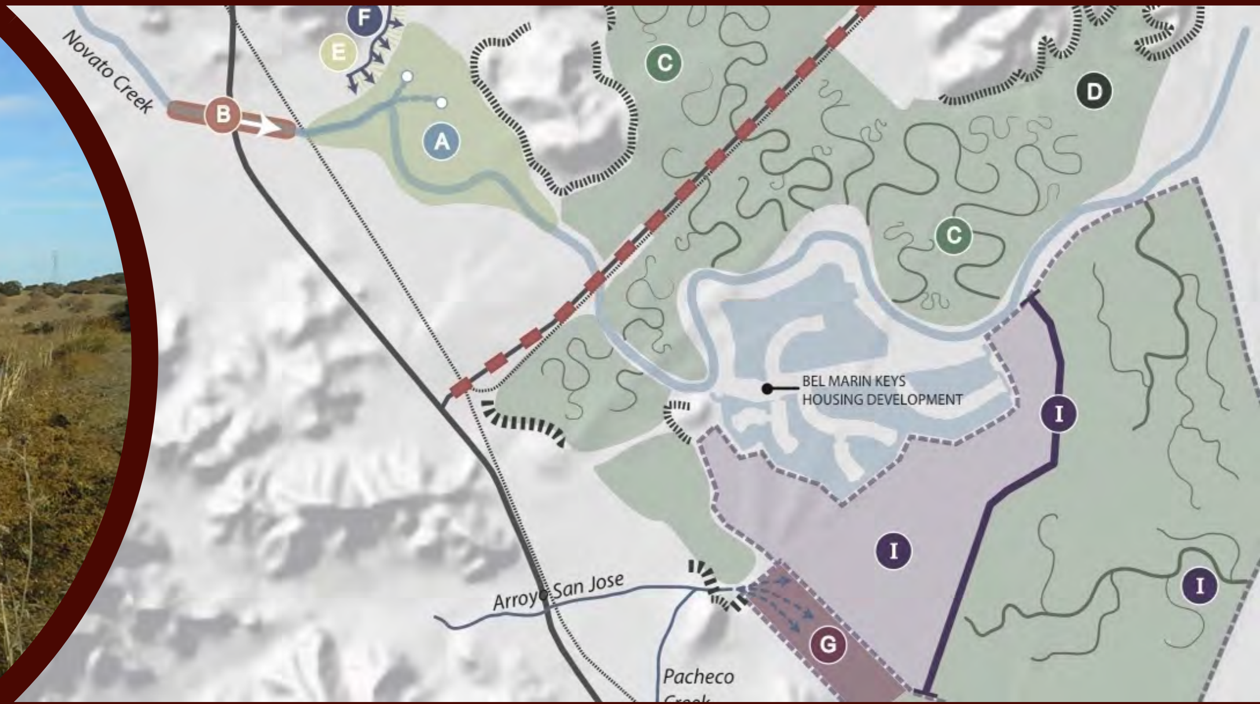
NOVATO CREEK
ECONOMIC ANALYSIS
of Flood Control 2.0 Strategies

Integrative Economics, LLC



A PRODUCT OF FLOOD CONTROL 2.0

Flood Control 2.0: Economic Analysis

Economic Analysis of Flood Control 2.0 Strategies in Novato Creek

Prepared for the Flood Control 2.0 Project:

San Francisco Estuary Partnership
San Francisco Estuary Institute
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December 2016

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The Flood Control 2.0 Project

Efforts are underway in San Francisco Bay Area watersheds to simultaneously meet flood risk management and environmental restoration objectives in flood control projects. This approach to achieving multiple benefits has presented decision makers with regulatory, scientific, and economic questions that must be answered in order to determine their value in practical terms.

Responding to this need, a group of regional government, scientific, planning, and environmental organizations has undertaken the **Flood Control 2.0 Project** (FC 2.0), to help develop and implement these multi-benefit approaches in the San Francisco baylands.

A growing body of research has explored the benefits and costs of environmental restoration in the context of flood protection in the United States and around the world. To help provide information tailored specifically to the Bay Area, the Flood Control 2.0 project team has commissioned a two-part study of the economic benefits and costs of several emerging flood control strategies. The first is a case study of the Novato Creek watershed, the topic of this report. The second phase will enable the economic analysis to be extended to other Bay Area watersheds.

Economic Study Objectives

This case study compares the benefits and costs of "traditional" flood control approaches to a suite of new approaches that incorporate tidal ecosystem restoration to achieve multiple benefits in addition to flood protection.

Specific objectives of this case study include:

1. Highlighting the life cycle benefits, costs, and long-term resilience of FC 2.0 strategies as applied to Novato Creek
2. Quantifying the multiple economic values provided by the Novato Creek watershed (e.g., habitat, recreational/amenity values, flood risk management, and a medium for waste water and storm water discharge)

Benefit-Cost Analysis

The benefit-cost analysis for this project looked at two plausible alternatives for future flood control efforts in the Novato Creek baylands. The first alternative, dubbed **Flood Control 1.0**, consists of rebuilding the system of levees and detention basins in its current configuration, with additional work (e.g., increasing levee height) required to address rising sea levels and a predicted increase in storm severity over the next 50-85 years. In contrast, **Flood Control 2.0** employs a suite of activities intended to increase tidal marsh habitat and provide additional environmental benefits, including wastewater assimilation, recreation, and aesthetic values by reconnecting the Creek with its historical floodplain.

The benefit-cost ratios of the two alternatives are summarized in **Table ES-1**, below:

Table ES-1: Flood Control benefit/cost ratios by alternative (50-year time horizon).

a. Flood Control 1.0

Costs \ Benefits	Low	Med	High
Low	1.19	2.76	5.27
Med	0.96	2.23	4.24
High	0.73	1.70	3.25

b. Flood Control 2.0

Costs \ Benefits	Low	Med	High
Low	1.65	3.80	7.19
Med	1.16	2.67	5.07
High	0.85	1.96	3.72

Key Findings

1. **Flood Control 2.0 is favorable to FC 1.0 in terms of benefits and costs** in each of the scenarios evaluated.
2. **The range of FC 2.0 alternatives** are associated with substantial benefits from the ecosystem services of restored tidal marsh, though in some cases, increased recreational opportunities may represent the largest category of benefits.
3. **The improved performance of FC 2.0 in terms of life cycle O&M costs** may be more than enough to offset higher capital costs of floodplain restoration.
4. **The costs of each approach are sensitive to project design**: lower-cost restoration designs that make more use of natural processes can achieve higher benefit-cost ratios, though these may need to be balanced against the urgency of dealing with sea level rise.
    - Evidence suggests that if the pace of restoration does not keep up with rising sea levels, tidal marsh restoration opportunities may be lost.
5. **The benefits and costs of the Flood Control 2.0 alternative show more variability than the established FC 1.0 approach**. This reflects the emerging role of ecosystem restoration, with all of its complexity. Addressing this variability may require new institutional mindsets with respect to project risk and financing.

Acknowledgements

This case study and economic analysis of the lower Novato Creek benefitted greatly from the input and thoughtful comments of many participants in the Flood Control 2.0 project, including (in alphabetical order by agency):

Marin County Department of Public Works
Roger Leventhal, Liz Lewis, and Laurie Williams

San Francisco Bay Conservation And Development Commission
Brenda Goeden, Pascale Soumoy, and Heather Perry

San Francisco Bay Joint Venture
Beth Huning, Sandra Scoggin, and Caroline Warner

San Francisco Estuary Institute
Lester McKee, Scott Dusterhoff, Carolyn Doerhing, Sarah Pearce, and Micha Salomon

San Francisco Estuary Partnership
Caitlin Sweeney, Flood Control 2.0 Project Manager, and Adrien Baudrimont

U.S. Environmental Protection Agency
Luisa Valiela

Funding provided by the San Francisco Bay Water Quality Improvement Fund through EPA Region 9 and the San Francisco Estuary Partnership

The Integrative Economics, LLC project team
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May 2015
Revised December 2016

Flood Control 2.0: Economic Analysis

Economic Benefits of Flood Control 2.0 Strategies in Novato Creek

Introduction

The Flood Control 2.0 Project

Efforts are underway in San Francisco Bay Area watersheds to simultaneously meet flood risk management and environmental restoration objectives in flood control projects. This approach to achieving multiple benefits has presented decision makers with regulatory, scientific, and economic questions that must be answered in order to determine their value in practical terms.

Responding to this need, a group of regional government, scientific, planning, and environmental organizations has undertaken the **Flood Control 2.0 Project** (FC 2.0), to help develop and implement these multi-benefit approaches in the San Francisco baylands.

As the San Francisco Estuary Partnership (SFEP), one of the FC 2.0 partners, phrases the issue:

> Flood channels were designed to move water quickly to the Bay, with less consideration for sediment transport. As a result, coarser sediments often drop out of suspension and remain in many channels, requiring costly periodic maintenance removal. Resulting impacts include increased flood risk, frequent habitat disturbance, Bay marshes less resilient to rising sea levels, and shoreline development more vulnerable to sea level rise effects…
>
> …This project recognizes the environmental benefits and cost-savings that would be granted through recognition of sediment in flood control channels as a resource rather than a waste. By redesigning the flood control channel-Bay interface so that sediment is dispersed to missing points of connectivity such as historic delta wetlands and mudflats, we can re-create critical habitat features along marsh fronts, historic tributary deltas, and beaches, while simultaneously improving flood conveyance and re-establishing more resilient shorelines. [1]

To illustrate just a few economic measures of flood risk management in the Bay Area:

- Dredging project costs in Bay Area rivers and streams have totaled an estimated $120 million (in 2014 dollars) over the past 40 years – and this figure does not

[1] San Francisco Estuary Partnership (2014)

include associated costs such as planning, permitting, or staff resources devoted to managing dredging projects.[2]

- Annual operations and maintenance costs for the bayland reaches of Novato Creek are expected to average at least $1.3 million per year over the next 85 years (in 2014 dollars) if the flood risk management system is maintained in its current configuration.
- The nature of land use economic development, and regulation in California is expected to contribute to additional escalation of infrastructure costs in coming decades.[3]

This state of affairs presents clear incentives for flood protection agencies to continually evaluate their practices.

Achieving the objectives of FC 2.0 will require new approaches by the entities charged with implementing and approving flood control projects. Information about the comparative benefits and costs of these new approaches will provide helpful guidance to future flood control efforts.

A growing body of research has explored the benefits and costs of environmental restoration in the context of flood protection in the United States and around the world. To help provide information tailored specifically to the Bay Area, the Flood Control 2.0 project team has commissioned a two-part study of the economic benefits and costs of several emerging flood control strategies. The first is a case study of the Novato Creek watershed, the topic of this report. The second phase will enable the economic analysis to be extended to other Bay Area watersheds.

[2] San Francisco Estuary Institute (2014)
[3] Hanak, et al. (2011)

Economic Study Objectives[4]

This case study compares the benefits and costs of "traditional" flood control approaches to a suite of new approaches that incorporate tidal ecosystem restoration to achieve multiple benefits in addition to flood protection.

Specific objectives of this case study include:

1. Highlighting the life cycle benefits, costs, and long-term resilience of FC 2.0 strategies as applied to Novato Creek
2. Quantifying the multiple economic values provided by the Novato Creek watershed (e.g., habitat, recreational/amenity values, flood risk management, and a medium for waste water and storm water discharge)

In addition, the economic analysis of FC 2.0 strategies will be considered successful to the degree it addresses the needs of Bay Area stakeholders in:

- Supporting the view of sediment as a valuable resource by quantifying the benefits of sediment reuse;
- Helping to identify candidate sites for implementing FC 2.0 strategies;
- Lending support to the ecological and social cases for reconnecting watersheds to the Bay;
- Increasing the pace of wetland restoration;
- Assisting agencies in outreach efforts to communicate the value of new flood protection approaches, and in obtaining the funding to undertake them;
- Providing information that helps regulatory bodies understand the monetary benefits of sediment reuse in restoration projects

[4] From Economic Analysis kickoff meeting, December 10, 2014.

Novato Creek Background

Physical Setting

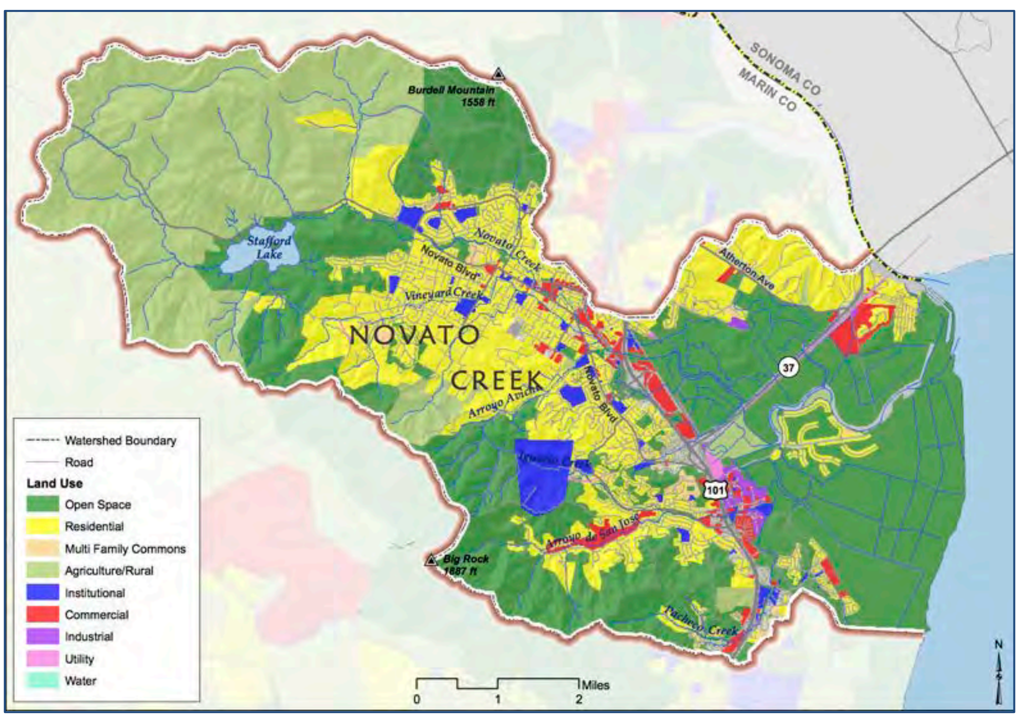
The Novato Creek watershed encompasses roughly 45 square miles in northern Marin County. From its headwaters in the coastal highlands, the creek runs for 17 miles through the City of Novato and extensive bayland habitat before draining into San Pablo Bay. The watershed encompasses most of the city of Novato, as well as unincorporated communities such as Bel Marin Keys. The baylands sit largely below sea level due to subsidence of lands that were diked and drained for agricultural use in the nineteenth and twentieth centuries. This presents unique opportunities and challenges to restoration and flood control efforts.

The baylands examined in this study provide valuable habitat for a variety of species, including the California clapper rail, migratory waterfowl, marsh-dwelling mammals, as well as spawning and rearing habitat for steelhead.

The natural setting of the Novato Creek baylands also provides for multiple recreational uses, including boating, bird watching, and active transportation, which are valued by residents and visitors alike.

The Novato Creek watershed is shown in **Figure 1** below.

Figure 1: Novato Creek watershed.



Source: Marin County Department of Public Works

Historical Changes[5]

Novato Creek has undergone dramatic changes since the European-American settlement of the area in the mid-19th century. By the 1850s, agriculture was well established, and tidal marshlands were diked and drained for farming and grazing. Dredging of the creek began as early as the 1880s. Much of the community's infrastructure is located in this floodplain and tidal transition zone, which understandably has given rise to numerous flooding events over the years.[6]

Novato experienced rapid growth in the 1970s and 1980s, leveled off in the 1990s, and resumed growing in the 2000s. Population growth in the Novato area has been roughly 1.4 percent per year since the 2010 Census. This steady urbanization has constrained the creek in its upland reaches and increased the timing and magnitude of peak runoff events, which has complicated flood control efforts.

Severe flooding in 1982 focused the community's attention on the need for investments in flood protection infrastructure. This resulted in a long-term flood control initiative to contain and route creek flows, including levees, constructing pump stations, and detention basins. The project, constructed over approximately 20 years, was completed in 2006.

The project's singular focus on flood control resulted in a number of unintended consequences, as the natural connections between the creek and the floodplain were further altered. Today, the county acknowledges that the lower reaches "no longer function optimally for sediment transport." As a result, the county flood control district must remove 30,000 to 40,000 cubic yards of sediment from Novato Creek every three-to-four years, at a cost approaching $1.5 million for each dredging project. [7]

A Current Look at the Novato Watershed Program

The Novato Creek Flood Control Project launched in the 1980s was designed to provide protection from a 50-year storm event along the lower reaches of Novato Creek. Shortly after the project was completed, flooding from a winter storm prompted local officials to consider additional measures to protect downtown Novato and other affected areas. [8]

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[5] Marin County Department of Public Works (2012)
[6] Collins (1998)
[7] Marin County Department of Public Works (2012)
[8] Novato Watershed Program (www.marinwatersheds.org)

To address the ongoing issues in Novato Creek, entities[9] have been coordinating efforts to develop a multi-benefit approach to flood control in the watershed. Marin County lists the following objectives for its efforts in Novato Creek:[10]

- Maintain and improve existing level of flood protection
- Reduce dredging costs and associated impacts
- Improve efficiency of flood control operations and maintenance
- Utilize and support natural processes
- Support integrated multi-benefit project alternatives
- Adapt to climate change

Marin County is currently studying its options for the next major flood control initiative in Novato Creek, with an alternatives analysis scheduled for completion in mid-2015. While this case study is separate from that effort, the findings of this study are intended to shed light on the economic impacts of the multi-benefit approach the County is pursuing.

[9] Marin County Flood Control Zone 1, City of Novato, North Marin Water District, and Novato Sanitary District

[10] Marin County Department of Public Works (2014)

Community Infrastructure

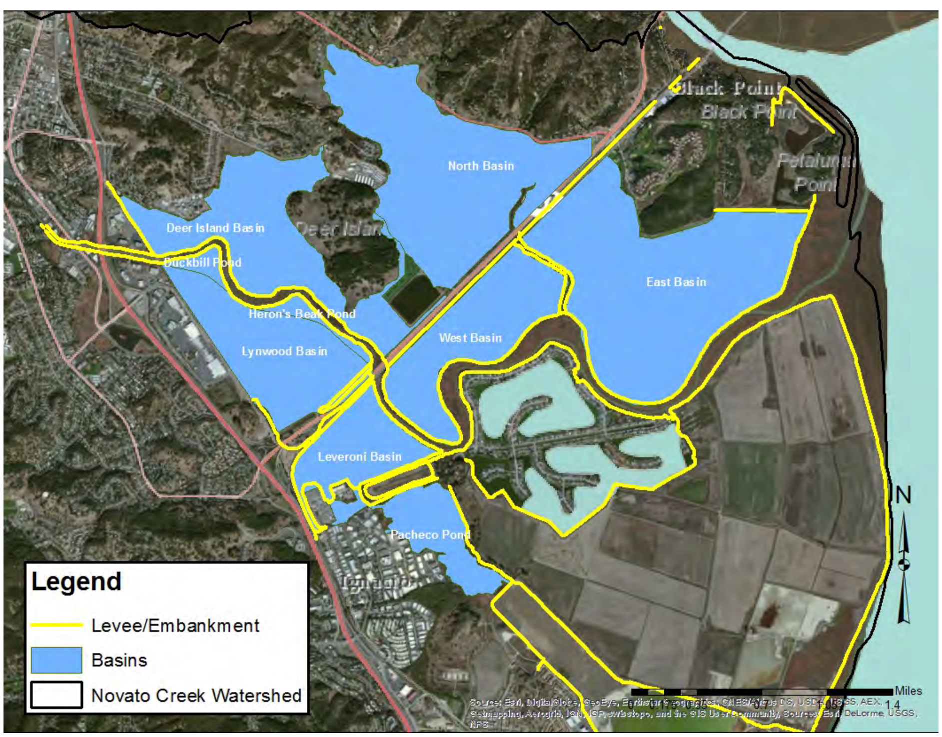
In addition to homes and businesses, the Novato Creek flood control system protects critical infrastructure managed by other agencies, including Novato Sanitary District wastewater facilities and regionally significant highway and railroad corridors. The resulting jurisdictional issues, while not the focus of this analysis, do serve to define what is possible in terms of implementing new flood control approaches in the Novato Creek Baylands.

Table 1 and **Figures 2 and 3** identify some of the infrastructure that is protected by or works in concert with the County's flood control efforts.

Table 1: Lower Novato Creek land and infrastructure ownership.

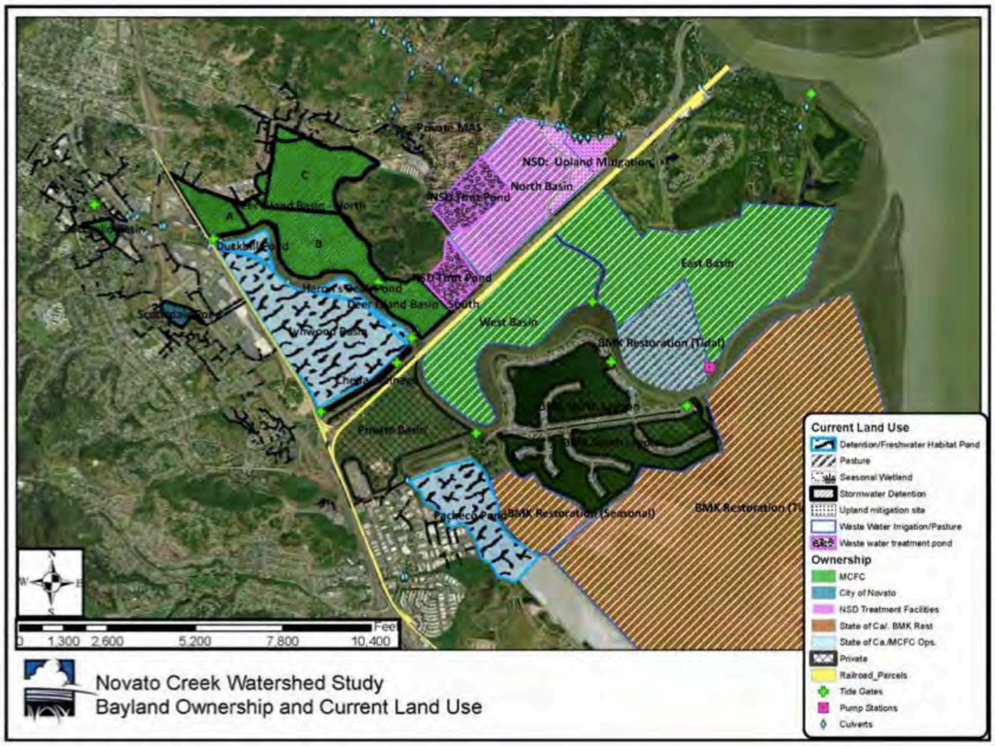
Entity	Notes
City of Novato	Storm water management
Bel Marin Keys CSD	Maintaining water quality & navigation in BMK service area
North Marin Water District	Drinking water source protection and conveyance
Novato Sanitary District	Waste water treatment
California State Lands Commission	Owner of bayland parcels
State Coastal Conservancy	Owner of bayland parcels
Private landowners	Owner of bayland parcels and levees
California Department of Fish and Wildlife	Management of nearby wildlife preserves
Caltrans	Maintenance/construction of transportation infrastructure

Figure 2: Flood control infrastructure in study area.



Sources: Marin County Department of Public Works, FEMA, SFEI

Figure 3: Novato Creek bayland ownership.



Source: Marin County Department of Public Works

Other community infrastructure includes:[11]

- 21 public and private schools
- 14 city and county facilities, including police and fire stations
- 10 medical/health care facilities
- Novato Sanitary District facilities and pipelines
- Over 30 city park facilities [12]
- Significant transportation routes, including US-101 and CA-37, that transport more than 300,000 vehicles per day and over $60 billion of goods per year[13]
- Approximately 5 million square feet of commercial and industrial office space[14,15]

[11] MarinMap GIS data, unless otherwise noted
[12] https://online.activenetwork.com/cityofnovato/Facilities/FacilitiesSearchWizard
[13] CalTrans (2015); Census Bureau (2015)
[14] Marin Economic Forum (2013)
[15] Marin Economic Forum (2014)

Economic Background

Marin County Flood District Zone 1 encompasses the entire Novato Creek watershed. Within this zone are roughly 63,000 residents, 25,000 households, 6,500 businesses with over 25,500 employees and an annual payroll of $1.2 billion.[16]

In 2014, the City of Novato reported nearly $9 billion in assessed property values. Property values in unincorporated areas within the Novato Creek watershed contribute an estimated $1 billion. Residential property values account for over 80 percent of this total. [17]

A socioeconomic profile of the Novato Creek watershed is shown in **Table 2**, below.

Table 2: Socioeconomic profile of the Novato Creek area.

Demographic profile	1980	1990	2000	2010
White	92.8%	88.9%	84.0%	80.0%
Asian	3.0%	4.0%	4.5%	5.5%
Black or African American	2.5%	3.5%	2.9%	2.8%
American Indian and Alaska Native	0.4%	0.4%	0.4%	0.6%
Native Hawaiian and Other Pacific Islander			0.2%	0.2%
Some other race			4.5%	6.7%
Two or more races			3.5%	4.2%
Hispanic or Latino (of any race)	4.2%	7.4%	11.1%	15.5%
White alone	89.8%	84.6%	78.6%	72.8%
Vulnerability Factors*				
Population living alone over age 65				13%
Population under age 18				23%
Households speaking little English				12%
Households without a vehicle				5%
Median Household Income				$78,628
Median Home Value				$750,000
Gross Domestic Product**				$5.57 billion
GDP per Capita				$88,000

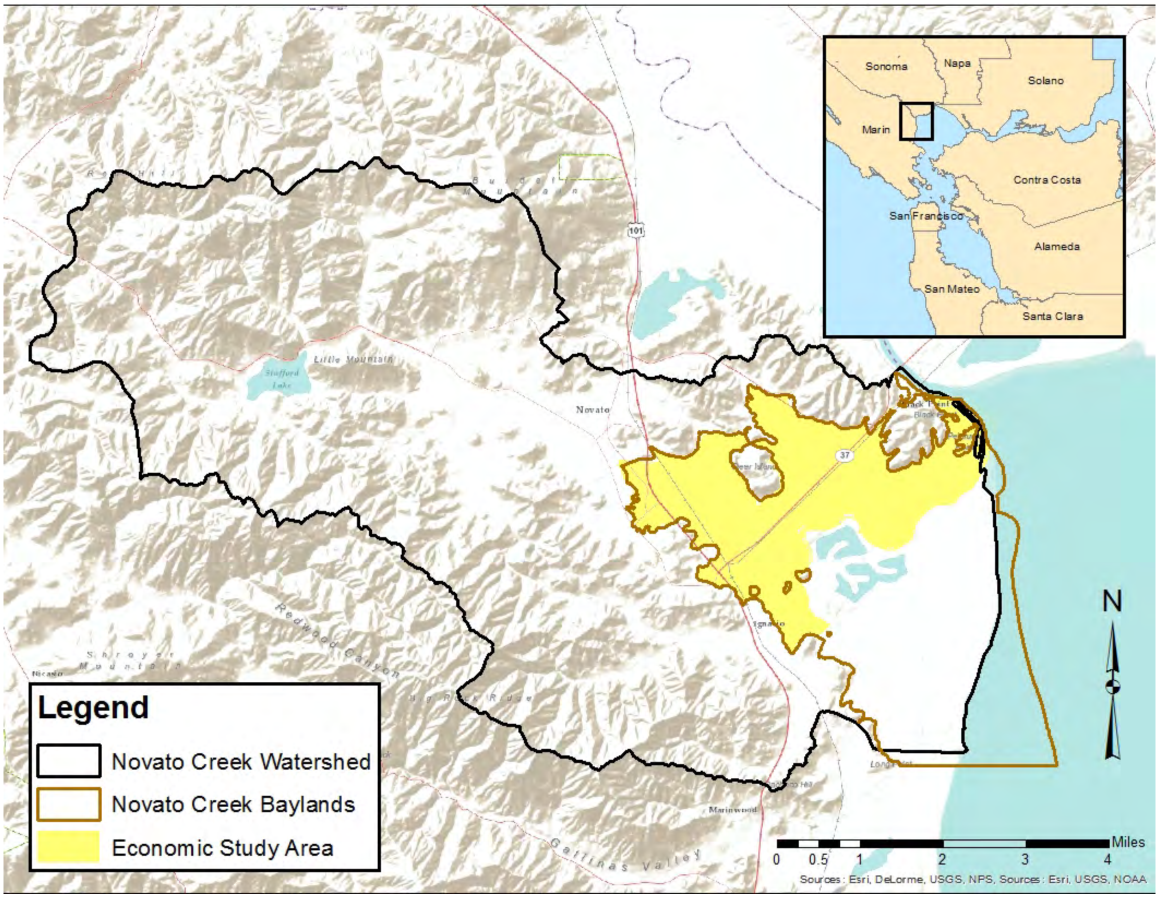
Source: U.S. Census Bureau, *Pacific Institute, **U.S. Bureau of Economic Analysis

[16] U.S. Census Bureau (2014); Novato Fire Protection District (2009)
[17] City of Novato. Adopted Budget, 2014-15

Study Area and Focus

The economic analysis focuses on the baylands of the Novato Creek watershed, as illustrated in **Figure 4**, below.

Figure 4: Novato Creek baylands and study area.



Sources: MarinMap, SFEI

The Novato Creek baylands encompass approximately 9,000 acres, over 30 percent of the entire watershed. The most prominent land cover types include farming and grazing land, marshlands, and developed areas.

The benefit-cost analysis will be limited to the area located mostly north of Novato Creek. The neighboring Bel Marin Keys Unit V (BMK-V) and Hamilton Wetlands restoration projects were conceived and (in the case of Hamilton) implemented as restoration, not flood control projects. The parcels that make up BMK-V and Hamilton are also owned and managed by different entities. The neighboring projects will instead be addressed in terms of their provision of environmental and ecosystem service benefits, but will not be included in the benefit-cost analysis.

Within the economic study area, land cover is shown in **Table 3**, below.

Table 3: Land cover types in economic study area.

Description	Total Bayland Acres	% of Total	Study Area Acres	% of Total
Developed Land	1,219	13%	1,219	29%
Farmed/Grazed Baylands	3,635	38%	1,399	33%
Woodland	45	<1%	45	1%
Diked/Managed Marsh	936	10%	927	22%
Tidal Marsh	1,112	12%	88	2%
Bay Flat	1,398	15%	81	2%
Ruderal	790	8%	155	4%
Fluvial Channel	71		71	
Lagoon	383		102	
Storage/Treatment Basin	132		116	
Total Water	586	6%	218	7%
Total	**9,606**		**4,203**	

Sources: NOAA, SFEI

Sea Level Rise Scenarios

The economic analysis takes into account a three-foot increase in sea levels by year 2100, a figure within the range of projections used in other studies in the Bay Area.[18] This scenario is intended to provide a general picture of future conditions; it is not intended to provide a definitive statement on the impacts of sea level rise on shoreline ecosystems and communities.

Historically, flooding in Novato Creek has been fluvial in nature; however, sea level rise brings another dimension to flood control in the bayland. According to Marin County's 2014 hydraulics and hydrology report for Novato Creek, higher sea levels are expected to increase the time period of inundation from high-flow storm events.[19] This suggests that an occurrence of high tides during a major storm event could result in considerably more severe flooding than the area has experienced. Adapting to this new state of affairs will require a re-evaluation of flood hazards and ways to mitigate them over the next century.

In addition to the flood protection aspects of sea level rise, the fate of tidal habitats is also a matter of concern. Ongoing research into tidal marsh response to sea level rise indicates that the accretion of marshland *may* keep up with SLR under appropriate conditions. It remains to be seen how the Novato Creek Baylands would respond to restoration efforts based on unaided processes, so to account for this uncertainty, we will evaluate different levels of intervention (e.g., placing fill material to accelerate tidal marsh formation).

[18] See, for example, Marin Countywide Plan (2005), San Francisco Bay Plan (2011), Adapting to Rising Tides (2012), National Research Council (2012)

[19] Kamman Hydrology & Engineering (2014)

For this study, we will incorporate SLR in the following ways:

1. For estimating the levee height required to protect against coastal waters (and subsequent costs of levee work)
2. For estimating the O&M costs associated with the need to move water during flood events
3. For estimating the amount of fill required to help the formation of desired habitats
4. For estimating the change in land cover (including tidal marsh migration) and associated ecosystem services

Climate Variability and Storm Severity

Recent work dealing with changing precipitation patterns in California adds another aspect to the future state of the Novato Creek watershed. A recent study has found that storm severity appears to have increased over the past 130 years in the northern San Francisco Bay Area.[20] The results illustrate one set of possibilities that would directly affect flood control planning: an increased intensity of storms, even if average annual rainfall remains the same, would put more short-term stress on flood control infrastructure. Unfortunately, there is no guidance for future storm severity that is easily translated into economic terms. For this analysis, we will presume a ten percent increase in certain O&M line item costs in the Flood Control 1.0 alternative. This would account for increased costs of pumping or in the effort required to clear channels of debris, for example.

[20] Russo, Fisher, and Winslow (2013)

Novato Creek Alternatives

This economic analysis addresses two divergent approaches to the future flood protection infrastructure in Novato Creek. These alternatives, along with their underlying assumptions, are detailed below.

Flood Control Alternatives

Flood Control 1.0 relies on reinforcing existing infrastructure, maintaining current management approaches, and increasing the scale of the current system to maintain flood protection capabilities. Considering the system does not currently function at its design capacity (50-year flood water conveyance), we omit the "no project" alternative from this analysis, instead focusing on a complete rebuilding of the levees, pump stations, and other infrastructure to not only provide flood protection from Novato Creek flooding, but also from sea level rise.

Flood Control 2.0 employs a suite of activities intended to increase tidal marsh habitat and provide additional environmental benefits, including wastewater assimilation, recreation, and aesthetic values. These activities are specific to Novato Creek; other watersheds will require different configurations based on their own unique characteristics.

Flood protection capacity

In order to make a meaningful comparison between the two approaches described below, we will assume that the level of flood protection attained from both approaches remains the same. If a particular approach results in a significant improvement in flood control as a consequence of its design, this will be noted.

Assumptions for Alternatives

The following assumptions are used to develop both alternatives:

- The study area consists of the portion of the watershed directly managed by Marin County Flood Zone 1 (Bel Marin Keys Unit V and Hamilton Wetlands are not considered in the benefit-cost calculations)
- The same level of flood protection is maintained in all scenarios

Assumptions for the two alternatives discussed here are shown in **Table 4**, below.

Table 4: Assumptions for flood control alternatives.

Flood Control 1.0	Flood Control 2.0
Existing levees, pump stations, tide gates, and other existing gray infrastructure are **maintained, rehabilitated, and replaced** to the extent they retain their functionality	Existing levees, pump stations, tide gates, and other existing gray infrastructure are expected to be **modified or removed** in order to reconnect lower Novato Creek with its historical floodplain
Additional infrastructure is built to address sea level rise (e.g., levees will need to be raised by 2-to-3 feet, pump station capacity will need to be increased to address more severe storm events)	Additional infrastructure may be required to address sea level rise, but will be constructed to minimize adverse impacts on tidal ecosystems
Operations in the basins and in the channel (e.g., dredging) continue, based on historical practices and frequency	Regular dredging is no longer required to maintain adequate flood conveyance, though O&M costs for active stream sediment management are incurred in later years
Future costs resemble the reference period (2006-2014) from which budget details are available	Future costs differ from "Flood Control 1.0" to the degree that certain activities will no longer be required.
Land cover remains similar to current conditions where protected by coastal levees; bayward lands convert to subtidal/open water	Land cover will adjust to rising sea levels (e.g. marsh migration)
O&M costs for pump stations and utilities will increase as these facilities are operated at higher levels in response to more severe storms.	O&M costs for levees, pump stations, and other flood control infrastructure will be eliminated to the extent these are no longer used

Flood Control 2.0 concepts: A description

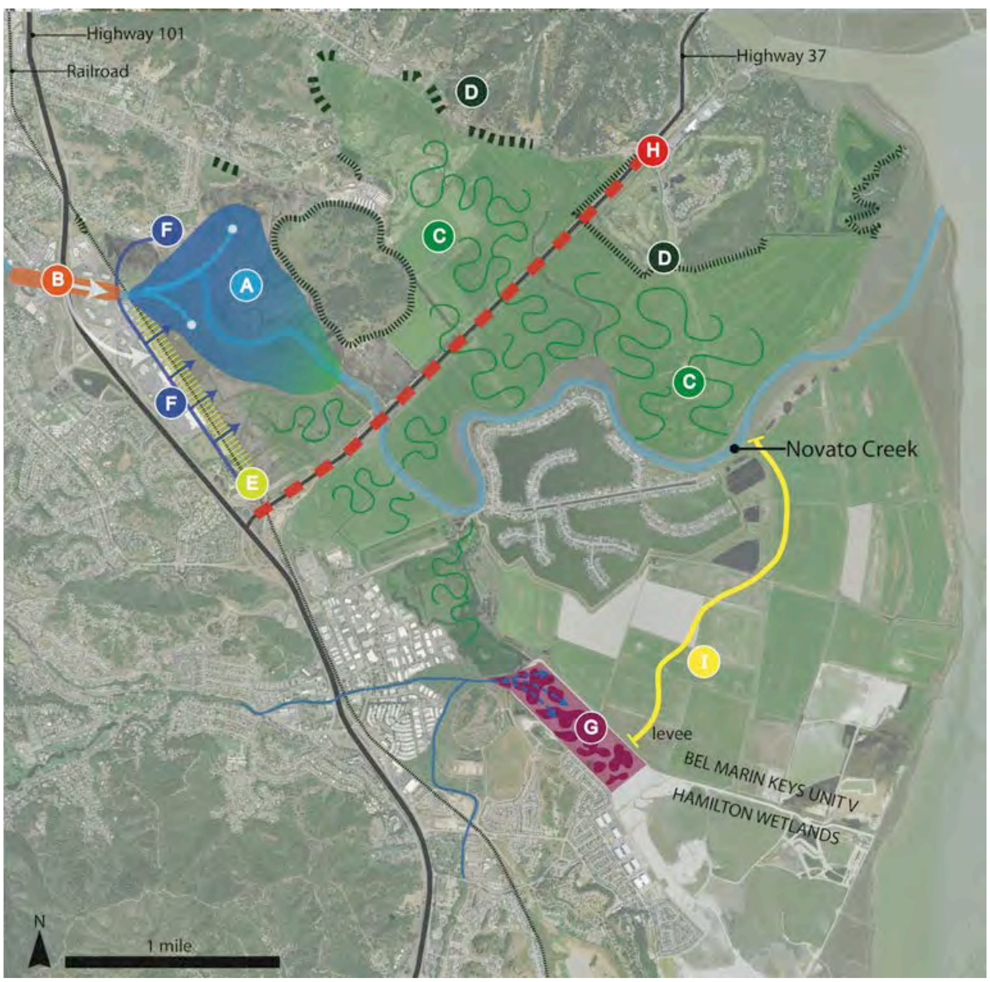
The *Novato Creek Baylands Vision 2100* details several management concepts aimed at re-establishing connections between lower Novato Creek and adjacent baylands. These concepts employ a combination of measures, such as removing flood control levees, restoring transitional zones, reconstructing wetland features that are known to have existed in the area, and modifying a key regional transportation route.

Two guiding principles have also been articulated:

- Solutions must be resilient to climate change, multi-benefit, and self-sustaining
- Sediment that must be managed should have some local beneficial reuse for bayland restoration efforts

The following concepts, depicted in **Figure 5** and described below, have been identified as possible approaches to incorporating ecosystem restoration into flood control efforts.

Figure 5: Flood Control 2.0 strategies in Novato Creek.



Source: SFEI - Novato Creek Baylands Vision 2100

Concept A –Depositional Plain

Immediately downstream of the SMART railroad crossing lies an area of approximately 660 acres, currently occupied by the Lynwood and Deer Island basins, that could be managed specifically as a depositional plain for the creek's sediment load. This concept could employ natural and managed accumulation of sediment to permit deltaic distributary formation and channel switching, while helping move fine sediment out of the channel. Flood pulses could help build marsh plain in the areas currently used and Deer Island, increasing local resilience to sea level rise.

This concept would support efforts to protect developed areas west of the railroad corridor and Highway 101 by providing a steady supply of sediment to build and maintain features such as a multi-purpose horizontal levee (Concepts E and F).

Concept B – Active Stream Sediment Management

This concept specifically relies on actively transporting sediment via slurry or by truck to the depositional plain described in Concept A above.

Concept C – Tidal Marsh With Dendritic Channel Networks

Reconnecting Novato Creek to adjacent baylands to the north could serve to re-establish over 1,800 acres of functioning marsh plain and complex tidal channel networks. The area between CA-37 and Novato Creek has experienced less subsidence compared to neighboring zones, which may allow for a more rapid (and less costly) transformation of these lands to functioning tidal marsh.

Concept D – Tidal-Terrestrial Transition Zone

At the margins of the baylands are a number of opportunities to reconnect tidal marsh to adjacent undeveloped grassland and oak woodland areas. This would increase high tide refugia habitat for tidal marsh mammals such as salt marsh harvest mice, and also provides opportunity for inland marsh migration in response to sea level rise.

Concept E – Horizontal Levee

A wide, gently-sloped coastal flood protection levee along the western edge of the Novato Creek Baylands could provide multiple benefits, including protection of critical infrastructure from tidal influence, provision of transitional zone habitats, inland marsh migration in response to sea level rise, and beneficial reuse opportunities for dredged sediment. The mile-long levee would be located along the SMART railroad alignment between Novato Creek on the north and the US-101 and CA-37 interchange on the south.

Concept F – Permeable Seepage Levee

Treated wastewater from Novato Sanitary District facilities could be redirected to permeable portions of a horizontal levee. This would allow natural processes to sequester and process nutrients and could promote the establishment of freshwater marsh habitat along the levee. This feature would be built into the horizontal levee discussed above.

Concept G – Marsh Ponds and Pannes

There may be opportunities to re-establish shallow pond habitats with direct freshwater inflow in various areas throughout the baylands. These would serve to provide additional shorebird and waterfowl habitat, along with potential areas for reintroducing extirpated species such as the tidewater goby.

This concept, while not specifically a flood control activity, is made possible by some of the other activities described here, and offers the opportunity to create additional valuable habitat in conjunction with flood protection elements.

Concept H – Highway 37 Causeway

There appears to be general agreement among local, regional, and state-level stakeholders that Highway 37 will need to be raised in the near future. While discussions are currently in the planning stage, the options for raising the highway range between raising the embankment through the Novasto Creek baylands and constructing a completely elevated causeway that would allow tidal influence to return to the areas north of the highway.

Converting the approximately 2.5-mile stretch of CA-37 between the Petaluma River and US-101 into an elevated causeway would open up an additional 1,300 acres to tidal marsh restoration, in addition to protecting this important transportation corridor from future sea level rise.

The calculations in this study are based on the cost differential between an embankment and an elevated causeway. The rationale for this is that the highway will be raised regardless of what Marin County chooses to do in terms of flood protection. The benefit-cost calculation, then, would be based on the *additional* cost of a fully-elevated highway.

Concept I – Coordinate With Existing Restoration Plans

The Bel Marin Keys Unit V and Hamilton Wetlands restoration projects in the southern Novato Creek Baylands are at varying stages of planning and implementation. Given their long histories and the fact that they are restoration-only projects owned and managed by other entities, they do not fit neatly into the Flood Control 2.0 framework as it applies to Novato Creek flood control. As such, these projects will not be included in the benefit-cost calculations for the County's flood control efforts, though the combined bayland restoration benefits of these projects will be discussed at the conclusion of this report.

Changes in dredging frequency

One of the motivations for the active stream sediment management and depositional plain concepts is that they will eliminate the need for regular dredging by providing a means to move fine sediment to a depositional plain on lands just downstream of the bottleneck. With some uncertainty about the efficacy of these measures, we will assume that dredging will remain necessary, though at a less frequent interval (every 12 years, in this case).

Benefit-Cost Analysis of Novato Creek Alternatives

Benefit and Cost Categories

The approach to evaluating Flood Control alternatives in Novato Creek is based on a generalized benefit-cost analysis framework, which looks at the lifetime benefits and costs of project alternatives. While it is similar to the methods used by the U.S. Army Corps of Engineers (USACE),[21] we also include elements from approaches used by the Federal Emergency Management Agency (FEMA)[22] and the California Department of Water Resources (DWR)[23] to the extent they provide useful information about the alternatives.

As discussed in the previous section, we analyze two alternatives in this report:

A. **Flood Control 1.0**: a continuation of past practices based on single-purpose (i.e., flood water conveyance) approach
B. **Flood Control 2.0**: a multi-benefit approach that employs tidal and ecological processes to attain comparable levels of flood water management, provide environmental and social benefits, and increase resilience to sea level rise

We evaluate the following benefit and cost categories, based on USACE Principles and Guidelines:

I. National Economic Development (i.e., project benefits)

- Avoided damages to building structures and contents from flooding events
- Avoided emergency response and cleanup costs
- Avoided transportation delays or detours
- Avoided costs of infrastructure upgrades (not estimated)
- Change in recreational values

II. Regional Economic Development (not considered by USACE)

- Changes in property values and taxes (not estimated)
- Changes in local employment and business activity (not estimated)
- Avoided lost business income

III. Environmental Quality (considered by USACE, but not in monetary terms)

- Net changes in ecosystem/land cover due to project
- Effects on fish and wildlife, such as water quality changes
- Carbon sequestration in saltwater marshes

[21] USACE (1983)
[22] FEMA (2009)
[23] California Department of Water Resources (2009)

IV. Other Social Effects (Considered by USACE, but not in monetary terms)

Other positive effects resulting from a project may be difficult to measure or quantify, such as improved human well-being due to enhanced habitat, or protection of historical and cultural resources. These are not explored in detail in this report.

V. National costs

- Operation, maintenance (O&M), and replacement costs
- Capital (i.e., construction) costs

Each of these categories is discussed in more detail below.

I. National Economic Development

In order to facilitate comparison, the benefits of Flood Control 1.0 and 2.0 are assumed to be largely the same for most elements of the National Economic Development account. These elements include:

Avoided damages to building structures and contents from flooding events

One of the common measures of the economic value of avoided flood risk is termed **Average Annual Loss** (AAL). This represents the expected total losses in a flood-prone area over a specified period of time (often 50 to 100 years), expressed in annual terms. The benefit, then, is the extent to which a flood risk management project prevents these losses from occurring.

USACE and FEMA follow detailed procedures to estimate AAL in a given floodplain, including property value surveys, interviews with local contractors, and engineering analyses of affected structures. We employ a simplified method based on this procedure, using the detailed damage report from the 1982 flood as a basis for our calculations.

The USACE damage report for the 1982 flooding in Novato includes the categories shown in **Table 5**, below. We take the property damage figures and adjust them to 2014 dollars using the index of historical construction costs compiled by RSMeans.[24] We then add the value of the contents of residential and commercial structures, estimated at 50 percent and 100 percent of structure value, respectively. Streambank erosion damages were adjusted to current dollars using the State and Local government price index (S&L) measured by the U.S. Bureau of Economic Analysis.[25]

The right-most column in Table 5 adjusts the damages based on the amount of growth that has occurred in the watershed since 1982. The number of homes and the square footage of commercial real estate have increased an estimated 38 percent over the past three decades, which implies that a flooding event similar to that of 1982 would affect a larger number of structures.

Table 5: Damage calculations from 1982 flood.

Category	1982 dollars	2014 dollars	Accounting for Growth (38%)
Residential-Structures	$18,976,000	$51,477,000	$71,319,000
Residential-Contents		$25,738,000	$35,660,000
Commercial-Structures	$2,511,000	$6,812,000	$9,437,000
Commercial-Contents		$6,812,000	$9,437,000
Streambank Erosion	$250,000	$733,000	$733,000
Total	$21,737,000	$91,572,000	$126,586,000

Sources: USACE, RSMeans, U.S. Bureau of Economic Analysis, City of Novato, Census Bureau

[24] RSMeans (2014)
[25] BEA (2015)

Table 6 summarizes the expected damages from four different flood recurrence intervals: 150 years (i.e., the 1982 flood), 50 years, 20 years, and 10 years. A 150-year event has a 33 percent probability of occurring in the 50-year study period under consideration here, so the $126.6 million figure from Table 5 is adjusted accordingly. Expected losses from more frequent events are estimated by the ratio of damage claims shown in the Appendix. In other words, a 50-year event is expected to cause roughly 33 percent the damages of a 150-year event, a 20-year event is expected to cause 13 percent, and a 10-year event is expected to cause roughly 7 percent of the damages from a 150-year event. These losses are then totaled and converted into annual values based on a 3.375 percent discount rate.

Since the design level of protection for the Novato Creek Flood Control Project is for a 50-year event, we only count the avoided losses for the 50-, 20-, and 10-year events. The AAL estimated by this method is $2.5 million.

Table 6: Average Annual Loss Calculations (2014 dollars; based on 50-year period).

Recurrence Interval	Damage / Event	Event Exceedance Prob.	Expected Annual Value
150yr	$125,852,500	0.0067	$839,000
50yr	$41,951,000	0.02	$839,000
20yr	$16,360,825	0.05	$818,000
10yr	$8,432,000	0.10	$843,000
Annual value of 50-year protection			**$2,517,000**
NPV over 50 years			**$60,390,000**

Sources: Calculated from data from USACE, FEMA, USGS

Avoided public costs (emergency response, cleanup, and infrastructure upgrades)

While specific data are not available for the Novato Creek watershed, there were countywide estimates from the December 2014 storms that can be used as a lower-bound estimate of avoided costs. According to the County Administrator's office, emergency response and cleanup costs associated with flooding were approximately $307,000. Assuming that roughly 25 percent of the costs were located in the vicinity of Novato Creek, then the estimated costs of a ten-year event in this category would be approximately $77,000, or an expected value of $7,700 per year.

If a flood control project makes it possible to *avoid* future infrastructure upgrades (such as a bridge that no would longer need to be raised if a new levee prevents high water from reaching it), then the avoided costs may be counted as a benefit.

The flood control system in Novato Creek protects critical infrastructure, such as the Novato Sanitary District's (NSD) wastewater treatment plant and conveyance facilities. The wastewater treatment plant alone represents about $90 million in asset value, and it has been identified as a potential facility at risk due to sea level rise.[26] At this point in time, it is

[26] City of Novato (2015)

not clear whether NSD has specific plans to address sea level rise by building flood protection features for its facilities, and there are no estimates to provide any guidance in terms of how much these activities would costs. Accordingly, **a value for this category is not estimated**, with the acknowledgement that it will result in an understatement of the National Economic Development benefits.

Avoided transportation delays or detours

The costs of traffic interruptions due to flooding are measured here in terms of the time it takes for floodwaters to recede, and the corresponding value of the time lost due to impassible roads. Like the avoided costs of emergency response and cleanup discussed above, we estimate a lower bound for the costs of transportation delays or detours.

Daily vehicle counts on the two major highways in Novato (US-101 and CA-37) are used as a proxy for all vehicle travel in the Novato Creek floodplain. We then estimate the costs of a four-hour disruption of traffic on these two throughways, as shown in **Table 7** below.

Table 7: Estimated transportation delays due to flooding on highways 101 and 37.

	Autos	Trucks	All
Vehicle count: CA-37	35,627	1,373	37,000
Vehicle count: US-101	129,033	5,967	135,000
Total Vehicles	164,660	7,340	172,000
Vehicles affected by 8-hr delay	**54,887**	**2,447**	**57,333**
Value of time/hr	$13.28	$35.24	
Value of lost time per event	**$728,895**	**$86,220**	**$815,115**

Sources: Caltrans, U.S. Department of Transportation

Change in recreational values

Recreational visit estimates are derived from multiple sources: reports from the San Francisco Bay Trail project, Marin County Open Space District, and a 2013 survey of residents of southern Novato. These estimates are reported in a visitors-per-day format, and are assigned daily values based on USACE guidance, as shown in **Table 8** below. Detailed visitor-day calculations can be found in the Appendix.

The primary drivers of the difference between the two alternatives are the enhanced tidal marsh habitat of Flood Control 2.0 and the projected loss of tidal habitat under sea level rise. Using the unit/day approach, which adjusts the value of one day's visit based on site qualities, the Flood Control 1.0 alternative would result in a value of $6.12 per day, while the Flood Control 2.0 alternative would yield a value of $7.58 per day.

Visitor estimates are based on an assumption that the number of bayland visitors increases at a rate of 1.1 percent per year under the FC 2.0 alternative (consistent with current trends and projections) due to the development of new recreational facilities that would not exist in the FC 1.0 alternative.

Table 8: Estimated recreational values of Novato Creek baylands.

Est. Usage	FC 1.0			FC 2.0		
	Visits/year	Value/Day	Annual Value	Visits/year	Value/Day	Annual Value
Low	293,400	$5.78	$1.70 million	400,200	$6.60	$2.64 million
Mid	326,000	$5.78	$1.88 million	444,600	$6.60	$2.94 million
High	358,600	$5.78	$2.07 million	489,100	$6.60	$3.23 million

* Compared to 2014 baseline

Sources: Marin County Open Space District, SF Bay Trail, City of Novato, USACE

Summary of National Economic Development benefits

The National Economic Development account is summarized in **Tables 9a and 9b**, below. All of the summary tables in the body of the report are for the 50-year time horizon; the 85-year figures are reported in the Appendix.

Table 9: National Economic Development summary (millions of 2014 dollars).

a. Flood Control 1.0

Item	Low		Mid		High	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Avoided damages to structures and contents	2.27	54.35	2.52	60.39	3.27	78.51
Avoided public costs	0.07	1.75	0.08	1.94	0.11	2.53
Avoided transportation delays or detours	0.07	1.76	0.08	1.96	0.11	2.54
Recreational values	1.70	40.69	1.88	45.21	2.02	49.73
Total	**4.11**	**98.55**	**4.56**	**109.5**	**5.51**	**133.31**

b. Flood Control 2.0

Item	Low		Mid		High	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Avoided damages to structures and contents	2.27	54.35	2.52	60.39	3.27	78.51
Avoided public costs	0.07	1.75	0.08	1.94	0.11	2.53
Avoided transportation delays or detours	0.07	1.76	0.08	1.96	0.11	2.54
Recreational values	2.64	63.40	2.94	70.45	3.23	77.49
Total	**5.05**	**121.26**	**5.62**	**134.74**	**6.72**	**161.07**

II. Regional Economic Benefits and Costs

We evaluate one category of regional economic benefits: the loss of agricultural income in areas that will become tidal marsh in the Flood Control 2.0 alternative.

Changes in local business activity: lost agricultural income

There are approximately 900 farmed acres in the Novato Creek study area, with an additional 2,200 acres in the Bel Marin Keys Unit V project area, primarily forage grasses. Both areas are the sites of planned tidal marsh restoration, which would permanently remove the land from agricultural production and grazing.

The economic value of agricultural land in the study area is estimated by the market value of the crop grown on it – in this case, we use the average price for oat hay (Solano County basis). Based on acreage, yield, and price trends, and farming the land every year for the next 50 years, the net present value of grass production in the baylands is estimated to total between $10.1 and $16.9 million in the FC 1.0 alternative. Agricultural revenues decline to zero in year 6 of the FC 2.0 alternative as tidal marsh is restored on the agricultural lands.

A note on other Regional Economic Development categories

The Regional Economic Development account includes other categories, such as changes in property values, taxes, and local employment and business activity. These are not estimated here, primarily because of limited economic data at the watershed level. Moreover, the literature on the recovery of communities after natural disasters indicates that business activity often makes up for lost time, rebounding to pre-existing levels as long as critical infrastructure remains in place after the disaster. Accordingly, local effects are assumed to be transient over the time period of this analysis and are not evaluated.

Summary of Regional Economic Development benefits and costs

The Regional Economic Development account is summarized in **Table 10**, below.

Table 10: Regional Economic Development summary (millions of 2014 dollars).

a. Flood Control 1.0

Item	Low		Mid		High	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Annual farm income	0.42	10.06	0.56	13.42	0.70	16.91
Total	**0.42**	**10.06**	**0.56**	**13.42**	**0.70**	**16.91**

*b. Flood Control 2.0**

Item	Low		Mid		High	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Annual farm income	0.42	1.88	0.56	2.51	0.70	3.16
Total	**0.42**	**1.88**	**0.56**	**2.51**	**0.70**	**3.16**

** Production phased out starting year 6*

III. Environmental Benefits and Ecosystem Services

Net changes in ecosystem/land cover due to project

The net change in the acreage of the target ecosystem in Novato Creek – tidal marsh – is the primary driver of the environmental benefits analysis. As discussed above, current land cover in the Novato Creek baylands is a combination of developed lands, disturbed wetlands, and simplified stream channel networks.

In the Flood Control 1.0 alternative, land cover is forecast to remain largely the same as today. Some conversion to subtidal and aquatic habitat is anticipated due to sea level rise, though this will be limited due to the assumed raising and reinforcing of the levee system around Novato Creek.

Flood Control 2.0 land cover projections are based on increased tidal marsh acreage to levels resembling pre-development conditions, as shown in **Table 11** below.

Table 11: Historical, modern, and future land cover in Novato Creek Baylands.

	Historical	Modern (2015)	Future (2100)
Tidal marsh area (acres)	4,490	620	3,000 to 5,100
Creek length (linear miles)			
Mainstem	5.4	6.4	6.4
Tributaries	98.0	6.0	82 to 139
Transition zones (linear miles)			
Narrow (hillslope => marsh transition) 5:1 slope	16.2	1.4	6.3
Wide (alluvium => marsh transition) 20:1 slope	6.6	0.0	1.5
Seepage Levee	0.0	0.0	1.1

Source: SFEI (acreage different than Table 3 due to slightly different definition of “bayland” in GIS data sets)

A review of the ecosystem service valuation literature (detailed in the Appendix) provides a range of values for tidal habitat. These are summarized in **Table 12**, below. Flood risk reduction benefits of tidal marshes are measured, similar to the Average Annual Loss estimates discussed above, by their ability to protect against flood damage. Water quality can be directly measured (with corresponding economic values discussed below). Aesthetic and amenity values are commonly measured by the effect of open space and environmental services on housing values. The economic of value of primary production and nursery services can be expressed by the role they play in the life cycle of economically-values species that are consumed (e.g. salmon) in their enjoyment by bird watchers and outdoor enthusiasts. Carbon sequestration values are of a more recent vintage, and work is currently underway to understand the atmospheric regulation services provided by saltwater habitats. Finally, option, bequest, and existence values are difficult to define, let alone measure, though the values from a small number of studies are reported here.

Table 12: Value (in 2014 dollars per acre) of tidal habitat*

Value per acre (2014 dollars)	Low	Mean	High
Flood risk reduction	$0	$14,744	$39,640
Water quality	$0	$10,056	$25.518
Aesthetic/amenity	$0	$6,181	$12,938
Primary production/nursery	$0	$799	$2,416
Option/bequest/existence	$24	$44	$65
Carbon sequestration	$16	$46	$188

See Appendix for sources and methods

*Excludes recreational value, which was calculated separately.

Effects on fish and wildlife, such as water quality changes

The effects of tidal marsh restoration on water quality are captured by the figures in Table 12 as well. The direct benefits of water quality are often measured in terms of supporting a specified level of water quality, such as "fishable" or "swimmable" (e.g. the "Water Quality Ladder"). The value of water quality is also implicit in aesthetic values, nursery services, and also option, bequest, and existence values.

Carbon sequestration in saltwater marshes

Carbon pricing has the benefit of being priced by markets, though valuing carbon is still a work in progress in California. Recent studies have looked at the potential of salt marshes to sequester atmospheric carbon in the effort to mitigate greenhouse gas emissions. Salt marshes are estimated to store between one-half to one-and-a-half tons per acre per year, primarily in the form of soil organic matter.[27]

We use three carbon prices in the ecosystem benefit calculations here. The low estimate, $12 per ton of carbon sequestered ($16/acre) comes from the results of a recent carbon allowance auction conducted by the California Air Resources Board under the state's cap-and-trade system. An intermediate value ($46 per acre) is provided by the federal government's Interagency Working Group on the Social Cost of Carbon. A markedly higher value ($188 per acre) is provided by recent work from researchers at Stanford University.

Total benefits of flood protection

The economic benefits of the two flood control alternatives are summarized in **Table 13** below. The benefits are close in magnitude, though FC 2.0 provides a slightly higher net present value on the strength of higher recreational and ecosystem service values.

Extending the time period of the analysis through 2100 increases the benefit-cost ratios for all of the Flood Control 2.0 scenarios, as we will see in the sensitivity analysis. This happens when the benefits take time to accrue, as is the case with ecosystem restoration.

[27] McLeod, et al. (2011)

Table 13: Summary of economic benefits of flood control alternatives ($ millions)

a. Flood Control 1.0

	Low		Mid		High	
I. National Economic	Annual	NPV	Annual	NPV	Annual	NPV
Avoided losses	2.27	54.35	2.52	60.39	3.27	78.51
Avoided emergency response	0.07	1.75	0.08	1.94	0.11	2.53
Avoided transportation delay	0.07	1.76	0.08	1.96	0.11	2.54
Recreational benefits	1.70	40.69	1.88	45.21	2.02	49.73
Total National	**4.11**	**98.55**	**4.56**	**109.5**	**5.51**	**133.31**
II. Regional Economic	Annual	NPV	Annual	NPV	Annual	NPV
Farm income	0.42	10.06	0.56	13.42	0.70	16.91
Total Regional	**0.42**	**10.06**	**0.56**	**13.42**	**0.70**	**16.91**
III. Environmental Quality	Annual	NPV	Annual	NPV	Annual	NPV
Ecosystem service values	0.01	0.15	5.42	130.13	13.84	332.16
Total Environmental	**0.01**	**0.15**	**5.42**	**130.13**	**13.84**	**332.16**
Total Benefits	**4.53**	**108.77**	**10.55**	**253.05**	**20.10**	**482.38**

b. Flood Control 2.0

	Low		Mid		High	
I. National Economic	Annual	NPV	Annual	NPV	Annual	NPV
Avoided losses	2.27	54.35	2.52	60.39	3.27	78.51
Avoided emergency response	0.07	1.75	0.08	1.94	0.11	2.53
Avoided transportation delay	0.07	1.76	0.08	1.96	0.11	2.54
Recreational benefits	2.64	63.40	2.94	70.45	3.23	77.49
Total National	**5.05**	**121.26**	**5.62**	**134.74**	**6.72**	**161.07**
II. Regional Economic	Annual	NPV	Annual	NPV	Annual	NPV
Farm income	0.42	1.88	0.56	2.51	0.70	3.16
Total Regional	**0.42**	**1.88**	**0.56**	**2.51**	**0.70**	**3.16**
III. Environmental Quality	Annual	NPV	Annual	NPV	Annual	NPV
Ecosystem service values	0.01	0.17	6.13	147.00	15.60	374.37
Total Environmental	**0.01**	**0.17**	**6.13**	**147.00**	**15.60**	**374.37**
Total Benefits	**5.48**	**123.32**	**12.30**	**284.25**	**23.02**	**538.61**

IV. Other Social Effects

As mentioned previously, these impacts are not estimated in this analysis.

V. National costs

The costs associated with each flood control alternative are discussed in the following section.

Operations and Maintenance

O&M cost projections are based on a review of seven years of Marin County Flood Zone 1 budgets (2008-2014). Approximately 25 line items from these budgets were grouped into the following categories:

- Personnel
- Dredging Projects
- Facility Operations
- Maintenance and Repair-Equipment
- Maintenance and Repair-Land & Buildings
- Utilities
- Other Services and Supplies

Future O&M estimates are based on the following assumptions:

- Personnel costs: Staff salaries total approx. $1 million in 2014. Professional service costs are based on the 7-year average.
- Pump stations: 4 pump stations, major work occurs every 8 years/station at $50,000 per project. Maintenance is staggered so work occurs on one station every other year.
- Dredging: Occurs every 4 years, roughly 40,000 CY per event. Dredging costs based on SFEI data. Planning costs based on 2008 and 2012 events. Permitting costs based on 7-year average.
- Facility Operations: $100,000/year for pump stations.
- Maintenance & Repair-Equipment: 7 pumps. Maintenance performed on one pump per year. Miscellaneous based on 7-year average.
- Maintenance & Repair-Land & Buildings: Levee repair required every 10 years at $1.5 million (based on 2014 cost estimates). Tree service based on 7-year average. Veg maintenance and monitoring based on contracted costs.
- Utilities: County staff estimate.
- Other Services & Supplies: Based on 7-year average

Annual O&M costs for County Flood Zone #1/Novato Creek are shown in **Table 14** below, along with an estimate of the costs that are believed to be associated only with the baylands.

Table 14: Baseline operations & maintenance costs, Novato Creek (Flood Zone #1).

Item	Novato Creek - Total	Novato Creek - Baylands
Personnel		
Staff Time	$1,000,000	$500,000
Professional Services	$110,000	$55,000
Total – Personnel	**$1,110,000**	**$555,000**
Dredging Projects - Annualized (based on 4-yr occurrence)		
Planning and Studies	$6,250	$6,250
Permitting	$3,000	$3,000
Dredging Activities	$375,000	$375,000
Mitigation	$5,000	$5,000
Total – Dredging (annualized)	**$389,250**	**$389,250**
Facility Operations		
Pump Station Operations (ends 2035)	$100,000	$100,000
Slurry Transport for Active Sediment Management (begins 2036)	$100,000	$100,000
Total - Facility Operations	**$100,000**	**$100,000**
Maintenance & Repair - Equipment		
Pump Maintenance	$25,000	$25,000
Miscellaneous Equip. Repair	$7,500	$7,500
Total Maint. & Repair-Equip.	**$32,500**	**$32,500**
Maintenance & Repair - Land & Buildings		
Levee Repair - Annualized ($1.5 million/10 yrs)	$150,000	$150,000
Pump Station Maintenance Repair	$25,000	$25,000
Tree Service & Fence Repair	$14,000	$7,000
Vegetation Maintenance & Monitoring	$202,000	$101,000
Miscellaneous Land & Bldg Repair	$29,000	$14,500
Total Maint. & Repair-Land & Bldgs.	**$450,000**	**$327,500**
Other O&M		
Utilities (Electricity)	$15,000	$15,000
Other Services & Supplies	$28,000	$14,000
Total - Other O&M	**$43,000**	**$29,000**
Grand Total - O&M (annualized)	**$2,094,750**	**$1,403,250**

Source: Marin County

Future O&M Scenarios

Annual O&M costs are projected through 2100 for both alternatives. Future costs do not reflect inflation, due to the use of a real (as opposed to nominal) discount rate. As with the benefits, the NPV of the cost of each alternative is expressed in current (2014) dollars. The assumptions of the two alternatives are illustrated in **Table 15** below.

Table 15: Expected change in O&M costs of flood control alternatives.

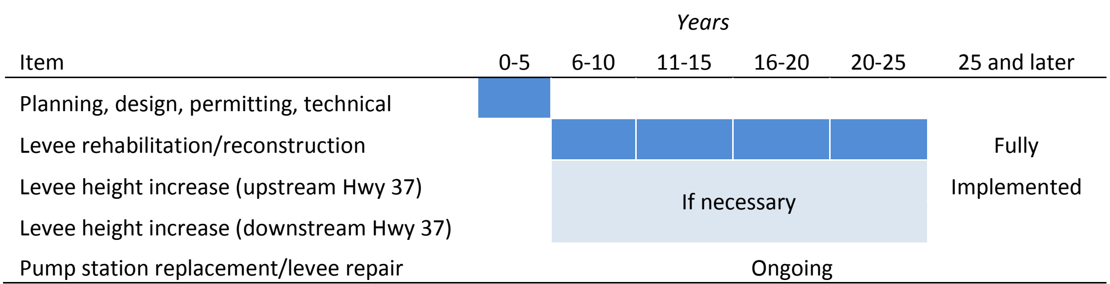
Item	FC 1.0	FC 2.0
Staff Time Professional Services	No change	No change
Dredging Projects		
Planning & Studies Permitting Construction Mitigation	No change	Dredging frequency decreases to 1X every 12 years in 2037
Facility Operations		
Pump Station Operations	No change	75% decrease in year 2025 (three pump stations removed w/levees)
Slurry Transport for Active Sediment Management	No change	$15/CY starting in 2036; assume 4k-8k CY per year
Maintenance & Repair – Equipment		
Pump Maintenance	10% increase beginning in 2050 due to increased use/more severe storm events	75% decrease in year 2025 (three pump stations removed w/levees)
Miscellaneous Equip. Repair	No change	No change
Maintenance & Repair - Land & Buildings		
Levee Repair	Decrease to zero in 2030 as levee reconstruction begins, resumes in 2050 as repairs are once again needed	37.5% decrease in 2025 due to removal of north levee betw Hwy 37 and Bay
Pump Station Maintenance & Repair	10% increase beginning in 2050 due to increased use/more severe storm events	75% decrease in year 2025 (three pump stations removed w/levees)
Tree Service & Fence Repair	No change	No change
Veg. Maintenance & Monitoring	No change	No change
Misc. Land & Bldg Repair	No change	No change
Other		
Utilities - Electricity	10% increase beginning in 2050 due to increased use/more severe storm events	75% decrease in year 2025 (three pump stations removed w/levees)
Other Services & Supplies	No change	No change

Capital Costs: Flood Control 1.0

Driven by the need to protect the community from flood risks in a time of rising sea levels, the Flood Control 1.0 alternative consists of scaling up and reinforcing the system of levees, basins, and pump stations that has been constructed over the years.

Both flood control alternatives are evaluated based on an assumption that construction activities will begin in the year 2020, due to planning, permitting, and financing issues. For the Flood Control 1.0 alternative, levees will be reinforced or rebuilt to more stringent specifications that will be able to accommodate increased creek flooding and sea level rise. Work will be phased in over approximately 25 years. The presumed timeline is shown in **Figure 6**, below.

Figure 6: Flood Control 1.0 implementation.



Note on Highway 37: There appears to be a consensus among regional stakeholders and Caltrans that Highway 37 will require work in the coming years to protect the route from flooding. Options for addressing this problem included in this analysis are: 1) raising the highway on its existing embankment and 2) constructing an elevated causeway that would allow tidal influence to return to the floodplain north of the highway. Raising the embankment would be the least expensive option, but would foreclose on any meaningful restoration efforts for the northern portion of the baylands.

The FC 1.0 analysis presumes that Highway 37 will be raised on the existing right-of-way, with minimal attention given to restoring tidal action to historical habitat upstream.

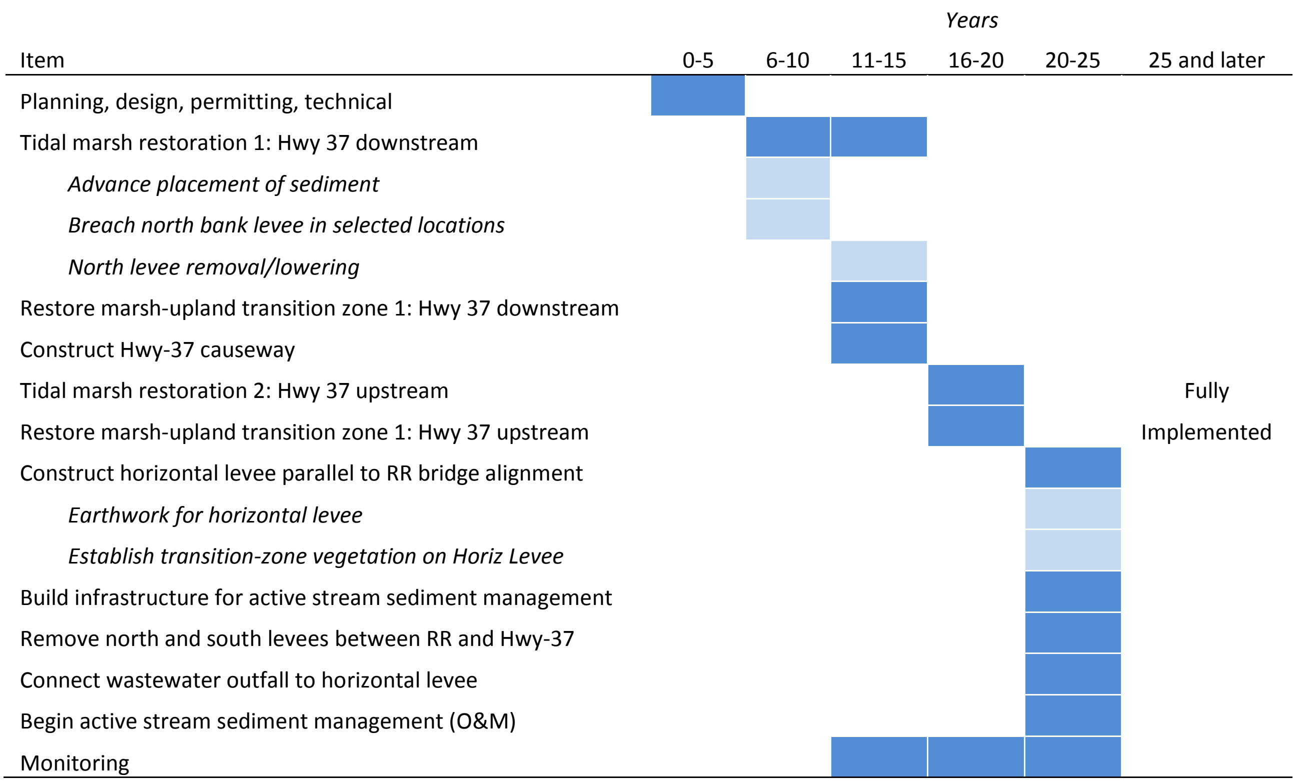
The benefit-cost analysis proceeds on the assumption that Flood Control 2.0 compatibility is represented by the difference in costs between raising the highway on an embankment and constructing a fully-elevated viaduct. This difference is estimated between $180-$265 million (2014 dollars).

Recognizing that Novato Creek represents a unique challenge due to the highway running across the floodplain, we also report the benefit-cost calculations *without* the highway costs. This illustrates how FC 2.0 approaches would measure up in areas without such constraints.

Capital Costs: Flood Control 2.0

Contemporary projects in the baylands, such as the Hamilton Wetlands restoration project, have made extensive use of dredged material to build elevations in formerly diked areas prior to breaching levees to restore tidal influence to the parcels. The Bel Marin Keys Unit V (BMK-V) restoration project, currently waiting to proceed in the area south of Novato Creek, will require approximately 13.8 million cubic yards of dredged material (at a cost upwards of $140 million) to raise subsided lands to elevations sufficient to permit the reestablishment of habitat. The presumed timeline is shown in **Figure 7**, below.

Figure 7: Flood Control 2.0 implementation.

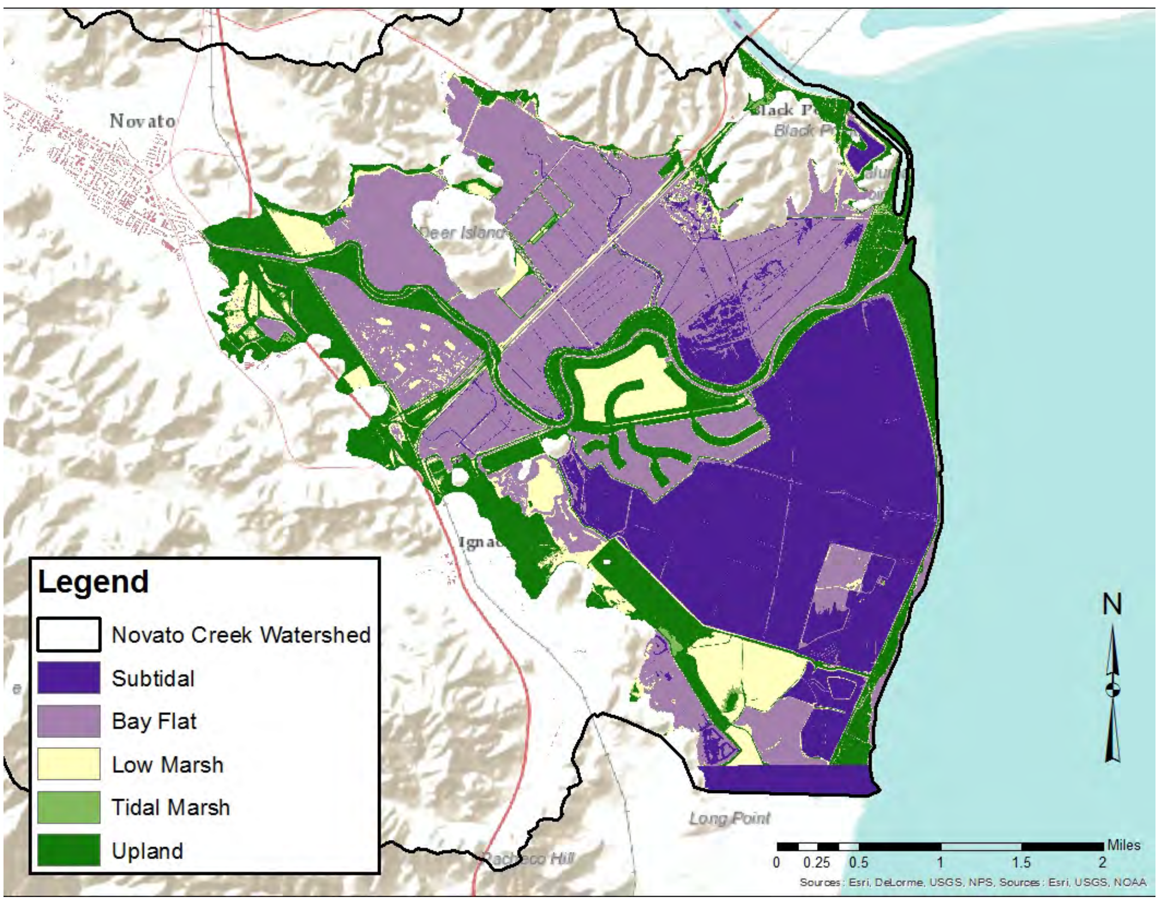


Fill requirements

The area between Highway 37 and Novato Creek does not appear to have experienced the same levels of subsidence compared to the adjacent Bel Marin Keys Unit V restoration project. Regardless, any attempt to restore tidal marsh will require a sizeable importation of dredged material.

The habitats expected to exist at current bayland elevations are shown in **Figure 8**, below. **Raising the ground elevation to levels that could support tidal marsh development would require between 3 and 9 million cubic yards of fill material**, depending on the desired elevation and the extent to which natural sediment deposition processes are used.

Figure 8: Bayland habitat potential based on current elevation.



Sources: NOAA, USACE

The estimates of restoration costs consider two approaches: a lower-cost, but more time-consuming approach that relies on unaided marsh accretion processes, and an accelerated approach that involves more active importation of sediment, with higher up-front costs.

The cost assumptions for this work are based on findings reported in the 2012 San Francisco Bay Long Term Management Strategy 12-year Review, which provided a detailed breakdown of the on-site costs of the Hamilton Wetlands restoration project. These figures, adjusted to 2014 dollars, are shown in **Table 16** below.

Local costs refer to the costs borne by the entity receiving the dredged material – Marin County Flood Control in this case. If it proceeds with a project that includes beneficial sediment reuse, the County is expected to reach a cost-sharing arrangement with one or more dredging project developers. In the example below, the dredging entity pays for the costs prior to the point of placement.

The benefit-cost calculations here include only the local portion of costs, based on the assumption that the dredging projects that would provide the sediment would occur regardless of whether there was a beneficial reuse.

Table 16: Estimated unit costs of placing dredged material in Novato Creek baylands.

Basis	**5.8 million CY**		
Local Costs (2014 dollars)	**$/CY**	**% of local costs**	**% of total costs**
Engineering planning and design	$6.28	36%	15%
Site shaping, culverts, nursery	$4.81	28%	12%
Offloading and placement	$4.48	26%	11%
Construction management	$0.59	3%	1%
Land, easements, rights of way & relocation	$0.47	3%	1%
Planting, surveying, monitoring	$0.36	2%	1%
Other	$0.23	1%	1%
Local Cost/CY	**$17.22**		**42%**
Dredging & Offloading Cost/CY (paid by dredging entity)	**$24.28**		**58%**
Total Cost/CY	**$41.50**		

Source: LTMS Program 12-year Review

Levee removal costs

For concepts involving removing the levees on the north side of Novato Creek, costs were estimated from a review of levee removal projects over the past 25 years. The key variable pertaining to the costs of the FC 2.0 alternative is the amount of levee removed, in other words, whether small breaches are made in specific locations or are removed completely. **Unit costs for levee removal are estimated at $450 per linear foot**.

The FC 2.0 alternative would result in the removal of between 5,600 and 56,000 linear feet of levee.

Horizontal levee construction

Costs for construction of horizontal and seepage levees are adapted from comparable costs used in the BMK-V cost projections. Horizontal levee cost assumptions include the following:

- Earthen levees, trapezoidal shape
- Design elevation: 10ft-12ft
- Crown width: 15ft
- 2:1 inboard slope / 10:1 outboard slope
- Suitable fill material is readily available
- Cost/linear foot: $688-$925

The costs of horizontal-style levees and more typical levees are compared in **Table 17**, below. According to proponents, one of the primary advantages of horizontal levees is the reduced height requirements due to the tidal attenuation provided by marshes on the outboard side of the levee. We estimate costs for horizontal levees of 12-foot and 10-foot height. It is clear from this table that the required levee height will be one of the key determinants of costs.

Table 17: Levee construction cost comparison.

	Crown Width	Crown Height	Outboard Width	Inboard Width	Volume/ LF	Cost/ CY	Cost/ LF
15-ft 3:1 Levee	15	15	45	45	900	$0.53	$750
12-ft Horizontal Levee	15	12	120	24	1,044	$0.53	$925
10-ft Horizontal Levee	15	10	100	20	750	$0.53	$688

Additional capital costs

With the exception of highway construction and dredged material placement (where these costs have already been included), additional project costs will be estimated based on a percentage relationship to construction costs, according to the schedule below:

- Planning, Design, Permitting, Technical: 30%
- Mobilization: 10%
- Contingency: 10%/20%/30% (sensitivity analysis parameter)
- Monitoring: 1%/2%/5% of project costs (sensitivity analysis parameter)

Projected costs of alternatives

The net present value of the two alternatives' costs are shown in **Table 18** below.

Table 18: Summary of capital and O&M costs of flood control alternatives.

a. Flood Control 1.0

	Low		**Mid**		**High**	
V. Life Cycle Costs	Annual	NPV	Annual	NPV	Annual	NPV
Capital	2.55	61.19	3.33	79.95	4.36	104.68
O&M	1.27	30.37	1.41	33.74	1.83	43.87
Total Costs	**3.82**	**91.56**	**4.74**	**113.69**	**6.19**	**148.54**

b. Flood Control 2.0 (Excluding Hwy 37)

	Low		**Mid**		**High**	
V. Life Cycle Costs	Annual	NPV	Annual	NPV	Annual	NPV
Capital	2.12	50.79	3.31	79.50	4.59	110.10
O&M	1.00	24.09	1.12	26.77	1.45	34.80
Total Costs	**3.12**	**74.89**	**4.43**	**106.26**	**6.04**	**144.90**

Comparison of FC 1.0 and FC 2.0 Approaches

The benefits and costs of flood control alternatives and scenarios are summarized in **Table 19**, below.

Table 19: NPV of benefits and costs of flood control alternatives.

	FC 1.0			FC 2.0		
	Low	**Med**	**High**	**Low**	**Med**	**High**
Benefits						
Avoided losses	54.35	60.39	78.51	54.35	60.39	78.51
Avoided public costs	1.75	1.94	2.53	1.75	1.94	2.53
Avoided transportation delays	1.76	1.96	2.54	1.76	1.96	2.54
Recreation benefits	40.69	45.21	49.73	63.40	70.45	77.49
Farm income	10.06	13.42	16.91	1.88	2.51	3.16
Ecosystem services	0.15	130.13	332.16	0.17	147.00	374.37
Total Benefits	**108.77**	**253.05**	**482.38**	**123.32**	**284.25**	**538.61**
Costs						
Capital	61.19	79.95	104.68	50.79	79.50	110.10
O&M	30.37	33.74	43.87	24.09	26.77	34.80
Total Costs	**91.56**	**113.69**	**148.54**	**74.89**	**106.26**	**144.90**

The benefit-cost ratios of each alternative are summarized in **Tables 20** and **21**, below. Two project planning periods were considered: a 50-year time frame, which is common in major infrastructure projects, and an 85-year horizon, which concludes in the year 2100. Following convention, scenarios (e.g., low-cost/high benefit) with B/C ratios greater than one would be economically justified, and are highlighted in green in the tables below.

1. **Flood Control 2.0 is favorable to FC 1.0 in terms of benefits and costs** in each of the scenarios evaluated.
2. **The range of FC 2.0 alternatives** are associated with substantial benefits from the ecosystem services of restored tidal marsh, though in some cases, increased recreational opportunities may represent the largest category of benefits.
3. **The improved performance of FC 2.0 in terms of life cycle O&M costs** may be more than enough to offset higher capital costs of floodplain restoration.
4. **The costs of each approach are sensitive to project design**: lower-cost restoration designs that make more use of natural processes can achieve higher benefit-cost ratios, though these may need to be balanced against the urgency of dealing with sea level rise.
    - Evidence suggests that if the pace of restoration does not keep up with rising sea levels, tidal marsh restoration opportunities may be lost.
5. **The benefits and costs of the Flood Control 2.0 alternative show more variability than the established FC 1.0 approach**. This reflects the emerging role of ecosystem restoration, with all of its complexity. Addressing this variability may require new institutional mindsets with respect to project risk and financing.

Table 20: Flood Control benefit/cost ratios by alternative (50-year time horizon).

a. Flood Control 1.0

Costs \ Benefits	Low	Med	High
Low	1.19	2.76	5.27
Med	0.96	2.23	4.24
High	0.73	1.70	3.25

b. Flood Control 2.0

Costs \ Benefits	Low	Med	High
Low	1.65	3.80	7.19
Med	1.16	2.67	5.07
High	0.85	1.96	3.72

Appendices

85-year calculations

The following tables illustrate the effect of increasing the time horizon from 50 years to 85 years (to coincide with the year 2100 in the Novato Creek Baylands Vision document).

Table A1: Flood Control benefit/cost ratios by alternative (85-year time horizon).

a. Flood Control 1.0

Costs \ Benefits	Low	Med	High
Low	1.29	2.81	5.22
Med	1.05	2.27	4.23
High	0.80	1.74	3.24

b. Flood Control 2.0

Costs \ Benefits	Low	Med	High
Low	2.09	4.19	7.51
Med	1.49	2.99	5.35
High	1.09	2.19	3.93

Benefits of Avoided Flood Damages – Detailed Calculations

The metric used to quantify the economic value of avoided flood damage is referred to as Average Annual Loss (AAL). The AAL is a measure of the expected flood damages in a watershed basin over a defined time period, typically 50 or 100 years. The AAL is constructed as follows:

1. Estimate the expected damage from a single event at the lowest feasible recurrence interval (typically a 100-year event, but here we have data from the equivalent of a 150-year flood)
2. Estimate the expected damage from events at more frequently-occurring intervals (50-, 20-, and 10-year events are typically used)
3. Multiply the expected damage from each event by the expected probability. For example, if the damages from a 100-year event are $100 million, then the expected annual loss of that event would be $100 million x 1% = $1 million.
4. Sum the expected annual damages from all events to obtain the AAL for the watershed

We were able to obtain detailed damage estimates from two events: the January 1982 storm (150-year event) and the December 11, 2014 storm (10-year event). We estimate two intermediate events (50-year and 20-year) by looking at FEMA damage claim history dating to the 1980s. Calculations for the Novato Creek watershed are shown below.

Damages from 150-year event:

Category	1982 dollars	2014 dollars
Residential-Structures	$18,976,000	$51,477,000
Residential-Contents		$25,738,000
Commercial-Structures	$2,511,000	$6,812,000
Commercial-Contents		$6,812,000
Streambank Erosion	$250,000	$733,000
Total	**$21,737,000**	**$91,572,000**

Damages to building contents were not estimated in the U.S. Army Corps report on the 1982 flooding, so they are added here, based on percentages calculated for the Napa River Flood Protection Project (value of residential contents = 50% of structure; value of commercial contents = 100% of structure).

The building stock in Novato Creek has increased approximately 38 percent over the past 30 years, so we assume that a greater number of structures and contents are exposed to damages form flooding:

Category	Bldg. stock-1982	Loss/Unit 2014 dollars	Bldg. stock-2014	2014 Value
Residential-Structures	2501	$20,583	3465	$71,319,000
Residential-Contents	2501	$10,291	3465	$35,660,000
Commercial-Structures (% of 1982 total)	100	$68,118	139	$9,437,000
Commercial-Contents (% of 1982 total)	100	$68,118	139	$733,000

The above values are summed (along with the stream bank erosion repair costs) to arrive at the 150-year flood damage estimate:

Category	(2014 dollars)
Residential + Contents	$106,978,820
Commercial + Contents	$18,874,636
Streambank Erosion	$732,905
Total	**$126,586,361**

Damages from 10-year event:

The December 2014 flood is taken as representative of the potential damages from a 10-year event. A report from March 2015 summarizes countywide damages; values for the Novato Creek watershed are assumed to be roughly 25 percent of the total, based on the population in the watershed as a percentage of the county total:

December 2014 Flood Damages	Countywide	Novato Creek	Notes
Damages to homes and business properties	$4,000,000	$1,000,000	
Agricultural damages	$40,000	$-	Not likely in baylands
Road and Bridge Systems (non-federal)	$4,800,000	$-	Pacific coast
Water Control Facilities (levees, dams, & channels)	$4,100,000	$1,025,000	
Public Buildings and Equipment	$194,000	$48,500	
Public Utilities (water and power, etc.)	$1,000	$250	
Total	**$13,135,000**	**$2,073,750**	

With the high and low damage estimates in place, the intermediate values are assumed to fall along a power-law distribution (i.e., a large number of low-damage events and a small number of highly-damaging events.)[28]:

[28] See, for example, Barton and Nishenko (2004), Burroughs and Tebbens (2005), and Pisarenko and Rodkin (2010)

Recreational Benefits – Unit Day Value Calculations

Recreational benefits were estimated using the U.S. Army Corps of Engineers Unit Day method. A point system is used to assess the quality of recreational experiences at the location of interest. The recreational benefits associated with the FC 2.0 are presumed to be an improvement over existing conditions due to increased tidal marsh habitat (with increases in wildlife viewing opportunities) and accessibility (greater area above water implying more access points to shoreline).

The unit/day values are multiplied by the estimated number of annual visits to arrive at a total economic benefit. This number is then adjusted to reflect the estimated net increase in recreational visits in future years.

Unit Day Values (2014)	FC 1.0	FC 2.0	Description	Justification
Recreation Experience	6	6	Type of activities	Hiking, biking, birdwatching, etc
Availability of Opportunity	2	2	Nearby alternatives	Several alternatives nearby (state/regional parks, Nat'l Wildlife Refuge)
Carrying Capacity	6	8	Adequate facilities	Higher acreage of FC 2.0 alternative, more resilient shore
Accessibility	10	14	Good access	More opportunities for access if shoreline is protected
Environmental Quality	10	14	Aesthetic quality	Wetlands more desirable than open water/armored levee
Total Points	**34**	**44**		
User Value/Day	**$5.78**	**$6.60**		**Based on point values**

Source: http://planning.usace.army.mil/toolbox/library/EGMs/EGM14-03.pdf

Capital Costs and Assumptions

Capital cost estimates and assumptions of each alternative and cost scenario are detailed in **Table A2**, below.

Table A1: Capital cost assumptions, by scenario.

FC 1.0: Low cost

Description	Unit	Qty	Unit Cost	Cost-Low ($million)
Levee rehabilitation/reconstruction	L.F.	46,000	$680	$31.3
Pump station replacement (4 stations 25-yr interval)	LS	13	$7.5 mil	$97.5
Mobilization (10%)				$12.9
Contingency (10%)				$12.9
Planning, design, engineering, permitting, technical (30%)	LS			$38.6

FC 1.0: Mid-cost

Description	Unit	Qty	Unit Cost	Cost-Mid ($millions)
Levee rehabilitation/reconstruction	L.F.	52,000	$750	$39.0
Pump station replacement (4 stations 25-yr interval)	LS	13	$10.0 mil	$130.0
Mobilization (10%)				$17.3
Contingency (20%)				$34.6
Planning, design, engineering, permitting, technical (30%)	LS			$51.9

FC 1.0: High cost

Description	Unit	Qty	Unit Cost	Cost-High ($millions)
Levee rehabilitation/reconstruction	L.F.	58,000	$975	$56.6
Pump station replacement (4 stations 25-yr interval)	LS	13	$12.5 mil	$162.5
Mobilization (10%)				$21.9
Contingency (10%)				$65.7
Planning, design, engineering, permitting, technical (30%)	LS			$65.7

Table A2: Capital cost assumptions, by scenario (cont.)

FC 2.0: Low cost

Description	Unit	Qty	Unit Cost	Cost-Low ($million)
Tidal marsh restoration 1: Hwy 37 downstream				
Placement of sediment to ensure desired habitat	*CY*	*2,000,000*	*$20*	*$40.0*
Breach north bank levee in selected locations	*L.F.*	*2,240*	*$405*	*$0.9*
North levee removal/lowering	*L.F.*	*20,160*	*$405*	*$8.2*
Restore transition zone 1: Hwy 37 downstream	Acre	8	$22,000	$0.0
Tidal marsh restoration 2: Hwy 37 upstream	Acre	433	$22,000	$2.2
Restore marsh-upland transition zone 1: Hwy 37 upstream	Acre	8	$22,000	$0.0
Construct horizontal levee parallel to RR bridge alignment				$4.0
Earthwork for horizontal levee	*L.F.*	*5,280*	*$736*	*$3.9*
Establish transition-zone vegetation on Horiz Levee	*Acre*	*18*	*$22,000*	*$0.1*
Breach and remove levees between RR and Hwy-37	L.F.	3,360	$405	$1.4

FC 2.0: Mid-cost

Description	Unit	Qty	Unit Cost	Cost-Mid ($million)
Tidal marsh restoration 1: Hwy 37 downstream				
Placement of sediment to ensure desired habitat	*CY*	*3,500,000*	*$20*	*$70.0*
Breach north bank levee in selected locations	*L.F.*	*2,240*	*$450*	*$1.0*
North levee removal/lowering	*L.F.*	*20,160*	*$450*	*$9.1*
Restore transition zone 1: Hwy 37 downstream	Acre	9	$45,500	$0.2
Tidal marsh restoration 2: Hwy 37 upstream	Acre	542	$45,500	$13.3
Restore marsh-upland transition zone 1: Hwy 37 upstream	Acre	9	$45,500	$0.2
Construct horizontal levee parallel to RR bridge alignment				$6.2
Earthwork for horizontal levee	*L.F.*	*18,480*	*$1,090*	*$5.8*
Establish transition-zone vegetation on Horiz Levee	*Acre*	*18*	*$45,500*	*$0.4*
Breach and remove levees between RR and Hwy-37	L.F.	3,360	$450	$8.3

FC 2.0: High cost

Description	Unit	Qty	Unit Cost	Cost-High ($million)
Tidal marsh restoration 1: Hwy 37 downstream				$113.1
Placement of sediment to ensure desired habitat	*CY*	*5,000,000*	*$20*	*$100.0*
Breach north bank levee in selected locations	*L.F.*	*2,240*	*$450*	*$1.3*
North levee removal/lowering	*L.F.*	*20,160*	*$450*	*$11.8*
Restore marsh-upland transition zone 1: Hwy 37 downstream	Acre	10	$69,000	$0.4
Tidal marsh restoration 2: Hwy 37 upstream	Acre	650	$69,000	$28.6
Restore marsh-upland transition zone 1: Hwy 37 upstream	Acre	10	$69,000	$0.4
Construct horizontal levee parallel to RR bridge alignment				$8.4
Earthwork for horizontal levee	*L.F.*	*5,280*	*$1,443*	*$7.6*
Establish transition-zone vegetation on Horiz Levee	*Acre*	*18*	*$69,000*	*$0.8*
Breach and remove levees between RR and Hwy-37	L.F.	33,600	$450	$19.7

Ecosystem Goods and Services Values

A total of 72 value estimates for ecosystem services in tidally influenced areas were obtained in a literature review covering the time period 1969 to 2014. Studies were selected based on several criteria:

- Geographic location: Preference given to Pacific Coast of North America, then North America in general, then case-specific studies with application to flood control
- Ecosystem/land cover: Tidal marsh, tidal flat, transitional/upland coastal habitat, streams, open space
- Ecosystem services: Aesthetic value, flood risk reduction, Habitat/refugia/nursery functions, recreational use, water quality/waste water treatment, existence/option/bequest value, carbon sequestration

Values from each study were converted to a dollars-per-acre basis. Recreation values were estimated separately, using the U.S. Army Corps of Engineers "Unit/day" value methods.

A summary of ecosystem service values is shown in **Table A2**, below:

Table A3. Tidal habitat value per acre, based on literature review.

Tidal habitat value per acre (2014 dollars)	# Value estimates	StdDev	-1 SD	Mean	+1 SD
Aesthetic/amenity	17	$6,566	$(391)	$6,181	$12,938
Water quality	7	$15,085	$(5,104)	$10,056	$25,518
Flood risk reduction	8	$24,310	$(9,710)	$14,744	$39,640
Option/bequest/existence	4	$20	$24	$44	$65
Carbon sequestration	3	N/A	$16	$46	$188
Primary production/nursery	5	$1,582	$(795)	$799	$2,416

A persistent phenomenon in the ecosystem valuation literature is the wide range of reported values for any given land cover type. In some cases, the estimated values of a specific habitat vary by one or more orders of magnitude between studies. To address the presence of these extreme values, we take the mean value of each, and then add (or subtract) one standard deviation to obtain high and low range estimates.

The bundle of ecosystem service values associated with a particular land cover type is summarized in the **Table A3**: one each for the low-, mid-, and high-range shown in the table above.

Table A4. Ecosystem service contribution by land cover class.

Ecosystem Service Values Per Acre – by Land Cover							
Low	**Acres**	**Aesthetic/ amenity**	**Water quality**	**Flood risk**	**Option/ bequest/ existence**	**Carbon seq.**	**Nursery**
Diked/Managed Marsh	927	$-	$-	$-	$16	$16	$-
Tidal Marsh	88	$-	$-	$-	$20	$16	$-
Bay Flat	81	$-	$-	$-	$20	$-	$-
Fluvial Channel	71	$-	$-	$-	$20	$-	$-
Lagoon	102	$-	$-	$-	$20	$-	$-
Storage/Treatment Basin	116	$-	$-	$-	$-	$-	$-

Mid	Acres	Aesthetic/ amenity	Water quality	Flood risk	Option/ bequest/ existence	Carbon seq.	Nursery
Diked/Managed Marsh	927	$4,945	$8,045	$11,795	$35	$37	$639
Tidal Marsh	88	$6,181	$10,056	$14,744	$44	$46	$799
Bay Flat	81	$-	$-	$7,372	$44	$-	$799
Fluvial Channel	71	$6,181	$-	$14,744	$44	$-	$799
Lagoon	102	$-	$-	$14,744	$44	$-	$799
Storage/Treatment Basin	116	$-	$8,045	$11,795	$-	$-	$-

High	Acres	Aesthetic/ amenity	Water quality	Flood risk	Option/ bequest/ existence	Carbon seq.	Nursery
Diked/Managed Marsh	927	$10,350	$20,414	$31,712	$52	$150	$1,933
Tidal Marsh	88	$12,938	$25,518	$39,640	$65	$188	$2,416
Bay Flat	81	$-	$-	$19,820	$65	$-	$2,416
Fluvial Channel	71	$12,938	$-	$39,640	$65	$-	$2,416
Lagoon	102	$-	$-	$39,640	$65	$-	$2,416
Storage/Treatment Basin	116	$-	$20,414	$31,712	$-	$-	$-

Notes on December 2016 revisions

The Novato Creek case study was produced before the standard methods embodied in the project's later deliverables. As these standards and conventions were developed during the progress of the Flood Control 2.0 project, it began to make sense to update the Novato Creek case study with these methods in order to maintain consistency with future uses of the benefit-cost materials. These changes to the Novato Creek report are notated below.

The following changes were made to make the Novato Creek methods consistent with the Benefit-Cost Workbook and the Lower Walnut Creek case study. *These applied equally to the two alternatives described in the report, and did not affect the relative benefit-cost ratios of the two alternatives*:

p 4 - Table and comments updated to reflect new calculations.

p 26 - Revised Table 6 using numbers without rounding; redesigned chart for readability. Re-ordered discussion of emergency response, cleanup, and infrastructure upgrades under a new heading for "Avoided public costs."

p 27 - Increased the delay from flooding in Table 7 from four hours to eight.

p 28 - Re-labeled "Emergency Costs" in Table 9 to "Avoided Public Costs,"

p 32 - Table 13 updated to reflect changes in benefits and costs.

p 41 - The costs of raising Hwy 37 have been removed from the main section of the report, as they were determined to be outside the scope of this study.

The following changes altered the relative benefits or costs of the two alternatives:

p 28 - Updated the estimated number of visitors per year to reflect the difference between FC 1.0 and FC 2.0 alternatives. The number of visitors in the FC 2.0 alternative are expected to increase due to the development of recreational facilities that would not exist in the FC 1.0 alternative. Also updated the unit/day values based on updated USACE guidance and the use of a linear regression model to estimate intermediate values on the USACE's point scale. The formula for this regression is included in the Benefit Cost spreadsheet. These adjustments favored the FC 2.0 alternative.

pp 28-29 - Adjusted farm income estimates to reflect a smaller acreage base (900 acres, down from 1,300). This is due to a number of factors: The original, larger figure was based on the assumption that the entire area would be cultivated and intensively managed. In agriculture, it is common practice to leave portions of parcels uncultivated to allow for vehicle access, and also to keep less productive areas out of production unless market pricing is sufficiently high. This may be justified during drought years, when there may be shortages of livestock forage, but these conditions are not expected to hold indefinitely. The low- and high-range scenarios were also narrowed to reflect the assumption that long-term crop yields and pricing will tend to be closer to the mean than was estimated in the original version of the case study. These changes favored the FC 2.0 alternative in the mid- and high-range scenarios.

p 31 - The values of tidal ecosystem services in Table 12 were updated to reflect methods refined during the Lower Walnut Creek case study. The discussion of carbon sequestration was edited to more clearly define the units of value of carbon sequestration (dollars per ton versus dollars per acre) - these estimates assume that 1.5 tons of carbon can be sequestered per acre. As the values were reduced in all cases, these changes favored the FC 1.0 alternative, in the sense that higher ecosystem benefits tend to favor the FC 2.0 approach.

p 32 - due largely to the improved methods for ecosystem and environmental benefits, the range of the benefits of each alternative narrowed substantially. Overall, looking at the final benefit-cost ratios, these changes appear to favor the FC 1.0 alternative.

p 40 - Table 17 were adjusted to include a 12-foot-high horizontal levee. This resulted in a lower cost for the horizontal levee that was part of the FC 2.0 alternative.

pp 41-42 - An update of the overall methods for calculating full lifecycle costs resulted in the costs of both alternatives being reduced. FC 1.0 costs were reduced by $20 million to $55 million over the 50-year time horizon, while FC 2.0 costs were increased on the low end by $3 million, reduced by $12 million in the midrange scenario, and reduced by $50 million at the high end. These changes all favored the FC 1.0 alternative.

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