for a given depth of flooding. However, because the curves were developed separately by different sources, they are not totally consistent with the idea that saltwater causes greater damage than freshwater at all depths. For consistency's sake, in the HEC-FDA models the saltwater curves have been adjusted so that they are at least equivalent to the freshwater damage at all depths.

Figure 5 below shows the structure depth-damage curves for freshwater and saltwater flooding. The Addendum contains figures for the remainder of the damage curves for both structures and their contents.

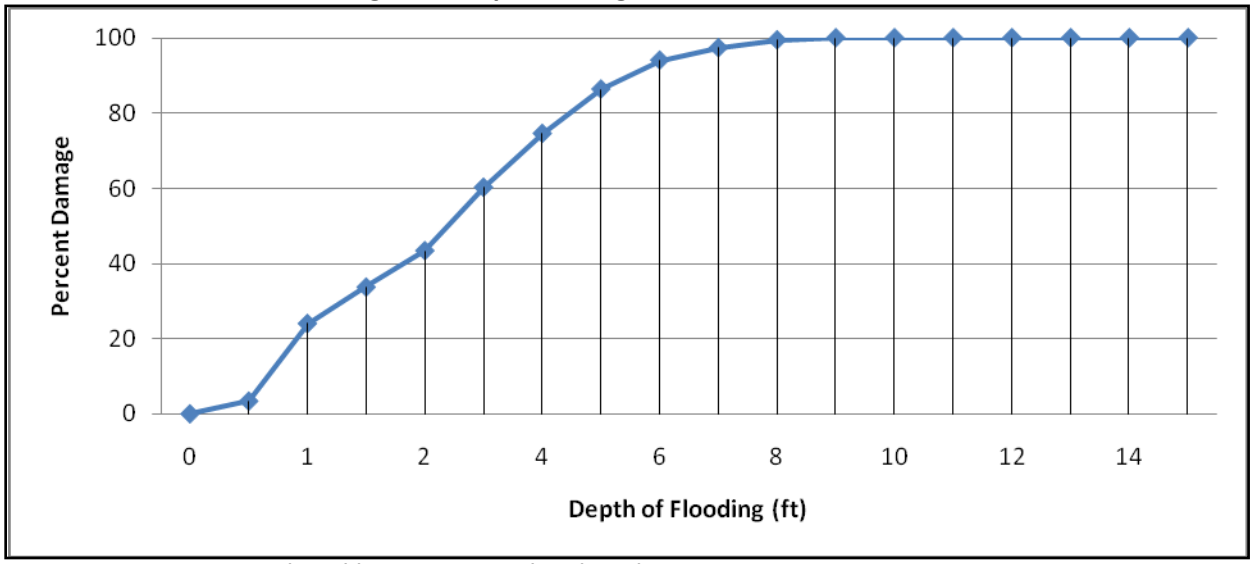
Figure 5: SFR1 Structure Depth-Damage Curve



5.8. Automobile Depth Damage Relationship

Damage to automobiles was estimated as a function of the number of vehicles per residence, average value per automobile, estimated percentage of autos removed from area prior to inundation, and depth of flooding above the ground elevation. Depth-damage relationships for autos come from USACE Economic Guidance Memorandum (EGM) 09-04 and modified based on weighted average of distributions of car types (SUV, truck, sedan, sports car, etc) in California. Damages for autos begin once flood depth has reached 0.5 feet, and this damage curve can be seen in the figure below. Since these curves were developed for freshwater flooding, they can be expected to slightly understate the damages from coastal flooding, but they are assumed to be reasonable for use in this study.

Figure 6: Depth-Damage Function for Vehicles



Source: USACE Economic Guidance Memorandum (EGM) 09-04

According to the U.S. Census, the average number of vehicles at households in the study area is just less than two. In general there should be significant warning time before a potential flood event, since regional gauges and storm tracking should effectively inform the communities of an approaching risk. The survey described in EGM 09-04 indicates that when there is greater than twelve hours warning time, almost 90% of residents are expected to move at least one vehicle to higher ground. The EGM does not indicate the percentage that moved both vehicles to higher ground. For this analysis, it will be assumed that all households remove at least once vehicle out of the floodplain, and that half of the households remove both vehicles. The result of these two assumptions is that 25% of the vehicles in the floodplain are exposed to flood risk. Vehicles that were exposed to flood risk are assumed to be at the structure first floor elevation, except for those structures that have been significantly raised from ground elevation. For those structures that are more than three feet above the ground elevation, the vehicles are assumed to be located at ground elevation.

Three-quarters of the vehicles are assumed to be moved out of harm's way

5.9. Residential Displacement Costs Depth Damage Relationship

Displacement costs were estimated for the relocation and emergency services provided for those displaced both during the peak flood event and during post-flood structural renovations. In order to estimate displacement costs, it is necessary to make assumptions regarding a) the level of structure damage from flooding that generally results in temporary displacement, b) the relationship between structure damage and displacement time, and c) the percentage of households that would be forced to find rental accommodations versus the percentage that would stay with friends or family. To this end, the analysis uses an algorithm contained in FEMA's '*Full Data Module for Benefit-Cost Analysis of Riverine Hazard Mitigation Projects, Mitigation BCA Toolkit CD, Version 2.0, January 2005*'.

This algorithm has the following features:

- If building damage is <10% of building replacement value, displacement time is zero.
- If building damage is 10%, displacement equals 30 days.
- If building damage is >10%, displacement time is 30 days plus 8 days for each one percent increase in building damage above 10%.
- Displacement time is capped at 365 days.

According to this approach, for example, 30% building damage results in a displacement time of 30 days plus 20 times 8 days, for a total of 190 days. The 365-day cap on displacement means that occupants of buildings with more than about 50% damage (52%) are assumed to be typically displaced for one year. Given that a structure that is over 50% damaged would have to be extensively renovated or rebuilt, a year of displacement seems reasonable.

No specific study has yet been conducted by the Corps to help estimate the percentage of displaced households that would be forced to rent alternative accommodations versus those that could relocate. This analysis makes the simple assumption that half of the displaced households would be able to temporarily relocate at little or no direct cost – that is, with family or friends[3].

It is assumed that half of the displaced residents would stay with family or friends

The remaining variable in the equation for the estimate of total displacement costs are the monthly rental and one-time relocation costs. For the purposes of this analysis, $2,000 is assumed as the total furnished monthly rental rate, and is based on the results of internet research on the cost of rental properties in the area. The one-time cost of moving is assumed to be $500. The result is a maximum cost of $24,900 was determined and used as the total value imported into FDA, (cost if displaced for 1 year). Uncertainty parameters applied for Displacement Costs were 10% about the mean for value and 0.5 ft foundation height – the same as used for the structures themselves. The relationship between percent structure damage and both displacement cost and days displaced is shown in the Figure 7. Figure 8 displays the depth-damage function for displacement for each of the residential structure categories. These functions were calculated by relating the depth of flooding to the percent damage to the structure, to the number of days per the FEMA algorithm, to the cost associated with that number of days, to the proportion of a full year displacement that the displaced number of days represents.

Figure 7: Displacement Cost and Days Displaced

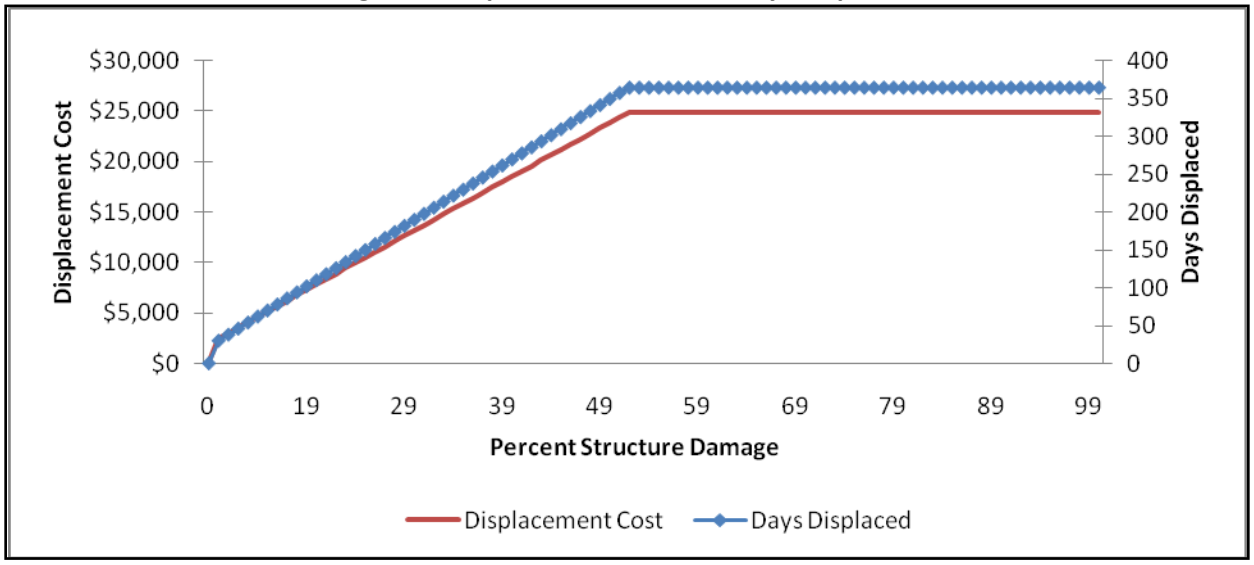
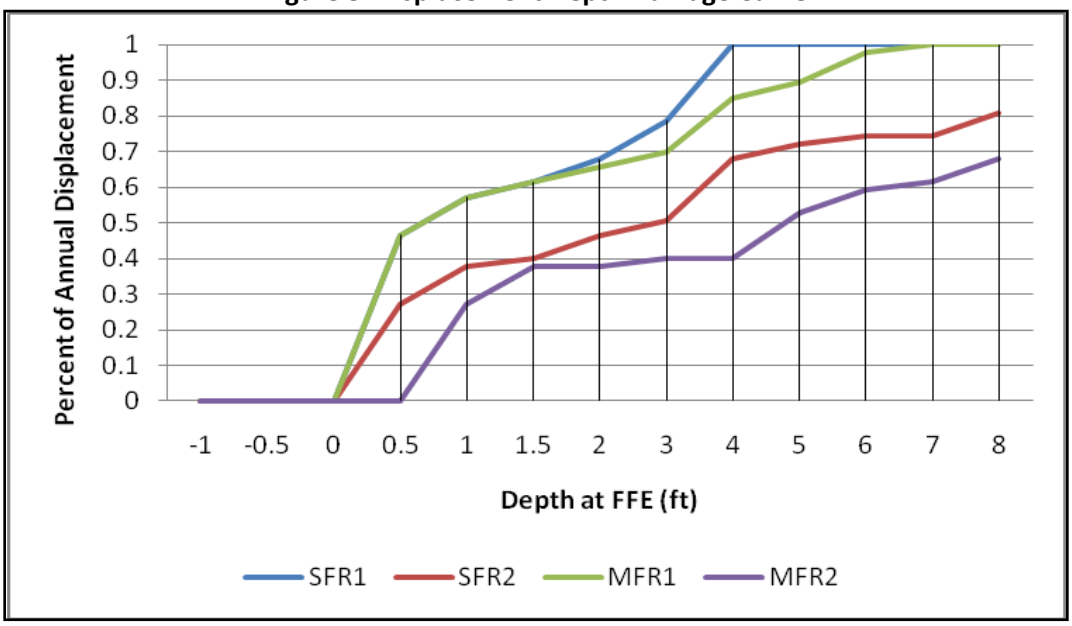


Figure 8: Displacement Depth Damage Curve



6. Expected Annual Damage (EAD)

The HEC-FDA program is used to combine water surface profile data and economic data (structure inventory values, FFEs, standard coefficients, etc.) in order to derive a probability-stage-damage function for each reach or impact area. HEC-FDA version 1.2.5a was used, which is a USACE certified model, and its use complies with EC 1105-2-412 (*Planning Model Improvement Program: Model Certification*).

Typically, among other inputs to this procedure are water surface profiles for the various channel or river reaches, which are an output of the HEC-RAS program that is used by engineers. For this study though, since the FLO2D program was used for reasons described in the H&H appendix, there are no discharges or rating curves (discharge-stage relationship), rather just an exceedance-probability to depth relationship for each EIA.

Additionally, for the fluvial part of the study, while there are existing levees at the downstream end of the portion of San Francisquito Creek under study, and while levee performance is a significant issue for the study, the existing levee features or levee failure probabilities were not included in the HEC-FDA models. The main reason for this is that the FLO2D floodplains were developed by modeling the water in the floodplain strictly as a result of levee overtopping. Therefore, there were no probability-based water surface profiles for any flood events that did not go over the downstream levees. That is, the mean depths of flooding provided to the Economics Section for use in the damage analysis were developed with the consideration of the existence and performance of the various levees in the study area. As a result of discussions in May 2009 with team members from SPN Geosciences Section as well as from the Hydrologic Engineering Center (HEC), it was decided that the consideration of the levees in the coastal modeling was sufficient, and that it would not be appropriate or necessary to include levee features in the HEC-FDA models.

Furthermore, the primary constraint causing overbank flooding is numerous bridge underpasses that restrict water-flow upstream of the existing levees. Thus, the H&H analysis shows that most of the floodwaters leave the channel before reaching the levees under the Without Project condition. The reliability of the existing levees will be a key concern to consider during the Alternatives Analysis phase of this feasibility study.

For each of the Base Year 2017, the FLO2D grids with depths for each flood event attached to GIS centroids were imported into HEC-FDA as HEC-RAS water surface profiles, and the exceedance-probability stage curves were derived with uncertainty (period of record 30 years gauge data).

6.1. EAD – Structures, Contents, Vehicles, and Residential Displacement

The Expected Annual Damage (EAD) for an EIA can be thought of as the average annual value of damage that would be expected to occur over a very long period of record. For example, if over a thousand years the total flood damage to an area were summed and divided by one-thousand, the result would be the expected annual damage for that area. We use what are believed to be the probabilities associated with storms of various sizes in order to calculate the probability-weighted value of damage for each area when considering the depth of flooding and the economic factors such as the number and type of structures.

Table 8 shows the EAD by category for each of the six categories analyzed in HEC-FDA for the fluvial floodplain, and Figure 9 depicts the data graphically.

Table 8: Expected Annual Damages ($1,000s), Fluvial Flooding

	Auto	Commercial	Displacement	Industrial	Public	Residential	Total
SM 1	1	332	2	118	0	5	457
SM 2	20	3	42	0	1	166	231
SM 3	18	12	38	51	7	130	255
SM 4	25	11	63	0	1	428	528
SM 5	179	0	381	0	21	1,057	1,638
SC 1	92	58	221	0	10	2,442	2,823
SC 2	227	0	404	0	11	1,515	2,157
SC 3	0	249	0	5	14	0	268
Total	561	666	1,150	174	63	5,743	8,356

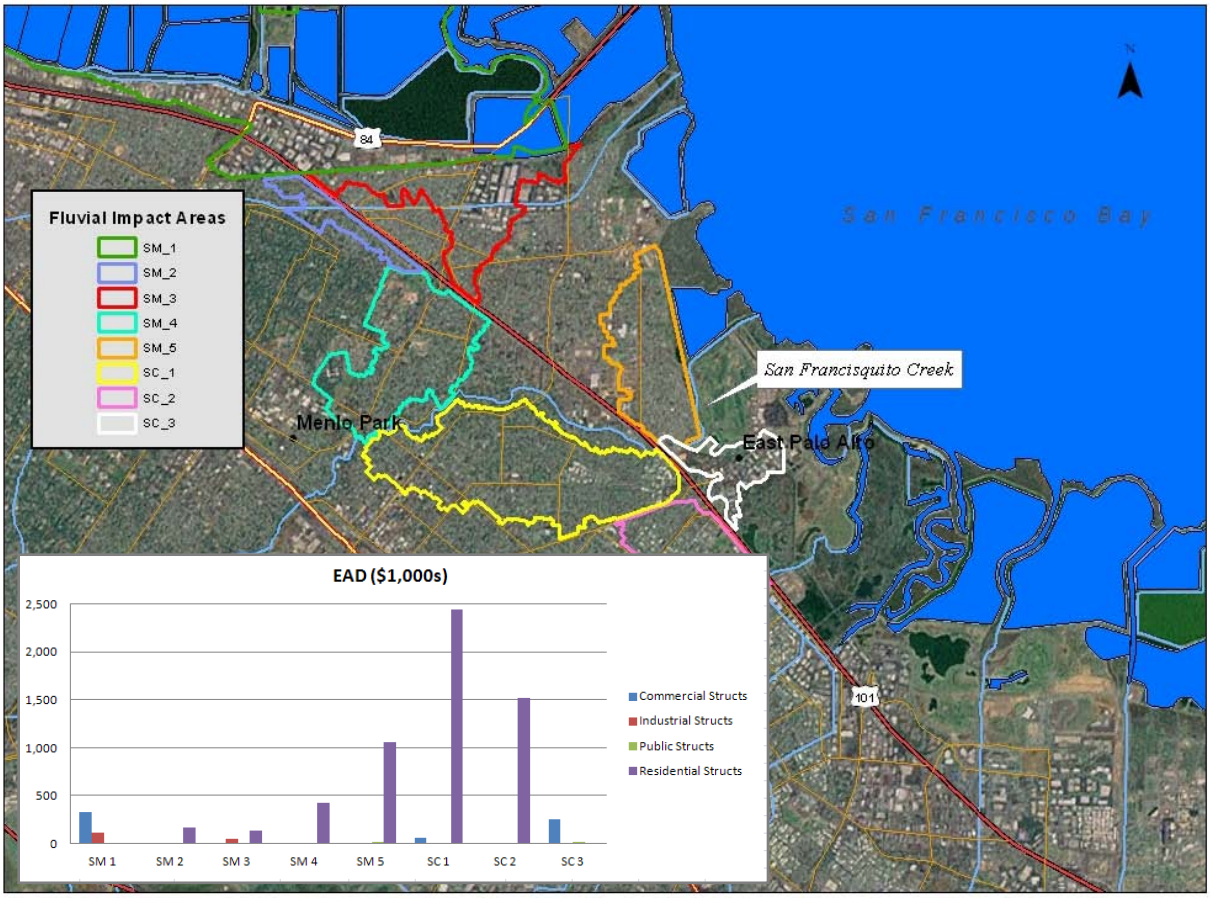


Figure 9: Fluvial EAD by Major Category and Impact Area ($1,000s)

Table 10 below shows the EAD by category for the coastal floodplain. The damage by category for each of the four EIAs is shown.

Table 10: Equivalent Annual Damages ($1,000s), Coastal Flooding

	Auto	Commercial	Displacement	Industrial	Public	Residential	Total
SM Coastal 1	151	12,072	251	3,507	559	2,509	19,049
SC Coastal 1	75	1,010	112	53	69	1,095	2,414
SC Coastal 2	130	312	213	153	45	2,007	2,860
SC Coastal 3	72	1,261	106	46	6	1,203	2,694
Total	428	14,655	682	3,759	679	6,814	27,017

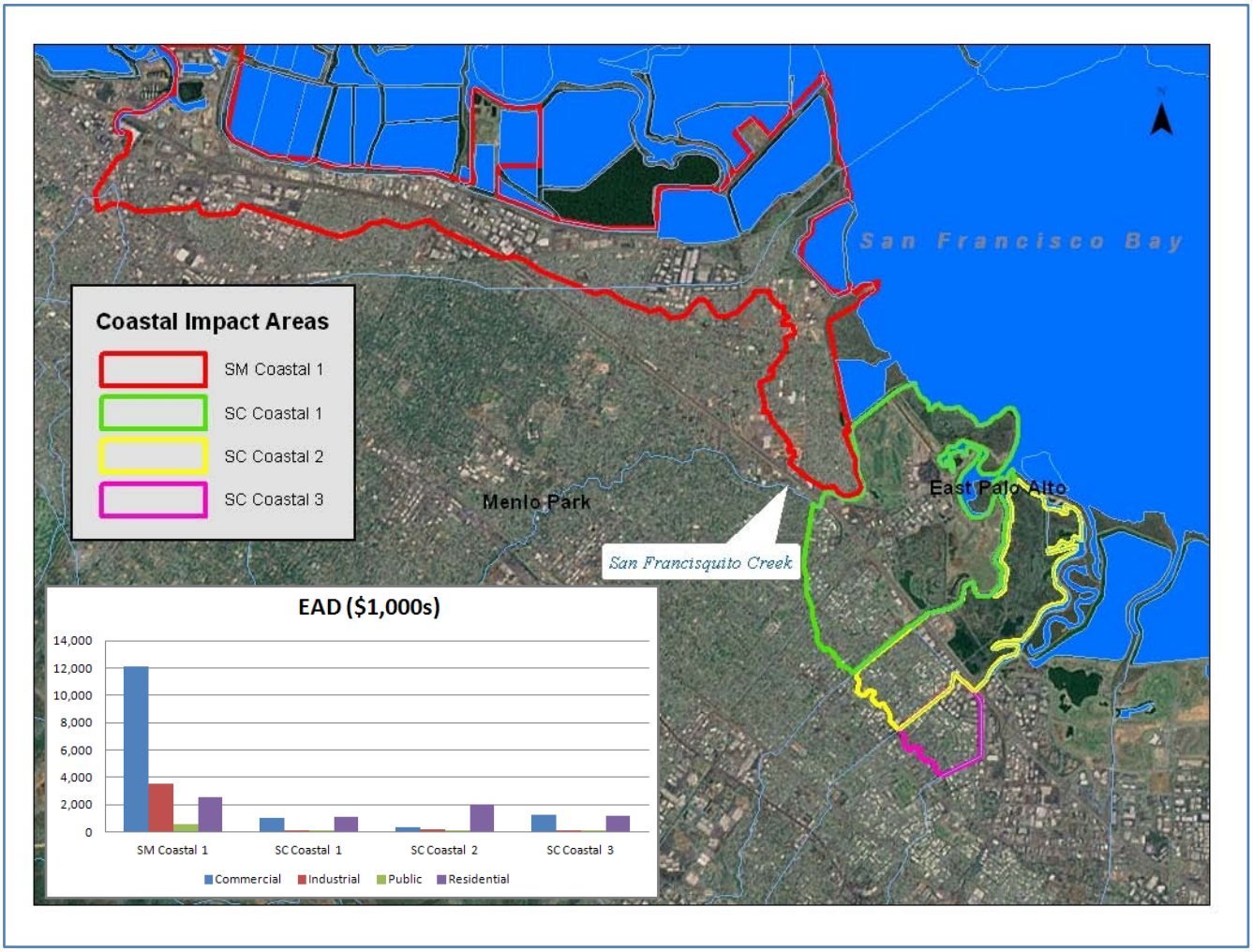


Figure 10: Coastal EAD by Impact Area and Structure Category

Independently, both fluvial flooding and coastal flooding represent a significant risk in the study area.

As currently estimated, a 1% fluvial flood event is anticipated to cause $225 million in overall damage. Future sea level rise did not factor significantly in the fluvial flood modeling. All else equal, further sea level rise scenario analysis would not be expected to change the results enough to affect plan formulation.

At this point, the coastal modeling for the area north of the creek is incomplete; thus, the damage estimates for this area are very preliminary

While the risk-based coastal modeling has not yet been completed for the area north of San Francisquito Creek, the preliminary results for a 1% coastal flood event in "Year 0" is estimated to cause $$131 million in overall damage. Factoring in sea-level rise impacts, the damage from the 1% event grows to approximately $767 million by "Year 50".

The Exceedance Probability - Damage functions are included in the Addendum to this report, and show the event-based damages for each EIA and for each of the damage categories analyzed in HEC-FDA.

6.2. Other Damage Categories Not Yet Quantified

There are some categories of damage from flooding that have not yet been quantified for this analysis. These include Emergency Costs associated with responding to a flood event, Insurance Policy Administration costs associated with the policies of those paying flood insurance that are located in the floodplain, travel delay and detour costs, and others. These categories typically comprise a small percentage of the total damages (or costs imposed) estimated from flooding, and this is believed to be the case for this study area. The categories are generally described below, and the damages will be quantified as the study progresses.

6.2.1. Emergency Costs

ER 1105-2-100 states, "Flood damages are classified as physical damages or losses, income losses, and emergency costs." The ER then defines emergency costs as "those expenses resulting from a flood that would not otherwise be incurred…" The ER further requires that emergency costs should not be estimated by applying an arbitrary percentage to the physical damage estimates. As with all flood damage estimates and especially in the case of emergency costs, the potential to double count damages are a distinct possibility and must be guarded against.

These costs include those emergency response costs that would not have been incurred in the absence of flooding. These costs include those associated with evacuation of the floodplain, flood fighting, disaster relief, and overtime pay for first responders and governmental employees. The ultimate cost of emergency services for a flood event depends on many factors, including the reach, depth and duration of flooding, the flood warning time, and the population and housing density within the flooded area.

Additional data will be obtained from local municipality officials regarding any information that could be used to understand the likely emergency preparation, response, or recovery costs from coastal flooding in the area. It is hoped that additional information will be available in the future to incorporate this category in the damage and benefit analyses.

6.2.2. Insurance Policy Administration

IWR Report 88-R-2 states that the administrative cost of flood insurance is considered a valid non-physical damage category, and thus a decrease in the number of flood insurance policies as a result of the removal of structures from the 1% floodplain represents a legitimate NED benefit category. This damage category will not be reported as part of the without-project damages, but instead, if appropriate, will be included as part of the with-project analysis, the NED benefit being the sum of those policy administration costs that are removed from the 1% floodplain as a result of a potential flood damage reduction project.

6.2.3. Income Loss to Businesses

According to IWR Report 88-R-2, "Income losses are reductions in the national income when flooding or the threat of flooding halts production or delivery of goods and services. National losses occur 1) when the production or delivery of these goods and services are not recuperated by postponing the activity or transferring it to another location, or, 2) when there are additional costs caused by delay or transfer of the activity." These losses can occur before, during, and after the flood event. The key to the definition of NED income losses is that the loss is not recuperated, in other words non-recoverable. Businesses where losses would be expected to be non-recoverable include public utilities, those where delays in delivery or processing causes spoilage of perishable items, businesses that produce unique products or whose competitors are at full production, and media outlets such as newspapers and radio stations that provide the only sources of local or national information.

When calculating these losses that are part of this NED category, it is important to include only factors that provide real increases in the value of the output, and, in order to avoid double-counting, exclude costs to the business not already included in the property and content estimates. Institute for Water Resources Report 88-R-2 provides guidance on how to compute income-loss for a given business. According to the report, the equation is as follows:

$$L = N * V * D / H$$

Where L = the income loss for an individual business;
N = the number of employees;
V = the annual value-added by the business per employee;
D = the duration in operating hours that a business is closed; and
H = the number of hours the business operates in one calendar year.

One of the redeeming qualities of this equation is that the broad estimates of all of the variables are readily available via sources like the U.S. Bureau of Economic Analysis. Given that the floodplain is so large though, there is great difficulty in determining just how many businesses would incur losses that classify as "non-recoverable". Given the complexity and uncertainty associated with estimating income loss (as narrowly defined within the NED framework) in this floodplain, and given that the magnitude of income loss is not likely to be significant relative to the sum of other damage categories such as structure and content damage, the analysis does not attempt to quantify income loss as a result of flood events.

6.2.4. Travel Delay and Detour Impacts

The value of travel delay and any additional costs imposed on persons as a result of flooding is a legitimate NED damage category, and should be included in the flood damage analysis. However, typically these costs constitute less than 5% of the total damages estimated from flooding.

For significant flood events, roads may be simply impassable both during the event and during any necessary cleanup operations following the event. An estimate of the cost of traffic delay and detour as a result of street flooding from the storm events can be calculated as the sum of the time value associated with the additional commuting time and the cost related to the additional mileage driven as part of an alternative, longer route between locations. The critical variables to estimate include the number of vehicles detoured or slowed, the additional travel time and distance involved, and the duration that the delays and detours are in effect.

While there are numerous major streets that would be flooded from the bay during large storm events, the most significant is undoubtedly Highway 101, which is a heavily traveled freeway running parallel to the bay coastline. Figure 11 shows the extent of the .2% coastal floodplain and its overlap with Highway 101. For practical purposes, the estimation of traffic delay and detour costs for this study will focus on the impact of flooding along this freeway. However, it is important to note that when estimating the benefits of a potential project in the study area that mitigates or reduces the likelihood of flooding to highways in the study area (this will be done for the with-project report), the proportion of traffic flood damage reduction benefits that the project can claim is to some extent dependent on whether or not reaches of Highway 101 that are outside of the study area will be flooded during future storm events from which the study area project was intended to provide protection.

The estimation of traffic delay costs for the floodplains that are a part of this study is especially difficult because the flooding occurs across such a massive number of streets, making the determination of the most likely combination of alternative routes very complicated and highly uncertain. Additional uncertainties abound, including what the impact of detoured vehicles will have on travel times for those vehicles traveling on roads outside of and adjacent to the flooded area.

Given these uncertainties, and in absence of a sophisticated traffic model for the flood events, several simplifying assumptions were made; these are listed further below. The analysis of the traffic impacts is simplified in a way that, given the USACE value of time estimate methodology, will ensure a conservatively low total damage estimate. For example, no attempt is made to estimate the value of delay for those indirectly impacted by the flooding, which are vehicles that are delayed as a result of increased traffic volumes outside of the flooded areas as a result of drivers detouring around the flooded areas.

According to USACE guidance (IWR Report 91-R-12 "*Value of Time Saved for Use in Corps Planning Studies*"), opportunity cost of time estimates are based upon the duration of the delay and the estimated annual wage of the motorist (the methodology recommends using family income). According to the U.S. Census Bureau, the average of median family annual incomes in the study area is approximately $90,000. The median family hourly wage is thus approximately $44. The guidance indicates that the hourly opportunity cost for automobile trips depends on the trip purpose and should be valued at various percentages of the motorist's hourly wage. The trip purposes are a) work, b) social/recreational, c) other trips including personal business, and d) vacation. For example, for those delayed more than 15 minutes, the appropriate *hourly* value should be calculated as 53.8%, 60%, 64.5%, and 75.1% of the family hourly income. It is important to clarify that the value is calculated by multiplying the hourly fraction of the actual delay by the percentages listed above (for example, a 30 minute delay of a work commuter would mean .5 x .538 x the median hourly income x the number of passengers). Also, only for those cars commuting to work

is the average passengers per vehicle relevant – as the calculation of average value for that purpose involves a summation of the median family incomes of all work commuters in a particular vehicle.

Because the trip purpose percentages on weekdays will vary considerably from the percentages on the weekends, this factor must be included in the valuation. The final valuation of the flood impacts to traffic is thus weighted for the probability of the timing of the flood event. While the traffic counts for the freeway is assumed to be equivalent for both weekday and weekend days, the proportions of trips by purpose are assumed to change between weekdays and weekend days.

Whereas during the week the trips by purpose are assumed half for work, it is assumed that on the weekend the proportion of work trips is one-quarter, while the remaining three-quarters are divided equally between the other non-work purposes. The calculations should account for the likelihood of the events occurring on different combination of days (two weekdays, one weekday and one weekend day, etc.), weighting them appropriately.

Traffic counts from 2008 from the California Department of Transportation indicate that the average daily total number of trips along Highway 101 through the study area is 200,000 in each direction, or about 400,000 in total. The figure below shows in red the coastal floodplains for the .2% probability event (500-year) for both San Mateo and Santa Clara Counties.

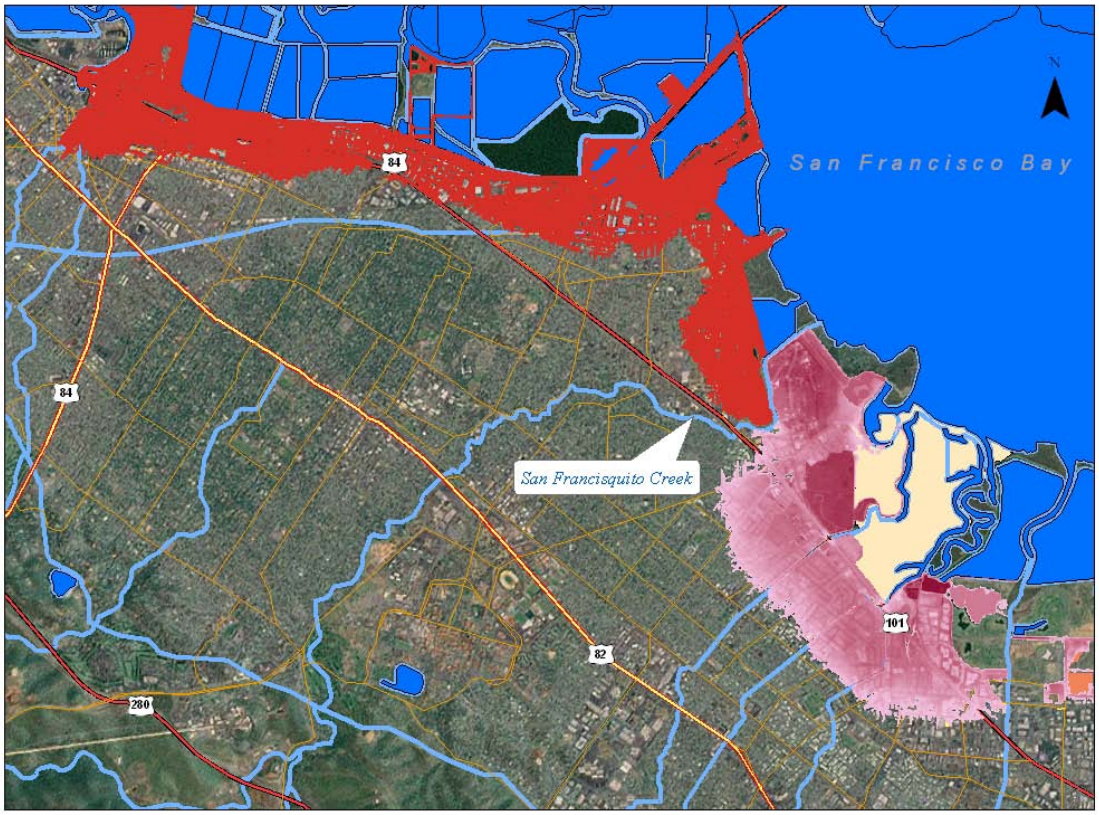


Figure 11: Coastal Flooding at Highway 101

The traffic delay impact analysis manages some of the uncertainty associated with the variables by running a Monte Carlo simulation within a simple spreadsheet model that uses the @RISK computer program. The average delay time was assigned a triangular distribution with 30, 45, and 60 minutes as parameters. Since the relative percentages of the trip purposes are expected to differ between weekdays and weekends, the one day delay cost was estimated as a weighted average: five-sevenths weekday values, and two-sevenths weekend values.

Figure 12: Distribution of Travel Delay Cost, Highway 101, 1 Day Closure

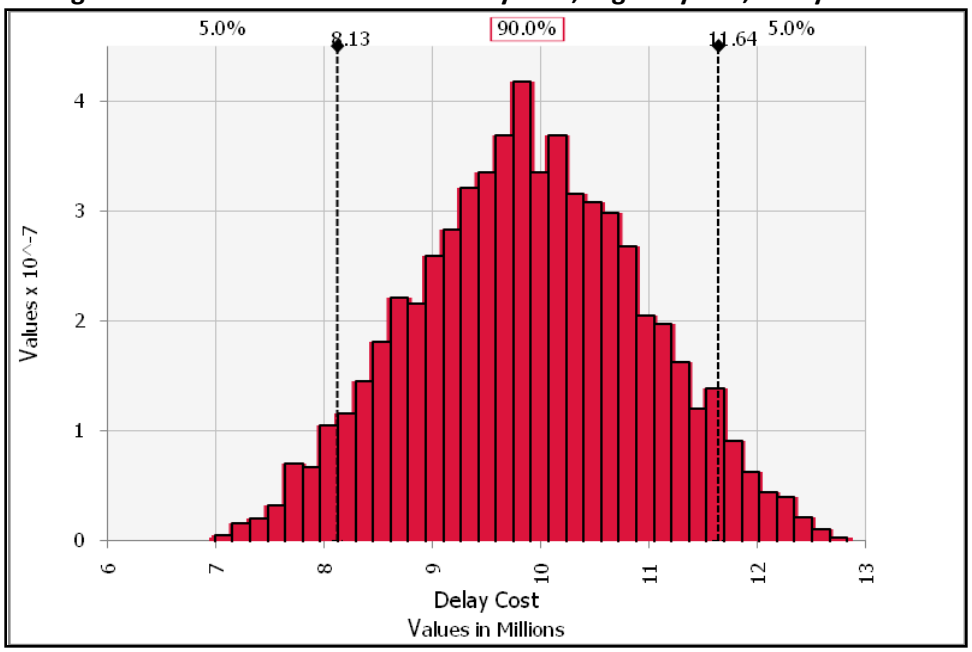


Figure 12 shows the results of the simulation for a single day's closure of Highway 101. The results of the traffic delay analysis are that the delay cost from one 24-hour period of Highway 101 closure in the study area is between $7 million and $13 million, with an expected value of $9.9 million. This is an event-based damage estimate; the probability-weighted damages for this study depend on the year (2017 or 2067) and the sea-level rise scenario because flooding of the highway and the surrounding study area could begin at different frequency events under each scenario.

Detailed coastal floodplain mapping for the existing condition has not been completed for the San Mateo coastal EIAs. As a result, the traffic delay and detour cost estimate has been derived only using the results of the Santa Clara coastal floodplain mapping. This fact is not expected to have much of an impact on the damage estimate, since the probabilities at which the highway is first flooded in each of the counties appears to be similar.

For the Santa Clara coastal impact areas, while the Year 2017 flooding occurs at the 2% event, each of the future scenarios shows flooding beginning at more frequent events: 10%, 20%, and 50% events under Curve H, Curve 1, and Curve 3 scenarios respectively. The expected annual damages at Year 2017 are estimated to be just over $275,000, while the Year 2067 expected annual damages are estimated to range from about $670,000 to not quite $2.5 million under the three future scenarios. The equivalent annual damages were calculated by amortizing the sum of the present value of the probability-weighted values (expected annual damages) over the period of analysis. For the equivalent annual damage calculation, between Year 2017 and 2067 the damages were interpolated linearly. Table 11 below shows the result of this calculation.

Table 11: Equivalent Annual Traffic Delay Costs, Highway 101

Scenario	Starting Flood Event	Equivalent Annual Damage (1,000s)
Base Year	2%	N/A
Curve H	10%	$669
Curve 1	20%	$1,323
Curve 3	50%	$2,467

6.2.5. Impacts to Palo Alto Airport

The Palo Alto Airport is located just south of San Francisquito Creek, and sits on the edge of the bay, and is at elevation 8 (NGVD). At this elevation, according to the coastal flooding model, the airport is expected to experience flooding from large storm events under the Base Year scenario, and relatively frequent events under the future scenarios – with flood depths as much as five feet in large storm events under the Curve 3 scenario. According to representatives of the airport (shown in Figure 13), there are approximately three-hundred planes located at the airport at any given time. There are several private hangars, and an adjacent area with commercial shops.

Detailed statistics on the types, sizes, and values of the planes were not available. A representative of a maintenance company that works at the airport explained that significant flooding damage would begin once flood waters reached the fuselage (body) of the airplane. If water reached the engine, it would have to be removed, dissembled, and cleaned.

Airport representatives were not able to provide additional, detailed information related to the potential or expected consequences of flooding at their facility. Thus, expected flood damages were not estimated for the airport for this report. It is hoped that additional information will be made available in the future to enable a damage estimate for subsequent feasibility report products.

Figure 13: Aerial Showing Location of Palo Alto Airport and WQCP

6.2.6. Impacts to the Palo Alto Water Quality Control Plant

The Palo Alto Water Quality Control Plant (WQCP) has approximately 30 million gpd treatment capacity, and is one of three plants in the South San Francisco Bay region. Figure 10 shows the location of the WQCP in relation to the bay and the San Francisquito Creek.

There are no standardized depth damage curves or established methodologies for determining a) the value of structural/mechanical/electrical damage from flooding to these types of facilities, or b) the economic impact to the serviced communities from a decrease or cessation of waste water treatment services of various lengths of time. In order to estimate the impact of flooding at each of the plants, Corps Economists interviewed representatives from the plant. The sections below describe the results of the interviews.

In the instance of a flood event, the WQCP would take measures to insulate critical mechanical and electrical components to prevent inundation. These measures include placing sandbags and soil at entrances to pump stations or motor control centers, to act as a physical barrier between flood waters and vital operational equipment. Temporary sump pumps are also used to drain any flood waters that seep in. If flooding of the equipment seems inevitable, mechanical and electrical components are turned off immediately, resulting in limited to no treatment capabilities during inundation. Shutting down these components helps to reduce damage to equipment and shorten overall operational downtime. All of these measures will require special means of transportation for implementation by plant employees depending on flood depths.

Following the shutting down of mechanical and electrical components prior to inundation a procedure must be adhered to before returning to operation. When flood waters recede, the components must be removed and taken off-site to undergo a baking/drying process in order to be restored to full functionality. Once thoroughly dried out, the components go through an exhaustive testing and decommissioning phase. During this process, the WQCP is expected to shut down for a 2 to 3 month period unless temporary components are installed while the permanent fixtures are restored to working order. If mechanical and electrical components are not shut off before inundation, however, the impacts to the equipment and plant operation will be more significant. Mechanical and electrical components would likely require replacement, which takes 6 to 12 months for procurement and installation.

The expected damage to the communities serviced by the WQCP varies by storm event. If the WQCP does not need to shutdown, normal operations will continue and any effects to the community will be the result of overflows of untreated sewage into the San Francisco Bay, which generally only occurs with the shutdown of a plant during larger storm events. During larger flood events, the WQCP will likely have to shut down. The ramifications of a plant shut down include the inability to treat raw sewage and a lack of availability of recycled water to local customers who depend on it for the cooling of machinery during industrial processes. These customers include local power providers. In general, large flood events which result in plant shutdown will lead to potential sewage overflows in the communities served by the plant, degradation of the Bay, and a shutdown of recycled water customers. According to WQCP personnel, the worst case scenario resulting from inundation would include significant environmental impacts from discharge of raw sewage.

As with the impacts to the communities served by the WQCP, the expected damage to the WQCP varies with the elevation of flood waters. It should be noted that damage estimates provided by the WQCP to USACE assume above ground flood depths from 1 to 2 feet and a coastal storm surge lasting approximately 24 hours, after which water surface levels return to current levels. Structural components of the WQCP's can withstand the build-up of 2 to 3 feet of flood waters without incurring any significant damage; however, extensive clean-up will likely be required. Since most of the mechanical and electrical components at each plant are elevated a foot above the ground, events that flood more than a foot are expected to result in repair or complete replacement of mechanical and electrical components, while events that cause flooding less than a foot will tend to have little to no impact except to any underground facilities. As discussed previously, damages to electrical and mechanical components are dependent upon flood depths, and whether or not components have been powered down in the event that inundation occurs.

Table 12 below shows an example of how the various treatment plant equipment, rooms, and facilities are susceptible to damage at various flood depths. This list was created by the Palo Alto Water Quality Control Plant for this study.

Table 12: Example of Height at Which Treatment Plant Facilities Exposed to Flooding Damage

Depth at Which Damage First Occurs (ft)	System or Equipment
Any	Sewer Trunk Lines Leading to the Plant
Any	Raw Sewage Pumping Plants' Pump Room, Motor Room, and Pretreatment Systems
Any	Meter Pit
Any	Tunnels
Any	Administration Building Basement
Any	Recycled Water Pump Room
Any	Incinerator Building Basement
0.5	Clarifier 5/6 Control Room Floor
0.5	Equipment Room Floors
0.6	Grit Building Floor
0.75	New Pumping Plant Ground Floor
1	Administration Building Ground Floor
1	Blend Tank and Sludge Feed Pump Pad
1	Maintenance Building and Warehouse Floor
1.5	Operations Building Ground Floor
2	Solids Incineration Building Ground Floor
2.5	Septic Pit Area
2.8	Outfall Box Pad
3	New Pumping Plant Hydraulic Equipment Building Floor
3	Plant Process Water Pump Room Floor
3.25	Sodium Hypochlorite and Sodium Bisulfite Storage Pad
3.32	Old Pumping Plant Ground Floor
3.7	Air Pollution Control Pad
4.08	Old Pumping Plant Control Equipment
4.25	Water Transmission Shop Floor
4.45	Oil Storage Room Floor
4.7	Recycled Filter Piping Room Floor

Because of the complexity, scale, and uniqueness of the treatment plant facility, given time and study funding constraints it was not possible at this point in the feasibility study to develop a comprehensive depth-damage relationship for this damage analysis. Instead, USACE provided the plant with a flooding scenario and asked to describe the impacts to operations, and to estimate the type and cost of direct damage to the facility. The table below contains a summary of the estimated flood damage cost for each WQCP in the study area after a flood event with depths from 1 to 2 feet and standing water for 24 hours.

Table 13: Repair and Replacement Damage to Palo Alto WQCP ($M)

WPCP	Clean-Up	Mechanical		Electrical	
		Repair	Replace	Repair	Replace
Palo Alto	0.5	20-50*			

*Estimate includes mechanical and electrical repairs only

According to the plant representatives, Palo Alto plants would sustain between $21 million and $51 million in physical damage.

More detailed flood damage information needs to be collected before any event-based estimates or expected annual damage calculations can be performed.

7. Summary & Discussion of the Without-Project NED Flood Damages

This appendix describes the data, methodology, and policy requirements for documenting the results of the without-project fluvial and coastal flood damage analysis for the San Francisquito study area. The damages were computed separately for eight different fluvial EIAs, and four different coastal EIAs, incorporating the effect on the creek and the coastal floodplain resulting from the Curve III sea-level rise scenario.

For the fluvial flood damage analysis, the Economics Section received floodplain maps from SPN's Water Resources section for the 4%, 2%, 1%, 0.4%, and 0.2 floodplains and depths were determined using the GIS maps of ground elevations for each parcel within the Study Area (by definition in this case, the 0.2% chance event). Due to the stage uncertainty generated by providing the HEC-FDA with a period of record of 30 years, the probability-damage curves shown in the Addendum lists damages for smaller events (such as the 10% event or smaller) in some EIAs. This is primarily due to the slight changes in flood depths between probability events, reflecting the sheet-flow nature of flooding in many of the inundated areas; rather than get demonstrably deeper from, say, the 4% event to the 2% event, a given depth of water expands on the floodplain to trigger larger damages.

For the coastal flood damage analysis, the results show a significant flood risk in the future. The risk is currently relatively low, but the preliminary coastal modeling results show that the future risk is significantly higher as a result of sea-level rise. The coastal modeling south of the creek in the study area is considered complete, but the area north of the creek is not. Additional risk analysis needs to be incorporated, the current condition needs to be mapped, and additional sea-level rise scenarios need to be analyzed.

As is generally the case in USACE flood damage analyses, physical damages to structures and contents comprise the vast majority of damages expected from flooding. Residential structures are expected to sustain over 90% the total damages from flooding.

Emergency Costs, NED Income Loss to businesses, Travel Delay and Detour Costs, and Insurance Policy Administration costs are all categories that will also get further treatment at the next phase of the feasibility analysis and report. It is not anticipated that these damage categories will significantly change the total expected annual damage estimates, but it is important to thoroughly describe the full range of impacts from flooding as well as the potential benefits from projects that reduce flood risk.

8. Preliminary Project Options Proposed by the JPA

The non-Federal sponsor has developed some conceptual alternatives (at this point referred to as "options") to reduce the flood risk from both fluvial and coastal flooding. Preliminary cost estimates have been completed for these project options, but there are potentially significant costs that have not been included for many of the options such as real estate costs, interest during construction (IDC), mitigation costs, and operation and maintenance costs. In order to determine an NED alternative at a later study phase, a more complete set of alternatives will need to be developed that have varying "levels of protection," and more complete cost estimates will need to be developed.

The preliminary options are shown in the figures below. For each option, the preliminary EAD is shown (which is the without-project damages for the affected area), the preliminary total and annualized cost is shown (at 4% over 50 years), and the assessment of residual coastal or fluvial risk is described (low, medium, high). The EAD can be thought of as the annual project benefits if a project effectively eliminates the flood risk in the area. The EAD can be compared to annualized cost of the option in order to get a preliminary, rough idea of the economic justification at this point.

8.1. Fluvial Options

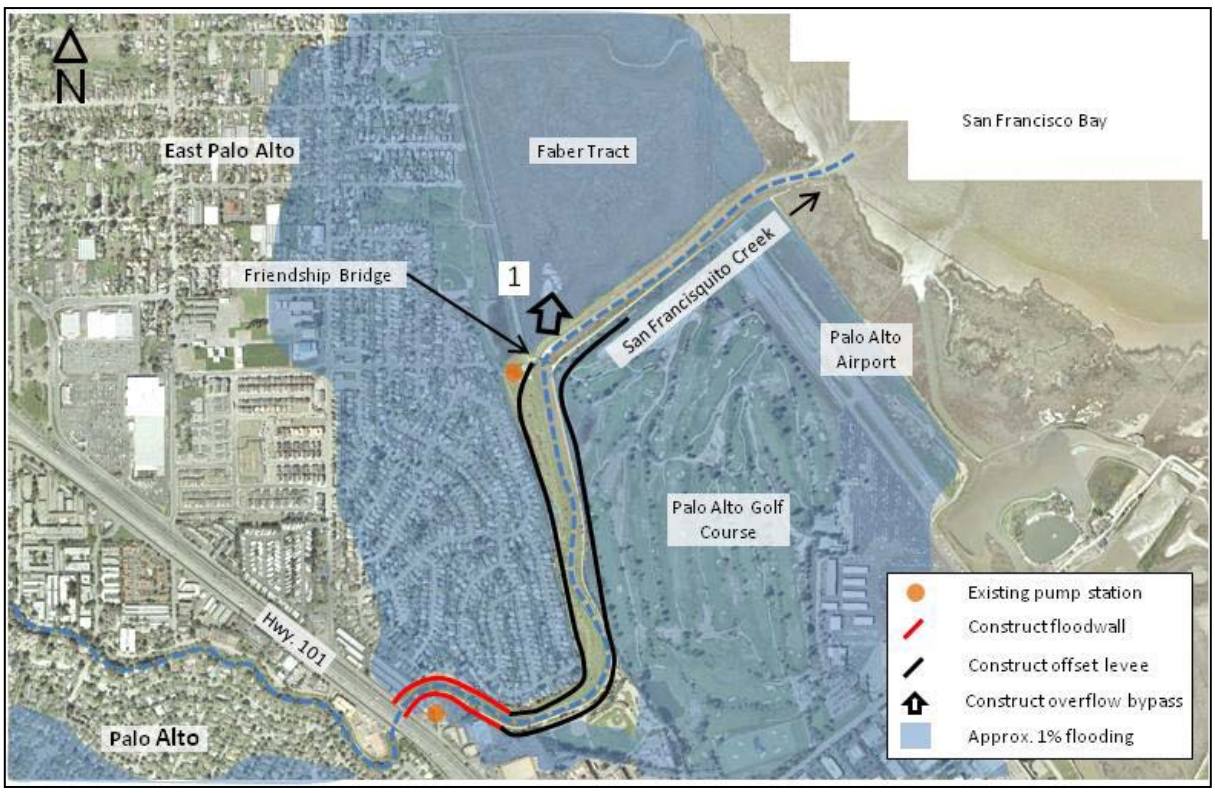


Figure 14: Reach 1, Option 1 (Source: JPA)

Preliminary EAD Estimate: $1.91 million (does not include WQCP)
Preliminary Project Cost Estimate: $37 million (no RE included)
Annualized Cost: $1.75 million
Residual Coastal Risk: High

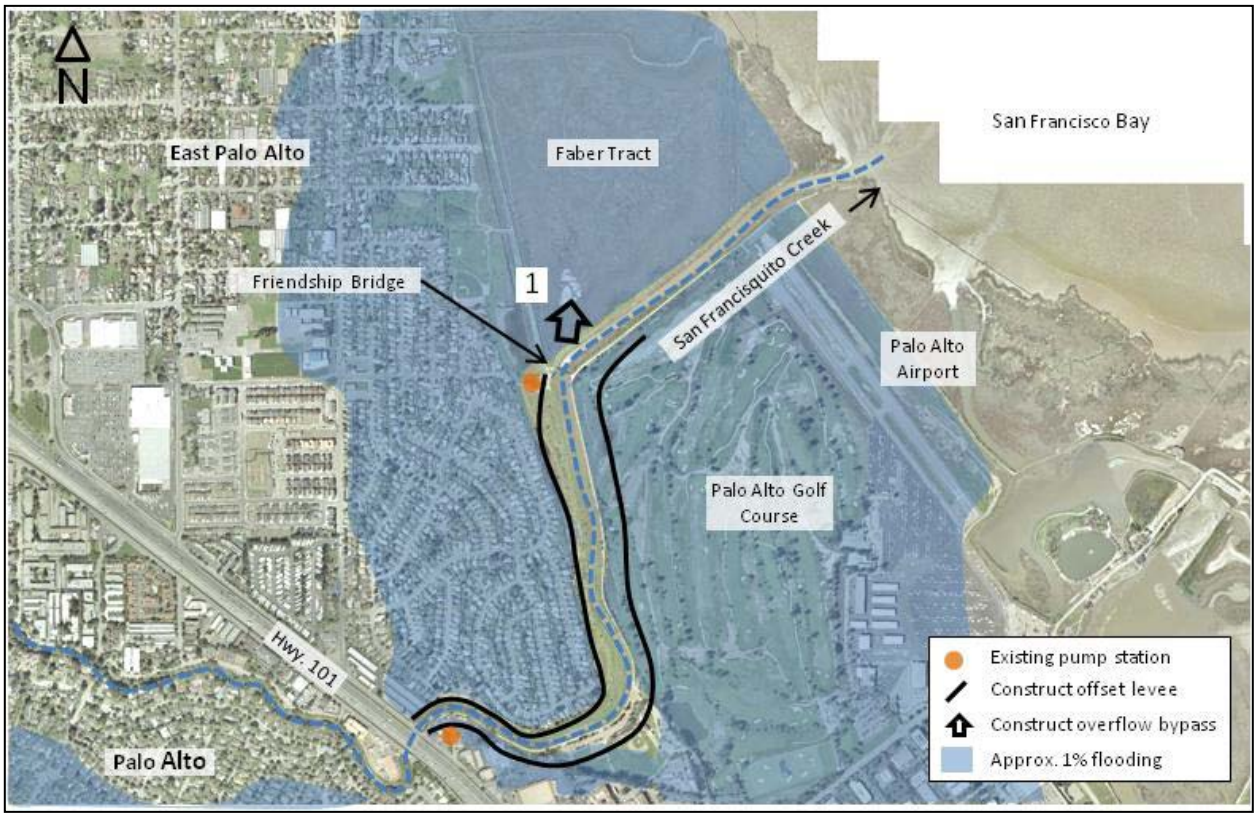


Figure 15: Reach 1, Option 2 (Source: JPA)

Preliminary EAD Estimate: $1.91 million (does not include WQCP)
Preliminary Project Cost Estimate: $39 million (no RE included)
Annualized Cost: $1.82 million
Residual Coastal Risk: High

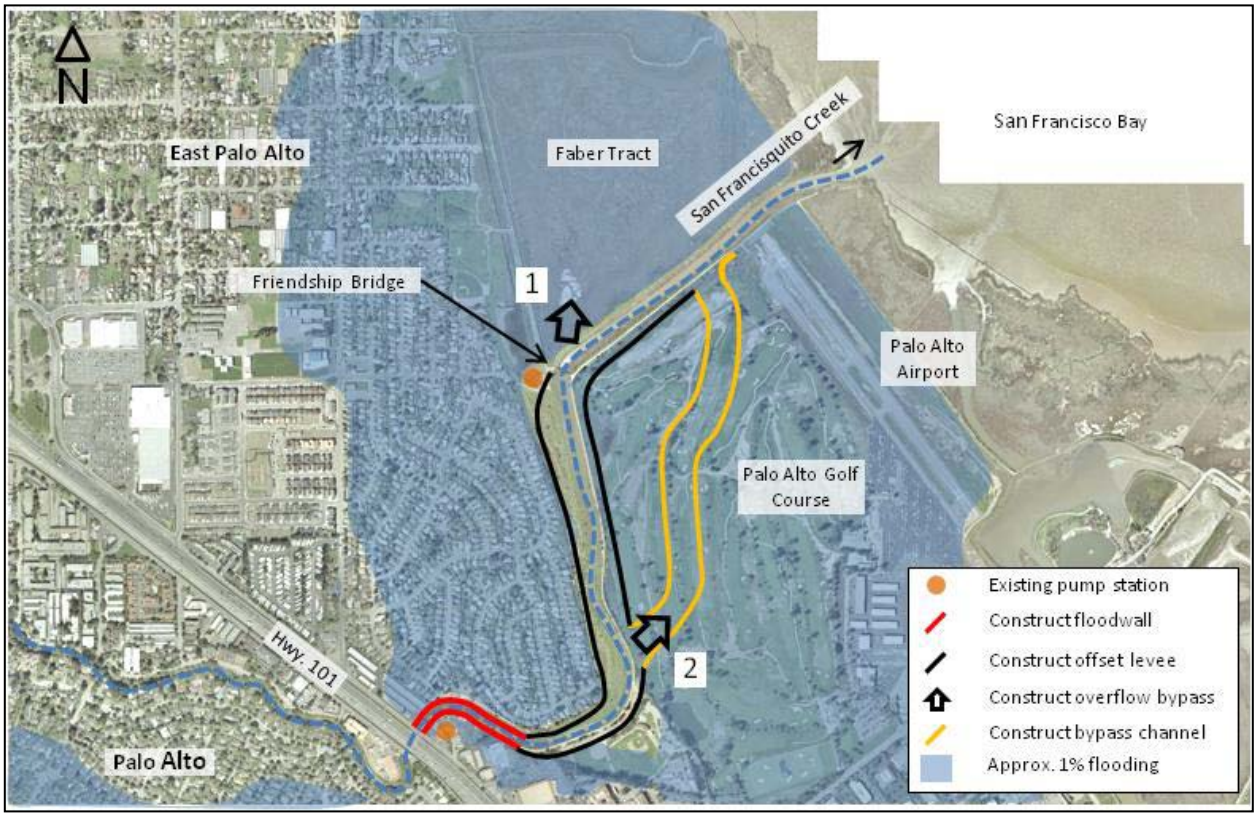


Figure 16: Reach 1, Option 3 (Source: JPA)

Preliminary EAD Estimate: $1.91 million (does not include WQCP)
Preliminary Project Cost Estimate: $96 million (no RE included)
Annualized Cost: $4.47 million
Residual Coastal Risk: High

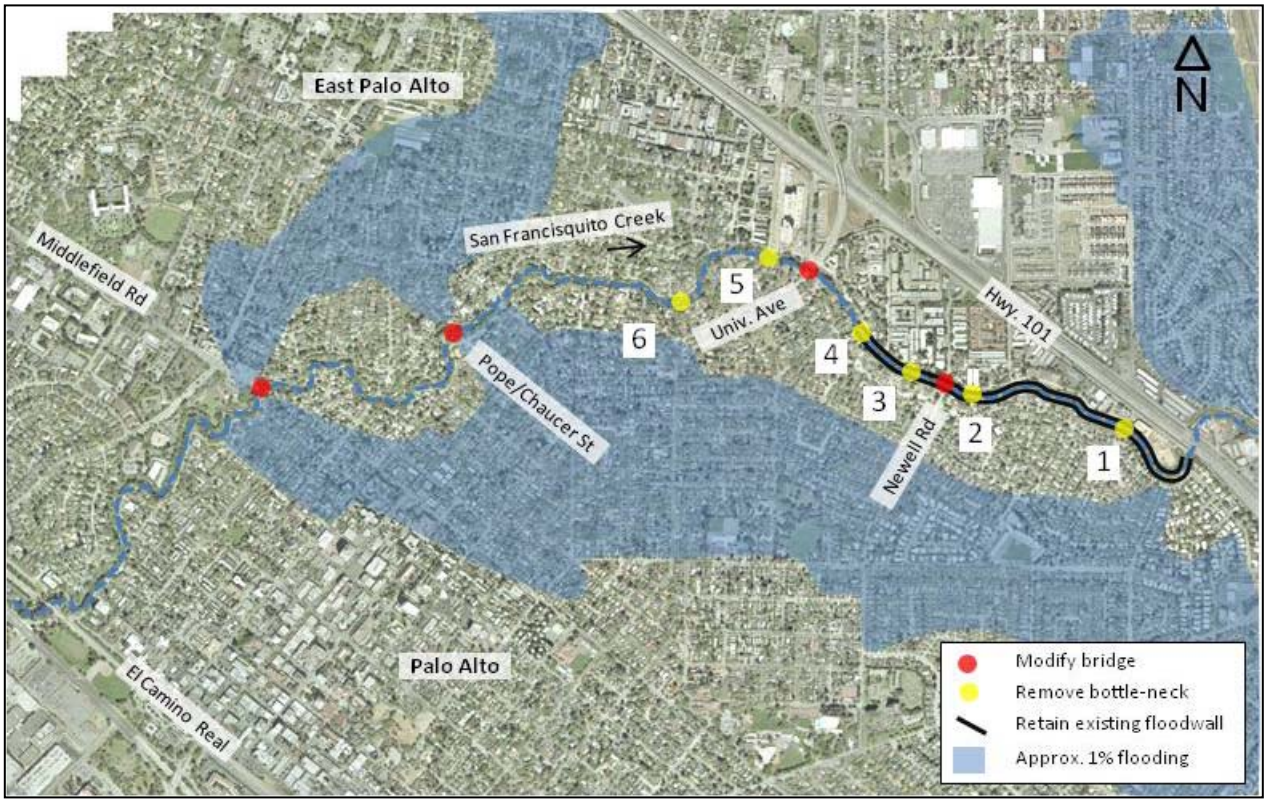


Figure 17: Reach 2, Option 1 (Source: JPA)

Preliminary EAD Estimate: $3.35 million (assumes effective elimination of the 1% flood risk)
Preliminary Project Cost Estimate: $49 million
Annualized Cost: $2.28 million
Residual Coastal Risk: Low

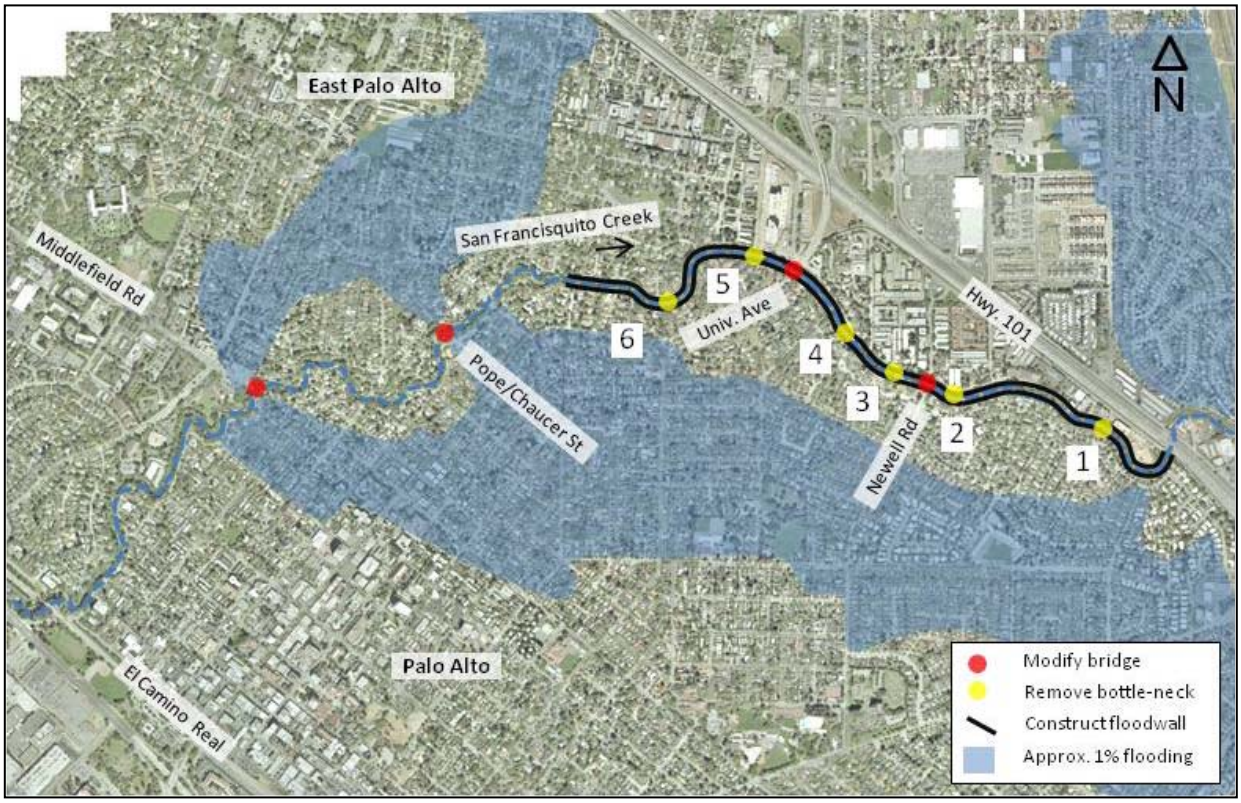


Figure 18: Reach 2, Option 2 (Source: JPA)

Preliminary EAD Estimate: $3.35 million (assumes effective elimination of the 1% flood risk)
Preliminary Project Cost Estimate: $84 million
Annualized Cost: $3.9 million
Residual Coastal Risk: Low

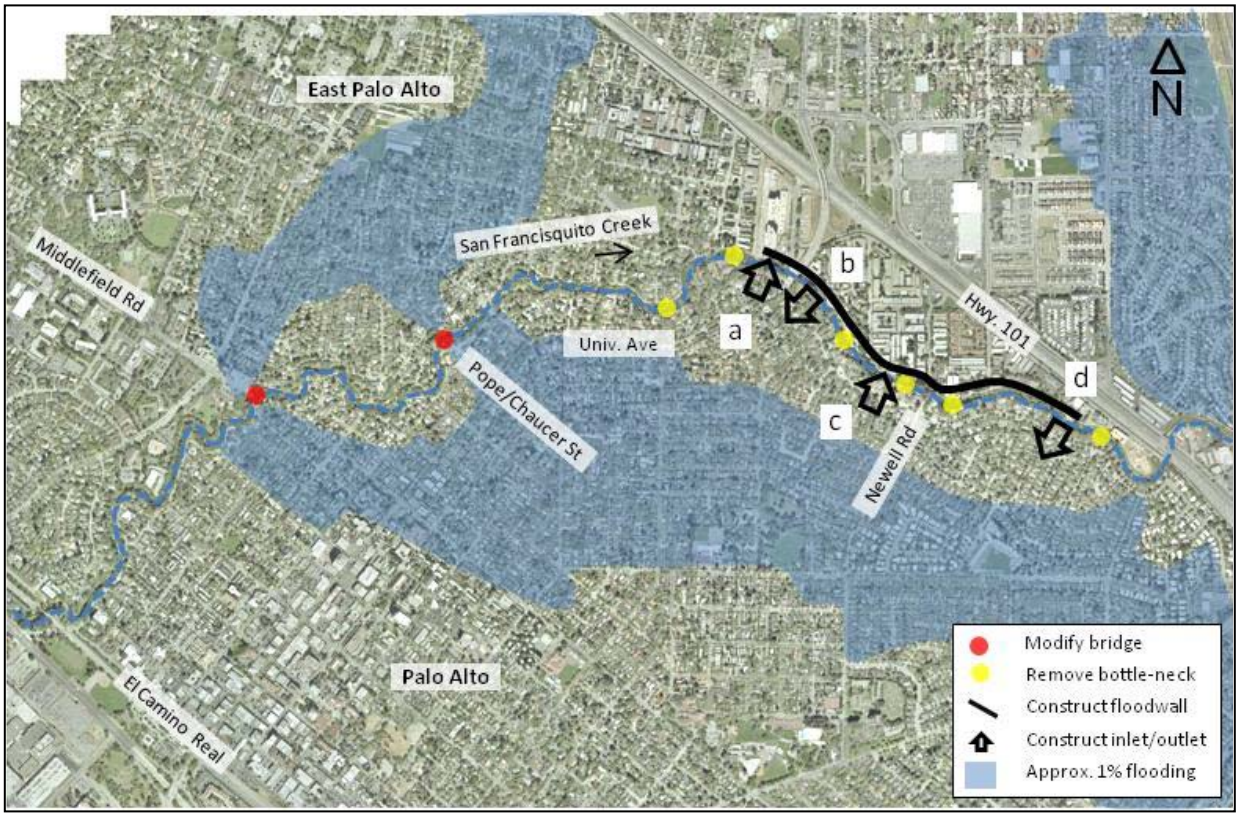


Figure 19: Reach 2, Option 3 (Source: JPA)

Preliminary EAD Estimate: $3.35 million (assumes effective elimination of the 1% flood risk)
Preliminary Project Cost Estimate: $82 million
Annualized Cost: $3.82 million
Residual Coastal Risk: Low

8.2. Coastal Options

Figure 20: Reach 1, Options 1 & 2 (Source: JPA)

Preliminary EAD Estimate: $19 million (assumes Curve 3 sea-level rise scenario); (need to confirm whether or not project would reduce the risk to area west of the project footprint shown here)??
Preliminary Project Cost Estimate: $38 million (No RE included)
Annualized Cost: $1.77 million
Residual Fluvial Risk: High

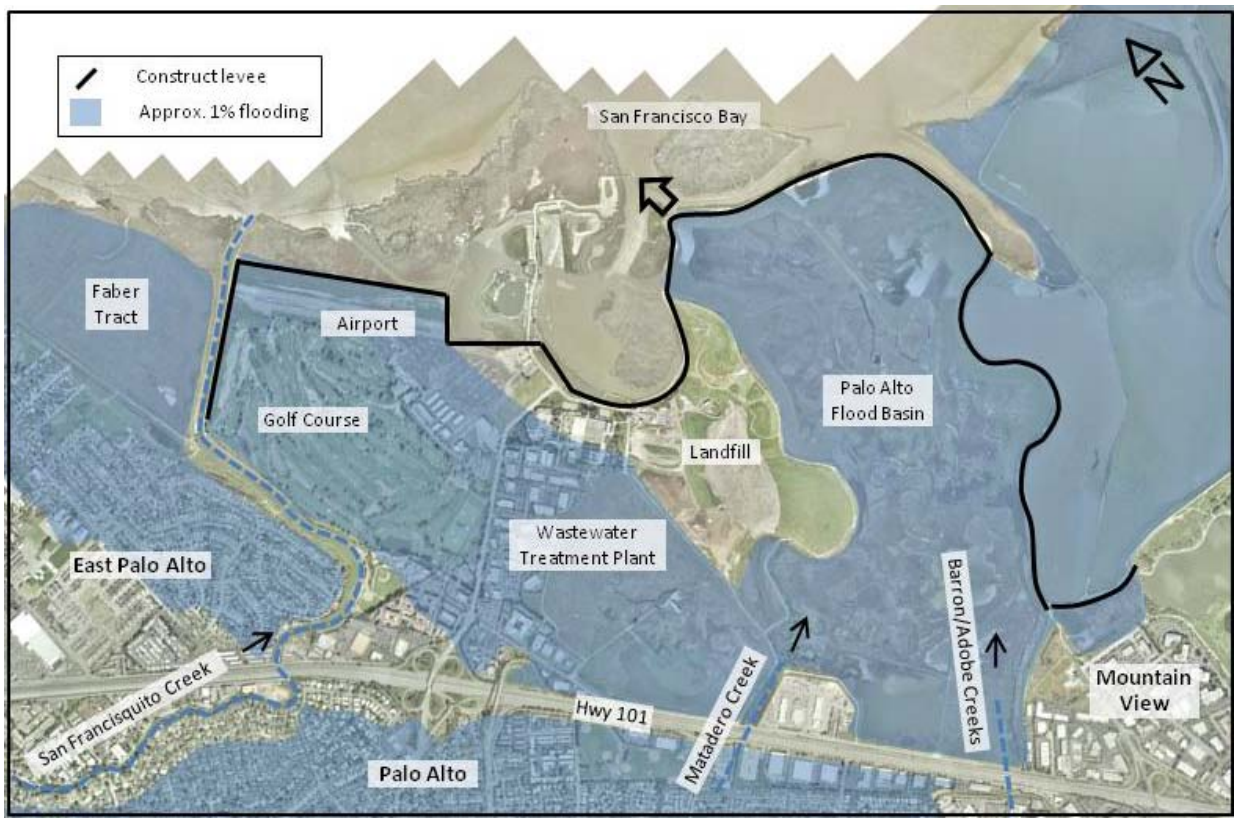


Figure 21: Reach 2, Option 1 (Source: JPA)

Preliminary EAD Estimate: $7.68 million (assumes Curve 3 sea-level rise scenario; does not include WQCP damage); (unsure if the area north of the creek in East Palo Alto would benefit from this project)??
Preliminary Project Cost Estimate: $25 million (No RE included)
Annualized Cost: $1.16 million
Residual Fluvial Risk: Medium (one of three EIAs have a high fluvial risk)

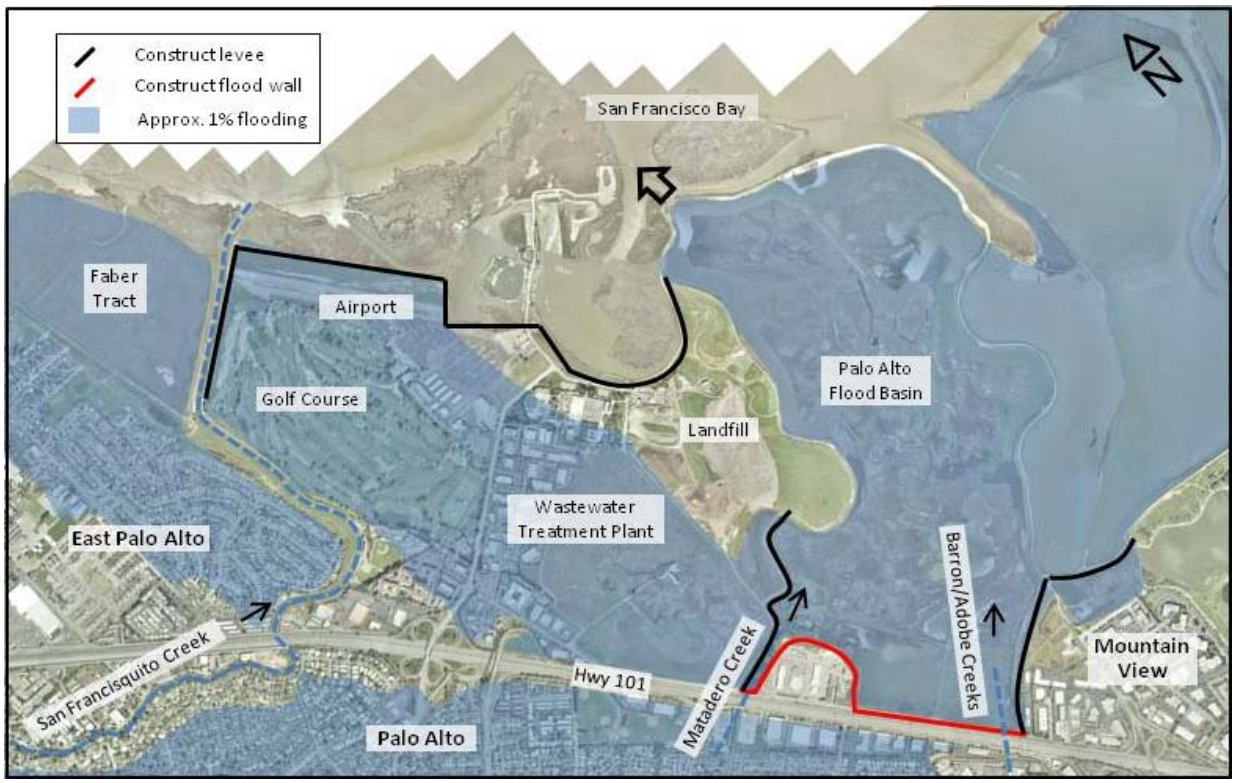


Figure 22: Reach 2, Option 2 (Source: JPA)

Preliminary EAD Estimate: $7.68 million (assumes Curve 3 sea-level rise scenario; does not include WQCP damage); (unsure if the area north of the creek in East Palo Alto would benefit from this project)??
Preliminary Project Cost Estimate: $20 million (No RE included)
Annualized Cost: $.93 million
Residual Fluvial Risk: Medium (one of three EIAs have a high fluvial risk)

9. Discussion of Potential Federal Interest

A comprehensive flood risk management solution comprised of various options thus far developed by the non-Federal sponsor would cost between $144 million and $243 million (preliminary estimates that don't include USACE cost elements—such as real estate valuation, interest during construction, and other economic (not necessarily financial) costs.

At the current FY12 water resources discount rate of 4% and amortized over fifty years, this equates to annualized costs between $6.7 million and $11.3 million. Effectively reducing the flood risk in the area to all but the most extreme events (beyond the 1% annual exceedence probability event) is preliminarily estimated to result in $30 million in average annual flood damage reduction benefits.

Annual benefits of $30 million would support total project costs up to $644.5 million, while maintaining a benefit-cost ratio of unity (i.e. 1.0). Given the preliminary estimates, in order to have a B-C ratio of 2.0 or greater the project would need to cost less than $323 million. Finally, to achieve a B-C ratio of 2.5 the total project costs could not exceed $258 million. While these scenarios all seem to support the economic feasibility of the preliminary project options (which the sponsor has estimated will cost between $144 million and $243million), the data and model results completed thus far (both hydraulic engineering and economics) are not yet sufficient to claim any plan or plans as economically viable (i.e. b-c ratio >= 1) at the feasibility study level.

Moreover, USACE Planning Guidance requires that separable elements of a project must be economically justified based upon their own benefits. In other words, measures that protect from riverine flooding but not coastal flooding would have to be justified solely upon fluvial benefits. Likewise, coastal solutions that did not help reduce riverine damages would have to rely only upon coastal benefits. There could be plans that protect against both types of flooding, and the appropriate accounting of benefits would need to be conducted based upon coincidental floodplain depths that have yet to be developed for this study.

Another concern for USACE regarding Federal Interest would be the consideration of non-structural alternatives to lower flood damage risk. USACE's Planning Guidance Notebook requires that planning studies properly consider alternatives such as temporary or permanent relocations, raising structures in place, and/or developing comprehensive flood warning systems to achieve economic benefits. Since the preliminary Year 50 coastal floodplains show substantial flooding at the 50% and 20% annual exceedance probability events (2 and 5-yr return periods, respectively), significant changes in future land use for the area would have to be considered and analyzed.

Still, all of these preliminary numbers leads to a reasonable conclusion that there do exist potential solutions—either proposed by the Federal Government, the non-Federal sponsor, or a combination of the two—that justify continuing this feasibility study. Although there are inevitably many hurdles during a planning feasibility study—engineering as well as environmental concerns involving people, animals, and fauna—there seem to be sufficient without-project damages that could be prevented and count towards flood risk reduction benefits to support substantial project implementation cost figures, as just described. At this point in the analysis, the numbers seem to indicate that the criterion of economic feasibility would likely be met in order to justify continuing Federal Interest in the San Francisquito Creek feasibility study.

10. Regional Economic Development and Other Social Effects

Per USACE EC 1105-2-409, any alternative plan that has net beneficial effects across the four USACE Planning & Guidance (P&G) accounts may be the recommended plan. Furthermore, "highest budgetary priority will be given to collaborative planning activities that embrace the full range of the national Federal interest." The description of any estimated RED impacts within the study area as a result of a federal project will be included in subsequent report phases as warranted, and as further guidance and instruction becomes available. The following two sections will briefly describe each of the accounts.

10.1. Regional Economic Development (RED)

According to EC 1105-2-409, "the regional economic development account registers changes in the distribution of regional economic activity that result from each alternative plan". According to the EC, measurement of RED effects is generally to be quantitative within available and selected methods. USACE is currently developing a handbook of contemporary techniques for RED.

This type of impact analysis requires relatively sophisticated input/output modeling, which would require a significant amount of additional funds and time to incorporate in this study. While a quantitative analysis is not included here, it is useful to describe in generalities some of the more easily identifiable indirect impacts of a major flood event in this area. Possible impacts include changes in gross regional product, employment, sales and property tax revenues, and development patterns.

In the aftermath of a significant flood event, sales and business activity in some sectors will be hurt, while others will receive a boost. For example, while it could be expected that some sectors would be adversely impacted in the short-term, other sectors such as construction and some retail businesses would likely benefit as homeowners rebuild and repair their homes and replace damaged goods. Thus, in the absence of a more detailed analysis, the net effect on sales tax revenues is uncertain.

For property tax revenues, assuming that nearly all damaged or destroyed homes would be repaired or replaced, a decrease in property taxes as a result of a flood event is not expected. It is possible to imagine both positive and negative effects on property taxes in the region. Decreased property value of land in the floodplain would decrease tax revenues, while, as a result of California's Proposition 13, an increase in property taxes would be associated with parcels where substantial improvements were made to the structure or with those parcels where ownership changed in the aftermath of the flooding.

10.2. Other Social Effects (OSE)

OSE is defined by EC 1105-2-409, "The other social effects account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts". Measurement of OSE effects is generally qualitative; however quantitative data is encouraged within available and accepted methods.

Flooding on a massive scale, which would occur under the storm events analyzed in this study, would cause disruptions in the availability of important health, safety, and social services. Table 13 contains an estimate of the number of important public and social service structures in the coastal and fluvial floodplains. The following paragraphs attempt to describe the social and community impacts of flood damages to these structures.

Table 14: OSE Structure Counts

	Schools	Infrastructure	Public Service	Hospitals	Libraries	All Structures
Coastal	8	2	6	3	0	19
Fluvial	11	0	2	2	1	16
Coastal & Fluvial	9	1	1	1	1	13
Total	28	3	9	6	2	48

Schools make up the largest percentage of important service-providing structures in the coastal, fluvial, and co-mingled floodplains. Given that a large storm event is most likely to occur in the non-summer months, flooding of these facilities represents a significant inconvenience and cost to the affected communities. In addition to short-term closures before, during, and immediately following a large storm event, damage to school facilities could result in long-term closures while buildings undergo storm clean-up and repair. The cost to affected families could be as small as a few missed or delayed school days, or as large as a long-term displacement if students are forced to resume classes at a different school due to extensive flood damage. In the latter case, costs will be spread to neighboring community school systems if and when they absorb the flood impacted students. Damage to the school buildings throughout the floodplains would undoubtedly contribute greatly to the social and financial costs associated with a flood event.

Six hospitals and medical centers lie within the study area. The short-term danger facing hospital staff and patients in a large flood event is great due to the difficulty of relocating the ill and/or immobile population that is at risk inside of a hospital. In addition to this short-term challenge, hospital closures would affect the overall safety of the residents in the floodplain who, without access to a local emergency room or urgent care clinic, will be at a disadvantage if there is a need for immediate health care. Even if hospital closures are short-lived and take place only immediately following a flood event, emergency services will be unavailable at a time when a flood ravaged community may need them most.

A third set of vital structures falls within the “Public Service” category in Table 13. Two police stations lie within the coastal floodplain and one fire station within the fluvial floodplain. Flood damage to any of these structures would have an obvious detrimental impact to the safety of the surrounding population. In addition to police and fire stations, one jail is included among the public service structure count. The need to assure the safety of an incarcerated population poses an additional challenge in the event of a large flood. The remaining public service buildings are all administrative. Their closure would have less significant social costs than those accrued due to the threat to health, safety, and human life that result from hospital, police, and fire station closures.

The infrastructure referred to in Table 13 includes the Palo Alto Airport and the waste water treatment plant, both of which have been detailed previously in the analysis. The Port of Redwood City also represents important infrastructure in the coastal floodplain. While the losses associated with a closure of the Port due to flood damages are economic, as a vital access point for goods to and from the southern portion of the San Francisco Bay Area, the economic ramifications of a Port closure are large enough to deserve consideration. Other Bay Area ports would likely absorb the Port’s business during a closure, resulting in a regional shift in economic activity away from Redwood City, which would have a negative effect on the local economy. The potential higher cost of importing or exporting goods out of alternative Bay Area ports may result in some national economic losses, as well, contributing to the NED account for this study. For now, a qualitative

evaluation indicates that there are great potential economic losses due to flooding of the Port of Redwood City.

With a wealth of schools, hospitals, and public service buildings, the impact of a large storm event on collective social and community services within the San Francisquito study area would be significant. Though the effect cannot be easily quantified, the scope of the damages to vital health and safety services deserves ample consideration in the planning process.

11. Recreation Analysis

There are potentially many opportunities to improve the quality and quantity of recreation in the study area as part of a project. In order to describe and estimate the value of potential future project-related recreational resources, the without-project Economic Analysis typically defines the market area and describes the existing and expected future without-project recreational resources. At the next, with-project, study phase, understanding the level of unmet demand for recreation in the study area will help the study team understand and estimate the value of potential future recreation management measures. It is not yet clear whether or not recreation features will be part of the potential array of alternatives. If warranted, the next study phase will include a definition of the recreation market area, the existing supply of recreation opportunities, and it will use one of several possible valuation methodologies to estimate using well-established parameters the users' willingness to pay for potential future recreation experiences created as part of the project.

12. Addendum

12.1. Flood Maps

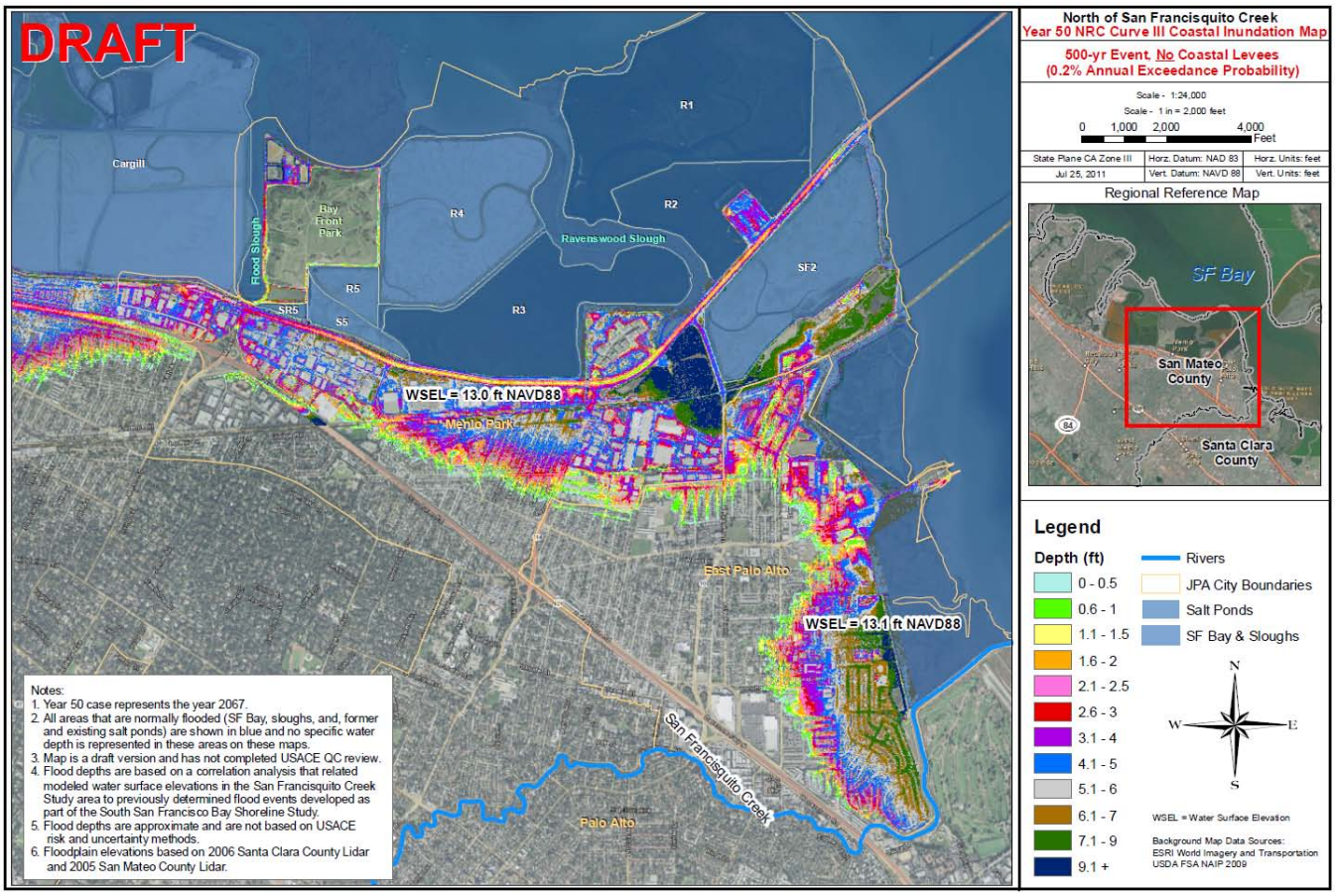


Figure 23: Draft .2% Coastal Floodplain

12.2. Structure and Content Depth-Damage Curves

Figure 24: SFR1 Content Depth-Damage Curve

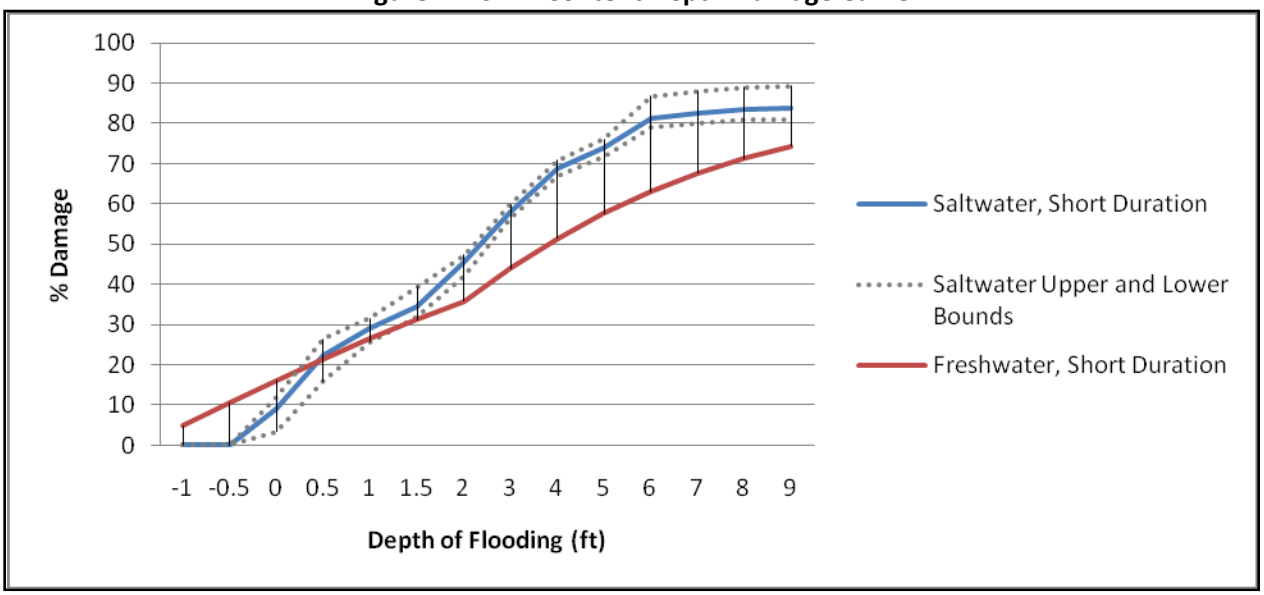


Figure 25: SFR2 Structure Depth-Damage Curve

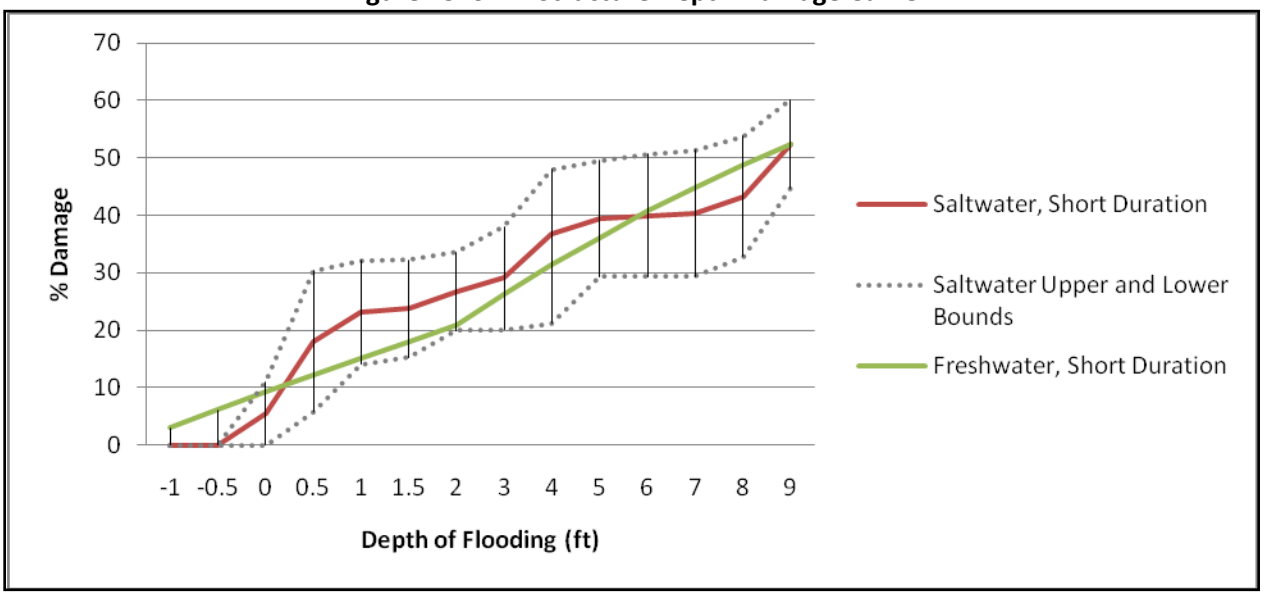


Figure 26: SFR2 Content Depth-Damage Curve

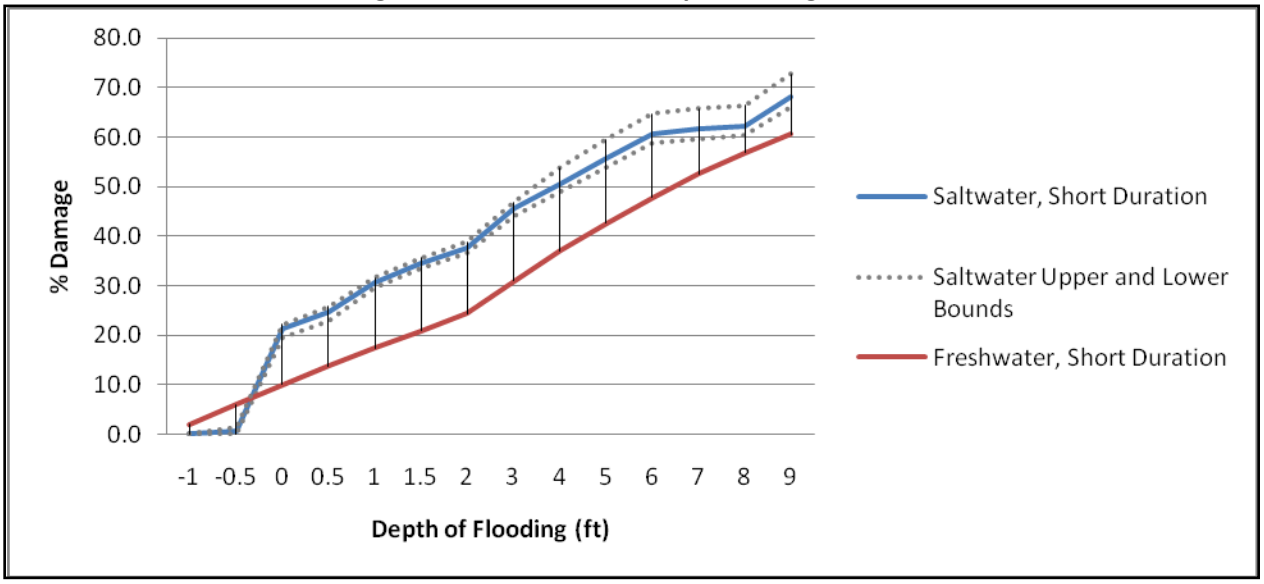


Figure 27: Commercial Structure Depth-Damage Curve

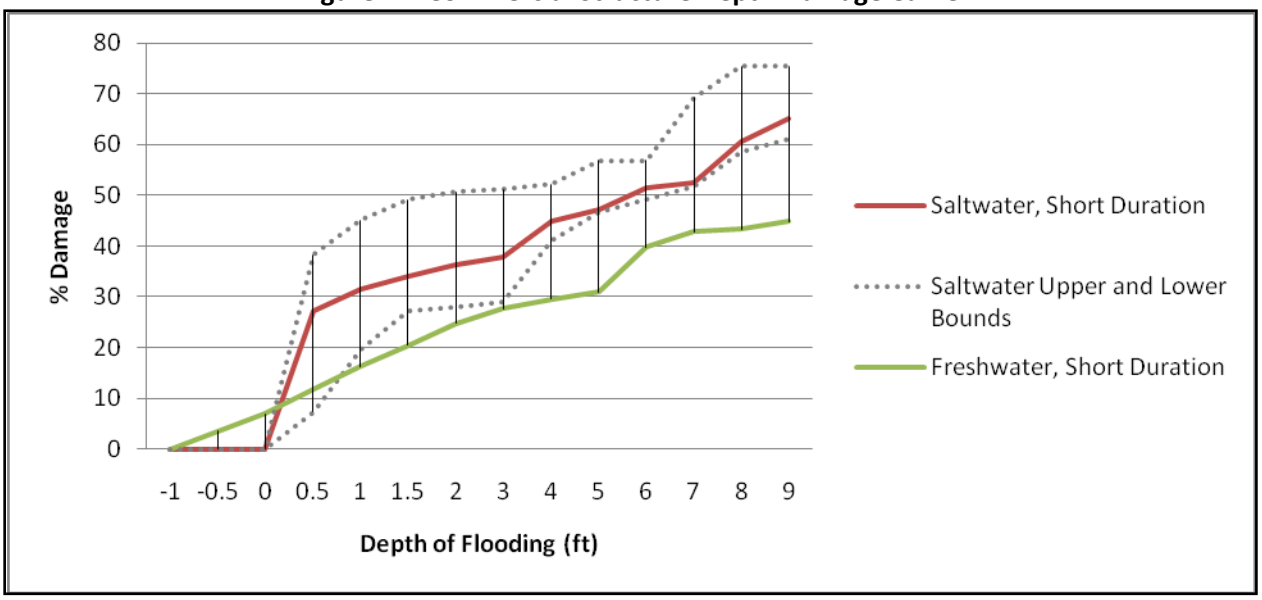


Figure 28: Commercial Content Depth-Damage Curves

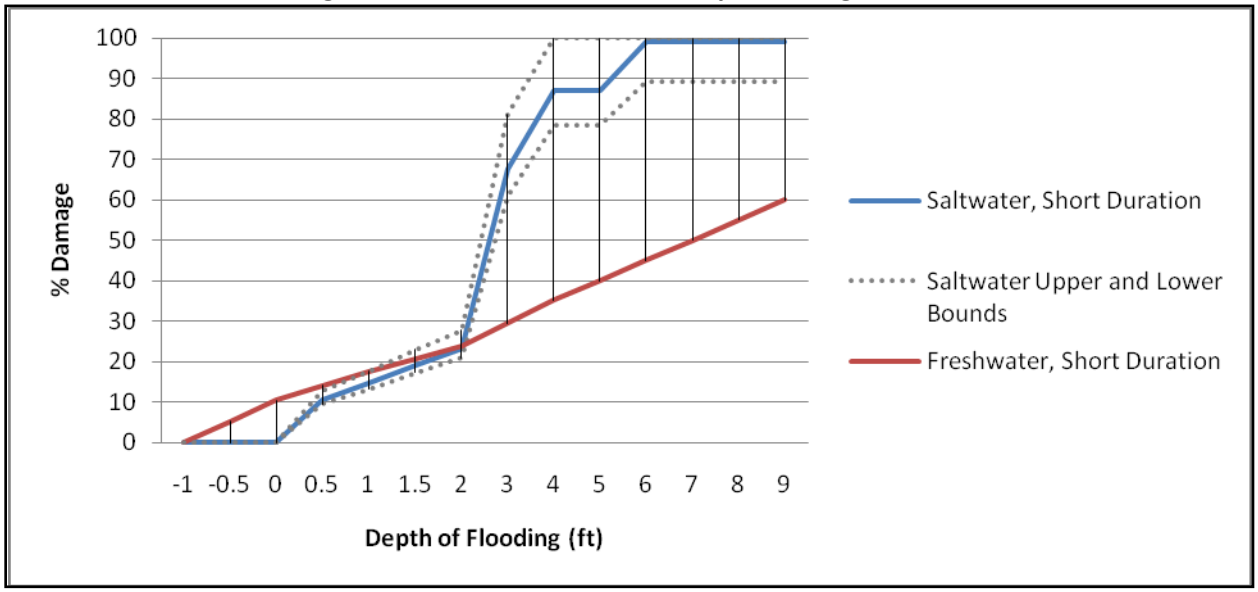


Figure 29: Industrial Structure Depth-Damage Curve

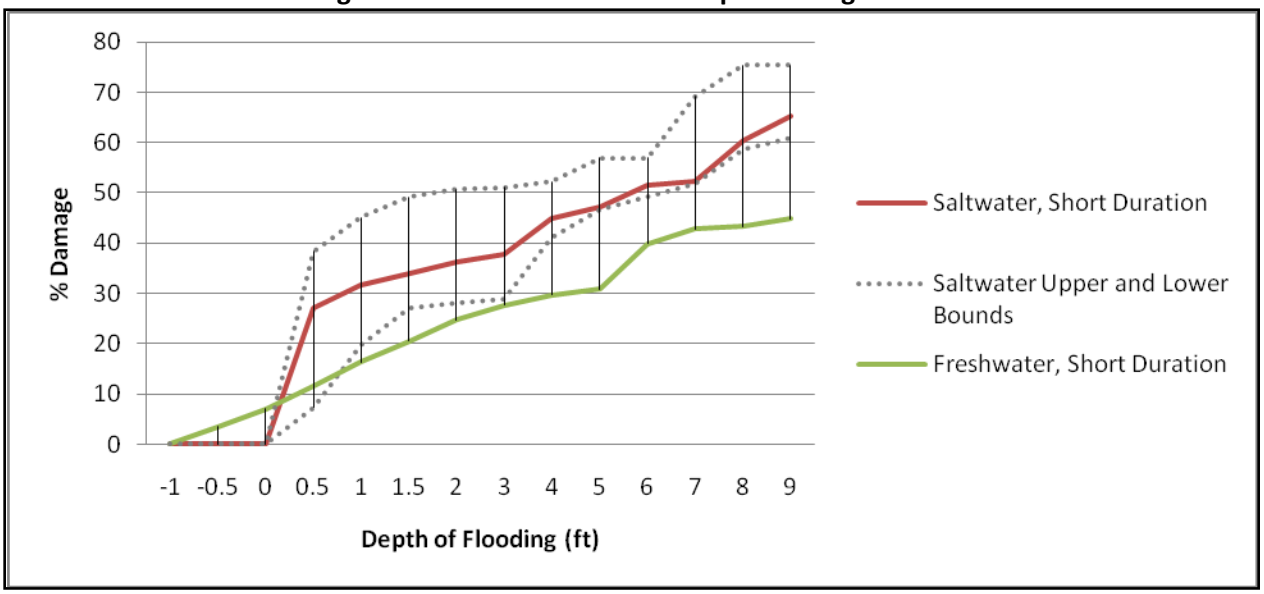
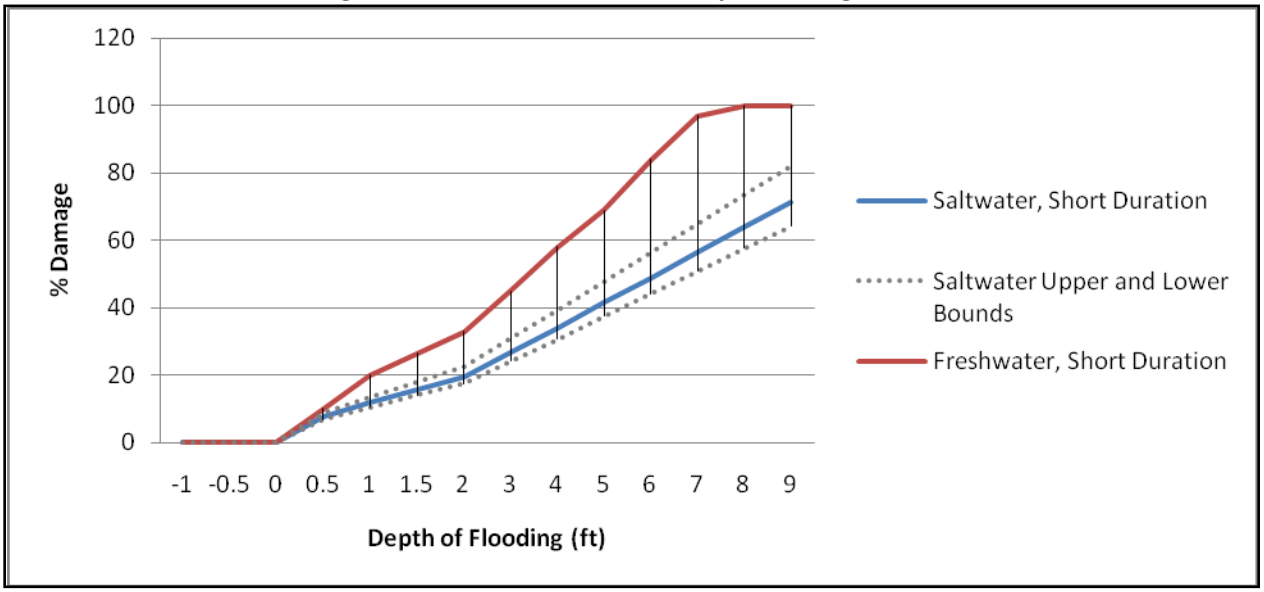


Figure 30: Industrial Contents Depth-Damage Curve



12.3. Fluvial Analysis HEC-FDA Screen Captures*

Table 9: Exceedance Probability - Damage Functions, 2017, SM 1 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0400	0.01	3.62	0.02	1.28	0.00	0.05	4.98
0.0250	1.48	789.56	3.64	279.32	0.00	11.61	1085.61
0.0200	4.76	2535.42	11.70	896.95	0.00	37.27	3486.09
0.0150	10.22	5443.07	25.11	1925.58	0.00	80.00	7483.99
0.0100	19.24	10247.93	47.28	3625.39	0.00	150.63	14090.46
0.0090	21.66	11537.19	53.22	4081.49	0.00	169.58	15863.15
0.0080	24.34	12964.69	59.81	4586.49	0.00	190.56	17825.89
0.0070	27.37	14578.41	67.26	5157.38	0.00	214.28	20044.69
0.0060	30.96	16486.35	76.06	5832.35	0.00	242.32	22668.03
0.0050	35.60	18957.99	87.46	6706.73	0.00	278.65	26066.43
0.0040	42.47	22618.59	104.35	8001.74	0.00	332.46	31099.61
0.0020	70.63	37618.36	173.55	13308.17	0.00	552.93	51723.64
0.0010	100.53	53538.42	246.99	18940.19	0.00	786.93	73613.05

*The Analysis Year field in the screen captures shows the year 2014, which was the year originally entered upon initial model setup. As noted elsewhere in the report, the actual base year is 2017. This discrepancy makes no difference to the model or the results.

Table 10: Exceedance Probability - Damage Functions, 2017, SM 2 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.9000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.8000	0.00	0.00	0.01	0.00	0.00	0.03	0.04
0.7000	0.00	0.00	0.01	0.00	0.00	0.04	0.06
0.6000	0.01	0.00	0.01	0.00	0.00	0.06	0.08
0.5000	0.01	0.00	0.02	0.00	0.00	0.07	0.10
0.4750	0.01	0.00	0.02	0.00	0.00	0.07	0.10
0.4500	0.01	0.00	0.02	0.00	0.00	0.08	0.11
0.4250	0.01	0.00	0.02	0.00	0.00	0.08	0.11
0.4000	0.01	0.00	0.02	0.00	0.00	0.08	0.12
0.3750	0.01	0.00	0.02	0.00	0.00	0.09	0.12
0.3500	0.01	0.00	0.02	0.00	0.00	0.09	0.13
0.3250	0.01	0.00	0.02	0.00	0.00	0.09	0.13
0.3000	0.01	0.00	0.02	0.00	0.00	0.10	0.14
0.2750	0.01	0.00	0.03	0.00	0.00	0.10	0.14
0.2500	0.01	0.00	0.03	0.00	0.00	0.10	0.15
0.2250	0.01	0.00	0.03	0.00	0.00	0.11	0.15
0.2000	0.01	0.00	0.03	0.00	0.00	0.11	0.16
0.1750	0.03	0.00	0.06	0.00	0.00	0.24	0.33
0.1500	0.13	0.02	0.28	0.00	0.00	1.13	1.57
0.1250	0.32	0.05	0.68	0.00	0.00	2.72	3.78
0.1000	1.93	0.29	4.07	0.00	0.00	16.20	22.49
0.0750	10.58	1.58	22.31	0.00	0.00	88.84	123.31
0.0500	33.51	5.00	70.65	0.00	0.00	281.39	390.55
0.0400	73.26	10.93	154.46	0.00	0.00	615.21	853.87
0.0250	171.22	25.55	361.01	0.00	0.00	1437.91	1995.70
0.0200	297.16	44.35	626.54	0.00	0.00	2495.49	3463.53
0.0150	456.03	68.06	961.51	0.00	0.00	3829.71	5315.31
0.0100	650.40	97.07	1371.33	0.00	0.00	5462.03	7580.83
0.0090	693.31	103.47	1461.80	0.00	0.00	5822.36	8080.95
0.0080	739.86	110.42	1559.96	0.00	0.00	6213.31	8623.55
0.0070	790.85	118.03	1667.47	0.00	0.00	6641.53	9217.89
0.0060	847.62	126.50	1787.17	0.00	0.00	7118.30	9879.60
0.0050	914.60	136.50	1928.37	0.00	0.00	7680.72	10660.19
0.0040	1034.15	154.34	2180.45	0.00	0.00	8684.75	12053.71
0.0020	1430.24	213.46	3015.57	0.00	0.00	12011.03	16670.29
0.0010	1849.09	275.97	3898.69	0.00	0.00	15528.51	21552.26

Table 11: Exceedance Probability - Damage Functions, 2017, SM 3 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.01
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.01
0.5000	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4750	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4500	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4250	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4000	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.3750	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.3500	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.3250	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.3000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2750	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2500	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2250	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1750	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1500	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1250	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.0750	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.0500	0.07	0.05	0.15	0.20	0.03	0.51	1.01
0.0400	0.25	0.15	0.50	0.68	0.09	1.74	3.42
0.0250	9.72	6.08	19.82	26.87	3.55	68.78	134.82
0.0200	45.34	28.37	92.42	125.26	16.53	320.67	628.59
0.0150	93.13	58.27	189.83	257.28	33.95	658.63	1291.10
0.0100	390.86	244.57	796.74	1079.81	142.51	2764.33	5418.82
0.0090	533.83	334.04	1088.19	1474.80	194.64	3775.52	7401.02
0.0080	689.14	431.21	1404.77	1903.84	251.26	4873.88	9554.10
0.0070	859.28	537.68	1751.59	2373.88	313.30	6077.20	11912.92
0.0060	1048.75	656.24	2137.83	2897.33	382.38	7417.26	14539.79
0.0050	1270.52	795.00	2589.88	3509.99	463.24	8985.67	17614.29
0.0040	1586.80	992.91	3234.60	4383.76	578.56	11222.54	21999.15
0.0020	2570.89	1608.68	5240.61	7102.45	937.36	18182.46	35642.44
0.0010	3551.01	2221.98	7238.54	9810.19	1294.72	25114.36	49230.80

Table 12: Exceedance Probability - Damage Functions, 2017, SM 4 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.01
0.9500	0.00	0.00	0.00	0.00	0.00	0.02	0.03
0.9000	0.00	0.00	0.01	0.00	0.00	0.05	0.06
0.8000	0.01	0.00	0.02	0.00	0.00	0.10	0.13
0.7000	0.01	0.00	0.03	0.00	0.00	0.15	0.19
0.6000	0.01	0.01	0.04	0.00	0.00	0.20	0.26
0.5000	0.02	0.01	0.05	0.00	0.00	0.25	0.32
0.4750	0.02	0.01	0.05	0.00	0.00	0.26	0.34
0.4500	0.02	0.01	0.05	0.00	0.00	0.27	0.35
0.4250	0.02	0.01	0.05	0.00	0.00	0.28	0.37
0.4000	0.02	0.01	0.06	0.00	0.00	0.29	0.38
0.3750	0.02	0.01	0.06	0.00	0.00	0.31	0.40
0.3500	0.02	0.01	0.06	0.00	0.00	0.32	0.42
0.3250	0.03	0.01	0.06	0.00	0.00	0.33	0.43
0.3000	0.03	0.01	0.07	0.00	0.00	0.34	0.45
0.2750	0.03	0.01	0.07	0.00	0.00	0.36	0.46
0.2500	0.03	0.01	0.07	0.00	0.00	0.37	0.48
0.2250	0.03	0.01	0.07	0.00	0.00	0.38	0.50
0.2000	0.03	0.01	0.08	0.00	0.00	0.39	0.51
0.1750	0.12	0.05	0.30	0.00	0.00	1.55	2.01
0.1500	0.36	0.16	0.91	0.00	0.01	4.74	6.17
0.1250	0.69	0.30	1.74	0.00	0.01	9.11	11.86
0.1000	7.15	3.16	18.06	0.00	0.14	94.48	122.99
0.0750	42.18	18.64	106.54	0.00	0.81	557.33	725.51
0.0500	91.53	40.46	231.19	0.00	1.77	1209.40	1574.34
0.0400	123.76	54.71	312.60	0.00	2.39	1635.30	2128.76
0.0250	198.26	87.64	500.79	0.00	3.83	2619.72	3410.24
0.0200	265.61	117.41	670.91	0.00	5.13	3509.67	4568.73
0.0150	351.70	155.47	888.35	0.00	6.79	4647.15	6049.45
0.0100	508.54	224.80	1284.51	0.00	9.82	6719.59	8747.26
0.0090	560.02	247.55	1414.55	0.00	10.81	7399.81	9632.75
0.0080	615.86	272.24	1555.59	0.00	11.89	8137.63	10593.20
0.0070	677.03	299.27	1710.09	0.00	13.07	8945.88	11645.35
0.0060	745.13	329.38	1882.09	0.00	14.39	9845.63	12816.61
0.0050	826.14	365.19	2086.71	0.00	15.95	10916.06	14210.05
0.0040	1091.02	482.27	2755.77	0.00	21.07	14416.08	18766.22
0.0020	2034.98	899.54	5140.09	0.00	39.29	26888.98	35002.89
0.0010	3264.17	1442.89	8244.84	0.00	63.03	43130.64	56145.58

Table 13: Exceedance Probability - Damage Functions, 2017, SM 5 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0400	1612.27	3.23	3420.36	0.00	183.92	9497.17	14716.94
0.0250	2801.44	5.61	5943.12	0.00	319.58	16502.01	25571.75
0.0200	3455.96	6.92	7331.66	0.00	394.24	20357.52	31546.30
0.0150	4281.64	8.57	9083.30	0.00	488.43	25221.22	39083.17
0.0100	5345.05	10.70	11339.27	0.00	609.74	31485.28	48790.04
0.0090	5598.69	11.21	11877.36	0.00	638.68	32979.37	51105.30
0.0080	5873.73	11.76	12460.85	0.00	670.05	34599.52	53615.91
0.0070	6175.12	12.36	13100.22	0.00	704.43	36374.84	56366.98
0.0060	6510.63	13.03	13811.99	0.00	742.71	38351.18	59429.54
0.0050	6895.57	13.80	14628.63	0.00	786.62	40618.70	62943.32
0.0040	7466.18	14.95	15839.15	0.00	851.71	43979.91	68151.90
0.0020	9266.37	18.55	19658.17	0.00	1057.07	54584.02	84584.19
0.0010	10950.84	21.92	23231.70	0.00	1249.23	64506.50	99960.20

Table 14: Exceedance Probability - Damage Functions, 2017, SC 1 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.9500	0.00	0.00	0.00	0.00	0.00	0.04	0.05
0.9000	0.00	0.00	0.01	0.00	0.00	0.08	0.09
0.8000	0.01	0.00	0.01	0.00	0.00	0.16	0.18
0.7000	0.01	0.01	0.02	0.00	0.00	0.24	0.28
0.6000	0.01	0.01	0.03	0.00	0.00	0.32	0.37
0.5000	0.01	0.01	0.04	0.00	0.00	0.40	0.46
0.4750	0.02	0.01	0.04	0.00	0.00	0.42	0.48
0.4500	0.02	0.01	0.04	0.00	0.00	0.44	0.51
0.4250	0.02	0.01	0.04	0.00	0.00	0.46	0.53
0.4000	0.02	0.01	0.04	0.00	0.00	0.48	0.55
0.3750	0.02	0.01	0.05	0.00	0.00	0.50	0.57
0.3500	0.02	0.01	0.05	0.00	0.00	0.52	0.60
0.3250	0.02	0.01	0.05	0.00	0.00	0.54	0.62
0.3000	0.02	0.01	0.05	0.00	0.00	0.56	0.64
0.2750	0.02	0.01	0.05	0.00	0.00	0.58	0.67
0.2500	0.02	0.01	0.05	0.00	0.00	0.60	0.69
0.2250	0.02	0.01	0.06	0.00	0.00	0.62	0.71
0.2000	0.02	0.02	0.06	0.00	0.00	0.64	0.74
0.1750	1.75	1.12	4.24	0.00	0.19	46.71	54.00
0.1500	5.17	3.28	12.47	0.00	0.55	137.51	158.98
0.1250	9.14	5.81	22.05	0.00	0.98	243.22	281.20
0.1000	43.26	27.49	104.41	0.00	4.64	1151.44	1331.24
0.0750	214.95	136.60	518.73	0.00	23.06	5720.74	6614.07
0.0500	444.80	282.68	1073.41	0.00	47.71	11838.00	13686.59
0.0400	569.87	362.17	1375.26	0.00	61.13	15166.92	17535.35
0.0250	865.59	550.10	2088.91	0.00	92.84	23037.30	26634.75
0.0200	1195.61	759.83	2885.32	0.00	128.24	31820.42	36789.42
0.0150	1611.40	1024.08	3888.75	0.00	172.84	42886.58	49583.64
0.0100	2211.95	1405.74	5338.03	0.00	237.26	58869.82	68062.78
0.0090	2375.00	1509.36	5731.53	0.00	254.75	63209.44	73080.07
0.0080	2551.88	1621.77	6158.37	0.00	273.72	67916.80	78522.52
0.0070	2745.64	1744.91	6625.98	0.00	294.50	73073.85	84484.88
0.0060	2961.38	1882.02	7146.62	0.00	317.64	78815.66	91123.32
0.0050	3215.71	2043.65	7760.39	0.00	344.92	85584.48	98949.15
0.0040	3755.31	2386.57	9062.57	0.00	402.80	99945.47	115552.71
0.0020	5580.86	3546.75	13468.14	0.00	598.61	148531.73	171726.09
0.0010	7843.37	4984.62	18928.19	0.00	841.29	208747.23	241344.69

Table 15: Exceedance Probability - Damage Functions, 2017, SC 2 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0400	1671.97	0.00	2982.54	0.00	81.73	11186.82	15923.06
0.0250	2905.23	0.00	5182.49	0.00	142.01	19438.31	27668.04
0.0200	4156.53	0.00	7414.61	0.00	203.17	27810.48	39584.79
0.0150	5762.51	0.00	10279.43	0.00	281.67	38555.75	54879.36
0.0100	7578.59	0.00	13519.04	0.00	370.44	50706.78	72174.85
0.0090	7932.79	0.00	14150.88	0.00	387.75	53076.66	75548.09
0.0080	8316.98	0.00	14836.21	0.00	406.53	55647.17	79206.89
0.0070	8737.79	0.00	15586.86	0.00	427.10	58462.70	83214.45
0.0060	9206.22	0.00	16422.48	0.00	450.00	61596.91	87675.62
0.0050	9743.14	0.00	17380.26	0.00	476.24	65189.30	92788.95
0.0040	10433.47	0.00	18611.70	0.00	509.99	69808.16	99363.32
0.0020	12502.74	0.00	22302.95	0.00	611.13	83653.19	119070.01
0.0010	14493.52	0.00	25854.21	0.00	708.44	96973.13	138029.31

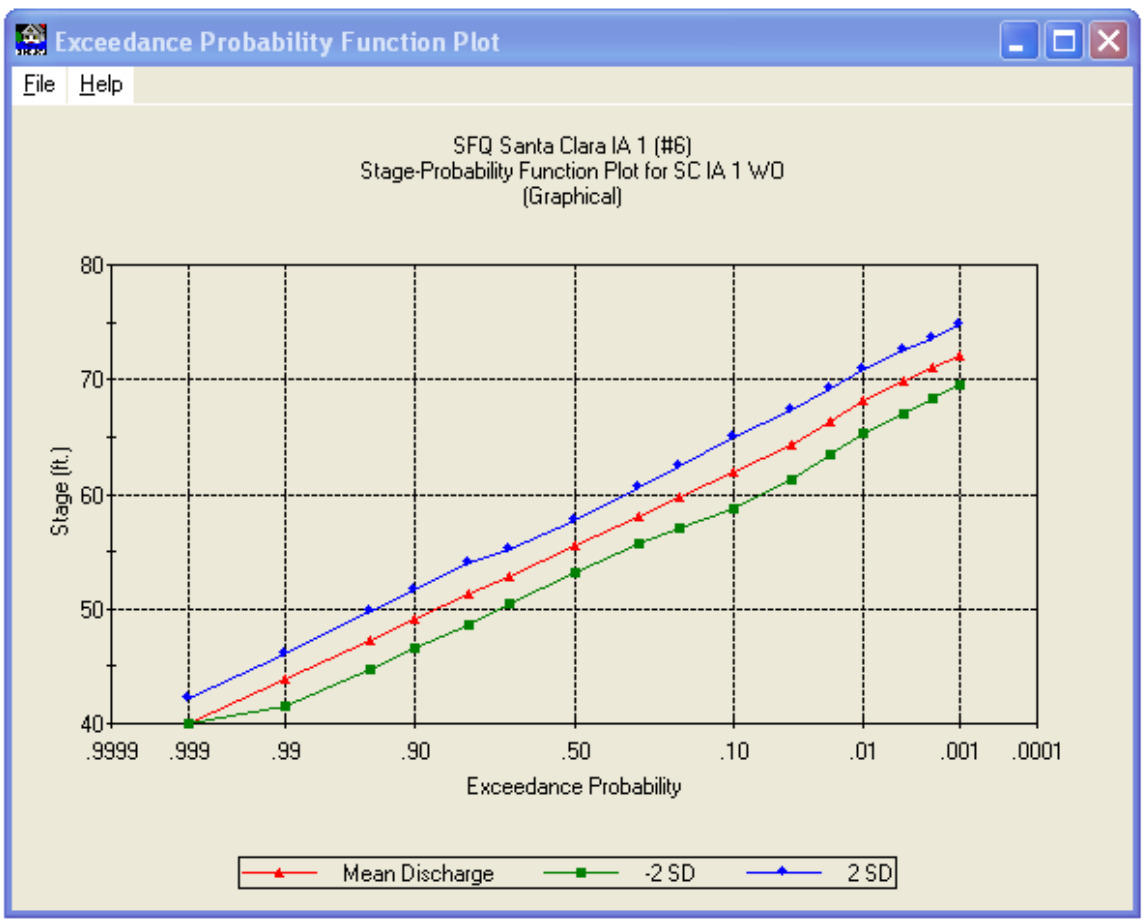
Table 16: Exceedance Probability - Damage Functions, 2017, SC 3 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.05	0.00	0.00	0.00	0.00	0.06
0.9500	0.00	0.30	0.00	0.01	0.02	0.00	0.32
0.9000	0.00	0.60	0.00	0.01	0.03	0.00	0.64
0.8000	0.00	1.20	0.00	0.02	0.07	0.00	1.29
0.7000	0.00	1.81	0.00	0.04	0.10	0.00	1.94
0.6000	0.00	2.41	0.00	0.05	0.13	0.00	2.59
0.5000	0.00	3.02	0.00	0.06	0.16	0.00	3.24
0.4750	0.00	3.17	0.00	0.06	0.17	0.00	3.41
0.4500	0.00	3.32	0.00	0.07	0.18	0.00	3.57
0.4250	0.00	3.47	0.00	0.07	0.19	0.00	3.73
0.4000	0.00	3.62	0.00	0.07	0.20	0.00	3.89
0.3750	0.00	3.77	0.00	0.08	0.20	0.00	4.06
0.3500	0.00	3.92	0.00	0.08	0.21	0.00	4.22
0.3250	0.00	4.08	0.00	0.08	0.22	0.00	4.38
0.3000	0.00	4.23	0.00	0.09	0.23	0.00	4.54
0.2750	0.00	4.38	0.00	0.09	0.24	0.00	4.71
0.2500	0.00	4.53	0.00	0.09	0.25	0.00	4.87
0.2250	0.00	4.68	0.00	0.10	0.25	0.00	5.03
0.2000	0.00	4.83	0.00	0.10	0.26	0.00	5.19
0.1750	0.00	4.98	0.00	0.10	0.27	0.00	5.36
0.1500	0.00	5.13	0.00	0.11	0.28	0.00	5.52
0.1250	0.00	5.28	0.00	0.11	0.29	0.00	5.68
0.1000	0.00	5.44	0.00	0.11	0.30	0.00	5.84
0.0750	0.00	125.06	0.00	2.56	6.79	0.00	134.41
0.0500	0.00	596.40	0.00	12.22	32.39	0.00	641.00
0.0400	0.00	897.39	0.00	18.38	48.74	0.00	964.51
0.0250	0.00	1577.90	0.00	32.32	85.70	0.00	1695.92
0.0200	0.00	1972.82	0.00	40.41	107.14	0.00	2120.37
0.0150	0.00	2398.30	0.00	49.12	130.25	0.00	2577.67
0.0100	0.00	3873.18	0.00	79.33	210.35	0.00	4162.86
0.0090	0.00	5005.18	0.00	102.52	271.83	0.00	5379.53
0.0080	0.00	6567.53	0.00	134.52	356.68	0.00	7058.73
0.0070	0.00	8352.40	0.00	171.07	453.62	0.00	8977.09
0.0060	0.00	10430.88	0.00	213.64	566.50	0.00	11211.02
0.0050	0.00	12953.81	0.00	265.32	703.52	0.00	13922.65
0.0040	0.00	16149.60	0.00	330.77	877.08	0.00	17357.46
0.0020	0.00	26502.62	0.00	542.82	1439.36	0.00	28484.80
0.0010	0.00	38490.63	0.00	788.36	2090.42	0.00	41369.42

Table 17: Exceedance Probability Function with Uncertainty

Exceedance Probability	Stage (ft.)	Confidence Limit Curves Stage (ft.) -2 SD	-1 SD	+1 SD	+2 SD
0.9990	40.00	40.00	38.92	41.08	42.16
0.9900	43.83	41.51	42.67	44.99	46.15
0.9500	47.25	44.77	46.01	48.48	49.72
0.9000	49.07	46.51	47.79	50.35	51.62
0.8000	51.27	48.62	49.95	52.60	53.93
0.7000	52.86	50.47	51.67	54.06	55.26
0.5000	55.49	53.20	54.35	56.64	57.78
0.3000	58.12	55.73	56.92	59.32	60.52
0.2000	59.71	57.05	58.38	61.04	62.37
0.1000	61.92	58.80	60.36	63.48	65.03
0.0400	64.27	61.28	62.77	65.77	67.26
0.0200	66.29	63.40	64.84	67.74	69.18
0.0100	68.17	65.38	66.77	69.57	70.96
0.0040	69.79	67.08	68.43	71.15	72.50
0.0020	71.00	68.35	69.68	72.32	73.65
0.0010	72.13	69.54	70.84	73.43	74.73



US Army Corps of Engineers

San Francisquito Creek

Flood Risk Management Feasibility Study

Without-Project Economics (DRAFT)

Fluvial Only

August 2011

Table of Contents

1. Introduction 1
1.1. Purpose 1
1.2. Flood Damage Analysis Overview 1
1.3. Brief Description of the Flood Modeling 2
1.4. Consideration of Sea-Level Rise 3
2. Structures, Contents, and Infrastructure at Risk from Fluvial Flooding 4
2.1. Delineation of Economic Impact Areas 4
2.2. Structure Types and Flooding Characteristics by EIA 6
2.2.1. San Mateo EIAs 7
2.2.2. Santa Clara EIAs 7
3. Structure, Content & Vehicle Valuation 8
3.1. Structure Inventory 8
3.2. Structure Valuation 8
3.3. Content Valuation 9
3.4. Structure Inventory and Valuation Results 11
4. Elevation and Flood Damage Relationships 13
4.1. Structure and Content Depth-Damage Relationships 14
4.2. Automobile Depth Damage Relationship 19
5. EAD – Structures, Contents, Vehicles, & Displacement 21
5.1. Expected Annual Damages 21
5.2. Residential Displacement Costs Depth Damage Relationship 22
5.3. Emergency Costs 24
5.4. Insurance Policy Administration 25
5.5. Income Loss to Businesses 25
6. Summary & Discussion of the Without-Project NED Flood Damages 26
7. Regional Economic Development and Other Social Effects 27
7.1. Regional Economic Development (RED) 27
7.2. Other Social Effects (OSE) 27
8. Recreation Analysis 28
9. Addendum—HEC-FDA Screen Captures 29

List of Tables

Table 1: Description of Economic Impact Areas 6
Table 2: CSVRs per Structure Type 10
Table 3: Structures in .2% Floodplain 11

List of Figures

Figure 1: Aerial Showing All 8 EIAs 5
Figure 2: Example of Parcel Centroid Location 13
Figure 3: SFR1 Structure Depth-Damage Curve 15
Figure 4: SFR1 Content Depth-Damage Curve 16
Figure 5: SFR2 Structure Depth-Damage Curve 16
Figure 6: SFR2 Content Depth-Damage Curve 17
Figure 7: Commercial Structure Depth-Damage Curve 17
Figure 8: Commercial Content Depth-Damage Curves 18
Figure 9: Industrial Structure Depth-Damage Curve 18
Figure 10: Industrial Contents Depth-Damage Curve 19
Figure 11: Depth-Damage Function for Vehicles 19
Figure 39: Displacement Cost and Days Displaced 23
Figure 40: Displacement Depth Damage Curve 24

1. Introduction

1.1. Purpose

The purpose of this report is to document the methodology and updated results of the Economic Analysis conducted to assess the without-project condition as it relates to damages from potential future fluvial flooding in the area known as the San Francisquito Creek study area.

The analysis focuses on without-project conditions related to flood damages to structures and contents. Other damage categories such as autos, utilities & infrastructure, and foregone costs related to flood fighting, evacuation, and cleanup will be added in the next Planning Milestone economics analysis. The primary focus of this analysis is to estimate the economic damages associated with potential future flood events in the study area assuming no Federal project is constructed/implemented. At subsequent study phases, the difference between the without-project damages and with-project damages (benefits) will be compared to the costs of various alternatives, and the net economic benefits (benefits minus costs) to the Nation resulting from each of the alternatives be compared to identify the National Economic Development (NED) alternative, per the *"Planning Guidance Notebook"*

1.2. Flood Damage Analysis Overview

The principal guidance referenced for this analysis comes from the U. S. Army Corps of Engineers (USACE) "*Planning Guidance Notebook*", ER 1105-2-100, with specific guidance from Appendix D – Economic and Social Considerations. Additional guidance on risk-based analysis has been obtained from USACE ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*, dated January 3, 2006. Benefits and costs are expressed in average annual terms at FY 2011 (Oct 2010) price levels using the mandated federal discount rate of 4.125%. The period of analysis is 50 years. The study/project Base Year, defined as the year when the project is expected to be operational and benefits begin to be realized, is 2017. Within the floodplain there is little or no vacant, developable land, and for this reason the analysis assumes that the future without-project floodplain inventory of structures and land use is equivalent to the current without-project condition.

By policy, USACE Flood Risk Management feasibility reports must evaluate the flooding problem (and potential measures to reduce the risk of flooding) against four "accounts." These are National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). While all four accounts will ultimately be considered in the evaluation of potential federal investments, this without-project flood damage analysis focuses on the NED account. The USACE Planning Guidance Notebook (PGN) describes the NED account as such:

> *Contributions to national economic development (NED) are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the Nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed.*

The NED account is exclusively concerned with national net economic benefits, and thus does not include local or regional economic transfers. For example, according to the PGN, the prevention of income loss results in a contribution to national economic development only to the extent that such loss cannot be compensated for by postponement of an activity or transfer of the activity to other establishments.

The primary NED damage categories evaluated for this study phase is as follows:

- Structure and Content Damages to residences, business & industry, and public buildings

The following list represents typical benefits categories that will be included during the Alternatives Analysis phase of this feasibility study:

- Cost to Temporarily Displaced Residents
- Automobile Damages
- Traffic Delay and Detour Costs
- Emergency and Cleanup Costs

There is a likelihood that much of the analysis for these categories completed for the South San Francisco Shoreline study can be adapted to this San Francisquito study, based upon the close proximity of both study areas. Also, such damages to certain EIAs for the San Francisquito study area (i.e. those located between US 101 and San Francisco Bay) will most likely be more of a function of coastal storm damage rather than fluvial flooding; the coastal floodplains are currently being developed by SPN Water Resources Section.

The damage to structures, contents, automobiles, and the cost of residential displacement are all estimated within the computer program HEC-HEC-FDA v.1.2.5a, while damages related to the other categories will be estimated outside of the HEC-FDA program. Traffic delay costs are typically estimated via a simple spreadsheet model that is based on the methodology and value of time recommended by IWR Report 91-R-12 "*Value of Time Saved for Use in Corps Planning Studies*." For those damage categories calculated in HEC-HEC-FDA, the value of these assets was estimated outside of the program, and then imported into the program along with probability-stage data for each particular structure. The base structure elevation data (not including a first floor adjustment) was provided to the USACE San Francisco Economics Section by the Geographic Information System (GIS) Section.

The HEC-HEC-FDA models were built with data for each structure for each of exceedance probabilities – 4%, 2%, 1%, .4% and .2% events. This report uses exceedance probabilities to describe flood events. The exceedance probability is the reciprocal of what is often referred to as the "return period." The return period (or recurrence interval) of an annual maximum flood event has a return period of X years if its magnitude is equaled or exceeded once, on the average, every X years. As an example, a 1% return period (1/100) means that there is a 1% probability of an occurrence in any one year. HEC-FDA uses Monte Carlo simulation to calculate a stage-damage relationship with uncertainty, and the program then annualizes the probability-weighted damages to calculate an equivalent annual damage value for each scenario considered.

This analysis used the procedures of directly inputting the a set of water depths for each of the economic impact areas (EIAs) into HEC-FDA as a water surface profile, then calculating the exceedance-probability stage data within HEC-FDA, and including the ground elevations of the structures (with first floor elevation (FFE) adjustments) in the inventory import file. As such, HEC-FDA calculates the depth of flooding at each structure for each event and develops an aggregated stage-damage curve. Finally, the program calculates an Expected Annual Damage figure by linking the exceedance probabilities to stage-damages, incorporating risk and uncertainty based upon the Period of Record assigned to the probability-stage curve and the standard deviations resulting from the aggregated stage-damage curves.

1.3. Brief Description of the Flood Modeling

This without-project flood damage analysis considers damages from San Francisquito Creek fluvial flooding. Coastal flooding models are currently being developed (June 2011), and any damages resulting from that analysis will be incorporated into the next iteration of this Economic Appendix. In all likelihood, flooding from

each of these two sources will be coincidental, and proper procedures to avoid double-counting will need to be incorporated during the next phase of this study. The figures included in the following results do not attempt to qualitatively nor quantitatively assess any damages caused by coastal flooding.

According to the Without Project H&H analysis, flooding in the EIAs is primarily dependent upon lack of capacity for conveying water volumes under several bridges that cross San Francisquito within the study area. Moreover, there are existing levees at the downstream end of the study area that would be overtopped for the 4% event and greater. Geotechnical investigations completed for this study indicates that the levees do have fragility curves (i.e., there is a probability of some type of engineering failure before being overtopped), but due to the volume of water escaping into the upstream floodplains because of the too-small bridge underpasses, the geotechnical fragility curves were not used for the Without Project damages calculation. These levee fragility curves will be incorporated in the subsequent Alternatives Analysis phase of this feasibility study.

The flood modeling effort involves the integration of multiple numerical models, and one of the primary results is a description of the statistical distribution of flood damages for each of the EIAs in the study area. For the Without-Project scenario, the floodplains were developed with a model named FLO2D, and the mechanism of flooding is either insufficient conveyance capacity or levee overtopping into the floodplain. The modeling output that the flood damage analysis uses as an input to the HEC-FDA model is the mean in-basin water surface elevation for each probabilistic flood event.

1.4. Consideration of Sea-Level Rise

This flood damage analysis is being conducted in accordance with EC 1165-2-211 (1 July 2009), which mandates the consideration of various future sea level rise scenarios in the Corps' planning process. From the EC:

> *Potential relative sea-level change must be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence. Fluvial studies (such as flood studies) that include backwater profiling should also include potential relative sea-level change in the starting water surface elevation for such profiles, where appropriate. The base level of potential relative sea-level change is considered the historically recorded changes for the study site. Areas already experiencing relative sea-level change or where changes are predicted should analyze this as part of the study.*

Importantly, the EC recommends: "*a multiple scenario approach to deal with key uncertainties for which no reliable or credible probabilities can be obtained. In the context of USACE planning, multiple scenarios address uncertainty and help us develop better risk-informed alternatives*."

This Economic Analysis is based upon floodplains incorporating a future sea level rise scenario – termed here Curve III (per H&H mapping results). Curve III represents a scenario forecast by the National Research Council (NRC). The following is the anticipated change in mean sea level between the project Base Year (2017) and Year 50 (2067):

- Curve III - 2.13 ft

Detailed information regarding the effect on fluvial flooding from San Francisquito Creek resulting from this sea-level rise scenario can be found in the Water Resource (Hydrology & Hydraulics) Engineering section of the Feasibility Report.

2. Structures, Contents, and Infrastructure at Risk from Fluvial Flooding

The sections below briefly describe the structures (i.e. buildings) classifications and contents values of each of the 8 economic impact areas within the floodplain. These areas have been analyzed separately in order to aid in an incremental approach to plan formulation and the economic analysis.

2.1. Delineation of Economic Impact Areas

The Economic Impact Areas (EIAs) were generally constructed based upon the following main criteria:

1. visual examination of the floodplain maps showing several flooded areas within the overall study area,

2. consideration of major streets and roads within the floodplains that obviously serve as de facto borders between residential and commercial/industrial neighborhoods, and

3. ensuring that no EIA straddled San Francisquito Creek due to its being the natural borderline between San Mateo and Santa Clara counties; five (5) EIAs in San Mateo and three (3) are in Santa Clara counties. Figure 4 and Table 1 describe and show the general location of each of the EIAs.

Figure 1: Aerial Showing All 8 EIAs

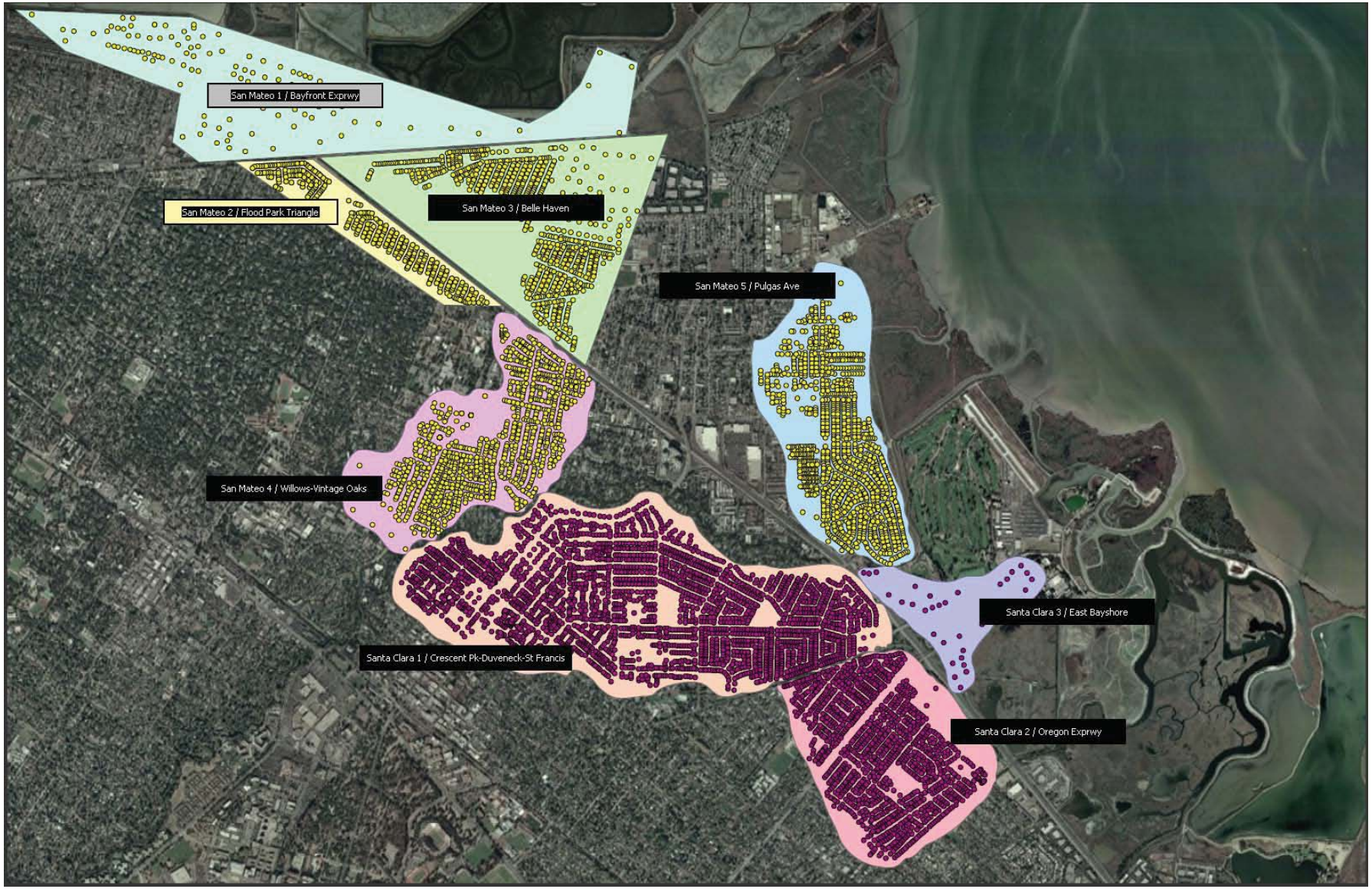


Table 1: Description of Economic Impact Areas

EIA	Description
San Mateo 1	BAYFRONT EXPRESSWAY (mostly industrial/commercial area north of Bohannon Dr/RR tracks between Marsh and Willow Rds.)
San Mateo 2	FLOOD PARK TRIANGLE (mostly residential generally bound by Bohannon, Van Buren, and Bay Rd. -- west of US 101)
San Mateo 3	BELLE HAVEN (mostly residential with some industrial located south of Bohannon/RR tracks, east of US 101 and west of Ralmar Ave)
San Mateo 4	WILLOWS/VINTAGE OAKS (mostly residential west of US 101, east of Middlefield Rd, between the north bank of San Francisquito Creek and Willow Rd)
San Mateo 5	PULGAS AVENUE (mostly residential straddling Pulgas Ave east and west by several blocks, bounded between Bay Rd to the north and US 101 to the south)
Santa Clara 1	CRESCENT PARK/DUVENECK-ST FRANCIS (mostly residential with commercial; south of San Francisquito Crk. across University, north of Embarcadero Rd between Waverly St and US 101)
Santa Clara 2	OREGON EXPRESSWAY (residential south of Embarcadero Rd. and north of Clara Dr. between Ross Rd. and US 101)
Santa Clara 3	EMBARCADERO/EAST BAYSHORE (mostly commercial with industrial located west of US 101 straddling Embarcadero Rd eastward to Embarcadero Way

2.2. Structure Types and Flooding Characteristics by EIA

This section describes the types of structures (buildings) and flooding characteristics in each of the eight EIAs. The land use maps were created based on the structure inventory work performed by the Corps between during February and March 2011. The source of the raw data (particularly square footage) was county assessor parcel data obtained directly from San Mateo and Santa Clara counties, with field investigations done by Corps economists. The construction characteristics of the homes and businesses in the study area are consistent with other regions of California.

The structure inventory database and the flood damage analysis contain 16 structure types. A description of these structure types is contained in Section 3. The extent of the inventory was based on an estimate of the .2% floodplain extent of the Curve III sea-level rise scenario. Due to FFE adjustments, in reality the number of structures susceptible to flood damage is somewhat fewer than is reflected in the inventory maps.

For the Base Year 2017, each EIA was assigned a water surface elevation profiles which were actually floodplain depths generated by FLO2D and overlaid onto GIS maps of the study area. All of the EIAs floodplains were then attached to an H&H (hydrology and hydraulics) Index point at the upper end of the creek. This adjustment was necessary due to the relatively "flat" probability-stage relationship within the overbank floodplains. Since HEC-FDA is largely dependent upon change-in-depth flooding (as opposed to sheet-flow flooding where subsequent larger events tend to have similar depths but larger geographical extents), the FLO2D floodplains depths were attached to an in-channel HEC-RAS probability-stage curve. This methodology has been used in other San Francisco and Sacramento District studies as an appropriate way to accurately model

damages while using the USACE-approved HEC-FDA model. Flood maps are displayed showing the depths of flooding for the 5 modeled events previously noted. The actual depths in and around the structures generally averages no more than a few feet, due to the sheet-flow nature of the overbank flooding.

2.2.1. San Mateo EIAs

Bayfront Expressway (San Mateo 1) is primarily a commercial and industrial area located between the San Francisco Bay and US 101. There is one small pocket of residential structures at the most eastern extent of this EIA called Harbor Village Mobile Home Park. This EIA contains the Carlsen Porsche dealership as well as several industrial and commercial park areas with a wide variety of companies: mailing & shipping, medical technology, banking, and machining just to name a few.

San Mateo 2 – 5 contain the neighborhoods of Belle Haven and the Pulgas Avenue area on the east side of US 101 (generally, East Palo Alto). West of US 101 the neighborhoods of Flood Park Triangle and Vintage Oaks (Menlo Park) lie within the study area. All are almost completely residential, with only a few commercial structures susceptible to flood damage. In addition to residences, these neighborhood EIAs have several schools, parks, libraries, hospitals, and churches. In Base Year 2017, the first significant floodplain damage occurs at approximately the 4% event.

2.2.2. Santa Clara EIAs

Santa Clara 1 (Crescent Park/Duveneck-St Francis) is the largest geographic EIA within the study area (Palo Alto). It covers several older and more established neighborhoods and the accompanying shops, restaurants, and grocery stores typical near residential areas. The Edgewood Plaza Shopping Center is located within this EIA. It also has several schools and medical facilities, as well as a community center and library branches. This EIA is directly adjacent to San Francisquito Creek. The Oregon Expressway EIA (Santa Clara 2) shares Embarcadero Road as a border; EIA 2 is similar in structure type and land use as Santa Clara 1.

Santa Clara 3 is also within the city limits of Palo Alto, although it is located across US 101 from both Santa Clara 1 & 2. This EIA contains mostly commercial structures (restaurants, office parks, and car dealerships) as well as several public buildings including the Palo Alto Post Office. Nearby, there is the Palo Alto commercial airport and the Palo Alto Municipal Golf course; neither of these land parcels were shown to incur flooding at the .2% event however and do not factor into this economic damage analysis.

3. Structure, Content & Vehicle Valuation

In order to estimate the value of damages to property as a result of flood events within the study's floodplains, it is first necessary to inventory the structures and other assets within the floodplain. This section describes how the inventory and valuation of structures were accomplished. The next section will describe how this data was used to develop an estimate of the value of the damages expected to occur from flooding.

3.1. Structure Inventory

An initial inventory of the parcels in each .2% floodplain was compiled in ArcGIS (ArcMap) software by linking the raster flooding depth file with a point shapefile containing the parcel information, and then exporting to a spreadsheet those parcels in the modeled floodplains. For each parcel, the data was linked to the geographic center of mass of the particular parcel by creating a data centroid within the ArcMap program. Because only those parcels whose centroid overlaps the floodplain are considered as impacted, only those parcels that are at least bisected by the floodplain are included in the inventory. This is done in an attempt to improve the accuracy of the structure inventory – eliminating the inclusion (and ultimate valuation) of those parcels that are least likely to have structures that are actually impacted by the flooding, even while a portion of the parcels receive some non-zero level of flooding. However, there are cases where the centroid of the parcel shape does not accurately enough reflect the location of the structure – for instance, some commercial, industrial, or public parcels contain more than one structure. In order to manage this eventuality, and to make sure the damage model includes all of the structures at risk of flooding, spot checking of the parcels and structures along the outer edge of each floodplain was conducted during the economic fieldwork. When it was the case that aerial photography showed a structure to be located in the floodplain when the ArcMap centroid method did not, this structure was added to the database with the appropriate depth of flooding referenced.

3.2. Structure Valuation

The parcels identified as within the .2% floodplain via the procedure described above were then matched to data obtained from the San Mateo and Santa Clara assessor offices. These real property databases include parcel-specific information on structure type, square footage, construction date, information on improvements, etc. The vast majority of the residential structures inventoried fit into the Class D category. Class D buildings are characterized by combustible construction. The exterior walls may be made up of closely spaced wood or steel studs, as in the case of a typical frame house, with an exterior covering of wood siding, shingles, stucco, brick, or stone veneer, or other materials. They may also consist of an open-skeleton wood frame on which some form of a curtain wall is applied including the pre-engineered pole or post-frame buildings.

For the valuation of the structures in the floodplain, structures were classified as one of the following 16 categories listed below:

• Single Family Residential (SFR) 1-Story	• Office D (Marshall & Swift)
• SFR 2-Story	• Restaurants
• Multi-Family Residential (MFR) 1-Story	• Retail
• MFR 2-Story	• Public - Wood Frame
• Manufactured Housing (MH)	• Public – Masonry
• Commercial	• Industrial (Generic)
• Grocery & Gasoline	• Ind. R&D
• Office C (Marshall & Swift)	• Ind. Warehouse

The calculation of structure value in a floodplain can be done several different ways, each having their advantages and disadvantages. One method, estimating the Depreciated Replacement Cost of the structures in the floodplain, involves integrating the following: size of the structure, the unit cost of construction as measured in cost per square foot, and an allowance for deterioration as measured as a percent of total value. An alternative way of calculating the total structure value in the floodplain would be to use tax assessment records on each parcel's improvement value. While this assessment information is readily available, California's Proposition 13, which limits increased assessments until a home is sold, results in unequal valuations of one home relative to another. It is primarily for this reason that this study uses the Depreciated Replacement Cost method. More information on the different structure valuation methods can be found in IWR Report 95-R-9, *Procedural Guidelines for Estimating Residential and Business Structure Value for Use in Flood Damage Estimations*. The Depreciated Replacement Cost method requires visits to the structures themselves in order to attain the necessary information, which includes foundation height, structure type, and structure condition. This process is explained below.

The valuation of the structures in the floodplain requires information on structure type, construction quality, current condition, and number of stories[1]. Once collected, this information was used to calculate the structure depreciated replacement values. Base per square foot construction cost estimates for each structure type were determined by utilizing the Marshall and Swift Real Estate Valuation Service method according to the following procedure:

- Construction quality and current condition of the structures were noted from field surveys.
- For a given structure type, the per square foot construction cost (replacement cost) was determined using the most current Marshall & Swift Valuation Service data. This per square foot cost estimate reflects the construction quality of the structure.
- The per square foot costs, which are based on a national average, were modified to reflect local cost conditions using Marshall & Swift local cost multipliers.
- This current, locally adjusted cost per square foot was then adjusted additionally for the condition of the structure, which determines the appropriate depreciation factor to apply. In order to correlate the current condition of the structure to a percent depreciation, the study used Tables 7 through 9 of IWR Report 95-R-9, '*Procedural Guidelines for Estimating Residential and Business Structure Value for Use in Flood Damage Estimations*'.
- The depreciated replacement cost per square foot values were multiplied by square footage to arrive at the total depreciated replacement value for the different types of structures.
- If the square footage was not available within the real estate records for a particular property, square footage estimates were made from aerial photography measurements using the Google Earth application.

3.3. Content Valuation

As described above, under this study's methodology, the value of the contents within each structure is assumed to be a function of the value of the structure. The value of the contents of each structure was estimated by multiplying the Content Structure Value Ratio (CSVR) for the particular structure type by the estimated structure value (as calculated per the method described in the previous section).

The table below shows the ratios assumed for the content-to-structure values of the different classifications of residential and non-residential buildings in the floodplain. The primary source of CSVR estimates used for this analysis is a report produced for the USACE New Orleans District. The report is the product of a very thorough and extremely detailed expert panel elicitation.

[1] Structure first floor elevation was also recorded for each structure visited as part of the field inventory work. While this data is not relevant for the structure valuation, it is a critical variable in the estimate of flooding damage.

Table 2: CSVRs per Structure Type

Structure Type		CSVR	Standard Deviation
Residential	SFR	0.5	0.12
	MFR	0.5	0.12
	MH	0.5	0.12
Commercial	Eating and Recreation	0.4	0.7
	Groceries & Gas Stations	1.4	0.7
	Professional Businesses	0.9	0.9
	Retail and Personal Services	1.7	1.45
Other	Industrial	0.7	1.0
	Public	0.4	0.5

3.4. Structure Inventory and Valuation Results

Table 3 shows the numbers of structures by type that was inventoried for the .2% floodplain. Not all of these buildings ultimately end up contributing to damage estimates. Based upon the depth of water for the .2% flood event and the data gathered during the economic fieldwork—specifically the building foundation height--, many of these structures' first floor were in fact elevated well above the floodplain.

Table 3: Structures in .2% Floodplain

EIA	Residential	Commercial	Industrial	Public
SM 1	5	31	89	0
SM 2	356	3	0	1
SM 3	791	6	56	16
SM 4	1,123	25	1	6
SM 5	1,263	8	4	10
SC 1	2,646	61	0	9
SC 2	1,266	1	0	4
SC 3	0	26	4	2
Total	7,450	161	154	48

The following tables display the total claimable value of structures and contents, by structure type, in the .2% floodplain for Year 2017. It is important to note that the values are estimates of depreciated replacement value of structures and contents only, and do not represent expected damages. Instead, the estimates can be seen as the total estimated value of the structures and contents that are within the extent of the .2% floodplain. The values only include structures and contents, and do not include automobiles or the value of infrastructure in the floodplain such as the three water pollution control plants. As is generally the case with USACE flood damage analysis, the value of land is not included in the damage analysis.

As can be seen in the tables and figures below, residential structures far outnumber commercial and industrial structures in the study area. Commercial and industrial buildings represent the majority of value in the Bayfront Expressway EIA (SM 1) and in the East Bayshore EIA (SC 3). Even in EIAs where residential structures are predominant, there are concentrated areas along both sides of US 101 within the study area that contain commercial and industrial parks that also include important warehouse/distribution facilities.

Table 4: Value of Structures and Contents in .2% Floodplain ($1,000s)

	Residential		Commercial		Industrial		Public		Total
	Structure	Content	Structure	Content	Structure	Content	Structure	Content	
SM 1	15,700	7,900	154,700	138,100	128,700	87,600	-	-	532,700
SM 2	38,200	19,100	1,100	960	-	-	124	46	59,500
SM 3	63,00	31,600	4,300	4,300	93,000	63,300	8,500	3,150	271,200
SM 4	128,600	64,300	24,700	22,000	57	39	13,000	4,800	257,500
SM 5	113,500	56,800	750	680	2,200	1,500	11,200	4,200	190,800
SC 1	599,900	300,000	36,800	33,100	-	-	8,800	3,300	981,800
SC 2	178,400	89,200	2,900	2,600	-	-	1,700	611	275,400
SC 3	-	-	90,740	81,700	3,200	2,200	1,600	580	180,000
Total	1,137,300	568,900	315,990	283,440	227,157	154,639	44,924	16,687	2,750,000

Table 5 shows the median depreciated replacement value, as well as square footage statistics for the four broad structure categories included in this study. The residential value is consistent with those calculated for other recent Corps studies in the area, while the commercial and industrial are somewhat higher than usual because of the unusually large size of the structures of these types.

Table 5: Depreciated Replacement Value And Square Footage of Structures

County	Structure Type	Mean DRV (1,000s)	Mean Sq. Footage	Median Sq Footage
SAN MATEO	Commercial	$2,612	24,850	8,900
	Industrial	$1,555	31,600	20,289
	Public	$1,023	8,560	5,616
	Residential	$102	1,435	1,225
SANTA CLARA	Commercial	$1,535	13,200	5,000
	Industrial	$722	15,230	14,640
	Public	$828	7,700	4,850
	Residential	$199	2185	1800

4. Elevation and Flood Damage Relationships

For structure and content damages, depth of flooding relative to the structure's first floor is the primary factor in the magnitude of the damage. The GIS database, provided by San Mateo and Santa Clara County, contained spatially-referenced polygons for each parcel in the study area. Each parcel was then assigned a centroid in order to determine the ground elevation at the parcel, which was taken from the latest Digital Elevation Model available. A parcel centroid is the point that represents the geographic center of mass of a parcel. Figure 2 shows an example of the location of the parcel centroid relative to the structure in a residential area of the floodplain.

The USACE San Francisco GIS Section ran statistics on the elevation of each of the parcel centroids, and provided the Economics Section with data tables containing depths at each centroids for each probability event modeled.

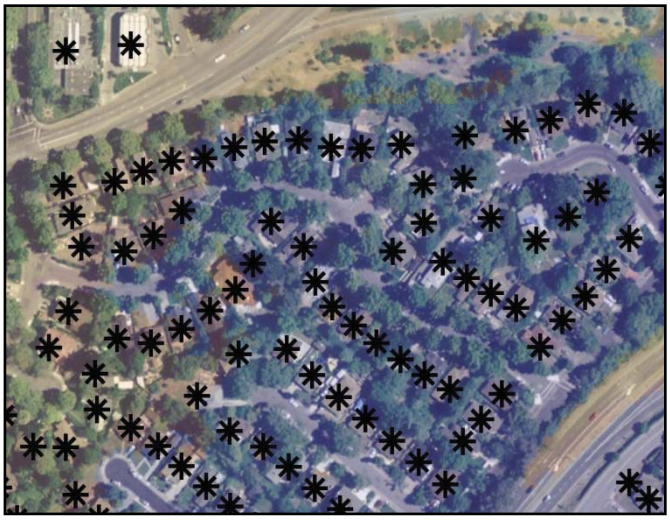


Figure 2: Example of Parcel Centroid Location

The centroid elevation method described above reasonably describes the elevation at a structure only to the extent that the structure is located approximately at the center of the parcel. Using this method to determine flooding depth and damage, it is possible that structures located on large parcels could be left out of the analysis and assumed to not be impacted for a particular event or events. It could also be the case that the elevation varies across the large parcel, and that the depth of flooding at the centroid does not reasonably represent the depth of flooding at the structure. This error would be expected to occur most often for non-residential parcels, especially some commercial and public parcels. In order to minimize the chance of this error, the study area parcels, centroids, and floodplains were reviewed in combination with aerial photography. In several cases the elevation assigned to a structure was changed to more accurately reflect the observed floodplain characteristics.

The elevation of each structure in the study area - along with an adjustment for the first floor elevation (FFE) - were combined with economic data (structure and content value, uncertainty of value expressed as a standard deviation percentage, etc.) and imported into the HEC-FDA model. For residential structures, a representative sample of first floor heights was observed in the field and applied with uncertainty to the population of structures in that EIA. For the non-residential structures, the complete inventory was observed in the field. Table 6 shows the average FFE adjustment for each of the major structure categories in each of the EIAs.

Table 6: Average FFE Adjustments by EIA and Structure Type

	Structure Type			
EIA	**Residential**	**Commercial**	**Industrial**	**Public**
SM 1	2.5	0.5	0.5	N.A.
SM 2	0.5	0.7	N.A.	1.0
SM 3	0.5	0.7	0.2	0.6
SM 4	1	0.5	0.5	0.6
SM 5	0.8	0.5	0.8	0.6
SC 1	0.7	0.5	N.A.	0.6
SC 2	0.5	1.0	N.A.	0.3
SC 3	N.A.	0.3	0.3	0.4

The table below shows some of the descriptive statistics of the flooding in the study area as calculated at the parcel centroid. The depths were calculated in the HEC-FDA models using WSEL data, structure value data, and FFEs. Three exceedance probabilities are shown for each of the floodplain scenarios. The decrease in mean depth for less frequent events at Year Zero can be explained by a greater number of structures getting shallow flooding as the outer edge of the floodplain expands.

Table 7: Selected Depth of Flooding Statistics (ft), Base Year Curve III)

Scenario		Year Zero		
Return Period		1%	2%	4%
Depth (ft)	Mean	1.4	1.1	0.6
	Median	0.9	0.8	0.4
	Maximum	7.6	6.0	3.8

4.1. Structure and Content Depth-Damage Relationships

Flooding can cause significant damage to structures of all types. Water can cause a structure's structural components to shift or warp – including the studs and foundation. Water can also damage the wiring, gas lines, and septic system. For high water, ceilings may sag under the weight of trapped water or soggy drywall, wet floorboards can bend and buckle, and the roof may leak or break altogether. Flooding in a basement can be especially dangerous; if the water is removed too quickly, pressure from the soaked earth outside can push inward and crack the foundation walls. In all types of residential housing flooding will most likely destroy the interior walls. Soaked wallboard becomes so weak that it must be replaced, as do most kinds of wall insulation, and any plywood in the walls is likely to swell and peel apart. Water can also dissolve the mortar in a chimney, which creates leaks and thus a risk of carbon monoxide poisoning once the heat comes back on.

Also, floods often deposit dirt and microorganisms throughout the house. Silt and sediment can create short circuits in the electrical system as residue collects in walls and in the spaces behind each switch box and outlet. Appliances, furnaces, and lighting fixtures also fill with mud, making them dangerous to use. Anything that gets soaked through with water may contain sewage contaminants or provide a substrate for mold. Most upholstered items must be thrown away, as well as carpets and bedding.

Damages to structures, contents, and vehicles were determined based on depth of flooding relative to the structure's first floor elevation. To compute these damages, depth damage curves were used. These curves assign loss as a percentage of value for each parcel or structure. The deeper the relative depth, the greater the percentage of value damaged. The sources of the relationships were different depending on structure type.

The depth-damage relationships for the primary structure types, contents, and vehicles are shown in the following figures below. SFR1 and SFR2 stand for Single Family Residential 1-Story and 2-Story, respectively. The curves for these are taken from USACE Economic Guidance Memorandum (EGM) 04-01, and are shown for comparison's sake. Although the current analysis pertains only to freshwater fluvial flooding, the tables also show the saltwater curves that will likely be used once the coastal flooding models for the San Francisquito study are completed.

Figure 3: SFR1 Structure Depth-Damage Curve

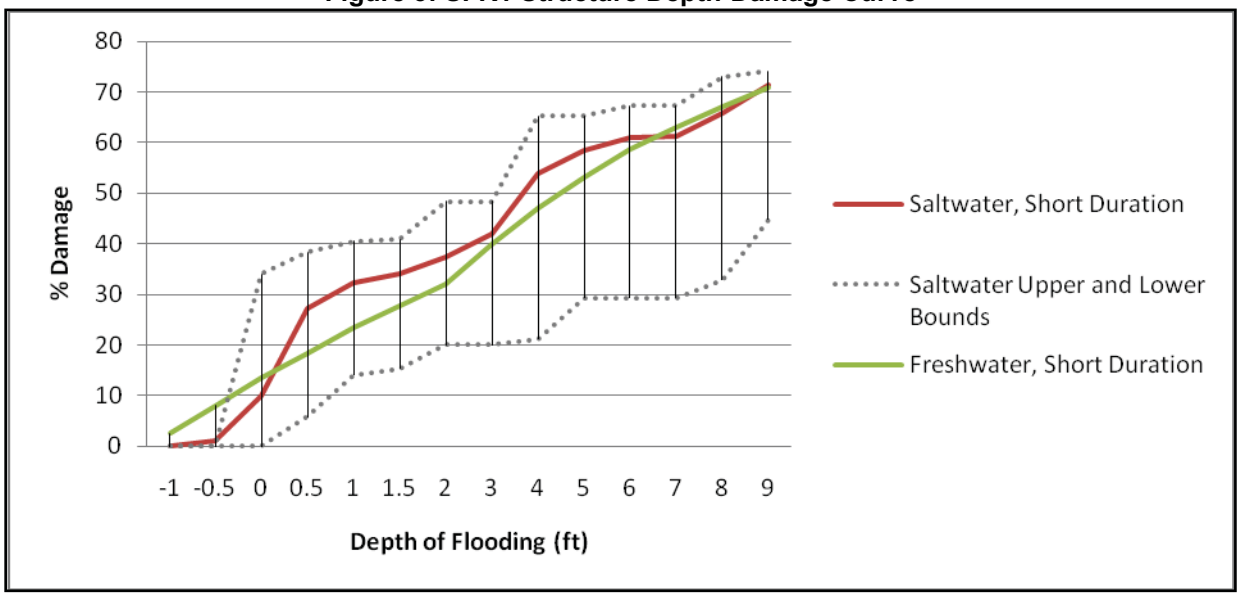


Figure 4: SFR1 Content Depth-Damage Curve

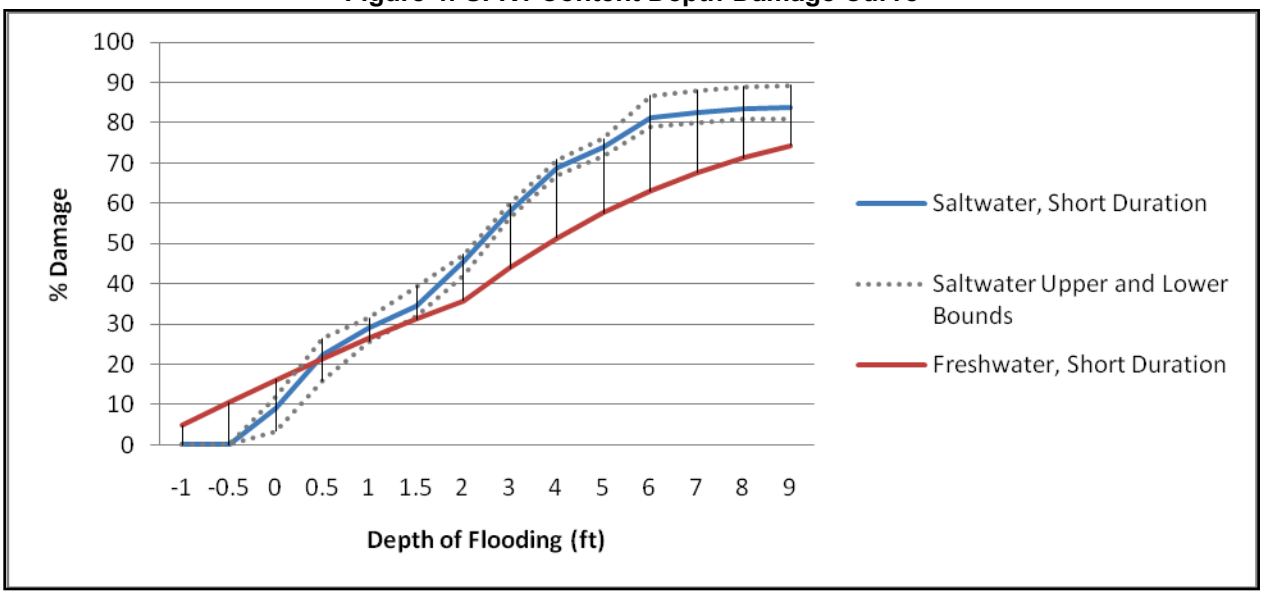


Figure 5: SFR2 Structure Depth-Damage Curve

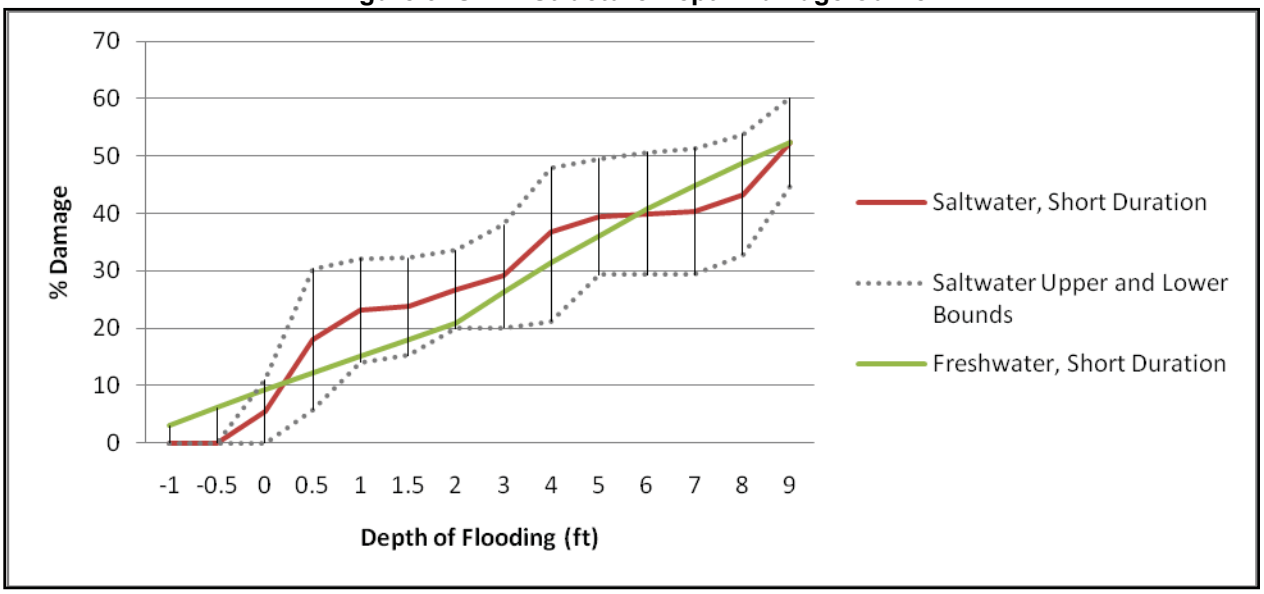


Figure 6: SFR2 Content Depth-Damage Curve

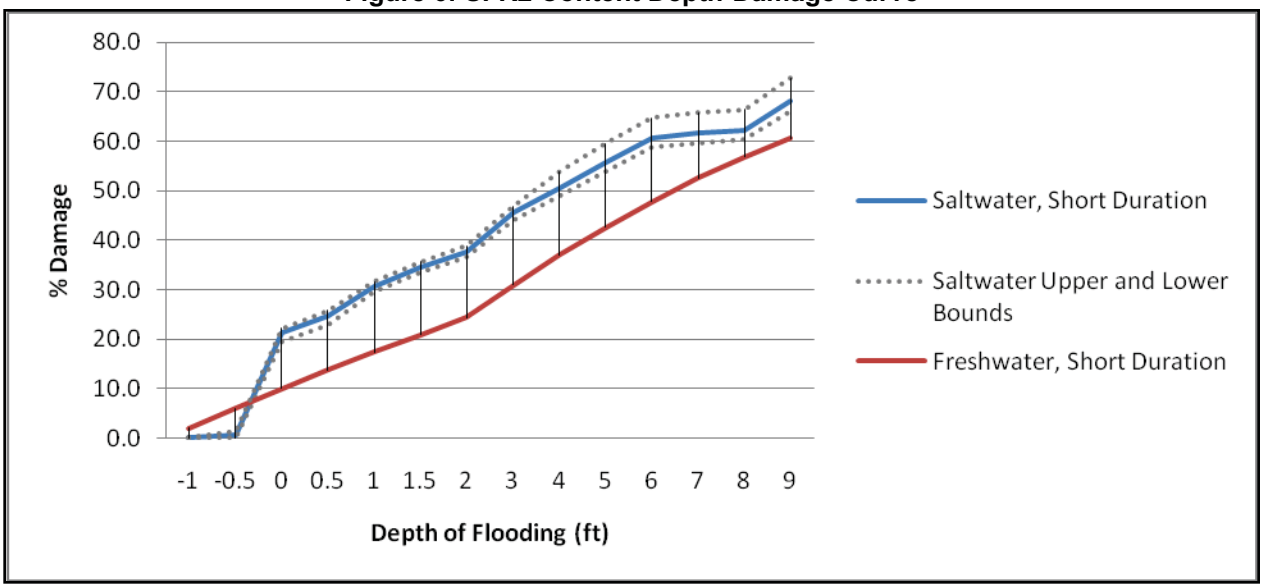


Figure 7: Commercial Structure Depth-Damage Curve

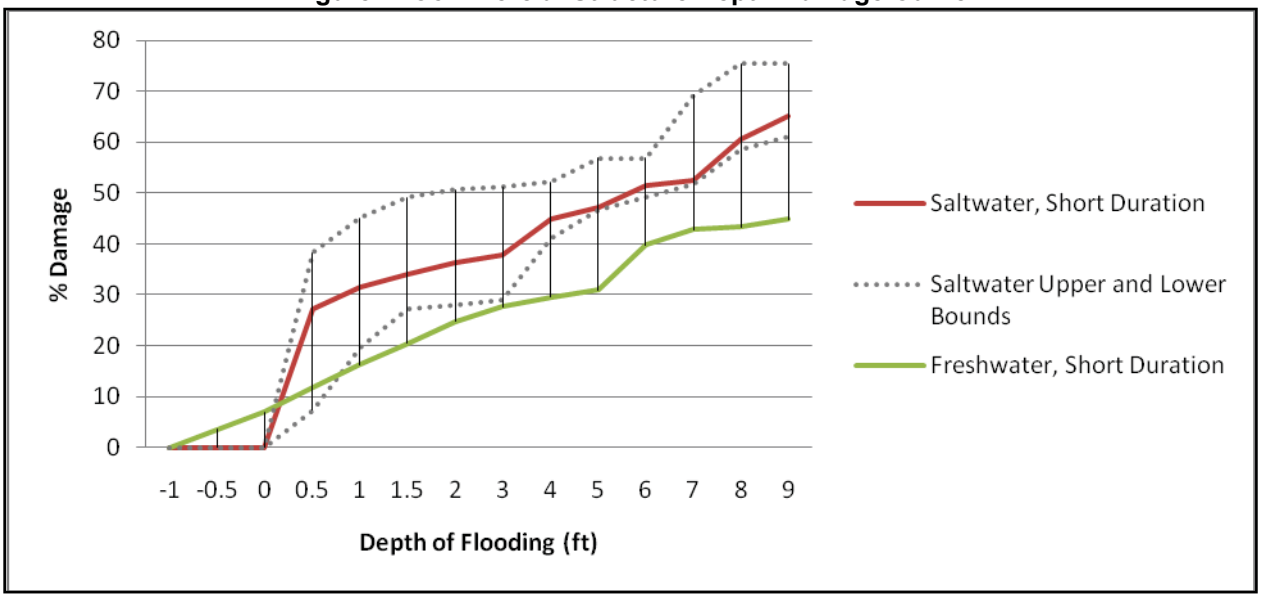


Figure 8: Commercial Content Depth-Damage Curves

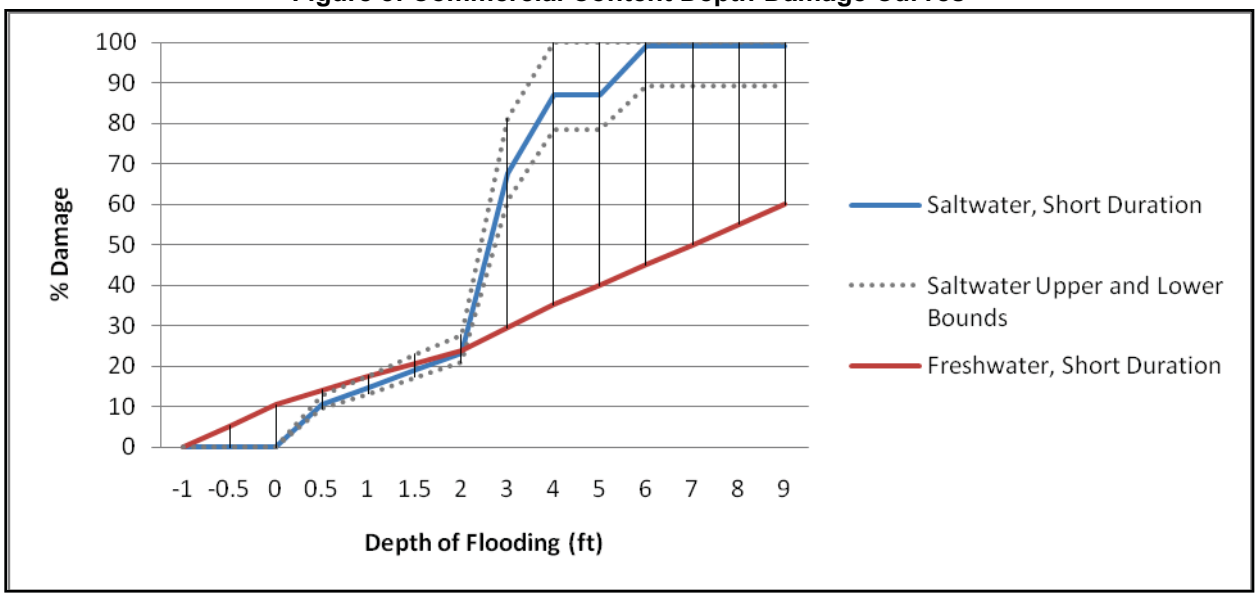


Figure 9: Industrial Structure Depth-Damage Curve

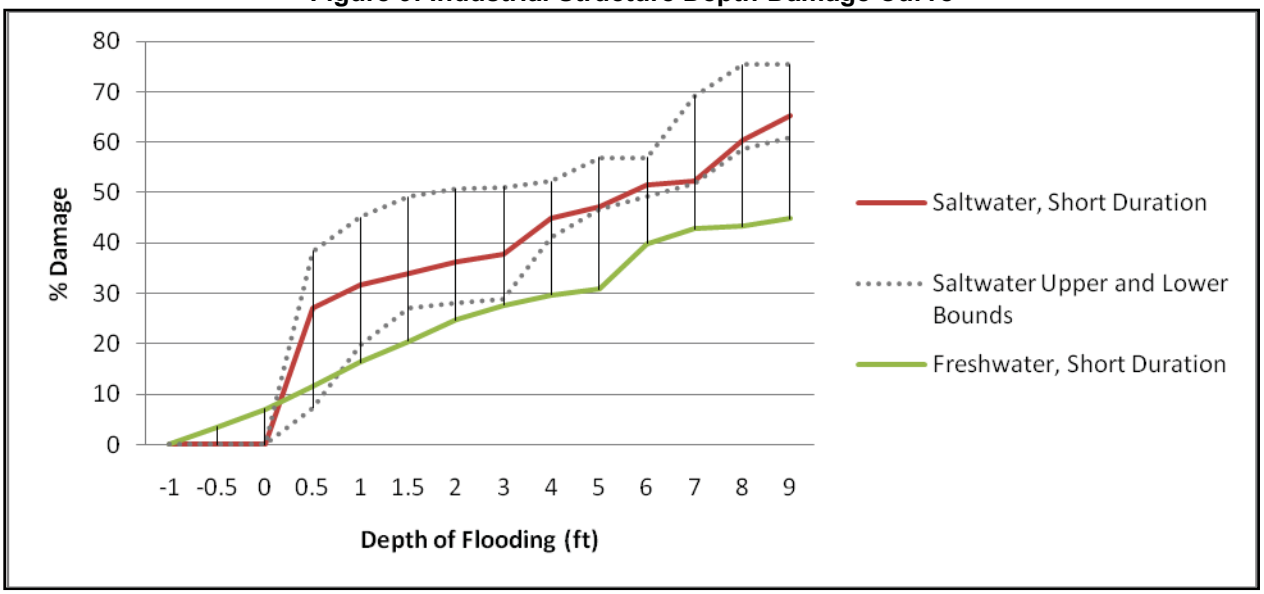
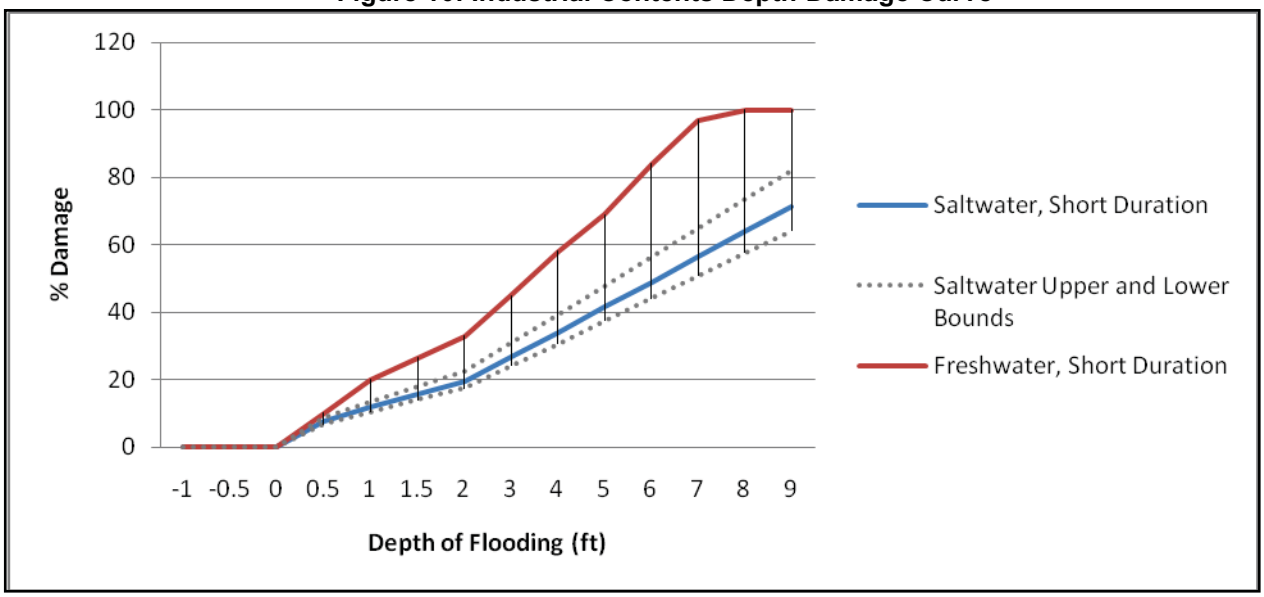


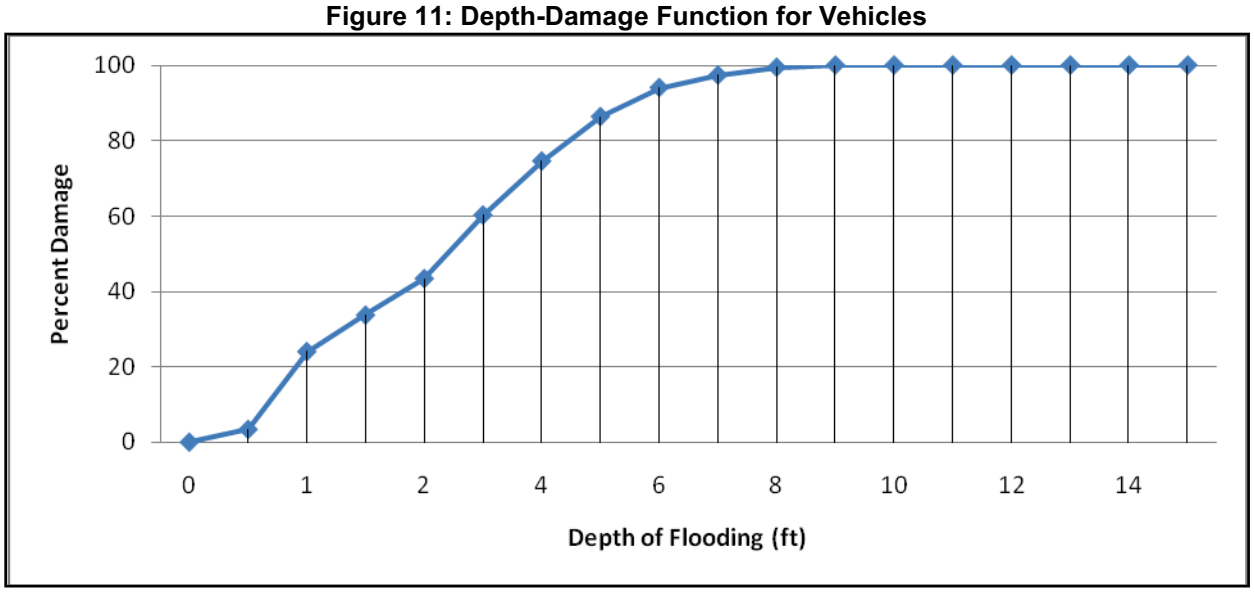
Figure 10: Industrial Contents Depth-Damage Curve



4.2. Automobile Depth Damage Relationship

Damage to automobiles was estimated as a function of the number of vehicles per residence, average value per automobile, estimated percentage of autos removed from area prior to inundation, and depth of flooding above the ground elevation. Depth-damage relationships for autos come from USACE Economic Guidance Memorandum (EGM) 09-04 and modified based on weighted average of distributions of car types (SUV, truck, sedan, sports car, etc) in California. Damages for autos begin once flood depth has reached 0.5 feet, and this damage curve can be seen in the figure below. Since these curves were developed for freshwater flooding, they can be expected to slightly understate the damages from flooding, but they are assumed to be reasonable for use in this study.

Figure 11: Depth-Damage Function for Vehicles



Source: USACE Economic Guidance Memorandum (EGM) 09-04

According to the U.S. Census, the average number of vehicles at households in the study area is just less than two. In general there should be significant warning time before a potential flood event, since regional gauges and storm tracking should effectively inform the communities of an approaching risk. The survey described in EGM 09-04 indicates that when there is greater than twelve hours warning time, almost 90% of residents are expected to move at least one vehicle to higher ground. The EGM does not indicate the percentage that moved both vehicles to higher ground. For this analysis, it will be assumed that all households remove at least once vehicle out of the floodplain, and that half of the households remove both vehicles. The result of these two assumptions is that 25% of the vehicles in the floodplain are exposed to flood risk. Vehicles that were exposed to flood risk are assumed to be at the structure first floor elevation, except for those structures that have been significantly raised from ground elevation. For those structures that are more than three feet above the ground elevation, the vehicles are assumed to be located at ground elevation.

Three-quarters of the vehicles are assumed to be moved out of harm's way

5. EAD – Structures, Contents, Vehicles, & Displacement

The HEC-FDA program is used to combine water surface profile data and economic data (structure inventory values, FFEs, standard coefficients, etc.) in order to derive a probability-stage-damage function for each reach or impact area. HEC-FDA version 1.2.5a was used, which is a USACE certified model, and its use complies with EC 1105-2-412 (*Planning Model Improvement Program: Model Certification*).

Typically, among other inputs to this procedure are water surface profiles for the various channel or river reaches, which are an output of the HEC-RAS program that is used by engineers. For this study though, since the FLO2D program was used for reasons described in the H&H appendix, there are no discharges or rating curves (discharge-stage relationship), rather just an exceedance-probability to depth relationship for each EIA.

Additionally, while there are existing levees at the downstream end of the portion of San Francisquito Creek under study, and while levee performance is a significant issue for the study, the existing levee features or levee failure probabilities were not included in the HEC-FDA models. The main reason for this is that the FLO2D floodplains were developed by modeling the water in the floodplain strictly as a result of levee overtopping. Therefore, there were no probability-based water surface profiles for any flood events that did not go over the downstream levees. That is, the mean depths of flooding provided to the Economics Section for use in the damage analysis were developed with the consideration of the existence and performance of the various levees in the study area. As a result of discussions in May 2009 with team members from SPN Geosciences Section as well as from the Hydrologic Engineering Center (HEC), it was decided that the consideration of the levees in the coastal modeling was sufficient, and that it would not be appropriate or necessary to include levee features in the HEC-FDA models.

Furthermore, the primary constraint causing overbank flooding is numerous bridge underpasses that restrict water-flow upstream of the existing levees. Thus, the H&H analysis shows that most of the floodwaters leave the channel before reaching the levees under the Without Project condition. The reliability of the existing levees will be a key concern to consider during the Alternatives Analysis phase of this feasibility study.

For each of the Base Year 2017, the FLO2D grids with depths for each flood event attached to GIS centroids were imported into HEC-FDA as HEC-RAS water surface profiles, and the exceedance-probability stage curves were derived with uncertainty (period of record 30 years gauge data).

5.1. Expected Annual Damages

The Expected Annual Damage (EAD) for an EIA can be thought of as the average annual value of damage that would be expected to occur over a very long period of record. For example, if over a thousand years the total flood damage to an area were summed and divided by one-thousand, the result would be the expected annual damage for that area. We use what are believed to be the probabilities associated with storms of various sizes in order to calculate the probability-weighted value of damage for each area when considering the depth of flooding and the economic factors such as the number and type of structures. Table 8 shows the EAD by category for each of the six categories analyzed in HEC-HEC-FDA for the year 2017.

Table 8: Expected Annual Damages ($1,000s), Year 2017

	Auto	Commercial	Displacement	Industrial	Public	Residential	Total
SM 1	0.6	332.4	1.5	117.6	0.0	4.9	457.0
SM 2	19.8	3.0	41.6	0.0	1.0	165.8	231.2
SM 3	18.4	11.5	37.5	50.8	6.7	130.0	254.9
SM 4	24.9	11.0	62.9	0.0	0.5	428.4	527.7
SM 5	179.4	0.4	380.6	0.0	20.5	1,056.7	1,637.6
SC 1	91.7	58.3	221.4	0.0	9.9	2,441.5	2,822.8
SC 2	226.5	0.0	404.0	0.0	11.1	1,515.2	2,156.8
SC 3	0.0	249.1	0.0	5.1	13.5	0.0	267.7
Total	561.3	665.7	1,149.5	173.5	63.2	5,742.5	8,355.7

The Exceedance Probability - Damage functions for Year 2017 are included in the Addendum to this report, and show the event-based damages for each EIA and for each of the damage categories analyzed in HEC-FDA.

5.2. Residential Displacement Costs Depth Damage Relationship

Displacement costs were estimated for the relocation and emergency services provided for those displaced both during the peak flood event and during post-flood structural renovations. In order to estimate displacement costs, it is necessary to make assumptions regarding a) the level of structure damage from flooding that generally results in temporary displacement, b) the relationship between structure damage and displacement time, and c) the percentage of households that would be forced to find rental accommodations versus the percentage that would stay with friends or family. To this end, the analysis uses an algorithm contained in FEMA's '*Full Data Module for Benefit-Cost Analysis of Riverine Hazard Mitigation Projects, Mitigation BCA Toolkit CD, Version 2.0, January 2005*'.

This algorithm has the following features:

- If building damage is <10% of building replacement value, displacement time is zero.
- If building damage is 10%, displacement equals 30 days.
- If building damage is >10%, displacement time is 30 days plus 8 days for each one percent increase in building damage above 10%.
- Displacement time is capped at 365 days.

According to this approach, for example, 30% building damage results in a displacement time of 30 days plus 20 times 8 days, for a total of 190 days. The 365-day cap on displacement means that occupants of buildings with more than about 50% damage (52%) are assumed to be typically displaced for one year. Given that a structure that is over 50% damaged would have to be extensively renovated or rebuilt, a year of displacement seems reasonable.

It is assumed that half of the displaced residents would stay with family or friends

No specific study has yet been conducted by the Corps to help estimate the percentage of displaced households that would be forced to rent alternative accommodations versus those that could relocate. This analysis makes

the simple assumption that half of the displaced households would be able to temporarily relocate at little or no direct cost – that is, with family or friends[2].

The remaining variable in the equation for the estimate of total displacement costs are the monthly rental and one-time relocation costs. For the purposes of this analysis, $2,000 is assumed as the total furnished monthly rental rate, and is based on the results of internet research on the cost of rental properties in the area. The one-time cost of moving is assumed to be $500. The result is a maximum cost of $24,900 was determined and used as the total value imported into FDA, (cost if displaced for 1 year). Uncertainty parameters applied for Displacement Costs were 10% about the mean for value and 0.5 ft foundation height – the same as used for the structures themselves. The relationship between percent structure damage and both displacement cost and days displaced is shown in the Figure 12. Figure 13 displays the depth-damage function for each of the residential structure categories. These functions were calculated by relating the depth of flooding to the percent damage to the structure, to the number of days per the FEMA algorithm, to the cost associated with that number of days, to the proportion of a full year displacement that the displaced number of days represents.

Figure 12: Displacement Cost and Days Displaced

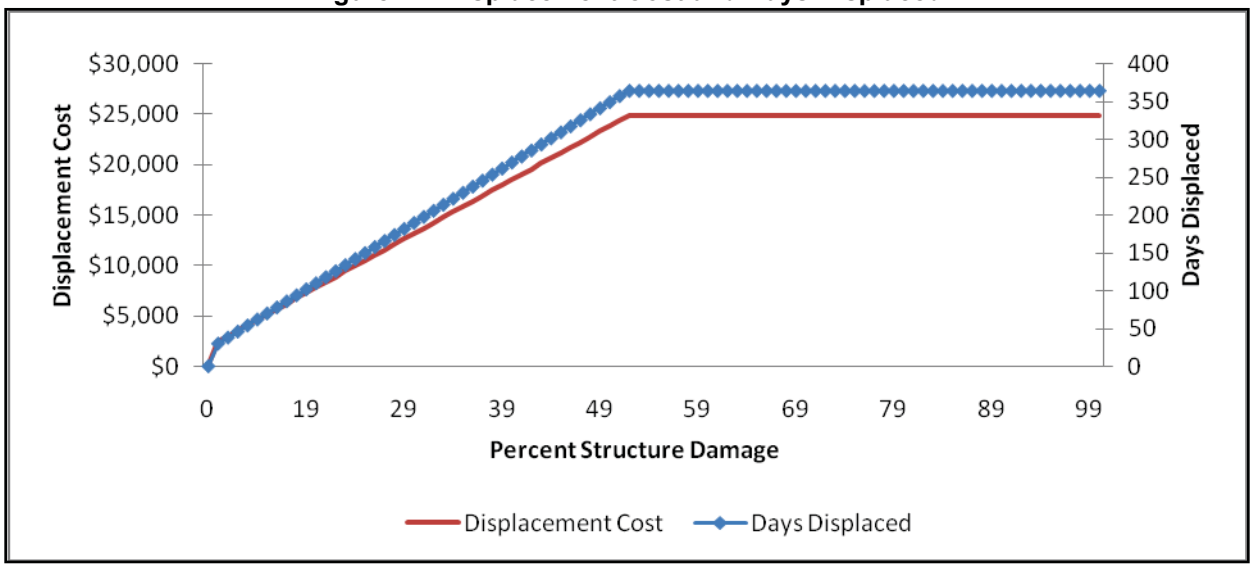
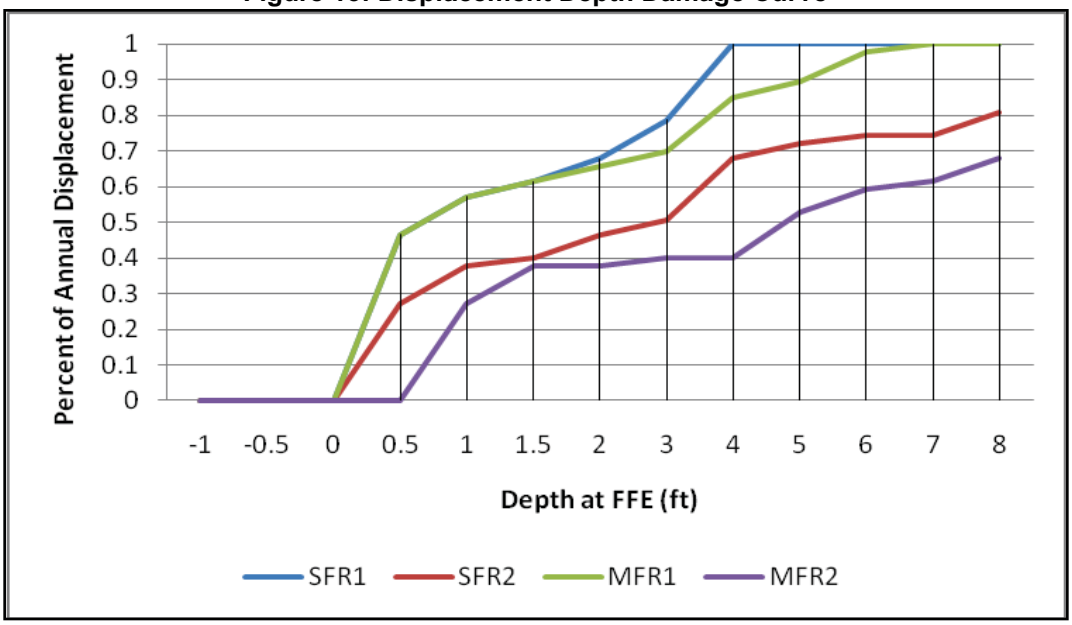


Figure 13: Displacement Depth Damage Curve



5.3. Emergency Costs

ER 1105-2-100 states, "Flood damages are classified as physical damages or losses, income losses, and emergency costs." The ER then defines emergency costs as "those expenses resulting from a flood what would not otherwise be incurred…" The ER further requires that emergency costs should not be estimated by applying an arbitrary percentage to the physical damage estimates. As with all flood damage estimates and especially in the case of emergency costs, the potential to double count damages are a distinct possibility and must be guarded against.

These costs include those emergency response costs that would not have been incurred in the absence of flooding. These costs include those associated with evacuation of the floodplain, flood fighting, disaster relief, and overtime pay for first responders and governmental employees. The ultimate cost of emergency services for a flood event depends on many factors, including the reach, depth and duration of flooding, the flood warning time, and the population and housing density within the flooded area.

Additional data will be obtained from local municipality officials regarding any information that could be used to understand the likely emergency preparation, response, or recovery costs from coastal flooding in the area. It is hoped that additional information will be available in the future to incorporate this category in the damage and benefit analyses.

5.4. Insurance Policy Administration

IWR Report 88-R-2 states that the administrative cost of flood insurance is considered a valid non-physical damage category, and thus a decrease in the number of flood insurance policies as a result of the removal of structures from the 1% floodplain represents a legitimate NED benefit category. This damage category will not be reported as part of the without-project damages, but instead, if appropriate, will be included as part of the with-project analysis, the NED benefit being the sum of those policy administration costs that are removed from the 1% floodplain as a result of a potential flood damage reduction project.

5.5. Income Loss to Businesses

According to IWR Report 88-R-2, "Income losses are reductions in the national income when flooding or the threat of flooding halts production or delivery of goods and services. National losses occur 1) when the production or delivery of these goods and services are not recuperated by postponing the activity or transferring it to another location, or, 2) when there are additional costs caused by delay or transfer of the activity." These losses can occur before, during, and after the flood event. The key to the definition of NED income losses is that the loss is not recuperated, in other words non-recoverable. Businesses where losses would be expected to be non-recoverable include public utilities, those where delays in delivery or processing causes spoilage of perishable items, businesses that produce unique products or whose competitors are at full production, and media outlets such as newspapers and radio stations that provide the only sources of local or national information.

When calculating these losses that are part of this NED category, it is important to include only factors that provide real increases in the value of the output, and, in order to avoid double-counting, exclude costs to the business not already included in the property and content estimates. Institute for Water Resources Report 88-R-2 provides guidance on how to compute income-loss for a given business. According to the report, the equation is as follows:

$$L = N * V * D / H$$

Where L = the income loss for an individual business;
N = the number of employees;
V = the annual value-added by the business per employee;
D = the duration in operating hours that a business is closed; and
H = the number of hours the business operates in one calendar year.

One of the redeeming qualities of this equation is that the broad estimates of all of the variables are readily available via sources like the U.S. Bureau of Economic Analysis. Given that the floodplain is so large though, there is great difficulty in determining just how many businesses would incur losses that classify as "non-recoverable". Given the complexity and uncertainty associated with estimating income loss (as narrowly defined within the NED framework) in this floodplain, and given that the magnitude of income loss is not likely to be significant relative to the sum of other damage categories such as structure and content damage, the analysis does not attempt to quantify income loss as a result of flood events.

6. Summary & Discussion of the Without-Project NED Flood Damages

This appendix describes the data, methodology, and policy requirements for documenting the results of the without-project fluvial flood damage analysis for the San Francisquito study area. The damages were computed separately for eight different EIAs, incorporating the effect on the creek resulting from the Curve III sea-level rise scenario as part of the H&H analysis.

The Economics Section received floodplain maps from SPN's Water Resources section for the 4%, 2%, 1%, 0.4%, and 0.2 floodplains and depths were determined using the GIS maps of ground elevations for each parcel within the Study Area (by definition in this case, the 0.2% chance event). Due to the stage uncertainty generated by providing the HEC-FDA with a period of record of 30 years, the probability-damage curves shown in the Addendum lists damages for smaller events (such as the 10% event or smaller) in some EIAs. This is primarily due to the slight changes in flood depths between probability events, reflecting the sheet-flow nature of flooding in many of the inundated areas; rather than get demonstrably deeper from, say, the 4% event to the 2% event, a given depth of water expands on the floodplain to trigger larger damages.

As is generally the case in USACE flood damage analyses, physical damages to structures and contents comprise the vast majority of damages expected from flooding. Residential structures are expected to sustain over 95% the total damages from flooding.

Emergency Costs, NED Income Loss to businesses, Automobile damage, and Insurance Policy Administration costs are all categories that will also get further treatment at the next phase of the feasibility analysis and report. It is not anticipated that these damage categories will significantly change the total expected annual damage estimates, but it is important to thoroughly describe the full range of impacts from flooding as well as the potential benefits from projects that reduce flood risk.

Based upon this first-step analysis of flooding, there appears to be ample potential benefits—achieved by reducing the risk of flood damages—to justify continuing on to the Alternatives Analysis phase of this feasibility study. Using the Grand Total of Expected Annual Damages of approximately $8.4M, the current discount rate of 4.125%, and an analysis period of 50 years, the upper bound of Total Project Cost that could theoretically be supported under an Annual Benefit to Cost ratio scenario would be approximately $175M. More pragmatically, almost any project still runs the risk of residual flooding, but even assuming that 80% of Expected Annual Damages could be protected against could support Total Project Costs in the neighborhood of $140M. It seems reasonable to conclude that there are potential solutions—either proposed by the Federal Government or the non-Federal Sponsors or a combination of the two—that justify continuing this feasibility study based upon the one criterion of economic feasibility.

7. Regional Economic Development and Other Social Effects

Per USACE EC 1105-2-409, any alternative plan that has net beneficial effects across the four USACE Planning & Guidance (P&G) accounts may be the recommended plan. Furthermore, "highest budgetary priority will be given to collaborative planning activities that embrace the full range of the national Federal interest." The description of any estimated RED impacts within the study area as a result of a federal project will be included in subsequent report phases as warranted, and as further guidance and instruction becomes available. The following two sections will briefly describe each of the accounts.

7.1. Regional Economic Development (RED)

According to EC 1105-2-409, "the regional economic development account registers changes in the distribution of regional economic activity that result from each alternative plan". According to the EC, measurement of RED effects is generally to be quantitative within available and selected methods. USACE is currently developing a handbook of contemporary techniques for RED.

This type of impact analysis requires relatively sophisticated input/output modeling, which would require a significant amount of additional funds and time to incorporate in this study. While a quantitative analysis is not included here, it is useful to describe in generalities some of the more easily identifiable indirect impacts of a major flood event in this area. Possible impacts include changes in gross regional product, employment, sales and property tax revenues, and development patterns.

In the aftermath of a significant flood event, sales and business activity in some sectors will be hurt, while others will receive a boost. For example, while it could be expected that some sectors would be adversely impacted in the short-term, other sectors such as construction and some retail businesses would likely benefit as homeowners rebuild and repair their homes and replace damaged goods. Thus, in the absence of a more detailed analysis, the net effect on sales tax revenues is uncertain.

For property tax revenues, assuming that nearly all damaged or destroyed homes would be repaired or replaced, a decrease in property taxes as a result of a flood event is not expected. It is possible to imagine both positive and negative effects on property taxes in the region. Decreased property value of land in the floodplain would decrease tax revenues, while, as a result of California's Proposition 13, an increase in property taxes would be associated with parcels where substantial improvements were made to the structure or with those parcels where ownership changed in the aftermath of the flooding.

7.2. Other Social Effects (OSE)

OSE is defined by EC 1105-2-409, "The other social effects account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts". Measurement of OSE effects is generally qualitative; however quantitative data is encouraged within available and accepted methods.

Flooding on such a massive scale as what would occur under the storm events analyzed in this study would clearly cause disruptions in the availability of important health, safety, and social services. These impacts are difficult to quantify, but are nonetheless important to capture in the analysis, even if only qualitatively.

There are numerous schools in the floodplain, and, given that a large storm event is most likely to occur in the non-summer months, flooding of these facilities represents a significant inconvenience and cost to the affected communities. In the aftermath of the flooding, many of these schools would require extensive cleanup and repair

before reopening to students and teachers. Many parents would be forced to miss some amount of work in order to care for young children that would normally be attending the affected schools.

These types of impacts will be further described in the next phase of the feasibility study reporting process, and the benefits of the various potential projects will also be evaluated and compared from an OSE perspective.

8. Recreation Analysis

There are potentially many opportunities to improve the quality and quantity of recreation in the study area as part of a project. In order to describe and estimate the value of potential future project-related recreational resources, the without-project Economic Analysis typically defines the market area and describes the existing and expected future without-project recreational resources. At the next, with-project, study phase, understanding the level of unmet demand for recreation in the study area will help the study team understand and estimate the value of potential future recreation management measures. It is not yet clear whether or not recreation features will be part of the potential array of alternatives. If warranted, the next study phase will include a definition of the recreation market area, the existing supply of recreation opportunities, and it will use one of several possible valuation methodologies to estimate using well-established parameters the users' willingness to pay for potential future recreation experiences created as part of the project.

9. Addendum—HEC-FDA Screen Captures*

Table 9: Exceedance Probability - Damage Functions, 2017, SM 1 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0400	0.01	3.62	0.02	1.28	0.00	0.05	4.98
0.0250	1.48	789.56	3.64	279.32	0.00	11.61	1085.61
0.0200	4.76	2535.42	11.70	896.95	0.00	37.27	3486.09
0.0150	10.22	5443.07	25.11	1925.58	0.00	80.00	7483.99
0.0100	19.24	10247.93	47.28	3625.39	0.00	150.63	14090.46
0.0090	21.66	11537.19	53.22	4081.49	0.00	169.58	15863.15
0.0080	24.34	12964.69	59.81	4586.49	0.00	190.56	17825.89
0.0070	27.37	14578.41	67.26	5157.38	0.00	214.28	20044.69
0.0060	30.96	16486.35	76.06	5832.35	0.00	242.32	22668.03
0.0050	35.60	18957.99	87.46	6706.73	0.00	278.65	26066.43
0.0040	42.47	22618.59	104.35	8001.74	0.00	332.46	31099.61
0.0020	70.63	37618.36	173.55	13308.17	0.00	552.93	51723.64
0.0010	100.53	53538.42	246.99	18940.19	0.00	786.93	73613.05

*The Analysis Year field in the screen captures shows the year 2014, which was the year originally entered upon initial model setup. As noted elsewhere in the report, the actual base year is 2017. This discrepancy makes no difference to the model or the results.

Table 10: Exceedance Probability - Damage Functions, 2017, SM 2 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.9000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.8000	0.00	0.00	0.01	0.00	0.00	0.03	0.04
0.7000	0.00	0.00	0.01	0.00	0.00	0.04	0.06
0.6000	0.01	0.00	0.01	0.00	0.00	0.06	0.08
0.5000	0.01	0.00	0.02	0.00	0.00	0.07	0.10
0.4750	0.01	0.00	0.02	0.00	0.00	0.07	0.10
0.4500	0.01	0.00	0.02	0.00	0.00	0.08	0.11
0.4250	0.01	0.00	0.02	0.00	0.00	0.08	0.11
0.4000	0.01	0.00	0.02	0.00	0.00	0.08	0.12
0.3750	0.01	0.00	0.02	0.00	0.00	0.09	0.12
0.3500	0.01	0.00	0.02	0.00	0.00	0.09	0.13
0.3250	0.01	0.00	0.02	0.00	0.00	0.09	0.13
0.3000	0.01	0.00	0.02	0.00	0.00	0.10	0.14
0.2750	0.01	0.00	0.03	0.00	0.00	0.10	0.14
0.2500	0.01	0.00	0.03	0.00	0.00	0.10	0.15
0.2250	0.01	0.00	0.03	0.00	0.00	0.11	0.15
0.2000	0.01	0.00	0.03	0.00	0.00	0.11	0.16
0.1750	0.03	0.00	0.06	0.00	0.00	0.24	0.33
0.1500	0.13	0.02	0.28	0.00	0.00	1.13	1.57
0.1250	0.32	0.05	0.68	0.00	0.00	2.72	3.78
0.1000	1.93	0.29	4.07	0.00	0.00	16.20	22.49
0.0750	10.58	1.58	22.31	0.00	0.00	88.84	123.31
0.0500	33.51	5.00	70.65	0.00	0.00	281.39	390.55
0.0400	73.26	10.93	154.46	0.00	0.00	615.21	853.87
0.0250	171.22	25.55	361.01	0.00	0.00	1437.91	1995.70
0.0200	297.16	44.35	626.54	0.00	0.00	2495.49	3463.53
0.0150	456.03	68.06	961.51	0.00	0.00	3829.71	5315.31
0.0100	650.40	97.07	1371.33	0.00	0.00	5462.03	7580.83
0.0090	693.31	103.47	1461.80	0.00	0.00	5822.36	8080.95
0.0080	739.86	110.42	1559.96	0.00	0.00	6213.31	8623.55
0.0070	790.85	118.03	1667.47	0.00	0.00	6641.53	9217.89
0.0060	847.62	126.50	1787.17	0.00	0.00	7118.30	9879.60
0.0050	914.60	136.50	1928.37	0.00	0.00	7680.72	10660.19
0.0040	1034.15	154.34	2180.45	0.00	0.00	8684.75	12053.71
0.0020	1430.24	213.46	3015.57	0.00	0.00	12011.03	16670.29
0.0010	1849.09	275.97	3898.69	0.00	0.00	15528.51	21552.26

Table 11: Exceedance Probability - Damage Functions, 2017, SM 3 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.01
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.01
0.5000	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4750	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4500	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4250	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.4000	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.3750	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.3500	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.3250	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.3000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2750	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2500	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2250	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.2000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1750	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1500	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1250	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.1000	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.0750	0.00	0.00	0.00	0.00	0.00	0.01	0.02
0.0500	0.07	0.05	0.15	0.20	0.03	0.51	1.01
0.0400	0.25	0.15	0.50	0.68	0.09	1.74	3.42
0.0250	9.72	6.08	19.82	26.87	3.55	68.78	134.82
0.0200	45.34	28.37	92.42	125.26	16.53	320.67	628.59
0.0150	93.13	58.27	189.83	257.28	33.95	658.63	1291.10
0.0100	390.86	244.57	796.74	1079.81	142.51	2764.33	5418.82
0.0090	533.83	334.04	1088.19	1474.80	194.64	3775.52	7401.02
0.0080	689.14	431.21	1404.77	1903.84	251.26	4873.88	9554.10
0.0070	859.28	537.68	1751.59	2373.88	313.30	6077.20	11912.92
0.0060	1048.75	656.24	2137.83	2897.33	382.38	7417.26	14539.79
0.0050	1270.52	795.00	2589.88	3509.99	463.24	8985.67	17614.29
0.0040	1586.80	992.91	3234.60	4383.76	578.56	11222.54	21999.15
0.0020	2570.89	1608.68	5240.61	7102.45	937.36	18182.46	35642.44
0.0010	3551.01	2221.98	7238.54	9810.19	1294.72	25114.36	49230.80

Table 12: Exceedance Probability - Damage Functions, 2017, SM 4 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.01
0.9500	0.00	0.00	0.00	0.00	0.00	0.02	0.03
0.9000	0.00	0.00	0.01	0.00	0.00	0.05	0.06
0.8000	0.01	0.00	0.02	0.00	0.00	0.10	0.13
0.7000	0.01	0.00	0.03	0.00	0.00	0.15	0.19
0.6000	0.01	0.01	0.04	0.00	0.00	0.20	0.26
0.5000	0.02	0.01	0.05	0.00	0.00	0.25	0.32
0.4750	0.02	0.01	0.05	0.00	0.00	0.26	0.34
0.4500	0.02	0.01	0.05	0.00	0.00	0.27	0.35
0.4250	0.02	0.01	0.05	0.00	0.00	0.28	0.37
0.4000	0.02	0.01	0.06	0.00	0.00	0.29	0.38
0.3750	0.02	0.01	0.06	0.00	0.00	0.31	0.40
0.3500	0.02	0.01	0.06	0.00	0.00	0.32	0.42
0.3250	0.03	0.01	0.06	0.00	0.00	0.33	0.43
0.3000	0.03	0.01	0.07	0.00	0.00	0.34	0.45
0.2750	0.03	0.01	0.07	0.00	0.00	0.36	0.46
0.2500	0.03	0.01	0.07	0.00	0.00	0.37	0.48
0.2250	0.03	0.01	0.07	0.00	0.00	0.38	0.50
0.2000	0.03	0.01	0.08	0.00	0.00	0.39	0.51
0.1750	0.12	0.05	0.30	0.00	0.00	1.55	2.01
0.1500	0.36	0.16	0.91	0.00	0.01	4.74	6.17
0.1250	0.69	0.30	1.74	0.00	0.01	9.11	11.86
0.1000	7.15	3.16	18.06	0.00	0.14	94.48	122.99
0.0750	42.18	18.64	106.54	0.00	0.81	557.33	725.51
0.0500	91.53	40.46	231.19	0.00	1.77	1209.40	1574.34
0.0400	123.76	54.71	312.60	0.00	2.39	1635.30	2128.76
0.0250	198.26	87.64	500.79	0.00	3.83	2619.72	3410.24
0.0200	265.61	117.41	670.91	0.00	5.13	3509.67	4568.73
0.0150	351.70	155.47	888.35	0.00	6.79	4647.15	6049.45
0.0100	508.54	224.80	1284.51	0.00	9.82	6719.59	8747.26
0.0090	560.02	247.55	1414.55	0.00	10.81	7399.81	9632.75
0.0080	615.86	272.24	1555.59	0.00	11.89	8137.63	10593.20
0.0070	677.03	299.27	1710.09	0.00	13.07	8945.88	11645.35
0.0060	745.13	329.38	1882.09	0.00	14.39	9845.63	12816.61
0.0050	826.14	365.19	2086.71	0.00	15.95	10916.06	14210.05
0.0040	1091.02	482.27	2755.77	0.00	21.07	14416.08	18766.22
0.0020	2034.98	899.54	5140.09	0.00	39.29	26888.98	35002.89
0.0010	3264.17	1442.89	8244.84	0.00	63.03	43130.64	56145.58

Table 13: Exceedance Probability - Damage Functions, 2017, SM 5 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0400	1612.27	3.23	3420.36	0.00	183.92	9497.17	14716.94
0.0250	2801.44	5.61	5943.12	0.00	319.58	16502.01	25571.75
0.0200	3455.96	6.92	7331.66	0.00	394.24	20357.52	31546.30
0.0150	4281.64	8.57	9083.30	0.00	488.43	25221.22	39083.17
0.0100	5345.05	10.70	11339.27	0.00	609.74	31485.28	48790.04
0.0090	5598.69	11.21	11877.36	0.00	638.68	32979.37	51105.30
0.0080	5873.73	11.76	12460.85	0.00	670.05	34599.52	53615.91
0.0070	6175.12	12.36	13100.22	0.00	704.43	36374.84	56366.98
0.0060	6510.63	13.03	13811.99	0.00	742.71	38351.18	59429.54
0.0050	6895.57	13.80	14628.63	0.00	786.62	40618.70	62943.32
0.0040	7466.18	14.95	15839.15	0.00	851.71	43979.91	68151.90
0.0020	9266.37	18.55	19658.17	0.00	1057.07	54584.02	84584.19
0.0010	10950.84	21.92	23231.70	0.00	1249.23	64506.50	99960.20

Table 14: Exceedance Probability - Damage Functions, 2017, SC 1 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.9500	0.00	0.00	0.00	0.00	0.00	0.04	0.05
0.9000	0.00	0.00	0.01	0.00	0.00	0.08	0.09
0.8000	0.01	0.00	0.01	0.00	0.00	0.16	0.18
0.7000	0.01	0.01	0.02	0.00	0.00	0.24	0.28
0.6000	0.01	0.01	0.03	0.00	0.00	0.32	0.37
0.5000	0.01	0.01	0.04	0.00	0.00	0.40	0.46
0.4750	0.02	0.01	0.04	0.00	0.00	0.42	0.48
0.4500	0.02	0.01	0.04	0.00	0.00	0.44	0.51
0.4250	0.02	0.01	0.04	0.00	0.00	0.46	0.53
0.4000	0.02	0.01	0.04	0.00	0.00	0.48	0.55
0.3750	0.02	0.01	0.05	0.00	0.00	0.50	0.57
0.3500	0.02	0.01	0.05	0.00	0.00	0.52	0.60
0.3250	0.02	0.01	0.05	0.00	0.00	0.54	0.62
0.3000	0.02	0.01	0.05	0.00	0.00	0.56	0.64
0.2750	0.02	0.01	0.05	0.00	0.00	0.58	0.67
0.2500	0.02	0.01	0.05	0.00	0.00	0.60	0.69
0.2250	0.02	0.01	0.06	0.00	0.00	0.62	0.71
0.2000	0.02	0.02	0.06	0.00	0.00	0.64	0.74
0.1750	1.75	1.12	4.24	0.00	0.19	46.71	54.00
0.1500	5.17	3.28	12.47	0.00	0.55	137.51	158.98
0.1250	9.14	5.81	22.05	0.00	0.98	243.22	281.20
0.1000	43.26	27.49	104.41	0.00	4.64	1151.44	1331.24
0.0750	214.95	136.60	518.73	0.00	23.06	5720.74	6614.07
0.0500	444.80	282.68	1073.41	0.00	47.71	11838.00	13686.59
0.0400	569.87	362.17	1375.26	0.00	61.13	15166.92	17535.35
0.0250	865.59	550.10	2088.91	0.00	92.84	23037.30	26634.75
0.0200	1195.61	759.83	2885.32	0.00	128.24	31820.42	36789.42
0.0150	1611.40	1024.08	3888.75	0.00	172.84	42886.58	49583.64
0.0100	2211.95	1405.74	5338.03	0.00	237.26	58869.82	68062.78
0.0090	2375.00	1509.36	5731.53	0.00	254.75	63209.44	73080.07
0.0080	2551.88	1621.77	6158.37	0.00	273.72	67916.80	78522.52
0.0070	2745.64	1744.91	6625.98	0.00	294.50	73073.85	84484.88
0.0060	2961.38	1882.02	7146.62	0.00	317.64	78815.66	91123.32
0.0050	3215.71	2043.65	7760.39	0.00	344.92	85584.48	98949.15
0.0040	3755.31	2386.57	9062.57	0.00	402.80	99945.47	115552.71
0.0020	5580.86	3546.75	13468.14	0.00	598.61	148531.73	171726.09
0.0010	7843.37	4984.62	18928.19	0.00	841.29	208747.23	241344.69

Table 15: Exceedance Probability - Damage Functions, 2017, SC 2 ($1,000s)

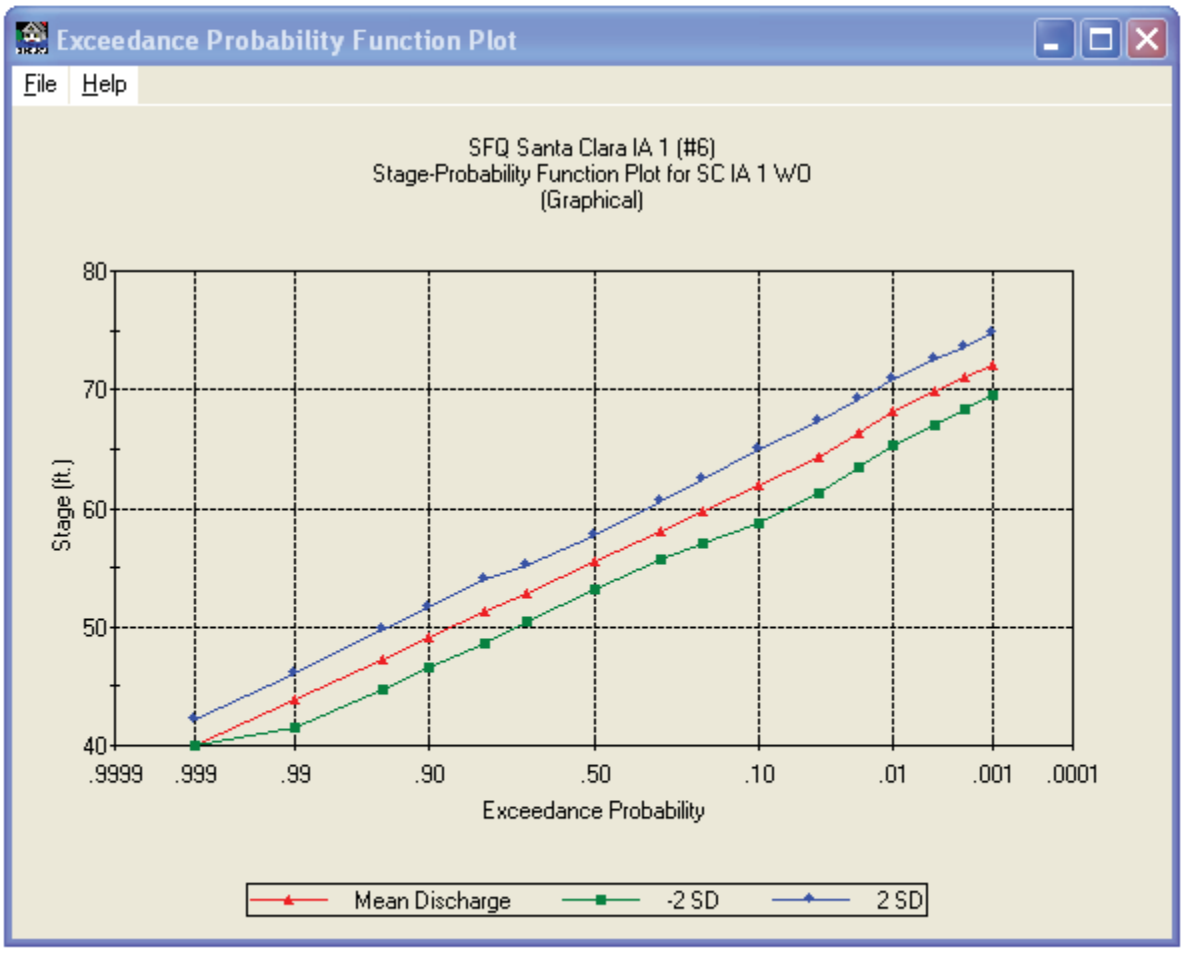
Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.6000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1250	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0750	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0500	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0400	1671.97	0.00	2982.54	0.00	81.73	11186.82	15923.06
0.0250	2905.23	0.00	5182.49	0.00	142.01	19438.31	27668.04
0.0200	4156.53	0.00	7414.61	0.00	203.17	27810.48	39584.79
0.0150	5762.51	0.00	10279.43	0.00	281.67	38555.75	54879.36
0.0100	7578.59	0.00	13519.04	0.00	370.44	50706.78	72174.85
0.0090	7932.79	0.00	14150.88	0.00	387.75	53076.66	75548.09
0.0080	8316.98	0.00	14836.21	0.00	406.53	55647.17	79206.89
0.0070	8737.79	0.00	15586.86	0.00	427.10	58462.70	83214.45
0.0060	9206.22	0.00	16422.48	0.00	450.00	61596.91	87675.62
0.0050	9743.14	0.00	17380.26	0.00	476.24	65189.30	92788.95
0.0040	10433.47	0.00	18611.70	0.00	509.99	69808.16	99363.32
0.0020	12502.74	0.00	22302.95	0.00	611.13	83653.19	119070.01
0.0010	14493.52	0.00	25854.21	0.00	708.44	96973.13	138029.31

Table 16: Exceedance Probability - Damage Functions, 2017, SC 3 ($1,000s)

Plan Name: Without, Without project condition
Analysis Year: 2014
Stream Name: San Francisquito

Exceedance Probability	Damage by Damage Categories						Total Damage
	Autos	Commercial	Displacement	Industrial	Public	Residential	
0.9900	0.00	0.05	0.00	0.00	0.00	0.00	0.06
0.9500	0.00	0.30	0.00	0.01	0.02	0.00	0.32
0.9000	0.00	0.60	0.00	0.01	0.03	0.00	0.64
0.8000	0.00	1.20	0.00	0.02	0.07	0.00	1.29
0.7000	0.00	1.81	0.00	0.04	0.10	0.00	1.94
0.6000	0.00	2.41	0.00	0.05	0.13	0.00	2.59
0.5000	0.00	3.02	0.00	0.06	0.16	0.00	3.24
0.4750	0.00	3.17	0.00	0.06	0.17	0.00	3.41
0.4500	0.00	3.32	0.00	0.07	0.18	0.00	3.57
0.4250	0.00	3.47	0.00	0.07	0.19	0.00	3.73
0.4000	0.00	3.62	0.00	0.07	0.20	0.00	3.89
0.3750	0.00	3.77	0.00	0.08	0.20	0.00	4.06
0.3500	0.00	3.92	0.00	0.08	0.21	0.00	4.22
0.3250	0.00	4.08	0.00	0.08	0.22	0.00	4.38
0.3000	0.00	4.23	0.00	0.09	0.23	0.00	4.54
0.2750	0.00	4.38	0.00	0.09	0.24	0.00	4.71
0.2500	0.00	4.53	0.00	0.09	0.25	0.00	4.87
0.2250	0.00	4.68	0.00	0.10	0.25	0.00	5.03
0.2000	0.00	4.83	0.00	0.10	0.26	0.00	5.19
0.1750	0.00	4.98	0.00	0.10	0.27	0.00	5.36
0.1500	0.00	5.13	0.00	0.11	0.28	0.00	5.52
0.1250	0.00	5.28	0.00	0.11	0.29	0.00	5.68
0.1000	0.00	5.44	0.00	0.11	0.30	0.00	5.84
0.0750	0.00	125.06	0.00	2.56	6.79	0.00	134.41
0.0500	0.00	596.40	0.00	12.22	32.39	0.00	641.00
0.0400	0.00	897.39	0.00	18.38	48.74	0.00	964.51
0.0250	0.00	1577.90	0.00	32.32	85.70	0.00	1695.92
0.0200	0.00	1972.82	0.00	40.41	107.14	0.00	2120.37
0.0150	0.00	2398.30	0.00	49.12	130.25	0.00	2577.67
0.0100	0.00	3873.18	0.00	79.33	210.35	0.00	4162.86
0.0090	0.00	5005.18	0.00	102.52	271.83	0.00	5379.53
0.0080	0.00	6567.53	0.00	134.52	356.68	0.00	7058.73
0.0070	0.00	8352.40	0.00	171.07	453.62	0.00	8977.09
0.0060	0.00	10430.88	0.00	213.64	566.50	0.00	11211.02
0.0050	0.00	12953.81	0.00	265.32	703.52	0.00	13922.65
0.0040	0.00	16149.60	0.00	330.77	877.08	0.00	17357.46
0.0020	0.00	26502.62	0.00	542.82	1439.36	0.00	28484.80
0.0010	0.00	38490.63	0.00	788.36	2090.42	0.00	41369.42

Table 17: Exceedance Probability Function with Uncertainty

Exceedance Probability	Stage (ft.)	Confidence Limit Curves Stage (ft.) -2 SD	-1 SD	+1 SD	+2 SD
0.9990	40.00	40.00	38.92	41.08	42.16
0.9900	43.83	41.51	42.67	44.99	46.15
0.9500	47.25	44.77	46.01	48.48	49.72
0.9000	49.07	46.51	47.79	50.35	51.62
0.8000	51.27	48.62	49.95	52.60	53.93
0.7000	52.86	50.47	51.67	54.06	55.26
0.5000	55.49	53.20	54.35	56.64	57.78
0.3000	58.12	55.73	56.92	59.32	60.52
0.2000	59.71	57.05	58.38	61.04	62.37
0.1000	61.92	58.80	60.36	63.48	65.03
0.0400	64.27	61.28	62.77	65.77	67.26
0.0200	66.29	63.40	64.84	67.74	69.18
0.0100	68.17	65.38	66.77	69.57	70.96
0.0040	69.79	67.08	68.43	71.15	72.50
0.0020	71.00	68.35	69.68	72.32	73.65
0.0010	72.13	69.54	70.84	73.43	74.73