Flood Control 2.0: Economic Analysis

Guidebook for Economic Analysis of Flood Control Alternatives

Prepared for the Flood Control 2.0 Project:
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Project Background

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 Lower Novato Creek watershed, which is reported in a separate case study. The second phase consists of the guidelines for economic analysis contained in this document, along with an accompanying spreadsheet model, will enable the economic analysis to be extended to other Bay Area watersheds.

These Guidelines are based on general principles of economic analysis for water resources projects, and are also informed by an economic analysis conducted in the Lower Novato Creek watershed in the winter and spring of 2015/2015. Objectives of the analyses include:

1. Highlighting the life cycle benefits, costs, and long-term resilience of Flood Control 2.0 strategies
2. Quantifying the multiple economic values provided by Bay Area watersheds (e.g., habitat, recreational, and amenity values, flood risk management, and a medium for waste water and storm water discharge)

A key takeaway of the Flood Control 2.0 concept is that economic benefits are often positively related to environmental benefits. While restoration projects may be quite costly, and may sometimes result in the loss of developed land uses, environmental benefits may produce economic benefits that, if accounted for, may improve the feasibility of a project and help generate community support. At the same time, it is important to not overstate the benefits of a project, and the approach described herein takes a conservative approach to estimating these benefits. Ultimately, water resource projects are complex undertakings, requiring multiple types of decision-making criteria, of which the economic aspects are merely one.

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Guidelines for Economic Analysis of Flood Control Alternatives

Why develop an economic framework for FC 2.0 approaches?

Earlier generations of flood control projects were typically evaluated on criteria limited to the economic benefits of a narrow range of activities influenced by the project.[1] Changes in the way federal, state, and local agencies plan and develop flood risk management (flood control) projects have required more recognition of environmental outcomes, including impacts on threatened and endangered species, water quality, and the disposition of sediment, for example from dredging projects. While extensive work has been underway for decades to study the physical and ecological characteristics of the baylands, the economic impacts of these elements have not been studied at a local scale in the San Francisco Bay Area.[2]

The economic perspective is only one of many that apply to flood risk management and bayland restoration, but it can help provide a crucial connection between ecosystems and the human activities that impact them. The human activities that have impacted the greater San Francisco Bay Area over the past 150 years: dredging and filling lands at the bay margin, diking and draining areas for agriculture and other developed uses, paving streets and parking lots, and channelizing streams have largely been to accommodate economic activity of some sort. When economic interests are combined with other facets of human behavior, change can be especially difficult to make.

On the other hand, change is inevitable, whether due to rising sea levels, aging infrastructure, or changing patterns of development in Bay Area communities. Facing these challenges is certainly within our abilities as a society, but even so, directing or accommodating change requires that we make decisions about how and where to allocate scarce resources, about when we decide to take action (proactively or reactively), and about how comprehensively we choose to deal with these challenges. Economic analysis can provide valuable help in informing these decisions, as in the following examples:

1. **To estimate the costs of doing nothing,** or maintaining the status quo.
2. **To make a case for the specific timing or sequencing of project activities.** For projects being implemented in phases, an economic analysis could shed light on whether the order of project implementation changes the total benefits or costs in a meaningful way.
3. **To evaluate tradeoffs when facing budget limitations.** For example, if a particular alternative provides a similar level of habitat function at a lower cost, then more funds can be allocated to other beneficial activities.
4. **To meet statutory/funding agency requirements.** In many cases, agencies require a benefit-cost analysis (BCA) in order for a project to qualify for funding.
5. **To help identify how multiple benefits of a project affect various stakeholders.** Flood risk management activities may provide benefits far outside the jurisdiction in which they

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[1] Council on Environmental Quality. 2013. Principles and Requirements for Federal Investment in Water Resources Projects.

[2] See the Natural Capital Project (Arkema et al. 2013), Pacific Institute (Heberger, et al. 2012), and Costanza, et al, (2008) for analyses of large-scale impacts. These are national or regional in scale, and have not addressed issues at the watershed or sub-basin-level.

take place. This may help broaden support for regional initiatives that provide correspondingly higher levels of benefits.

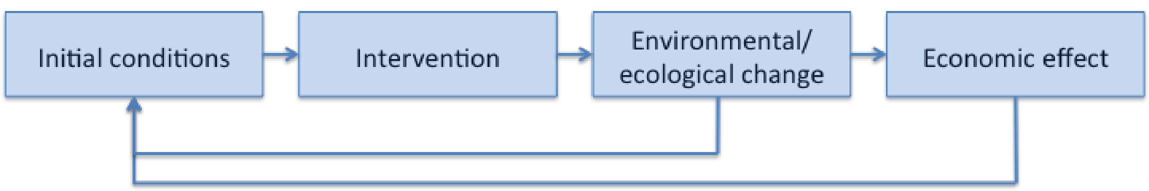
6. **To provide a consistent process that can be applied across the region**. An economic framework followed consistently by regional stakeholders can allow for comparisons and evaluations of project opportunities in common terms.

One important subtext to consider with the above examples is that **economic benefits are often positively related to environmental benefits**. While restoration projects cost money, and sometimes results in the loss of developed land uses, **environmental benefits may produce economic benefits that, if accounted for, may make more projects feasible**. While there has been increasing recognition of the economic benefits of restoration in recent years, there is still a need for continued study in the Bay Area, and on the West Coast in general. The regional application of economic analysis in the Flood Control 2.0 effort hopefully represents a step in this direction.

Overview of economic issues in flood risk management

The economic impact of a flood control strategy is based on the model depicted in **Figure 1**, below:

Figure 1: Economic impact model for FC 2.0 activities.



The **initial conditions** are the current characteristics of a project site. An **intervention** is an activity that changes the site in some way (e.g., removing a levee, depositing dredged material). The **environmental/ecological change** resulting from the intervention also manifests in the **economic effects** discussed in this guidebook. In turn, information obtained from the environmental/ecological and economic changes provide inputs to a new cycle of activity, as shown by the arrows in the figure.

This chart also illustrates how much the economic analysis depends on the preceding steps. Put simply, an economic analysis without the availability of high-quality environmental and other physical data will be forced to rely on assumptions and generalizations in place of measured and validated conditions.

What to include in the economic analysis

The components of an economic analysis of flood risk management activities will depend on the issue under consideration and the physical setting of the project. Whether these components can be full addressed in an analysis depends greatly on the availability of data, a topic we return to in the next sections. The components may include some or all of the following:

- The value of reduced property damage from flood events
- The avoided costs of emergency response, transportation delays, and business interruptions from flooding

- Avoided costs of additional infrastructure upgrades
- Changes in property values due to the perceived risks of living in flood-prone areas
- The value of changes in land use (e.g. from agricultural use to tidal marsh)
- The value of recreational opportunities and other amenities
- The social value of well-functioning ecosystems
- The costs of developing and maintaining the project over its entire life cycle, including external costs to neighboring parties (e.g. increased truck traffic moving dredged materials through residential neighborhoods)

The above items will be discussed in more detail in the economic analysis process described in the following section.

Comparison of financial and economic perspectives

The distinction between financial analysis and economic analysis is also important to note. While both convey important information to stakeholders and decision makers, they serve different purposes in terms of planning restoration and flood control projects.

A financial analysis is undertaken to determine the financial feasibility of a project, in other words, whether there are sufficient resources to pay for a project. Financial analyses are not intended to address broader societal concerns about how resources are allocated among competing needs. This analysis is relevant to projects like flood control or drinking water system improvements, where the costs are repaid through levies or user fees, but do not apply to projects whose primary goal is restoration.

In contrast, an economic analysis is intended to measure the effect of a project on social welfare. Social welfare may be defined very broadly to include measures of environmental and social benefits and costs, and can address concerns about equity and the geographic distribution of a project's effects.

Because the methods of the two approaches differ, projects with economic benefits in excess of costs may not be feasible under the criteria of a financial analysis, and projects that pencil out in a financial analysis may not be desirable under benefit-cost criteria.

There are other methodological differences between the two types of analysis, in terms of what elements are counted and how future cost are treated. These are summarized in **Table 1**, below, taken from California Department of Water Resources' *Economic Analysis Guidebook* (DWR 2008).

Table 1. Comparison of financial and economic analyses.

	Economic Analysis	Financial Analysis
Analysis perspective	Can vary from individuals, communities, state, and/ornational; DWR uses statewide perspective	Project beneficiaries
Evaluation period	Economic life of project (usually 50 to 100 years)	Bond repayment period (usually 20 years)

Adjustment for inflation	Exclude inflationary effects; price changes different from inflation can be included (escalation)	Include inflationary effects
Project input valuation	Project inputs valued using their economic opportunity costs	Project inputs valued using their purchase costs
Adjustment for benefits and costs over time	Determine present values using economic discount rate	Determine present values using financial discount rate
Discount rate	Economic discount rate; real rate of return (**excluding** inflation) that could be expected if money were invested in another project; DWR currently uses 6%	Financial discount rate; financial rate of return (**including** inflation) that could be expected if money were invested in another project; DWR uses expected interest rate of bonds sold to finance project
Interest paid on borrowing funds during construction	Not included (financial cost)	Included; DWR uses State revolving fund cost
Forgone investment value during construction	Included; real rate of return that could be expected if construction funds were invested in another project (opportunity cost)	Not included
Financial costs	Not included	Included

Source: California Department of Water Resources

Economic analysis methods

This guidebook focuses on **benefit-cost analysis (BCA)** methods, which take into account environmental and ecological values. The California Department of Water Resources (DWR) describes BCA in the following terms (DWR 2008):

> Benefit-cost analysis determines whether the direct social benefits of a proposed project or plan outweigh its social costs over the analysis period. Such a comparison can be displayed as either the quotient of benefits divided by costs (the benefit/cost ratio), the difference between benefits and costs (net benefits), or both. **A project is economically justified if the present value of its benefits exceeds the present value of its costs over the life of the project** [emphasis added].

Another commonly used method is **cost-effectiveness analysis (CEA)**, which considers the costs required to achieve specific physical outcomes (e.g., "*x acres* of tidal marsh created per $1,000 spent"). CEA may also be considered an intermediate form of a benefit-cost analysis, in that costs are fully counted in both cases, while benefits are expressed in physical, not monetary terms.

Finally, **socioeconomic impact analysis** (also known as regional impact or input/output analysis), measures how economic output and employment responds to implementation of a project. This type of analysis may be useful in some circumstances, but may not generate useful information unless there is a significant shift in employment or economic activity resulting from a restoration project.

Steps in the Economic Analysis Process

These guidelines for economic analysis are meant to serve a variety of purposes depending on the needs of the agency (or agencies) involved in planning a multi-benefit flood control/restoration project. The process described here can be used for preliminary planning activities, or it can provide a foundation for a more comprehensive study in support of a fully-committed project. While the level of detail and scope of economic activities to be considered will vary considerably between these two extremes, the approach is essentially the same. As such, the framework described in this guidebook should be compatible with most prevalent planning models used by federal, state, or local agencies.

In order to determine the appropriate scale and level of detail for the report, it is useful to proceed through the following steps.

1. **Define the issue**
2. **Determine the scope and economic methodology**
3. **Describe baseline conditions**
4. **Define alternative scenarios**
5. **Develop the life cycle costs of each alternative**
6. **Identify quantifiable and non-quantifiable benefits**
7. **Report the results**

These steps are described in more detail below.

1. **Define the issue.** Affirm the consensus of project stakeholders, and obtain specific direction on the course of the research.

    - What issues will this study address? Is this a high-level planning exercise, a requirement for funding, or some intermediate level of analysis?
    - What are the specific institutional concerns of the project partners? Who is interested in the economic analysis, and how will they use it?
    - What level of detail will be required to conduct the study?
    - What critical topics need to be addressed in order for this analysis to be successful?
    - What are the data gaps or areas of uncertainty, and how can they be addressed?

2. **Determine the scope and economic methodology**
    Clearly define what to consider in the analysis: such as geographic scope, affected populations, fiscal impacts, time period, sea level rise, and the number/variety of alternatives to consider.

    Following these steps, there should be a clear roadmap for the analysis.

3. **Describe baseline conditions**
    The existing conditions of the study area provide the basis for the without-project conditions – the baseline against which the alternatives are compared. Current baseline conditions need to be forecast out over the entire planning window in order

to allow the with-project/without-project comparisons to be made for the entire project life cycle.

In each of the following categories, current and projected figures will provide valuable information for the analysis, especially when it includes spatial information suitable for GIS analysis.

Physical data

- Study area delineation (e.g., SFEI head-of-tide study)
- Land use/land cover
- Elevation
- Flood control and stormwater infrastructure
- Critical infrastructure (e.g., roads and bridges, transmission lines, emergency services facilities, hospitals, water/wastewater facilities)
- Other community infrastructure (parks, libraries, non-emergency healthcare facilities, schools)
- Building envelope/impervious area
- Population/households/dwelling units
- FEMA Flood Insurance Rate Maps
- Streamflow data/details from previous flooding events
- Sea level rise projections

Economic data

- Property values – residential, commercial, industrial, and others as appropriate
- Costs/values of other physical property at risk (e.g. vehicles, street trees)
- Vehicle count data for roads (to estimate costs of transportation delays)
- Costs of emergency response to storms/flooding events
- Capital costs of flood control infrastructure (levees, pump stations, conveyance, detention basins)
- Operations and Maintenance costs of flood control systems (personnel, consultants and technical services, debris/vegetation removal, dredging)
- Existing flood damage reports
- Existing damage estimation models, such as HEC-FDA (USACE) or HAZUS-MH (FEMA)
- Socioeconomic data (e.g. Pacific Institute's Social Vulnerability Index)

In many cases, the available data will need to undergo additional processing or interpretation in order to be usable for the analysis. This process benefits greatly from working closely with flood district/public works staff and others who are well acquainted with the floodplain and its management to ensure that the data are used appropriately in the valuation effort.

4. **Define alternative scenarios**
   These guidelines assume that the alternatives under consideration have been developed in enough detail to determine their long-term impacts on the baseline variables discussed in Step 3, above. The viability of any alternative must also be conditioned on whether it meets the same flood control objectives (i.e., the same level of flood protection) as a conventional, "Flood Control 1.0" approach. One exception is when a managed realignment or abandonment of floodplain development is part of the alternative, in which case the economic analysis proceeds by calculating the foregone value of floodplain use (for example, when cropland is converted to restored tidal marsh).

   Following the conceptual model described above, the economic values of each alternative will be based on the environmental/ecological changes that occur for that alternative.

5. **Develop the life cycle costs of each alternative**
   Based on the fully defined alternatives, the life cycle costs of design, permitting, construction, and O&M can then be estimated. The level of detail and sophistication of the cost estimating procedures will depend on the nature of the analysis. For projects further along in the design phase, the level of detail may be quite specific, and will be made in consultation with project engineers. For preliminary planning purposes, cost elements can be estimated from the following sources (in general order of preference):

   - Completed, as-built costs from similar, nearby projects (e.g., Hamilton Wetlands, Cullinan Ranch)
   - Estimated/projected costs from similar, nearby projects (e.g. Bel Marin Keys-V)
   - A meta-analysis of comparable projects (e.g., SFEI survey of dredging costs)
   - Estimated or as-built costs from similar projects in other regions (used to estimate levee removal costs in the FC 2.0 Novato Creek case study)
   - Spreadsheet-based models, such as the CalTrans bridge construction cost model (used for Hwy 37 costs in the Novato Creek case study)

6. **Identify the quantifiable and non-quantifiable benefits of each alternative**
   The quantifiable benefits of each alternative may include reductions in flood damage risk, avoided transportation delays and emergency response costs, increased recreational benefits, and increased values of ecosystem services from restored tidal marshes.

   Avoided costs are the most easily quantified, and are based on the effect of each alternative on the flood protection aspects of a project. Changes in recreational values, where applicable, also have a demonstrated track record in the economic literature, and may represent a significant proportion of a project's benefits. Changes in ecosystem service values are increasingly being recognized, and evidence to date suggests they may be substantial, though in some cases may be difficult to measure. The opportunities and challenges of valuing ecosystem restoration are discussed in more detail in the Appendix.

7. **Report the results**

   Depending on the needs of stakeholders determined in Step 1, the results of the economic analysis can help inform future project design, communicate the value of Flood Control 2.0 approaches in different watersheds, or support the development of a particular project to funders and regulators.

User Guide: Benefit-Cost Analysis Spreadsheet Model

OVERALL DESCRIPTION

Throughout the workbook, areas highlighted in blue are intended to receive user-inputted information, while gray-shaded cells are meant to display calculated values. Users should avoid entering data directly into any gray-shaded cell.

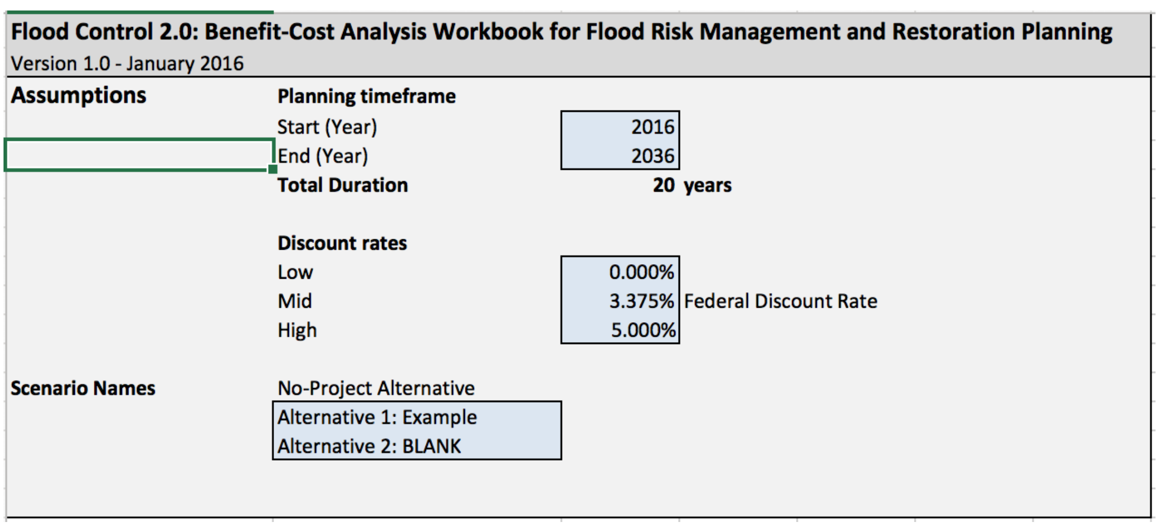
The following process integrates the benefit-cost analysis principles described earlier in this Guidebook with the Excel-based workbook that actually handles the benefit-cost calculations.

1. **Issue definition.** This step presents the opportunity to establish a consensus on what the alternatives analysis will include, including changes to infrastructure, operations and maintenance assumptions, study area definition, and intended land cover changes. While there is no quantitative data to be collected in this step, the subsequent analysis can be compared with the issue definition to ensure that it remains consistent with the overall project vision.

2. **Scope and methodology.** The major elements of this step are the spatial definition of the study area (maps are a useful tool here), the planning timeframe, and the discount rate to be evaluated.

The first tab in the workbook allows users to set a few key parameters for the entire model. These include the planning timeframe for the project, the range of discount rates that may be used in comparing the scenarios, and names for up to two alternative project designs, as shown in **Figure 1** below.

Figure 1. Model input tab.



The second tab captures physical design data relating to the alternatives under consideration, as shown in **Figure 2**, below. This includes such information as the number of linear feet of levees to be built, modified, or removed, the number of acres to be restored to tidal marsh, and the construction of other facilities and infrastructure over the planning timeframe. A baseline must be established, detailing what conditions are likely to be in the future *if no project is undertaken*. Some examples might include the need to raise levees to address sea level rise, or the need to replace aging equipment. There is space to enter data for up to two alternatives. Unit costs included in the workbook example are taken from figures obtained in Phase 1 of the Flood Control 2.0 Economic Analysis.

Figure 2. Project alternatives description worksheet.

No-Project Alternative		*Calculated value*		*User-entered value*	
Capital Cost Assumptions	**Unit**	**Low**	**Mid**	**High**	**Notes**
New Levee		**$1,700,000**	**$1,875,000**	**$2,437,500**	
Total length	L.F.	2,500	2,500	2,500	
Avg height from base	ft.	12	12	12	
Cost per linear foot (12ft height)	$	$680	$750	$975	Mid range = estimates from
Raise Levee		**$212,500**	**$234,375**	**$304,688**	
Total length	L.F.	1,250	1,250	1,250	
Avg height increase	ft.	3	3	3	
Cost per linear foot/CY	$	$57	$63	$81	WILL NEED TO ADJUST BASE
Reinforce Levee		**$35,417**	**$425,000**	**$425,000**	
Total length	L.F.	2,500	2,500	2,500	
Cost per linear foot/CY	$	$14	$170	$170	WILL NEED TO ADJUST BASE
New Horizontal Levee		**$0**	**$0**	**$0**	
Total length	L.F.	-	-	-	
Avg Height	ft.	10	10	10	
Cost per linear foot/CY	$	$680	$750	$975	ADJUST BASED ON SHAPE OI
Other embankment/floodwall construction		**$27,500**	**$30,000**	**$40,000**	
Total length	L.F.	500	500	500	
Avg Height	ft.	1	1	1	
Cost per linear foot/CY	$	$55	$60	$80	Based on 2 ft floodwall-on-le
Pump Station Replacement		**$0**	**$0**	**$0**	
Number of pump stations	LS	-	-	-	
Cost/station	$	$909,091	$1,000,000	$1,300,000	Based on capacity - pump st
Other Major Replacement	**LS**	**$0**	**$0**	**$0**	Structures w/ lifespan great
Excavation (e.g. channel network)		**$5,750,000**	**$6,250,000**	**$8,250,000**	
Total volume	CY	250,000	250,000	250,000	
Cost per CY	$	$23	$25	$33	BMK-V unit costs
Placement of fill		**$1,800,000**	**$2,000,000**	**$2,600,000**	
Total volume	CY	100,000	100,000	100,000	
Cost per CY	$	$18	$20	$26	Hamilton placement costs (L
Flow control/diversion		**$0**	**$0**	**$0**	
Number of structures	EA	-	-	-	
Cost/structure	$	$0	$0	$0	
Levee removal		**$0**	**$0**	**$0**	
Feet removed	L.F.	-	-	-	
Cost per linear foot	$	$410	$450	$585	Survey of levee removal pro
Habitat restoration		**$1,250,000**	**$6,125,000**	**$11,000,000**	
Area restored	Acre	250	250	250	
Cost per acre	$	$5,000	$24,500	$44,000	Based on SFBJV database (N
Planning, Permitting, Design					
Monitoring					% of total capital cost

3. **Baseline description and projections: without-project conditions.** As in Steps 1 and 2, the figures entered on the Project Alternative Definition worksheet are intended to arise from a consensus-based process, in which the existing conditions are defined for the physical, economic, and social setting of the project.

4. **Alternatives definition.** The potential benefits and costs (and values) of each alternative are then entered into the following worksheets.

5. **Project benefits.** The benefits of each alternative are broken down into three categories: flood risk reduction, recreational benefits, and environmental benefits.

The first worksheet allows for the calculation of flood risk avoidance to structures, building contents, streambank/levee repairs, and other costs associated with flooding events. **Figure 3a** shows a summary of these costs, with user-entered data shown for the discount rate, a low- and high-range setting for sensitivity analysis purposes, and optional user-entered values for items not already included in the worksheet.

Figure 3a. Flood risk benefits.

Benefits: Flood Risk Reduction

No-Project Alternative				
Discount rate	3.375%			
Project Life (Years)	20			
		-10%		30%
Loss Categories		**Low**	**Mid**	**High**
Damages to structures and contents		$ 1,035,000	$ 1,150,000	$ 1,495,000
Stream bank/levee repairs		$ 450,000	$ 500,000	$ 650,000
Emergency response costs		$ 9,000	$ 10,000	$ 13,000
Cleanup costs		$ 9,000	$ 10,000	$ 13,000
Transportation delays		$ 18,000	$ 20,000	$ 26,000
Cost of infrastructure upgrades		900,000	1,000,000	1,300,000
<User entered value>		$ -	$ -	$ -
<User entered value>		$ -	$ -	$ -
Expected Annual Damages (EAD)		**$ 36,963**	**$ 41,070**	**$ 53,391**
Net Present Value: 20 years, 3.375% discount rate		**$ 531,325**	**$ 590,361**	**$ 767,469**

Figure 3b allows for the most of the data entry. Depending on the level of development in the study area, this category can require a substantial amount of data gathering. This simplified form permits a limited number of data inputs, but if more precision is required, a more advanced risk assessment tool should be used, such as FEMA's HAZUS-MH or the U.S. Army Corps' HEC-FDA.

Regardless of the method used, the Net Present Value (NPV) and Expected Annual Damages (EAD) should be reflected in the appropriate cells on this sheet in order to calculate the benefit-cost summaries at the end of this process (more on this to follow).

Figure 3b. Flood damage data entry worksheet.

Detailed Worksheet				
100-year event	# Structures	Damage/Structur	Total Damage	
Damages to structures and contents			$ 1,150,000	
Residential-structures	10	$ 10,000	$ 100,000	
Residential-contents (50% of structure value)			$ 50,000	
Commercial & Industrial-structures	5	$ 100,000	$ 500,000	
C&I-contents (100% of structure)			$ 500,000	
100-year event	Units	Unit Cost	Total Cost	
Stream bank/levee repairs (linear feet)	100	$ 5,000	$ 500,000	
Emergency response costs (cost per day)	1	$ 10,000	$ 10,000	
Cleanup costs (cost per day)	1	$ 10,000	$ 10,000	
Transportation delays (cost per hour)	8	$ 2,500	$ 20,000	
Cost of infrastructure upgrades (misc)	1	$ 1,000,000	$ 1,000,000	*Raise RR bridge*

Figure 3c is a table used to calculate the probabilities of a specific "hydrologic event" (e.g. flooding). While these values may be changed to reflect specific data availability, some caution should be exercised when doing so. A technical explanation of how this process works can be found in the Appendix of the Novato Creek Case Study (2015).

Figure 3c. Expected Annual Damage probability table

Expected Annual Damage Calculator				
Hydrologic Event	Event Exceedar	Interval Probabilit	Structure Damage Coefficient*	
10-yr	0.1000		0.100	
25-yr	0.0400	0.0600	0.250	0.015
50-yr	0.0200	0.0200	0.500	0.01
100-yr	0.0100	0.0100	1.000	0.01
200-yr	0.0050	0.0050	2.000	0.01
500-yr	0.0020	0.0030	5.000	0.015
Sum of probabilities (100-yr design)		**0.0080**	**Assumed power l*	**0.025**

The changes in recreational values of project alternatives are calculated in the next worksheet, as described in **Figures 4a-4d** below.

Figure 4a uses the U.S. Army Corps' unit day values for various recreational use categories. This method uses a point-based system to assess the relative quality of recreational experiences made possible by a project. A detailed explanation can be found in the Army Corps guidance for using this method, which is updated annually. The current (year 2016) methods can be found at http://planning.usace.army.mil/toolbox/library/EGMs/EGM16-03.pdf. The point values are then translated into a dollar value per user/day, shown in the lower table in Figure 4a.

Figure 4a. Unit-day recreational value method.

Unit Day Values (2016)	No project	Justification	Alt 1	Justification	Alt 2	Justification	Max pts
Recreation Experience	0		6	Several general activities	6	Several general activities	30
Availability of Opportunity	0		2	Several within 1 hr travel time, some within 30 minutes travdel time	2	Several within 1 hr travel time, some within 30 minutes travel time	18
Carrying Capacity	0		8	Adequate facilities to conduct w/o deterioration of the resource/experience	8	Adequate facilities to conduct w/o deterioration of the resource/experience	14
Accessibility	0		12	Good access	12	Good access	18
Environmental Quality	0		12	High aesthetic quality	12	High aesthetic quality	20
Total Points	**0**		**40**		**40**		**100**
User Value/Day							
General Recreation	**$ 2.98**		**$ 6.27**		**$ 6.27**		
General Fishing and Hunting	**$ 5.05**		**$ 7.66**		**$ 7.66**		
Specialized Fishing and Hunting	**$ 22.71**		**$ 30.69**		**$ 30.69**		
Specialized Recreation other than Fishing and Hunting	**$ 8.64**		**$ 20.81**		**$ 20.81**		

Figure 4b shows the corresponding daily values based on the number of points. Values in between the 10-point increments (say, a value of 34 points), shown in the table are interpolated using linear regression.

Figure 4b. Daily recreational values from Army Corps method.

Army Corps Unit Day Values (2016)				
Point Values	**General Recreation**	**General Fishing and Hunting**	**Specialized Fishing and Hunting**	**Specialized Recreation other than Fishing and Hunting**
-	$ 3.90	$ 5.61	$ 27.33	$ 15.86
10	$ 4.64	$ 6.35	$ 28.07	$ 16.84
20	$ 5.12	$ 6.83	$ 28.55	$ 18.06
30	$ 5.86	$ 7.57	$ 29.29	$ 19.52
40	$ 7.32	$ 8.30	$ 30.02	$ 20.74
50	$ 8.30	$ 9.03	$ 32.95	$ 23.43
60	$ 9.03	$ 10.01	$ 35.87	$ 25.87
70	$ 9.52	$ 10.49	$ 38.07	$ 31.24
80	$ 10.49	$ 11.23	$ 41.00	$ 36.36
90	$ 11.23	$ 11.47	$ 43.93	$ 41.49
100	$ 11.71	$ 11.71	$ 46.37	$ 46.37
Source:	*http://planning.usace.army.mil/toolbox/library/EGMs/EGM16-03.pdf*			

The next step in the Unit-Day method is to estimate the number of daily recreational users resulting from the project. For the example shown in **Figure 4c**, below, the construction of a trail and associated facilities brings in 20,000 "General Recreation" users (e.g., hikers and bicyclists), 500 hunters/fishers, and 1,000 "Specialized" users (e.g., kayakers, windsurfers) per year (daily users multiplied by 365 days).

A proper estimate will often require its own recreational demand study, which is beyond the specific scope of this workbook. For the purposes here, it is assumed that such a study, or other credible source for an estimate exists. The worksheet allows for an annual increase in use to reflect population growth and the possibility of increased use over time as people become familiar with the recreational resource.

Figure 4c. Recreational demand estimates.

Recreational User Counts: No Project	General Recrea	General Fishing and Hunting	Specialized Fishing and Hunting	Specialized Recreation other than Fishing and Hunting
Year 1 expected trail use	0	0	0	0
Expected annual change in trail use	0.00%	0.00%	0.00%	0.00%
Average annual use over project life	0	0	0	0

The economic values for recreational use are calculated in the worksheet shown in **Figure 4d**, below. As with the flood damage estimates worksheet, if a separate recreational demand study has been conducted and is deemed more reliable, the NPV and expected Annual Value figures from that study can be used in place of the calculations in this worksheet.

Figure 4d. Economic calculations for recreational use.

Expected Annual Value: Alt 1	General Recreation	General Fishing and Hunting	Specialized Fishing and Hunting	Specialized Recreation other than Fishing and Hunting	Annual Value	Net Present Value
Low					$ 151,618	$ 2,179,429
Mid	$ 140,817	$ 4,298	$ -	$ 23,349	$ 168,464	$ 2,421,588
High					$ 185,310	$ 2,663,746

Environmental benefits are calculated in the next worksheet. These are represented by annual ecosystem service values, as estimated in the Phase 1 – Novato Creek case study for the Flood Control 2.0 economic analysis. **Figure 5a** reproduces these values, updated to 2015 dollars.

Figure 5a. Ecosystem service benefits – values per acre.

Tidal habitat value per acre (2015 dollars)	# Value estimates	StdDev	-1 SD	Mean	+1 SD
Aesthetic/amenity	17	$ 7,277	$ 890	$ 8,154	$ 15,663
Water quality	7	$ 25,772	$ (10,936)	$ 14,998	$ 41,382
Flood risk reduction	8	$ 29,790	$ (6,108)	$ 23,773	$ 54,367
Option/bequest/existence value	4	$ 11	$ 42	$ 53	$ 65
Primary production/nursery	5	$ 2,755	$ 801	$ 3,545	$ 6,394
Carbon sequestration	5	$ 181	$ (56)	$ 127	$ 312

The range of land cover types in the study area is used to estimate the relative flow of ecosystem services. The worksheet shown in **Figure 5b** shows an example of the value per acre for six land cover classes and six ecosystem service types.

Figure 5b. Ecosystem services by land cover type (example).

Ecosystem Service By Land Cover						
Low	Aesthetic/ amenity	Water quality	Flood risk reduction	Option/be quest/ existence value	Carbon sequestration	Primary production/ nursery
Disturbed (Veg/Unveg Unnatural)	$ -	$ -	$ -	$ -	$ -	$ 801
Tidal Marsh	$ 890	$ -	$ -	$ 42	$ -	$ 801
Bay Flat	$ -	$ -	$ -	$ -	$ -	$ 801
Fluvial Channel	$ 890	$ -	$ -	$ 42	$ -	$ 801
Lagoon	$ -	$ -	$ -	$ 42	$ -	$ -
Storage/Treatment Basin	$ -	$ -	$ -	$ -	$ -	$ -

A detailed technical description can be found in the Appendix of the Novato Creek Case Study.

Once per-acre values have been established, they are multiplied by the actual acreage in the study area, which is expected to evolve over time. The acreages shown in **Figure 5c**, are the approximate distribution in the Lower Walnut Creek study area. Changes in the acreage of each land cover type can be input on an annual basis for the project life span, which will ultimately be reflected in the level of ecosystem service values generated by the project.

Figure 5c. Acreage projections in study area.

No-Project Alternative									
Ecosystem Service Provision by Year				Discount rate	3.375%	NPV	$12,503,368	$376,226,314	$866,695,541
						EAV	$869,830	$26,173,167	$60,293,942
Acres by Land Cover									
Year	Disturbed (Veg/Unveg)	Tidal Marsh	Bay Flat	Fluvial Channel	Lagoon	Tidal Ditch	Low	Mid	High
1	1562	2133	50	94	1554	123	$ 869,830	$ 26,173,167	$ 60,293,942
2	1562	2133	50	94	1554	123	$ 869,830	$ 26,173,167	$ 60,293,942
3	1562	2133	50	94	1554	123	$ 869,830	$ 26,173,167	$ 60,293,942
4	1562	2133	50	94	1554	123	$ 869,830	$ 26,173,167	$ 60,293,942
5	1562	2133	50	94	1554	123	$ 869,830	$ 26,173,167	$ 60,293,942

6. **Cost details.** The costs of each alternative are captured in the next two worksheets. Operations and Maintenance costs are estimated on an annualized basis, which are then summed over the project life span, while capital costs are calculated based on the costs incurred by specific activities that are constructed over time (this should become clear when looking at the screenshots). Indirect costs of each alternative (often temporary, e.g. business interruptions) may also be included in the capital cost worksheet if they warrant the attention.

Figure 6a shows summary estimates for O&M costs. This table can be expanded using the [+] buttons to the left of each row, which follow Microsoft Excel conventions. The expanded view is shown in **Figure 6b**.

Figure 6a. O&M cost worksheet – summary view.

Baylands O&M Costs - Annualized	Baseline/Current Costs	
Total - Personnel	$	600,000
Total - Dredging	$	2,200,000
Total - Facility Operations	$	25,000
Total Maint. & Repair-Equip.	$	15,000
Total Maint. & Repair-Land & Bldgs.	$	135,000
Total - Other O&M	$	30,000
Grand Total - Annual O&M	$	3,005,000
Expand the rows above [+] to enter detailed O&M Costs for each scenario		

Figure 6b. O&M cost worksheet – expanded view.

Personnel		
Staff Time	$	100,000
Professional Services	$	500,000
Total - Personnel	**$**	**600,000**
Dredging Projects		
Planning and Studies	$	100,000
Permitting	$	1,000,000
Dredging Activities	$	1,000,000
Mitigation	$	100,000
Total - Dredging	**$**	**2,200,000**
Facility Operations		
Pump Station Operations	$	-
Misc	$	25,000
Total - Facility Operations	**$**	**25,000**
Maintenance & Repair - Equipment		
Pump Maintenance	$	-
Miscellaneous Equip. Repair	$	15,000
Total Maint. & Repair-Equip.	**$**	**15,000**
Maintenance & Repair - Land & Buildings		
Levee Repair (annualized)	$	100,000
Pump Station Maintenance Repair	$	-
Tree Service & Fence Repair	$	10,000
Vegetation Maintenance & Monitoring	$	25,000
Miscellaneous Land & Bldg Repair	$	-
Total Maint. & Repair-Land & Bldgs.	**$**	**135,000**
Other O&M		
Utilities	$	5,000
Other Services & Supplies	$	25,000
Total - Other O&M	**$**	**30,000**
Grand Total - Annual O&M	**$**	**3,005,000**

The O&M costs for the two alternatives are entered the same way as the baseline costs, but with the additional option of setting a lower and upper bound for estimates, which may be used for a sensitivity analysis, as shown in **Figure 6c**, below.

Figure 6c. Alternative O&M costs, with sensitivity analysis settings.

Baylands O&M Costs - Annualized	**No-Project Alternative**		
Discount rate	3.375%		
Project life (years)	20		
	Lower Bound		*Upper Bound*
Annual Costs (Net Present Value)	*-10%*		*30%*
Total - Personnel		**$ 600,000**	
Total - Dredging		**$ 2,200,000**	
Total - Facility Operations		**$ 25,000**	
Total Maint. & Repair-Equip.		**$ 15,000**	
Total Maint. & Repair-Land & Bldgs.		**$ 135,000**	
Total - Other O&M		**$ 30,000**	
Grand Total - Annual O&M	**$ 2,704,500**	**$ 3,005,000**	**$ 3,906,500**
Net Present Value: 20 years, 3.375% discount rate	**$ 38,875,848**	**$ 43,195,386**	**$ 56,154,002**

Capital costs are expected to be incurred over a project's entire life span, and may vary each year depending on the work performed. Accordingly, the capital cost worksheet calculates the expected costs year-by-year, as follows:

A. Cost assumptions for each element of the capital construction plan are carried over from the *Alternatives_Assumptions* worksheet (Figure 2, above).
B. User-entered start and end dates are entered in the blue-highlighted columns, **Start Year** and **End Year**, based on the anticipated project schedule.
C. If costs for a line item (such as placement of fill) take place over multiple years, it is assumed that costs are spread evenly over that time.
D. Each year's costs are calculated, along with the net present value and Equivalent Annual Value.

Figure 6d. Capital cost worksheet.

No-Project Alternative					
	(Project Year Basis)				
Capital Cost Assumptions	**Start Year**	**End Year**	**Low**	**Mid**	**High**
New Levee	6	10	$ 1,700,000	$ 1,875,000	$ 2,437,500
Raise Levee	1	5	$ 212,500	$ 234,375	$ 304,688
Reinforce Levee	1	4	$ 35,417	$ 425,000	$ 425,000
New Horizontal Levee	15	16	$ -	$ -	$ -
Other embankment/floodwall construction	15	16	$ 27,500	$ 30,000	$ 40,000
Excavation (e.g. channel network)	15	16	$ 5,750,000	$ 6,250,000	$ 8,250,000
Placement of fill	15	16	$ 1,800,000	$ 2,000,000	$ 2,600,000
Flow control/diversion			$ -	$ -	$ -
Levee removal	1	5	$ -	$ -	$ -
Habitat restoration	11	15	$ 1,250,000	$ 6,125,000	$ 11,000,000
Planning, Permitting, Design	1	5	$ 538,771	$ 846,969	$ 1,252,859
Monitoring	6	20	$ 107,754	$ 338,788	$ 1,252,859
Discount rate	3.375%	**NPV**	$ 7,432,417	$ 11,966,245	$ 18,159,848
		EAV	$ 517,056	$ 832,463	$ 1,263,337

No-Project Alternative			**Annual Costs (NPV)**		
Project Year	**Calendar Year**		**Low**	**Mid**	**High**
1	2017		$159,108	$322,519	$417,759
2	2018		$159,108	$322,519	$417,759
3	2019		$159,108	$322,519	$417,759
4	2020		$159,108	$322,519	$417,759
5	2021		$150,254	$216,269	$311,509
6	2022		$347,184	$397,586	$571,024
7	2023		$347,184	$397,586	$571,024
8	2024		$347,184	$397,586	$571,024
9	2025		$347,184	$397,586	$571,024
10	2026		$347,184	$397,586	$571,024
11	2027		$257,184	$1,247,586	$2,283,524
12	2028		$257,184	$1,247,586	$2,283,524
13	2029		$257,184	$1,247,586	$2,283,524
14	2030		$257,184	$1,247,586	$2,283,524
15	2031		$4,045,934	$5,387,586	$7,728,524
16	2032		$3,795,934	$4,162,586	$5,528,524
17	2033		$7,184	$22,586	$83,524
18	2034		$7,184	$22,586	$83,524
19	2035		$7,184	$22,586	$83,524
20	2036		$7,184	$22,586	$83,524

7. **Cost and benefit summary.** When all data have been entered, the benefits and costs are summarized in a final worksheet, *BCA_Summary*. In addition to a summary of these figures, this sheet compares benefit/cost ratios for three ranges of benefits and costs.

The BCA summary is shown in **Figure 7**, below. In the example shown, the B/C ratios are favorable (greater than one) in six of the nine scenarios (only the low-benefit scenarios would fail the benefit-cost test, according to convention).

Figure 7. Benefit-cost summary page.

Alternative 1: Example

Benefits	**Low**		**Mid**		**High**	
($ millions)	Annual	NPV	Annual	NPV	Annual	NPV
Flood Risk Reduction Benefits	0.03	0.37	0.03	0.41	0.04	0.54
Net Recreational Benefits	0.15	2.18	0.17	2.42	0.19	2.66
Ecosystem Service Benefits	0.87	12.50	26.17	376.23	60.29	866.70
Total Benefits	**1.05**	**15.06**	**26.37**	**379.06**	**60.52**	**869.90**

Costs	**Low**		**Mid**		**High**	
($ millions)	Annual	NPV	Annual	NPV	Annual	NPV
Capital	1.39	20.01	2.29	32.95	3.57	51.31
O&M	0.43	6.21	0.48	6.90	0.62	8.97
Total Costs	**1.82**	**26.22**	**2.77**	**39.85**	**4.19**	**60.28**

Benefit-Cost Ratio Comparison

	Benefit		
Cost	Low	Mid	High
Low	0.6	14.5	33.2
Mid	0.4	9.5	21.8
High	0.2	6.3	14.4

Practical Application of the Economic Guidelines

Based on experience gained in the Novato Creek case study (Phase 1 of this project), we have identified some procedures to further guide the economic analysis.

Compile an inventory of data assets, including all available data for infrastructure and land use relevant to the economic analysis, such as:

- Studies in the project area, and adjacent projects, if available
    - Hydraulics & Hydrology studies – for determining alternatives
    - Sediment budgets –for predicting future dredging costs
    - Biological assessments – for cost estimates and ecosystem service valuation
    - Flood risk assessments (HAZUS, HEC-FDA, or similar) – for determining flood control benefits
    - Recreational demand studies – for determining benefits
- GIS and/or specifications for levees, pump stations, channel modifications, diversions, conveyance, tide gates, weirs, and stormwater outfalls

Obtain detailed O&M costs on an annual basis, including the following items. The more historical data available, the more confident one can be of future costs.

- Personnel/staff time
- Professional services (engineering, geotechnical, LiDAR, biological)
- Dredging project costs
- Permitting
- Monitoring
- Contracted services (channel vegetation clearing, fence repairs)
- Repair/replacement schedules

Have a clearly-defined vision for future watershed states, including an implementation timeline.

Iterate: regularly obtain feedback from agency personnel and reach out to other project managers doing similar work, and adjust estimates as necessary.

Be aware of constraints and overall context of the project:

- Physical – floodplains, sea level rise, topography
- Technical – site conditions, project complexity
- Regulatory – endangered species, water quality, sediment management
- Political – public support, jurisdictional issues
- Economic – do alternatives seem reasonable compared to similar projects?

Additional Readings

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Appendices

Project-specific requirements

Projects receiving federal support, for example from USACE, FEMA, or the U.S. Department of Transportation (DOT), must address specific items or use specific methods in the economic analysis for the project. These will be discussed where applicable. Projects funded strictly from local sources are not bound by these requirements, but may still benefit from an economic justification based on the widely-used federal guidelines for investments in water resource projects. Now known as the *Principles, Requirements, and Guidelines* (PRGs), these guidelines were updated in 2013-2014 and apply to all agencies in the departments of Interior, Agriculture, and Commerce, as well as EPA and FEMA.[3]

In addition to projects undertaken or funded by federal agencies, the PR&Gs are also followed by the State of California's Department of Water Resources (DWR), with some modifications to address state-specific concerns.

The PR&Gs do not prescribe particular rules to be followed by federal agencies, but they do reflect an updated recognition of the multiple aspects of water resource projects. Where the previous *Principles and Guidelines* largely focused on "maximizing" national economic development, the new PR&Gs put economic, social, and environmental concerns on an equal footing. This approach signals a recognition of the multiple benefits of which water and environmental project are capable, and also signal support for a more environmentally- and socially-aware type of economic analysis.[4]

The PR&Gs also reinforce other federal directives introduced in recent years, for example, by requiring project proponents to address climate change, avoid development in floodplains, and address environmental justice concerns.

[3] https://www.whitehouse.gov/sites/default/files/docs/prg_interagency_guidelines_12_2014.pdf
[4] https://www.whitehouse.gov/sites/default/files/final_principles_and_requirements_march_2013.pdf

Defining baseline conditions and alternatives

The Army Corps of Engineers defines the without-project condition as "the land use and related conditions expected to occur during the period of analysis in the absence of the proposed project" (USACE 2000). This provides a standard baseline against which the alternatives can be compared. The Corps' process for defining baseline conditions is shown below:

1. Delineate the affected area (spatial extent)
2. Determine floodplain characteristics (H&H, land use/land cover, biological studies)
3. Project/forecast activities in affected area (land use change, construction)
4. Estimate potential land use (by land cover type/developed area)
5. Project land use (by land cover type/developed area)
6. Determine existing flood damages (hazard/risk assessment, e.g., Average Annual Loss)
7. Project future flood damages (sea level rise, land subsidence, aging infrastructure)
8. Determine other costs of using the floodplain (e.g., road maintenance)
9. Collect land market value and related data (
10. Compute National Economic Development (NED) benefits

The Corps defines "With-project conditions" as "the most likely conditions expected to exist in the future if a specific project is undertaken. There are as many with-project conditions as there are alternative projects."

Implicit in the above process is the assumption that data are readily available. When the project requires obtaining large amounts of primary data, the extent of coverage and level of detail of the analysis will depend on time and budget constraints. When such limitations are present, stakeholders/project decision makers may need to prioritize the categories to be estimated, based on the need to answer specific questions

Measuring values over time

Given the long time frames involved with flood control *and* ecosystem restoration, the costs and benefits of a project must be evaluated in a way that captures their contribution to the overall social value of the project. In the case of Flood Control 2.0-type projects, construction is expected to represent the largest share of total costs, most of which will be incurred at the beginning of the project. Meanwhile, benefits may only be realized after the completion of certain project phases, such as recreational trail construction or tidal marsh restoration. Ecosystem benefits, in particular, may take decades to reach their intended level of function.

Making meaningful comparisons between project benefits and costs requires evaluating the complete project life cycle – including the planning and design stages, initial construction, and long-term operations and maintenance (including periodic repairs and replacement). This requires accounting for costs and benefits over time.

A stream of future costs and benefits are often summed into a measure known as *net present value* (NPV). The NPVs of different project alternatives can then be compared on a common basis.

The formula for the NPV of a project's *benefits* is:

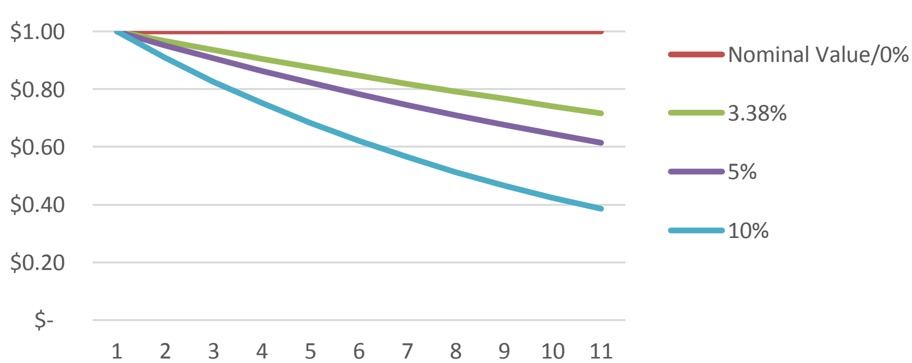
$$NPV_{Benefits} = \sum_{t=0}^{n} \frac{B}{(1+r)^t}$$

Where *r* is the discount rate,
n is the planning horizon (in years),
t is year 0, 1, …, *n*, and
B represents the gross benefits in year *t*

The NPV of costs are calculated in the same manner.

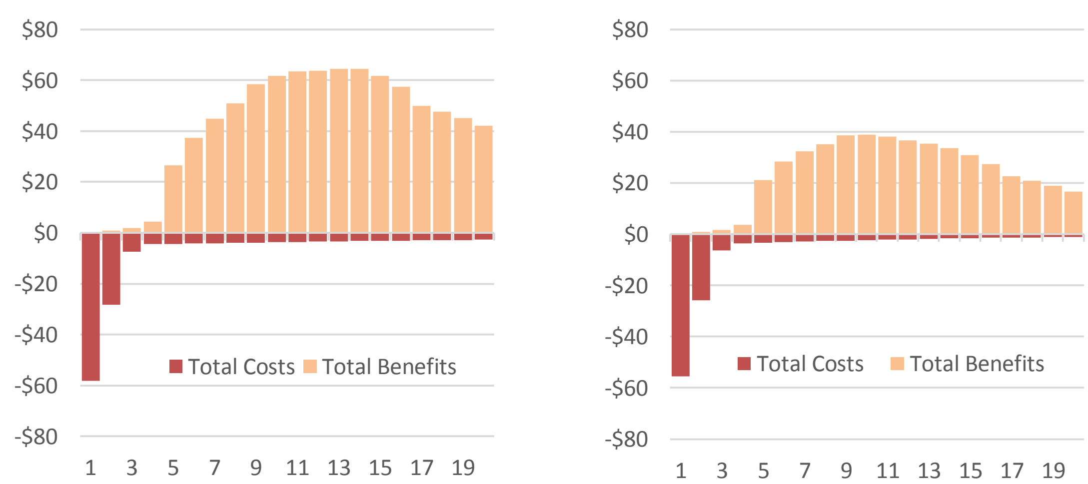
The discount rate reflects a judgment about how much weight is given to future generations in the analysis. A higher discount rate results in a more rapid decline in the value of each successive year's worth of benefits. **Figure A1** shows this graphically.

Figure A1. The value of one dollar over ten years at various discount rates



The choice of discount rate is a policy or ethical consideration rather than an economic decision, in that it represents a subjective preference for how future generations, who have no hand in today's decisions, are treated. High discount rates emphasize short-term, rather than long-term economic impacts, which will undervalue the benefits of ecosystem restoration that take decades to occur. Conversely, an analysis with lower discount rates will capture more of the benefits (and costs) that accrue in later years. **Figure A2** illustrates the effect of different discount rates on net present value and benefit/cost ratio of a hypothetical project. Both charts show the annual benefits and costs of the same project, with the only difference being the discount rate used in the analysis. The essence of Figure A2 is that the costs, which are incurred mostly near the start of the project, are only slightly discounted. Meanwhile, the benefits, most of which accrue in later years, are very sensitive to the choice of discount rate. This is reflected in the benefit/cost ratio, which is notably lower when a high discount rate is used to evaluate the project.

Figure A2. Effect of discount rate on key project indicators over 20-year horizon.



Nominal (undiscounted) value: $183 million	Nominal (undiscounted) value: $183 million
Discounted at r = 3.125%	r = 8.000%
Net Present (discounted) Value: $153 million	Net Present (discounted) Value: $123 million
Benefit/Cost Ratio: 5.5	**Benefit/Cost Ratio: 3.9**

In some cases, the discount rate to be used in an economic analysis is set by agency policy. For example, during the 2016 fiscal year, the discount rate used by the USACE in its analysis of projects is 3.125 percent. Other agencies have their own preferred rates.

Discount rates can also be negative, in cases where it is desirable to limit current consumption and invest more now for the benefit of future generations. Discount rates may also be weighted differently for different affected groups – for example, if benefits or costs are expected to fall disproportionally on a specific community. In practice, this adds more complexity to the analysis, and would likely require additional justification, so the discount rates used in this Guidebook are assumed to be uniform throughout the life of the project.

Addressing uncertainty

Like any environmental restoration and infrastructure project, the complex nature of approaches considered in the Flood Control 2.0 initiative all carry some level of uncertainty concerning their success. The ability to quantify these uncertainties will depend on many factors, but an economic study should at the very least identify and characterize them to the extent possible. Moreover, some care should be taken to identify whether the uncertainty stems from "natural" variability, for example, in weather events, or if it arises from an incomplete or imperfect understanding of how key processes will work in a given location (such as the character of sediment deposition in a reconstructed tidal wetland).

Project cost uncertainty arises from local market conditions for engineering and environmental services required to implement a project, as well as the particular requirements of the project. The more innovative the project, the more uncertainty is expected, due to the existence of fewer real-world examples to serve as a reference.

Project benefits may be especially difficult to capture with a high degree of certainty, due to the large number of unknown and unpredictable environmental factors. The establishment of desirable vegetation may take longer than anticipated, unusually severe storm events may disturb areas undergoing replanting, or exotic species may establish themselves before native populations have a chance to gain a foothold. These will delay or diminish the benefits of any project in ways that cannot be predicted with precision before the project begins.

The approach to uncertainty taken in the Flood Control 2.0 Novato Creek case study involved estimating three scenarios (low-, mid-, and high-ranges of costs and benefits) for each alternative under consideration. Thus, rather than arriving at one result, this approach produces a range of benefit/cost ratios for each alternative, which ideally provides more information to decision makers about the distribution of project benefits and costs.

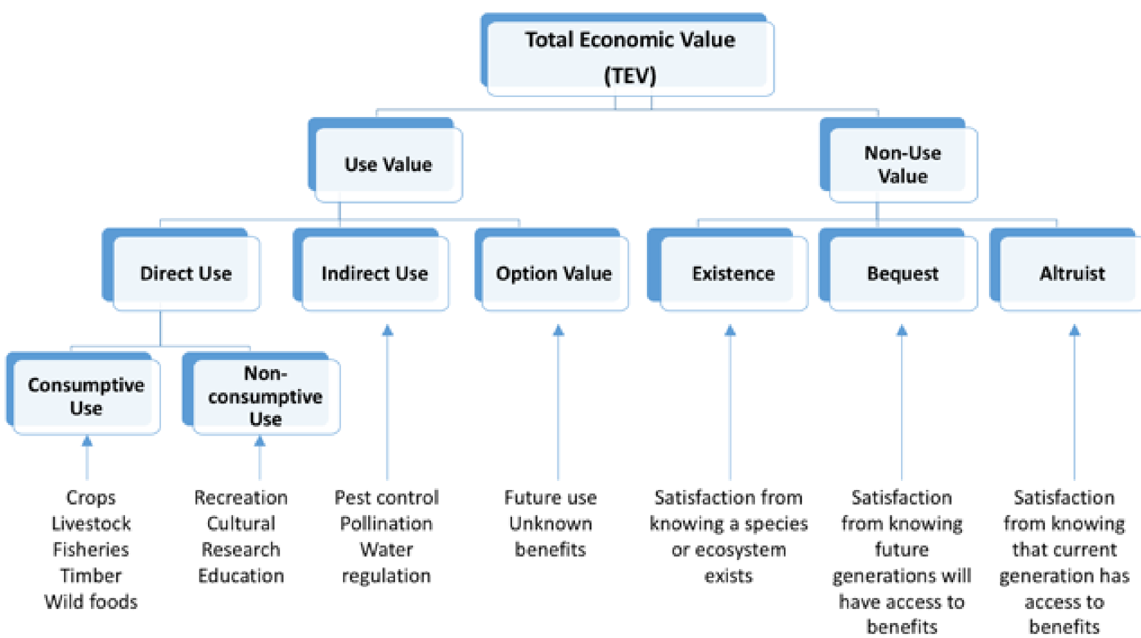
If time permits and the information is available, more precise estimates may be possible by using more detailed or sophisticated cost estimating tools, or improved hydraulics and hydrology modeling.

Valuing environmental benefits

Environmental benefits in benefit-cost studies have traditionally been confined to the role of environmental quality on human health and the availability of amenities, such as recreational opportunities (Farrow and Toman 1998). While these are important in their own right, ecosystems provide an even longer list of potential benefits, including marketed goods such as fish and timber, non-consumptive uses, such as recreational and cultural uses, indirect services, such biological control of pests, and a range of intangible benefits, explained in more detail below.

Numerous systems of classifying ecosystem services have been introduced over the past 15 years, though no clear standard has emerged among researchers, policy makers, and the public.[5] Rather than adopt a specific methodology, the approach used in these benefit-cost guidelines is based on the Total Economic Value (TEV) framework, particularly the incarnation described in The Economics of Ecosystems and Biodiversity project (TEEB 2000). The organization of TEV is shown in **Figure A3**, below.

Figure A3. Total Economic Value (TEV) of an ecosystem



Adapted from TEEB (2010)

The examples of ecosystem services shown at the bottom of Figure A3 can be grouped into several intermediate categories:

[5] See, e.g., the Millennium Ecosystem Assessment (MA), the United Nation's System of Environmental-Economic Accounts (SEEA), and EPA's Final Ecosystem Goods and Services Classification System (FEGS-CS)

Consumptive uses include the harvesting of physical resources from the ecosystem. The values of these ecosystem goods are typically represented by market prices.

Non-consumptive uses involve direct contact with the ecosystem, but do not usually involve a significant removal of biological resources. Some of these values, such as recreation, can be estimated through expenditures, while others, such as cultural or educational uses, must be estimated through less direct methods, which are explained in more detail below.

Indirect uses are valued for their role in supporting other beneficial services, such as biological control of pests, pollination services for crops and wild flowers (which may contribute, in turn, to other direct uses), and the regulation of water quality and storm surge protection. These values may be estimated through cost-based measures, described in more detail below.

Option value reflects the fact that some resources currently not being used may, at some point in the future, become valued in some way. The usefulness of as-yet undiscovered medicines derived from plant or animal species can be thought of as an option value, which may be lost if those species are extinguished. The role of biodiversity in promoting resilience may also fit into this category: in addition to its role in supporting other services, increased biodiversity may reduce some of the risks posed by climate change, and can help maintain genetic stocks of species that do not currently have an economic "value," but might have some value in the future.

Existence, **bequest**, and **altruistic** values are concerned with human preferences that, while difficult to measure and sometimes contested, have been recognized as legitimate by government entities, such as the recognition of existence value by U.S. courts in the wake of the Exxon *Valdez* oil spill (Carson et al. 2003).

Valuation methods

Direct market valuation approaches

In some occasions, ecosystem goods and services can be valued directly from market prices. Examples include the value of wild-caught fish and harvested shellfish, forestry products (including non-timber products such as ornamental plants and mushrooms), and fiber and dyes produced from wild plants.

Also considered a market-based method, *production function approaches* estimate the extent to which ecosystem services contribute to the provision of another good or service. For example, improved pollinator habitat may result in more effective pollination of marketed crops. If this results in a net increase in farm income (due to increased production, higher quality/price, or lower costs), then that value can be attributed to the habitat improvement.

Finally, *cost-based approaches* (including *avoided cost* and *averting behavior* approaches) estimate the cost to replace an ecosystem service. Continuing from the example above, a loss of native pollinator habitat can have detrimental effects on the efficacy of honey bees typically used in crop pollination. This may require the use of additional bee colonies to make up for the loss of native pollinators, which incurs an extra cost to the grower. This additional cost can be regarded as a proxy for the value of pollination services to crop growers.

Revealed preference methods

Revealed preference methods are concerned with the *actual behaviors* of economic actors. In these models, values are estimated by observing what people actually pay for particular services. For example, *travel cost models* (TCM) measure expenditures that can be attributed to specific activities, such as visiting a national park or using a local trail for recreation. TCM studies collect detailed information about users, such as how far they travel to reach their destination, specialized equipment they purchase (e.g., hiking gear, mountain climbing equipment), and other expenditures related to the resource being valued. Other revealed preference methods, known as *hedonic pricing models* (HPM), measure differences in what people pay for assets (e.g., houses) with differing attributes, such as proximity to beaches, wetlands, or parks. The "value" of the beach, wetland, or park is then inferred from the difference in sales prices for similar houses, controlling for other attributes, such as square footage and number of bedrooms.

Stated preference methods

Stated preference methods use indirect methods, such as surveys and experiments, to elicit responses from a sample of users of a resource. These approaches include contingent valuation (CV) and choice modeling (CM). CV studies pose hypothetical questions to users about their willingness to pay (WTP) for improvements in environmental outcomes (or conversely, their willingness to accept – WTA – monetary compensation for a reduction in environmental quality). Similarly, CM studies pose a range of hypothetical tradeoffs to survey participants in order to estimate WTP/WTA. For example, respondents may be asked to rank three unique scenarios in order of preference, in which tradeoffs may include different levels of biodiversity, recreational use opportunities, or water quality.

In practice, valuation studies may combine several approaches, which may improve the validity of the results.

Valuation using secondary sources

When resource limitations do not allow for ecosystem benefit values to be directly estimated for a project, two substitute methods are commonly used: *benefit transfer* and *meta-analysis*.

Benefit transfer methods use values obtained from previous studies as proxies for another site. This approach resembles the comparable sales approach used in real estate valuation. In a benefit-transfer study, a literature review is conducted of *study sites* where one or more ecosystem services were directly valued using the above methods. The value, or some aggregation of values, of ecosystem benefits are then transferred to a *policy site* where there is no existing valuation data.

Benefit transfers are most helpful when the domain of study sites closely resembles conditions at the policy site. For example, a study site consisting of tidal marsh, adjacent to a policy site also consisting of tidal marsh would be preferable to a freshwater wetland study site in a distant state.

The transfer of values can be done in two ways. A *point transfer* simply takes specific values (or ranges of values) from the study site and applies them to the policy site. A *function transfer* uses the economic model developed at a study site and replaces the model inputs with those of the policy site

Point transfer can be expressed in the following notation, where:

$Value/Acre_i \approx Value/Acre_j$	Value per acre at study site *i* is approximately the same as the value per acre at policy site *j*.

Benefit function transfer can be expressed as:

$Value/Acre_i = f(WQ_i, RQ_i, Loc_i)$	Value per acre at study site *i* is a function of the water quality, recreational quality, and location of site *i* The benefit function transfer uses the same equations for site *i*, but uses inputs from policy site *j*

As both examples above indicate, the validity of benefit transfer depends greatly on the physical similarity of the sites under question, but also the similarity of the social/economic context in which an ecosystem is valued. To use an example, the value of a freshwater marsh in northern Europe in which hunting is a major use is not likely to be a useful proxy for a saltwater marsh in the western United States in which the primary activity is bird watching. This can severely limit the number of suitable studies in the analysis.

When a sufficient number of studies do exist, a *meta analysis* may be used to estimate ecosystem benefits. This is done by controlling for various factors among the studies. For example, a particular study can be categorized by a variety of parameters, such as: the year in which it was conducted, the valuation method(s) used (CV, TCM, HPM, etc.), geographic location, types of uses valued, and other attributes. A sample of comparable studies can then be used as inputs to a multiple regression analysis, with coefficients on each variable indicating its relative effect on ecosystem service values. For example, some methods may systematically overestimate the WTP of respondents compared to others, or there may be systematic differences between studies that focus on only one ecosystem service and those that value bundles of services.

The choice to use secondary data as a proxy for ecosystem service values is a judgment call to be made by project managers and stakeholders. An increasing number of public agencies have recognized the utility of benefit transfer methods – see, for example FEMA (2013) and Santa Clara Valley Open Space Authority (Batker et al., 2014). For planning purposes, these secondary methods should be sufficient to provide useful guidance to decision makers, but when a more rigorous valuation is needed, such as when federal and state funds are at stake, primary valuations will likely be needed for at least some of the environmental/ecosystem benefits. In some cases, as with Army Corps projects, specific methods, will be spelled out.

Benefit-Cost Worksheets

Flood Control 2.0: Benefit-Cost Analysis Workbook for Flood Risk Management and Restoration Planning Version 1.0 - January 2016			
Project	**Planning timeframe**		
Assumptions	Start (Year)		
	End (Year)		
	Total Duration		**years**
	Discount rates		
	Low		
	Mid		
	High		
Scenario Names	No-Project Alternative		
	Alternative 1:		
	Alternative 2:		

Notes:

Where costs appear in these worksheets, they are taken from Flood Control 2.0 – Novato Creek Case Study, adjusted to 2015 dollars

No-Project Alternative

Capital Cost Assumptions	Unit	Low	Mid	High	Notes
New Levee					
Total length	L.F.				
Avg height from base	ft.				
Cost per linear foot (12ft height)	$	$680	$750	$975	
Raise Levee					
Total length	L.F.				
Avg height increase	ft.	3	3	3	
Cost per linear foot/CY	$	$57	$63	$81	
Reinforce Levee					
Total length	L.F.				
Cost per linear foot/CY	$	$14	$170	$170	
New Horizontal Levee					
Total length	L.F.				
Avg Height	ft.	10	10	10	
Cost per linear foot/CY	$	$680	$750	$975	
Other embankment construction					
Total length	L.F.				
Avg Height	ft.	1	1	1	
Cost per linear foot/CY	$	$55	$60	$80	
Pump Station Replacement					
Number of pump stations	LS	-	-	-	
Cost/station	$	$909,091	$1,000,000	$1,300,000	
Other Major Replacement	**LS**				
Excavation (e.g. channel network)					
Total volume	CY				
Cost per CY	$	$23	$25	$33	
Placement of fill					
Total volume	CY				
Cost per CY	$	$18	$20	$26	
Flow control/diversion					
Number of structures	EA	-	-	-	
Cost/structure	$	$0	$0	$0	
Levee removal					
Feet removed	L.F.	-	-	-	
Cost per linear foot	$	$410	$450	$585	
Habitat restoration					
Area restored	Acre				
Cost per acre	$	$5,000	$24,500	$44,000	
Planning, Permitting, Design					
Monitoring					
Other					

Alternative 1

Capital Cost Assumptions	Unit	Low	Mid	High	Notes
New Levee					
Total length	L.F.				
Avg height from base	ft.				
Cost per linear foot (12ft height)	$	$680	$750	$975	
Raise Levee					
Total length	L.F.				
Avg height increase	ft.	3	3	3	
Cost per linear foot/CY	$	$57	$63	$81	
Reinforce Levee					
Total length	L.F.				
Cost per linear foot/CY	$	$14	$170	$170	
New Horizontal Levee					
Total length	L.F.				
Avg Height	ft.	10	10	10	
Cost per linear foot/CY	$	$680	$750	$975	
Other embankment construction					
Total length	L.F.				
Avg Height	ft.	1	1	1	
Cost per linear foot/CY	$	$55	$60	$80	
Pump Station Replacement					
Number of pump stations	LS	-	-	-	
Cost/station	$	$909,091	$1,000,000	$1,300,000	
Other Major Replacement	**LS**				
Excavation (e.g. channel network)					
Total volume	CY				
Cost per CY	$	$23	$25	$33	
Placement of fill					
Total volume	CY				
Cost per CY	$	$18	$20	$26	
Flow control/diversion					
Number of structures	EA	-	-	-	
Cost/structure	$	$0	$0	$0	
Levee removal					
Feet removed	L.F.	-	-	-	
Cost per linear foot	$	$410	$450	$585	
Habitat restoration					
Area restored	Acre				
Cost per acre	$	$5,000	$24,500	$44,000	
Planning, Permitting, Design					
Monitoring					
Other					

Alternative 2

Capital Cost Assumptions	Unit	Low	Mid	High	Notes
New Levee					
Total length	L.F.				
Avg height from base	ft.				
Cost per linear foot (12ft height)	$	$680	$750	$975	
Raise Levee					
Total length	L.F.				
Avg height increase	ft.	3	3	3	
Cost per linear foot/CY	$	$57	$63	$81	
Reinforce Levee					
Total length	L.F.				
Cost per linear foot/CY	$	$14	$170	$170	
New Horizontal Levee					
Total length	L.F.				
Avg Height	ft.	10	10	10	
Cost per linear foot/CY	$	$680	$750	$975	
Other embankment construction					
Total length	L.F.				
Avg Height	ft.	1	1	1	
Cost per linear foot/CY	$	$55	$60	$80	
Pump Station Replacement					
Number of pump stations	LS	-	-	-	
Cost/station	$	$909,091	$1,000,000	$1,300,000	
Other Major Replacement	**LS**				
Excavation (e.g. channel network)					
Total volume	CY				
Cost per CY	$	$23	$25	$33	
Placement of fill					
Total volume	CY				
Cost per CY	$	$18	$20	$26	
Flow control/diversion					
Number of structures	EA	-	-	-	
Cost/structure	$	$0	$0	$0	
Levee removal					
Feet removed	L.F.	-	-	-	
Cost per linear foot	$	$410	$450	$585	
Habitat restoration					
Area restored	Acre				
Cost per acre	$	$5,000	$24,500	$44,000	
Planning, Permitting, Design					
Monitoring					
Other					

Intended Outcomes: Restoration, Recreation, Flood Protection

Item	No Project	Alt 1	Alt 2
Land Cover Change (acres) from Year 1 Conditions			
Subtidal			
Bayflat			
Tidal marsh			
Fluvial Channel			
Lagoon			
Storage/Treatment Basin			
Other Land Cover Type			
Recreational			
Trail (additional miles/annual users)			
Park (acres, additional users)			
Other Facility (additional users)			
Quality changes			
Flood Protection (Net of gray project design)			
Water Quality Improvement			
Other			

Notes on Alternatives Assumptions:

(e.g., levee cost per mile)

Flood Risk Benefits

If flood damage estimates have been made using another method (e.g. HEC-FDA or HAZUS-MH), then those estimates may be entered into the Benefit-Cost Workbook in place of these.

Item	No Project	Alt 1	Alt2
Level of Protection	25-year	100-year	100-year
Damages to structures and contents # Residential Structures Damage/structure Damage/contents (assume 50% of structural damage) # Commercial Structures Damage/structure Damage/contents (assume 100% of structural damage) Damage to specialty structures			
Stream bank/levee repairs Linear feet/Cubic Yards Emergency response costs/day Cleanup costs Transportation delays Cost/hour # hours Cost of infrastructure upgrades			
Other categories			

Notes:

Recreational Use Benefits

If recreational use studies have been conducted, then those estimates may be entered into the Benefit-Cost Workbook in place of these.

Army Corps Unit-Day Value Worksheet, Part 1 (General Recreation)

Criteria	Judgment factors				
Recreation experience[1] Total Points: 30 Point Value:	Two general activities[2] 0-4	Several general activities 5-10	Several general activities: one high quality value activity[3] 11-16	Several general activities; more than one high quality high activity 17-23	Numerous high quality value activities; some general activities 24-30
Availability of opportunity[4] Total Points: 18 Point Value:	Several within 1 hr. travel time; a few within 30 min. travel time 0-3	Several within 1 hr. travel time; none within 30 min. travel time 4-6	One or two within 1 hr. travel time; none within 45 min. travel time 7-10	None within 1 hr. travel time 11-14	None within 2 hr. travel time 15-18
Carrying capacity[5] Total Points: 14 Point Value:	Minimum facility for Development for public health and safety 0-2	Basic facility to Conduct activity(ies) 3-5	Adequate facilities to Conduct without Deterioration of the resource or activity experience 6-8	Optimum facilities to Conduct activity at Site potential 9-11	Ultimate facilities to Achieve intent of Selected alternative 12-14
Accessibility Total Points: 18 Point Value:	Limited access by any means to site or within site 0-3	Fair access, poor quality roads to site; limited access within site 4-6	Fair access, fair road to site; fair access, good roads within site 7-10	Good access, good roads to site; fair access, good roads within site 11-14	Good access, high standard road to site; good access within site 15-18
Environmental quality Total Points: 20 Point Value:	Low aesthetic factors[6] that significantly lower quality[7] 0-2	Average aesthetic quality; factors exist that lower quality to minor degree 3-6	Above average Aesthetic quality; any limiting factors can be reasonably rectified 7-10	High aesthetic quality; no factors exist that lower quality 11-15	Outstanding aesthetic quality; no factors exist that lower quality 16-20

[1]Value for water-oriented activities should be adjusted if significant seasonal water level changes occur.

[2]General activities include those that are common to the region and that are usually of normal quality. This includes picnicking, camping, hiking, riding, cycling, and fishing and hunting of normal quality.

[3]High quality value activities include those that are not common to the region and/or Nation, and that are usually of high quality.

[4]Likelihood of success at fishing and hunting.

[5]Value should be adjusted for overuse.

[6]Major esthetic qualities to be considered include geology and topography, water, and vegetation.

[7]Factors to be considered to lowering quality include air and water pollution, pests, poor climate, and unsightly adjacent areas.

Recreational Use Benefits, cont.

If recreational use studies have been conducted, then those estimates may be entered into the Benefit-Cost Workbook in place of these.

Army Corps Unit-Day Value Worksheet, Part 2 (Specialized Recreation)

Criteria	Judgment factors				
Recreation experience[1] Total Points: 30 Point Value:	Heavy use or frequent crowding or Other interference with use 0-4	Moderate use, other users evident and likely to interfere with use 5-10	Moderate use, some evidence of other users and occasional Interference with use due to crowding 11-16	Usually little evidence of other users, rarely if ever crowded 17-23	Very low evidence of other users, never crowded 24-30
Availability of opportunity[4] Total Points: 18 Point Value:	Several within 1 hr. travel time; a few within 30 min. travel time 0-3	Several within 1 hr. travel time; none within 30 min. travel time 4-6	One or two within 1 hr. travel time; none within 45 min. travel time 7-10	None within 1 hr. travel time 11-14	None within 2 hr. travel time 15-18
Carrying capacity[5] Total Points: 14 Point Value:	Minimum facility for Development for public health and safety 0-2	Basic facility to conduct activity(ies) 3-5	Adequate facilities to Conduct without deterioration of the resource or activity experience 6-8	Optimum facilities to Conduct activity at site potential 9-11	Ultimate facilities to achieve intent of selected alternative 12-14
Accessibility Total Points: 18 Point Value:	Limited access by any means to site or within site 0-3	Fair access, poor quality roads to site; Limited access within site 4-6	Fair access, fair road to site; fair access, good roads within site 7-10	Good access, good roads to site; fair access, good roads within site 11-14	Good access, high standard road to site; good access within site 15-18
Environmental quality Total Points: 20 Point Value:	Low aesthetic factors[4] that significantly lower quality[5] 0-2	Average aesthetic quality; factors exist that lower quality to minor degree 3-6	Above average Aesthetic quality; any limiting factors can be reasonably rectified 7-10	High aesthetic quality; no factors exist that lower quality 11-15	Outstanding aesthetic quality; no factors exist that lower quality 16-20

[1]Value for water-oriented activities should be adjusted if significant seasonal water level changes occur.
[2]Likelihood of success at fishing and hunting.
[3]Value should be adjusted for overuse.
[4]Major esthetic qualities to be considered include geology and topography, water, and vegetation.
[5]Factors to be considered to lowering quality include air and water pollution, pests, poor climate, and unsightly adjacent areas.

Recreational Use Benefits, cont.

Once points have been assigned to the recreational use opportunities, simply look up the nearest dollar value in the table below. This represents the value a single user places on the recreational resource per day.

To estimate annual values, multiply the Unit Day Value by the estimated number of annual users/visitors.

Point Values	General Recreation Values (1)	General Fishing and Hunting Values (1)	Specialized Fishing and Hunting Values (2)	Specialized Recreation Values other than Fishing and Hunting (2)
0	$ 3.90	$ 5.61	$ 27.33	$ 15.86
10	$ 4.64	$ 6.35	$ 28.07	$ 16.84
20	$ 5.12	$ 6.83	$ 28.55	$ 18.06
30	$ 5.86	$ 7.57	$ 29.29	$ 19.52
40	$ 7.32	$ 8.30	$ 30.02	$ 20.74
50	$ 8.30	$ 9.03	$ 32.95	$ 23.43
60	$ 9.03	$ 10.01	$ 35.87	$ 25.87
70	$ 9.52	$ 10.49	$ 38.07	$ 31.24
80	$ 10.49	$ 11.23	$ 41.00	$ 36.36
90	$ 11.23	$ 11.47	$ 43.93	$ 41.49
100	$ 11.71	$ 11.71	$ 46.37	$ 46.37

(1) Use points from Unit-Day Value Worksheet, Part 1
(2) Use points from Unit-Day Value Worksheet, Part 2

Notes: