Handbook for Assessing Value of State Flood Management Investments

June 2014

FloodSAFE CALIFORNIA

PUBLIC SAFETY ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

Background cover photo: The Folsom Dam Joint Federal Project Auxiliary Spillway is a collaborative effort by the U.S. Army Corps of Engineers, the Federal Bureau of Reclamation, the California Department of Water Resources, and the Sacramento Area Flood Control Agency to address dam safety and improve flood protection for Sacramento. The photo, courtesy of the U.S. Army Corps of Engineers, shows construction of the new control structure (dam) and new spillway. The use of consistent methods for economic analysis is essential for projects such as this one that involve partnerships among federal, state, and local agencies.

Inset photos:

1. Tower Bridge on the Sacramento River at high water. This vertical lift bridge connects the State Capital to West Sacramento and access to US Highway 50 and Interstate 80, and lifts to allow navigation of large vessels upstream and downstream of Sacramento. This transportation infrastructure project represents an integrated flood risk management investment that would include flood risk management and navigation benefits. Photo courtesy of Sara Miller
2. A floodwall protects Our Lady of Lourdes Hospital during Tropical Storm Lee in Binghamton, NY, when the Susquehanna River flooded in June 2011. This floodwall was the most cost effective solution to protect the hospital after it flooded in 2006 due to an earthen dam being breached. Investments in flood protection measures for site-specific critical and/or emergency service facilities provides resiliency and redundancy safeguarding public health from floods. Photo courtesy of the Federal Emergency Management Agency.

CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE CALIFORNIA

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June 2014

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Preface

Millions of people and over half a trillion dollars in assets are exposed to flood risk in California (DWR 2013a). This remains the case even as State, federal, and local flood management agencies have worked for decades to reduce the risk and consequences of flooding in the State. The people of California have shown that they understand the increasing flood risk due to population growth, environmental concerns, climate change, and land use practices, and they are willing to invest in flood risk management projects. This requires the public agencies responsible for California's flood risk management to demonstrate the value of those investments both before and after they are implemented. This *Handbook for Assessing Value of State Flood Management Investments* (HAV) supports that effort.

DWR's Foundational Goals for State Water Management Investment Strategy

The California Department of Water Resources (DWR) has identified foundational goals that shape the State's water management investment strategy. Those goals are:

- Improving public safety
- Fostering environmental stewardship
- Supporting economic stability

They are described further below.

DWR's foundational goals include improving public safety, fostering environmental stewardship, and supporting economic stability.

Photo credits (left to right): Marin County, UC San Diego, UC Division of Agriculture and Natural Resources

Improve Public Safety

In general terms, public safety means the prevention of and protection from events that could pose a risk of harm or injury to a broad set of citizens. Improving public safety in relation to water management results from actions that help to:

- Reduce loss of life, injuries, and health risks caused by flooding.
- Provide adequate water supply for domestic needs, sanitation, and fire prevention.
- Reduce exposure of people to water-borne health threats such as contamination or infectious agents.

Foster Environmental Stewardship

DWR defines environmental stewardship as a commitment to manage and protect natural resources (water, air, land, plants, and animals) and ecosystems in a sustainable manner that ensures they are available for future generations. Fostering environmental stewardship in relation to water management results from actions that help to:

- Educate the citizens of California about the interdependencies between water use, flood risk management, and ecosystem function and how citizen's choices and behaviors impact all three.
- Incorporate environmental stewardship principles and methods throughout the entire life cycle (planning, design, permitting, implementation, operation, and maintenance) of water-related projects and policies.
- Reduce wasteful or inefficient use of natural resources.
- Restore or enhance degraded habitat and watershed function.

Support Economic Stability

Economic stability is an absence of excessive fluctuations in an economy as a whole (e.g., national, regional, and global). An economy with fairly constant output growth and low stable inflation is generally considered stable. Water management actions that can support economic stability include those that:

- Provide reliable water supplies of suitable quality for a variety of beneficial uses (such as business, manufacturing, agriculture, and recreation) that generate economic income (where reliability is a function of quantity, quality, location, and timing).
- Reduce expected damages and economic disruption caused by flooding.

- Produce more benefit from economic activities by:
  - Reducing costs to provide a given level of service (including transaction costs).
  - Providing adequate flood protection to allow for continuing or expanded economic activities within a region.
- Reduce the likelihood of significant social disruption.

DWR's Planning Process for Flood Risk Management Investments

These foundational goals provide broad direction for State investments, but they do not provide specific direction for investment decision making. Once goals and objectives are clearly defined, remaining steps in the planning process include:

1. Formulating investment options.
2. Assessing the performance of each option.
3. Comparing options.
4. Selecting a recommended option.

HAV provides in-depth guidance for assessment of performance and comparison among investment options, as described further below.

Evaluation of flood management projects includes a description of resilience.

Assessment of Performance

The evaluation of system performance requires (a) a clearly defined list of all potential benefits (and costs) that might result from various water management options and (b) prescribed methods to estimate those benefits (and costs). Finally, to inform DWR investment decisions, the performance of these options must be categorized and characterized relative to the DWR foundational goals.

The evaluation of long-term level of service is the traditional approach to estimating benefits from a potential investment. This evaluation describes and estimates the long-term level of service for a specific output of the project (reduction of flood damage, delivery of acre-feet of water, restoration of acres of habitat, etc.) by comparing the change between "without-project" and "with-project" conditions.

Performance assessment also requires a description of changes to resiliency attributable to proposed options. Resiliency is the capacity of a system to respond under stressful conditions. Thus, a description of resiliency describes the following characteristics:

- **Robustness** – The inherent strength or resistance in a system to withstand external changes and demands without degradation or loss of the estimated level of service.
- **Redundancy** – System properties that allow for alternate options, choices, and substitutions to be used to attempt to provide the estimated level of service while the system is under stress.
- **Resourcefulness** – The capacity within the system to mobilize needed resources and services in response to significant stress events or long-term external changes.
- **Rapidity** – The speed with which a system can return to the estimated level of service after a significant disruption occurs.

Comparison of Options

Flood risk management investment decisions require a comparison of the gains and losses of proposed options. While comparisons of benefits and costs are facilitated if they are expressed in the same units (e.g., dollars), often this is not possible, requiring various analysis methods to be used. But the objective of the analysis is the same—determination of the overall value of the proposed project to prioritize investments that meet the DWR foundational goals.

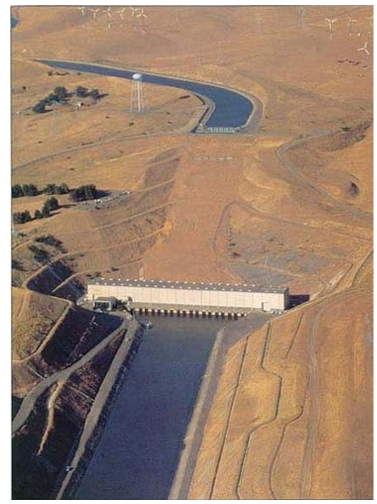
Methods that can be used to evaluate gains and losses include cost-effectiveness analysis, benefit-cost (B-C) analysis, socioeconomic impact analysis, and trade-off analysis. The use of one or more of these methods depends on the scope and objectives of the analysis, available project data, and whether benefits and costs can be expressed in the same units. These methods are summarized below (DWR 2008a).

Cost-Effectiveness Analysis

Cost-effectiveness analysis focuses on costs of achieving or exceeding an objective that can be expressed in specific, nonmonetary terms (acre-feet, milligrams per liter, habitat units, etc.). For example, if the objective of an option is to deliver x acre-feet of water to a service area per year, then a cost-effectiveness analysis would compare the costs of alternative plans that meet or exceed that objective. The option that delivers the specified water quantities at the least cost would be the preferred option. Cost-effectiveness analysis is particularly important when the objective cannot be expressed in monetary terms and therefore be included in traditional benefit-cost analysis (described below). However, a key limitation of cost-effectiveness analysis is that it does not consider explicitly the value of the gains, or benefits, of proposed options.

Benefit-Cost Analysis

Benefit-cost analysis is the procedure where the different benefits and costs of a proposed project are identified and measured in monetary terms and then compared with each other to determine if the benefits of the option exceed its costs. Traditionally, B-C analysis has been the primary method to determine if a project is economically justified (that is, benefits exceed total costs). Benefit-cost analysis is usually limited to primary benefits and costs, excluding secondary effects (described below). More importantly, it requires benefits and costs to be monetized, which is not always possible (or desirable). However, B-C analysis is required by current federal guidance for projects being developed with federal agency partners.



The Harvey O. Banks Pumping Plant on the California Aqueduct: socioeconomic impact analysis can include assessment of impacts in distant regions affected by project outputs.

Photo: University of California

Socioeconomic Impact Analysis

Whereas B-C analysis focuses on primary benefits and costs, socioeconomic impact analysis focuses on changes in regional population and economic activity as well as fiscal impacts on local governments (e.g., changes in public services and revenues). Socioeconomic impact analyses are particularly relevant in evaluating the effects of a project on the local communities where they are constructed, and also on communities in other regions which may not be affected by construction activities but would be affected by the project's outputs. (Examples of such impacts include changes in flood risk downstream of projects and water deliveries to other regions of the State.) Socioeconomic impact analyses are usually limited to describing the regional effects on people (and their institutions) resulting from project implementation.

Trade-Off Analysis

Trade-off analysis displays all monetary and nonmonetary effects of proposed projects such that the "gains" and "losses" among proposed options can be compared and a recommended option identified. One form of trade-off analysis is multiple criteria analysis (MCA). MCA is a decision support framework that facilitates the evaluation and selection of alternatives based on multiple differently scaled criteria. For each alternative, MCA transforms criteria values expressed in different units into a dimensionless, numerical score (which can be weighted to reflect stakeholder preferences), which is then used to evaluate the merit of each alternative on a common scale. Thus, MCA allows for a systematic, transparent, and repeatable evaluation of diverse criteria. MCA can also be used to conduct sensitivity analyses to analyze uncertainty and test the robustness of solutions.

MCA is particularly well suited to supplement multiobjective B-C analysis. To the extent that the benefits and costs can be quantified and expressed in monetary terms, then traditional B-C analyses will suffice. However, when benefits and/or costs cannot be expressed in monetary terms, or even quantified, they can still be evaluated (and weighted) using MCA.

Figure P-1 compares the relative scopes (i.e., breadth of analysis) of the methods described above. Of all the methods, MCA is the most comprehensive for comparing the “gains” and “losses” of proposed options. However, as noted above, B-C analysis is still required for projects being developed with federal participation.

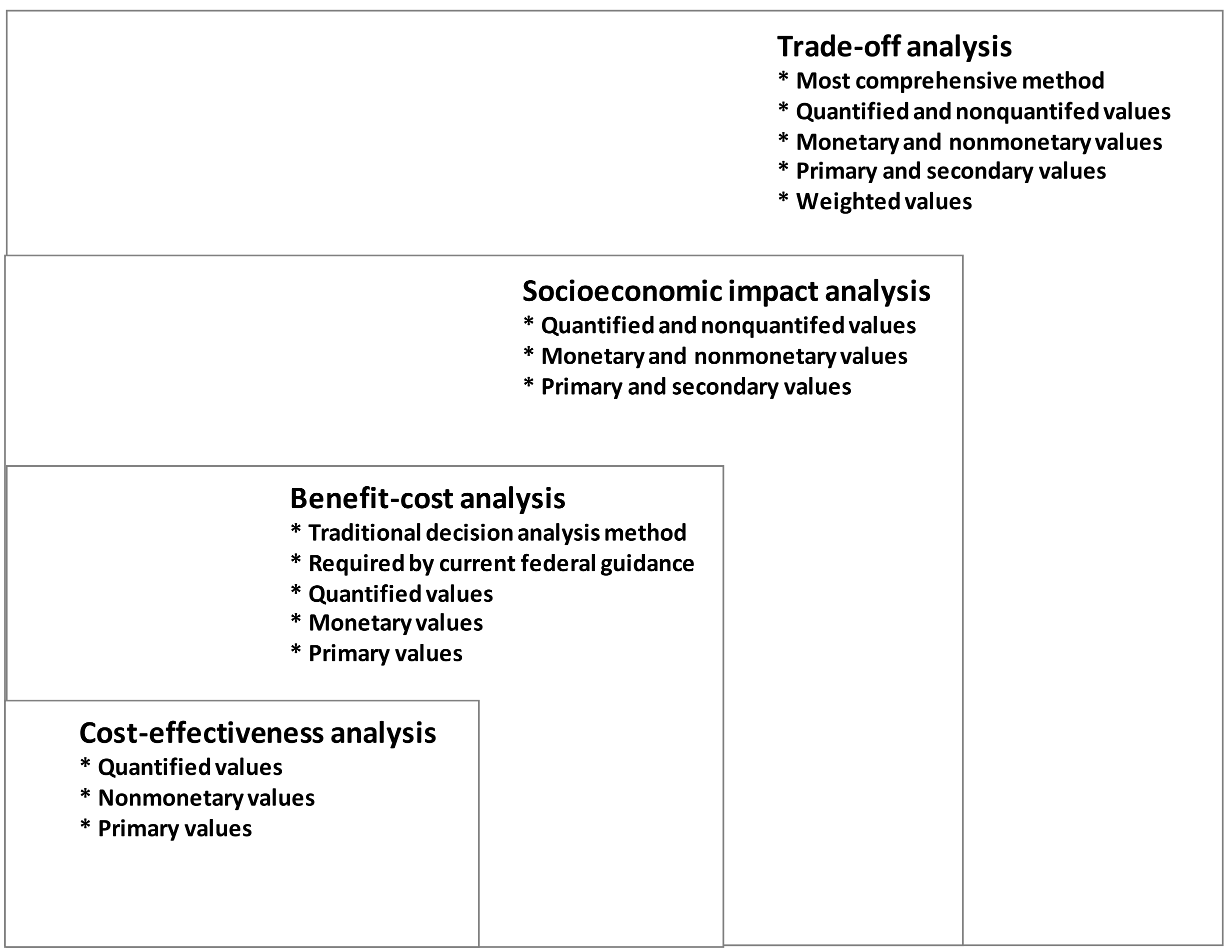


Figure P-1. Comparison of the Relative Scopes of Option Evaluation and Comparison Methods

Handbook Supports DWR's Planning Process for Flood Risk Management Investments

This HAV is a comprehensive guide for assessing the overall value of proposed flood management investments, which, in turn, supports the DWR investment strategy summarized above.

Handbook Supports DWR's Foundational Goals

A table linking these benefits to the DWR foundational goals is provided in Table P-1.

Table P-1. Relationship of HAV Benefit Categories to DWR Foundational Goals for Integrated Water Management

	DWR Foundational Goals for Integrated Water Management		
Benefit Category	**Improve public safety**	**Foster environmental stewardship**	**Support economic stability**
Flood risk management	✓	✓	✓
Water supply and quality	✓	✓	✓
Ecosystem restoration		✓	✓
Recreation and open space		✓	✓
Hydropower			✓
Navigation			✓
Commercial fisheries			✓
Reduced long-term system maintenance costs			✓
Regional economic and social effects	✓	✓	✓

Handbook Describes a Broad Array of Benefits

The HAV directly contributes to DWR's planning process by describing a broad array of integrated flood management benefit categories, including:

- Flood management
- Ecosystem restoration
- Water supply and quality
- Recreation and open space

- Hydropower
- Navigation
- Commercial fisheries
- Reduced long-term system maintenance costs
- Other effects, including regional economic and social effects

Handbook Builds on Prior Guidance

The HAV provides guidance for assessment and comparison of investment options. It builds upon the *Economic Analysis Guidebook* (*Guidebook*) DWR produced in 2008. The Guidebook describes benefit-cost analysis, cost-effectiveness analysis, and impact analysis in a general way as these are applied to water resource projects. The HAV goes beyond the Guidebook by describing in detail DWR-recommended methods, software applications, data sources, and analysis results templates. The HAV also updates and expands upon the 1977 draft *Economics Practices Manual* and the 2012 draft *Description and Screening of Potential Tools and Methods to Quantify Public Benefits of Water Storage Projects*.

Handbook Meets the Needs of Engineers and Scientists

The HAV's primary audience is DWR engineers and scientists. It provides consistent analysis principles, concepts, and definitions, and it describes various evaluation methods typically used for economic analyses. In addition to detailed descriptions of analysis methods for an array of benefits, an example analysis illustrates the application of the recommended benefit (and cost) evaluation methods and software applications to integrated flood management studies. This information allows engineers and scientists to be knowledgeable about the analysis procedures when consulting with DWR economics staff and to conduct some of the analysis themselves. In every case, the HAV recommends that engineers, scientists, planners, and other members of the analysis team consult with DWR economists prior to commencing these types of analyses and as needed thereafter.

The evaluation methods described herein may evolve over time. Thus, the HAV was designed with easily separable chapters for placement in a three-ring binder; specific sections can be easily updated and replaced as needed.

Executive Summary

This Handbook for Assessing Value of State Flood Management Investments (HAV) provides DWR scientists and engineers with comprehensive guidance on the principles, concepts, and methods that DWR uses to evaluate flood management investments in California.

Handbook Describes Broad Array of Benefit Categories

The HAV describes a broad array of benefit categories applicable to integrated flood management investment evaluations, including:

- Flood management
- Ecosystem restoration
- Water supply and quality
- Recreation and open space
- Hydropower
- Navigation
- Commercial fisheries
- Reduced long-term system maintenance costs
- Other effects, including regional economic and social effects

Handbook Describes DWR and USACE Benefit Evaluation Procedures

For each benefit category, the HAV describes:

- The conceptual basis of the benefit.
- The nexus between federal benefit (and cost) evaluation procedures and those used by DWR.
- The US Army Corps of Engineers (USACE) approach to computing the benefit.
- The recommended DWR approach to computing the benefit.
- Consistency between the USACE and DWR approaches to computing the benefit.
- What to do if the recommended DWR approach is not to be used.

Handbook Describes Several Methods for Evaluating and Comparing Investment Options

The HAV describes several decision analysis methods including cost-effectiveness analysis, benefit-cost analysis, socioeconomic impact analysis, and trade-off analysis. The use of one or more of these methods depends on the scope and objectives of the analysis, available data for a project, and whether benefits and costs can be expressed in the same units (e.g., dollars). Of these methods, trade-off analysis is the most comprehensive for comparing the "gains" and "losses" of proposed projects. However, benefit-cost analysis is still required for projects being developed with federal participation.

Summary of Handbook Chapters

The chapters and appendices of the HAV are summarized below.

Chapter 1. Background

Chapter 1 covers the purpose, objectives, and guiding principles of the HAV, and provides an overview of federal benefit assessment guidance.

Chapter 2. Basic Benefit-Cost Analysis Principles, Concepts, and Definitions

Chapter 2 covers these principles, concepts, and definitions:

- Role of benefit-cost analysis in the overall water resource planning process.
- How benefits are defined and measured.
- Water resources project benefit categories.
- How costs are described.
- How benefit-cost (B-C) analysis is defined.
- B-C analysis inputs and issues.
- How values are defined.
- How risk and uncertainty are considered in B-C analysis.
- Similarities and differences between State and federal B-C analysis.
- Financial analysis differentiated from economic analysis.
- Other types of economic analyses used in lieu of or in combination with B-C analysis.

Chapter 3. Flood Risk Management Benefits

Chapter 3 includes:

- The conceptual basis of flood risk management benefits, including the components of hazard, performance, exposure, vulnerability, and consequence.
- The categories of flood risk management benefits: inundation-reduction benefits, intensification and location benefits, agricultural flood risk management benefits, and loss-of-life benefits.
- USACE methods for computing flood risk management benefits, including the use of software application HEC-FDA.
- Recommended DWR approaches to computing flood risk management benefits.
- Consistency between USACE and DWR approaches to computing flood risk management benefits.
- Recommended templates for displaying analysis results.
- What to do if DWR-recommended procedures are not to be used.

Chapter 4. Ecosystem Restoration Benefits

Chapter 4 includes:

- The conceptual basis for measuring ecosystem restoration benefits, including monetized and nonmonetized benefits.
- The USACE approach to computing ecosystem restoration benefits, including cost-effectiveness analysis and incremental cost analysis.
- The recommended DWR approach to computing ecosystem restoration benefits.
- Consistency between USACE and DWR approaches to ecosystem restoration benefits.
- What to do if DWR-recommended procedures are not to be used.

Chapter 5. Water Supply and Water Quality Benefits

Chapter 5 includes:

- The conceptual basis for measuring water supply and water quality benefits, including the categories of urban, agricultural, and environmental water supply benefits.

- USACE approach to computing water supply and water quality benefits.
- Recommended DWR approach to computing water supply and water quality benefits, including Integrated Regional Water Management (IRWM) or Common Assumptions procedures.
- Consistency between USACE and DWR approaches to computing water supply and water quality benefits.
- Recommended templates for displaying analysis results.
- What to do if DWR-recommended procedures are not to be used.

Chapter 6. Recreation and Open Space Benefits

Chapter 6 includes:

- The conceptual basis for measuring recreation and open space benefits.
- USACE approach to computing recreation benefits.
- Recommended DWR approach to computing recreation benefits.
- Consistency between USACE and DWR approaches to computing recreation benefits.
- USACE approach to computing open space benefits.
- Recommended DWR approach to computing open space benefits.
- Consistency between USACE and DWR approaches to computing open space benefits.
- Recommended templates for displaying analysis results.
- What to do if DWR-recommended procedures are not to be used.

Chapter 7. Hydropower Benefits

Chapter 7 includes:

- The conceptual basis for measuring hydropower benefits.
- USACE approach to computing hydropower benefits.
- Recommended DWR approach to computing hydropower benefits.
- Consistency between DWR and USACE approaches to computing hydropower benefits.
- What to do if DWR-recommended procedures are not to be used.

Chapter 8. Navigation Benefits

Chapter 8 includes:

- The conceptual basis for measuring navigation benefits.
- USACE approach to computing navigation benefits.
- Recommended DWR approach to computing navigation benefits.
- Consistency between DWR and USACE approaches to computing navigation benefits.
- Recommended templates for displaying analysis results.
- What to do if DWR-recommended procedures are not to be used.

Chapter 9. Commercial Fisheries Benefits

Chapter 9 includes:

- The conceptual basis for measuring commercial fisheries benefits.
- USACE approach to computing commercial fisheries benefits.
- Recommended DWR approach to computing commercial fisheries benefits.
- Consistency between DWR and USACE approaches to computing commercial fisheries benefits.
- Recommended templates for displaying analysis results.
- What to do if DWR-recommended procedures are not to be used.

Chapter 10. Other Effects

Chapter 10 includes:

- Introduction to other effects.
- Conceptual basis of measuring secondary (regional economic) effects through metrics such as industry output, value added, and employment.
- USACE approach to computing secondary (regional economic) effects.
- Recommended DWR approach to computing secondary effects.
- Conceptual basis of measuring social effects such as health and safety, economic vitality, social connectedness, identity, social vulnerability and resiliency, participation, and leisure and recreation.
- USACE approach to computing social effects.
- Recommended DWR approach to computing social effects.

- Consistency between USACE and DWR approaches to computing other effects.
- Recommended templates for displaying analysis results.
- What to do if DWR-recommended procedures are not to be used.

Chapter 11. Multiobjective Benefit-Cost Analysis

Chapter 11 includes:

- The conceptual basis for multiobjective benefit-cost analysis.
- The USACE approach to multiobjective benefit-cost analysis.
- Recommended DWR approach to multiobjective benefit-cost analysis.
- Consistency between USACE and DWR approaches to computing flood risk management benefits.
- Recommended templates for displaying analysis results.
- Multiple criteria analysis.
- How risk and uncertainty are described.
- Cost allocation.

Other Sections

- Glossary.
- References.

Appendixes

Appendix A. Flood Risk Concepts. This appendix defines risk, risk analysis, and flood risk; defines several flood risk-related concepts; describes uncertainty in the context of flood risk analysis; and provides a list of USACE flood risk analysis resources.

Appendix B. Central Valley Flood Protection Plan Conservation Strategy Ecosystem Services and Benefit Assessment Methods

Appendix C. Cost Effectiveness/Incremental Cost Analysis Example

Appendix D. USACE Combined Plan Analysis Example

Appendix E. Common Assumptions Methods and Models. This appendix describes two methods—Least Cost Planning Simulation Model (LCPSIM) and Other Municipal Water Economics Model (OMWEM)—used to evaluate municipal and industrial water supply reliability benefits. It also describes the Statewide Agricultural Production (SWAP) model.

Appendix F. Cost Allocation. This appendix includes a description of the Separable Costs-Remaining Benefits (SCRB) method.

Appendix G. Multiple Criteria Analysis. This appendix describes multiple criteria analysis, which is a form of trade-off analysis.

Appendix H. Multiyear Analysis. This appendix describes the evaluation of changes in benefits and costs over a multiyear analysis period.

Appendix I. Software Applications. This appendix provides brief descriptions of the software applications mentioned in the HAV.

Appendix J. Example Integrated Flood Risk Management Benefit-Cost Analysis. This appendix demonstrates the recommended DWR approaches (for a specified set of benefits) based on an actual study, modified to illustrate the procedures described in the HAV.

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1.0 Background

In this chapter:

- Purpose of this *Handbook for Assessing Value*
- Objective of economic analysis
- DWR FloodSAFE themes and goals
- Support of integrated flood management
- Guiding principles of this handbook
- Objectives of this handbook
- Audience for this handbook
- Programs potentially affected by the recommendations in this handbook
- Other DWR benefit assessment guidance
- Overview of federal benefit assessment guidance

1.1 Purpose of the Handbook

Millions of people and over half a trillion dollars in assets are exposed to flood risk in California (DWR 2013a). This remains the case even as State, federal, and local flood management agencies have worked for decades to reduce the risk and consequences of flooding in the State. The people of California have shown that they understand the increasing flood risk due to population growth, environmental concerns, climate change, and land use practices, and they are willing to invest in flood risk management projects.

Thus, in conjunction with the Central Valley Flood Management Planning (CVFMP) program and other FloodSAFE programs, the California Department of Water Resources (DWR) is evaluating the benefits and costs for regional and basinwide flood risk reduction project feasibility studies. Although the primary objective of these feasibility studies is flood risk reduction, other objectives (such as water supply reliability and ecosystem restoration) are addressed. Many local and regional entities are participating in these feasibility studies; therefore, a measure of uniformity in the benefit and cost assessment is required. Furthermore, because these feasibility studies may recommend changes in the state and federal facilities of the State Plan of Flood Control (SPFC), consistency with federal benefit and cost evaluation procedures is critical to ensure future federal funding and permit approvals.

This *Handbook for Assessing Value of State Flood Management Investments* supports DWR's planning process for flood risk management investments. It (a) recommends benefit assessment methods for specified benefit categories, (b) describes the major steps for each benefit category's assessment method, (c) describes data requirements and sources, (d) recommends analysis software applications, (e) describes methods to combine monetary and nonmonetary benefits and costs, and (f) provides analysis results display templates. This HAV also describes the consistency of the recommend DWR assessment methods with those used by the US Army Corps of Engineers (USACE).

Note, however, that other methods may be more appropriate in some circumstances, and professional judgment is to be used in every case. It is recommended that the planning team consult early and often with DWR economics staff. In particular, if the method recommended in this HAV is not appropriate for a particular analysis, the study team shall discuss the choice of method with DWR Economic Analysis Section staff.

1.2 Objective of Economic Analysis

The objective of an economic analysis is to determine if a project represents the best use of resources over the analysis period (i.e., the project is economically justifiable). The economic analysis should help inform the decision makers to answer questions such as (DWR 2008a):

- Should a project be built at all?
- Should it be built now?
- Should it be built to a different configuration or size?
- Will the project have a net positive social value for Californians regardless of to whom the costs and benefits accrue?

Usually an economic analysis focuses on a comparison of the benefits and costs of proposed projects in a benefit and cost (B-C) analysis. Although such a comparison conceptually includes all benefits and costs, in practice, it is often limited to those effects that can be expressed in a common metric—dollars. However, other decision analysis methods are available to supplement a B-C analysis when monetization of effects is not possible, including cost-effectiveness analysis, socioeconomic impact analysis, and trade-off analysis. When none of these methods can be used, a project's effects can always be described in other quantitative and/or qualitative terms (without monetization) for decision makers to consider in combination with other information.

This HAV describes how to estimate the benefits and costs associated with integrated flood risk management projects undertaken by DWR. When the (monetized) B-C analysis is not appropriate to use, the HAV describes how to use other decision analysis methods.

Finally, economic analysis is not a “one-size-fits-all” approach; the focus, level of detail, data needs, etc., vary from study to study to reflect the planning process, individual study goals and objectives, and other factors.

1.3 DWR FloodSAFE Themes and Goals

The DWR FloodSAFE program has the following overarching themes:

- Public safety
- Environmental stewardship
- Economic stability

Specific FloodSAFE goals include the following (DWR undated):

- Reduce the chance of flooding
- Reduce the consequences of flooding
- Sustain economic growth
- Protect and enhance ecosystems
- Promote sustainability

Descriptions of project benefits and costs play an important role in evaluating how a given project furthers each of these FloodSAFE goals.

1.4 State Promotion of Integrated Flood Management

The California Water Plan Update 2009 promotes integrated flood management, which is “a comprehensive approach to flood management that considers land and water resources at a watershed scale within the context of integrated regional water management, employs both structural and nonstructural measures to maximize benefits of floodplains and minimize loss of life and damage to property from flooding, and recognizes the benefits to ecosystems from periodic flooding” (DWR 2009).

Description of project benefits and costs play an important role in describing how a given project furthers integrated flood management.

1.5 Guiding Principles of the Handbook

These principles have guided the development of this HAV:

- DWR recommends monetary benefit computation when comparing alternatives or projects when it is feasible to assign monetized values to benefits.
- Some areas of fundamental State interest, such as environmental stewardship, may be difficult to capture solely in monetary terms; in those cases, nonmonetary methods of benefit assessment are appropriate.
- State and federal benefit assessment methods and procedures must be consistent, to the extent practicable. (This HAV describes consistent procedures and highlights the differences between State and federal methods.)
- The level of effort to evaluate benefits for a study should be commensurate with the magnitude, scale, and complexity of the project.
- DWR recognizes that other methods and/or software applications are available besides those recommended in this handbook, and professional judgment must always be used when selecting methods for any study. The use of other methods and/or software applications shall be approved in advance by DWR Economic Analysis Section staff, as well as staff with other technical expertise, as necessary. The DWR Economic Analysis Section is currently located in DWR's Division of Statewide Integrated Water Management.
- DWR recognizes that this HAV should be updated as needed to reflect changes in benefit assessment procedures and/or changes in applicable USACE and DWR policies.

1.6 Objectives of the Handbook

The objectives of this HAV are to:

- Identify the categories of benefits that shall be described for flood risk management projects.
- Set standards for consistent and replicable benefit computation methods within the specific context of integrated flood management.

- For benefit categories in which monetary description may be challenging, such as ecosystem restoration, set standards for consistent and replicable benefit description methods.
- Identify the categories of costs that shall be described for flood risk management projects.
- Set standards for computing project net benefits to assess economic justification.
- Set standards for reporting project benefits and costs.
- Establish methods for acknowledging and accounting for uncertainties in the analysis.
- Establish procedures for using methods and/or software applications other than those recommended herein.

To meet these objectives, this HAV:

- Describes project categories of benefits that shall be described for integrated flood management projects.
- Identifies the recommended method of assessment for each benefit category.
- Describes the major steps required for each benefit category's recommended method of assessment.
- Identifies the physical outputs to be estimated before any benefits can be computed.
- Describes data requirements and sources for assessing each benefit category.
- Recommends analysis software applications.
- Describes methods to combine monetary and nonmonetary benefit and cost information to assess net benefits.
- Provides analysis result display templates.

Note: For the recommendations described in the HAV, the use of the term "shall" means "must."

1.7 Audience for the Handbook

The audience for this HAV is DWR multidisciplinary teams working on State-led basinwide feasibility studies and regional plans, as well as multidisciplinary teams working for local and regional entities on integrated flood management projects.

1.8 DWR Programs That Might Benefit from the Handbook's Guidelines

DWR programs that may benefit from these HAV guidelines include:

- Central Valley Flood Protection Plan
- Urban flood risk reduction (formerly Early Implementation Program)
- Integrated water management grant programs
- Stormwater grant programs
- Local levee assistance program
- Flood control subvention program
- State Water Project plan formulation and feasibility studies
- Delta feasibility studies

1.9 Other DWR Benefit Assessment Guidance

This HAV adds to the body of knowledge contained in these other DWR benefit assessment references:

- *DRAFT Economics Practices Manual* (1977)
- *Economic Analysis Guidebook* (2008a)
- *Water Resources Engineering Memorandum No. 66* (2008c)
- *DRAFT Economic Analysis Guidelines: Flood Risk Management* (2010a)
- *Description and Screening of Potential Tools and Methods to Quantify Public Benefits of Water Storage Projects* (2011a)
- *Implementation Proposal Solicitation Package: Integrated Regional Water Management Proposition 84 Round 2* (2012k)

1.10 Overview of Federal Benefit Assessment Guidance

Because DWR often partners with federal agencies, it is critical that it understand and be fundamentally consistent with federal economic analysis guidance, which is summarized here.

1.10.1 History of Federal Benefit Assessment Guidance

For over 40 years, the federal government has published standard criteria and procedures for the economic evaluation of water and related lands resources projects. The Water Resources Planning Act of 1965 created the Water Resources Council (WRC) which published the federal *Principles & Standards* (P&S) in 1971 (38 CFR Part III). The P&S established an evaluation framework including Public Safety (PS), National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE). The federal criteria identify the alternative with maximum combined NED and beneficial EQ effects that outweighed the NED and adverse EQ effects.

In 1983, the P&S were replaced by the *Principles and Guidelines for Water and Land Related Resources Implementation Studies* (P&G) which were also published by the WRC (US Water Resources Council 1983). The P&G used four "accounts" from the P&S—NED, EQ, RED, and OSE. However, the P&G also established a national objective that focused on NED effects; thus, analysis of the NED and EQ accounts was required and the other accounts became optional.

In March 2013, the President's Council on Environmental Quality issued a proposed update to the 1983 P&G (CEQ 2013). This new framework of principles and draft interagency guidelines included "important changes that modernize the current approach to water resources development." After further public review, the interagency guidelines will be finalized. However, it is not clear how soon (or by how much) these "important changes" will be implemented by federal agencies. Nevertheless, the updated P&G may inform feasibility studies in the future, so they are described briefly here, as well.

1.10.2 1983 Principles and Guidelines

The 1983 P&G were established by the Water Resources Planning Act of 1965 to be followed by the US Army Corps of Engineers (USACE), US Department of the Interior, the Bureau of Reclamation, the Tennessee Valley Authority, and the Natural Resources Conservation Service. The P&G set forth principles "intended to ensure proper and consistent planning by federal agencies in the formulation and evaluation of water and related land resources implementation studies" (i.e., planning principles and processes) and guidelines that "establish standards and procedures for use by federal agencies in formulating and evaluating alternative plans for water and related land resources implementation studies" (i.e., descriptions of analysis steps and display templates).

The P&G include four planning accounts that provide a framework for project evaluation studies:

- The National Economic Development (NED) account shows changes in the net value of the national output of goods and services expressed in monetary units, representing the direct (primary) benefits that result from the project. Evaluation of the NED account is required for federal projects.

- The Environmental Quality (EQ) account shows nonmonetary effects on ecological, cultural, and aesthetic resources, including the positive and adverse effects of ecosystem restoration plans.

- The Regional Economic Development (RED) account shows changes in the distribution of regional economic activity such as income and employment.

- The Other Social Effects (OSE) account shows plan effects on social aspects such as impacts on communities, health and safety, displacement, energy conservation, and other effects.

Display of the NED and EQ accounts is required. Display of the RED and OSE accounts is discretionary.

The federal objective is to "contribute to national economic development (NED) consistent with protecting the Nation's environment, in accordance with national environmental statues, applicable executive orders, and other federal planning requirements" (USACE 2000).

Although the 1983 P&G set forth overall planning and project formulation processes, federal agencies were able to adopt more specific planning guidance based on the P&G. In particular, the USACE published substantial guidance on water resources planning (e.g., Engineer Regulation [ER] 1105-2-100, *Planning Guidance Notebook* [2000]).

1.10.3 2013 Principles and Guidelines

A proposed update to the federal P&G was released in March 2013. The updated P&G include:

- Principles & Requirements that describe broad principles to guide water investments.

- Draft Interagency Guidelines that describe methods for conducting implementation studies. Once these guidelines are finalized, each agency (such as the USACE) will update its agency-specific procedures.

The 2013 P&G are intended to provide "a common framework for analyzing a diverse range of water resource projects." Significant changes from the 1983 P&G include the following:

- The Environmental Protection Agency and the departments of Commerce, Interior, Agriculture, and Homeland Security (including the Federal Emergency Management Agency [FEMA]) were added to the list of agencies required to follow the P&G.

- The federal objective was expanded from the focus on the NED perspective to specify that federal water resources investments "shall reflect national priorities, encourage economic development, and protect the environment" by:
  - Seeking to maximize sustainable economic development.
  - Seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used.
  - Protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems.

In addition, federal water resource investments should strive to "maximize public benefits, with appropriate consideration of costs." Public benefits:

- Encompass environmental, economic, and social goals.
- Include monetary and nonmonetary effects.
- Consider quantified and unquantified measures.

No hierarchical relationship is stated among the three goals mentioned above; thus, the 2013 P&Gs require that tradeoffs among potential solutions be assessed and communicated during the decision-making process. This contrasts with the 1983 P&G's emphasis on the NED account.

1.10.4 DWR to Follow 1983 P&G until 2013 P&G Are Finalized

When DWR partners with one of the federal agencies listed above on studies or projects, federal planning guidance must be followed to determine the federal interest in the project and eligibility for federal funding. Until the 2013 P&G are fully implemented, DWR will continue to follow the 1983 P&G, which contain relevant guidance for DWR studies. For example:

- Procedures presented in the P&G to estimate specific NED benefits (such as flood risk management, water supply, and recreation) are appropriate for DWR analyses, with differences described below.

- P&G procedures used for federal analyses to compute net benefits or benefit/cost ratios are appropriate for DWR analyses, although some of the parameters used to compute net benefits may be different (for example, the discount rate). But sensitivity analyses can be conducted to evaluate these differences and their implications for State and federal decision-making.

If and when the 2013 P&G are implemented, this handbook will be revised as necessary to accommodate changes in the new procedures.

2.0 Basic Benefit-Cost Analysis Principles, Concepts, and Definitions

In this chapter:

- Role of benefit-cost analysis in the overall water resource planning process
- How benefits are defined
- How benefits are measured
- Water resources project benefit categories
- How costs are described
- How benefit-cost (B-C) analysis is defined
- B-C analysis inputs and issues
- How values are defined
- How risk and uncertainty are considered in B-C analysis
- Similarities and differences between State and federal B-C analysis
- How financial analysis is differentiated from economic analysis
- Other types of economic analyses used in lieu of or in combination with B-C analysis

2.1 Role of Benefit-Cost Analysis in Overall Water Resources Planning Process

Benefit and cost (B-C) analysis plays an important role in the water resources project planning process. The *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* ("P&G," US Water Resources Council 1983) define a six-step planning process for water resources projects:

1. Specify problems and opportunities.
2. Inventory and forecast water and related land resource conditions.
3. Identify alternative plans.
4. Compare alternative plans.
5. Evaluate effects of alternative plans.
6. Select the recommended plan.

The P&G also stipulate four criteria to guide plan formulation:

- **Completeness –** the extent to which alternative plans provide and account for all necessary investments or other actions to ensure realization of the planning objectives.
- **Effectiveness –** the extent to which alternative plans contribute to the achievement of the planning objectives.
- **Efficiency –** the extent to which an alternative plan is the most cost-effective means of achieving the objectives.
- **Acceptability –** the extent to which alternative plans are acceptable in terms of applicable laws, regulations, and public policies.

A B-C analysis directly contributes to steps 4, 5, and 6, which compare the benefits and costs of alternative plans, help define the overall effectiveness and efficiency of alternative plans, and aid in selecting a recommended plan often (but not always) based on the plan that maximizes net benefits. Benefit assessment can also be used in Step 3 to inform formulation of alternative plans. It is important to note that the level of effort for the feasibility study should be commensurate with the size of the project.

Benefit accounting helps justify project selection (i.e., determine its economic justifiability). It also is used to allocate project costs to a specific purpose (flood risk management [FRM], water supply, recreation, ecosystem restoration, and so on) and then apportion the costs to different beneficiaries. The allocation and apportionment are done according to project purpose using Separable Cost Remaining Benefit (SCRB) or a similar method that allocates costs based on specific project purposes. These steps are part of a financial analysis to determine who ultimately pays for the project, especially important for multiple-purpose projects (i.e., financial justification).

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), and the Engineering Pamphlet (EP) 1165-2-1, *Digest of Water Resources Policies and Authorities* (1999), the USACE describes procedures for evaluating studies and projects. Study authorizations are either unique, study-specific authorities or standing, program authorities, usually called continuing authorities. The USACE is authorized by Congress to implement Civil Works projects within these principal project purposes: flood damage reduction (e.g., flood risk management), (commercial) navigation, ecosystem restoration, hurricane and (coastal) storm damage reduction, water supply, hydroelectric power generation, recreation, and multiple purpose studies/projects. The USACE is also authorized for project purposes of streambank (erosion) protection, aquatic plant control and four “other authorities” (refer to ER 1105-2-100 section 3-10). The benefit accounting associated with the USACE’s multi-purpose projects is described in Section 11.2. The term “mission area” is somewhat synonymous with “project purpose” for the USACE. Recreation cannot be a stand-alone project, but limited recreation features can be added to other purposes, if justified. For the USACE fiscal year 2015 budget, the first three of these missions (listed above) are identified as the main water resource mission areas of the USACE. The USACE also has eight budget business lines: emergency management, environment, flood risk management, hydropower, navigation, recreation, regulatory, and water supply. The USACE Five Year Development Plan submitted to the Office of Management and Budget and Congress includes funding streams for each business line.

Economic analysis may also contribute to socioeconomic impact assessments under the California Environmental Quality Act (CEQA) and/or National Environmental Policy Act (NEPA) processes. Many of the secondary and social effects described in Chapter 10 (“Other Effects”) can be included in these environmental documents.

2.2 How Benefits Are Defined

Benefits are defined as the value of the goods and services provided by a project or program. Benefits are net of all costs required to produce those goods and services, except for project costs (which are accounted for in the B-C analysis). For example, the value of agricultural production made possible with additional water supplies must be reduced to account for the cultural costs associated with that production (field preparation, seed and fertilizer costs, harvest costs, etc.). The resulting agricultural value is then compared to the proposed project’s costs.

Benefits are categorized and differentiated from one another in several ways (DWR 2008a):

- **Primary and secondary benefits –** Primary benefits are the increased values of goods and services to those immediately affected by the project or program (primary beneficiaries). They include benefit categories such as FRM, water supply, water quality, and recreation. Secondary benefits are the values of goods and services that subsequently accrue to other parties as a result of project construction and from the primary benefits generated by the project. For California Department of Water Resources (DWR) programs, a B-C analysis includes only primary benefits (and costs). However, secondary benefits (and costs) are important and should be evaluated supplemental to (but not added to) B-C analyses. Secondary benefits often include changes in regional jobs, income, and fiscal effects (such as taxes or other revenues), which are important to local stakeholders. The evaluation of secondary benefits and costs is included in a broader economic impact analysis, as illustrated in Figure 2-1.

- **Tangible and intangible benefits –** Tangible benefits can be quantified in monetary or other quantifiable terms (such as reduced structural flood damage) whereas intangible benefits cannot be directly expressed in quantifiable terms (for example, trauma or loss of peace of mind). Conceptually, a B-C analysis includes tangible and intangible benefits, but is typically limited to tangible benefits that have been monetized. Other methods (described below) can be used to evaluate intangible benefits. An important benefit for DWR programs is reducing loss of life, which can be quantified (thus is a tangible benefit); but, currently is not monetized by DWR. Thus, it must be evaluated using methods applicable for intangible benefits.

- **Private and public benefits –** Benefits derived from public goods (and services) can be characterized by (1) nonexcludability (it is not possible to exclude nonpayers from consuming the good) and (2) nonrivalry in consumption (additional people consuming the good do not diminish the benefit to others). If a good does not have both of these characteristics, it is a private good or falls somewhere in between public and private good.

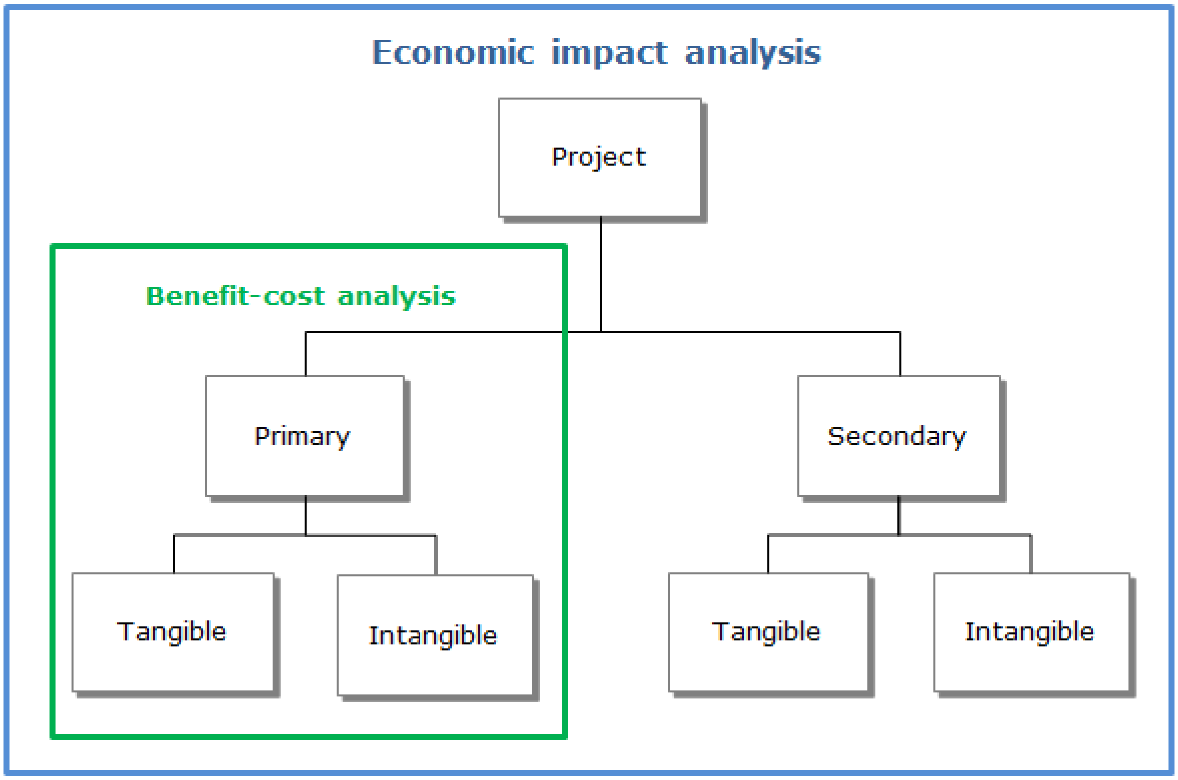

Figure 2-1. Economic Impact Analyses Consider Primary [Tangible] Effects and Should Also Describe Secondary Effects

2.3 How Benefits Are Measured

To the extent possible, benefits shall be measured physically (quantitatively) and monetarily.

2.3.1 Physical Measurement

Physical measurement quantifies the physical output (i.e., goods and services) produced by the project. This output may be described as either intermediate or end products. Examples of end products include:

- Reduced damage to consumer appliances resulting from improved water quality.
- Enhanced fish and wildlife populations.
- Enhanced ecosystem services from wetlands such as water treatment, flood water storage, or carbon sequestration.

- Increased recreation user days.
- Reduced flood damage.

Although the objective is to quantify end products, sometimes this is not possible. However, it may be possible to estimate intermediate products that lead to the end products. Examples of intermediate products include:

- Enhanced water quality indices, such as reduced total dissolved solids (TDS).
- Improved in-stream flow and temperature for salmonids.
- Increased riparian or wetland habitat acreage.
- Enhanced reservoir recreation amenities such as surface area.

Physical measurement of a project's output (intermediate or end products) is necessary for monetary measurement.

2.3.2 Monetary Measurement

Benefits shall be measured monetarily when comparing alternatives or projects if sufficient data are available. Monetary value is measured by the willingness to pay (WTP) by consumers and producers who benefit from the goods and services produced by the project or program. The use of WTP is consistent with existing federal policy (US Water Resources Council 1983). WTP measures the monetary value that project beneficiaries would be willing to relinquish to obtain the benefit. Methods for evaluating WTP include (DWR 2008a):

- **Revealed WTP –** Benefit values are estimated using some form of prices that reveal what consumers and producers would be willing to pay for goods and services traded in competitive markets. Examples include:
    - Market price, which uses prevailing prices for goods and services traded in markets to reflect the marginal (incremental) cost of producing those goods and services.
    - Productivity, which estimates the value of resources that are directly used in the production of marketed goods. This estimate is based on changes in production costs and/or the value of increased production (i.e., net revenue).

  - Hedonic pricing, which estimates WTP as the value of amenities that affect prices of marketed goods. This estimate assumes that the prices people pay for goods are influenced by the set of characteristics that people consider important when purchasing the good.
  - Travel cost, which estimates the value of recreational benefits as the value of time and travel cost expenses that people incur to visit a site, i.e., the "price" of access to the site.
- **Imputed WTP –** Benefit values are estimated based on without-project costs that can be avoided if a project is implemented. Examples include:
  - Avoided cost, which uses the estimate of existing (without project) costs that can be avoided if a project is implemented.
  - Alternative cost, which uses the estimate of the cost of the future (with project) alternative that would most likely be implemented in the absence of the proposed project.
- **Expressed WTP –** Benefit values are estimated from surveys that query people directly as to what they are willing to pay based on a hypothetical scenario. Examples include:
  - Contingent valuation surveys, which determine how much people would be willing to spend for specified project goods or services.
  - Contingent choice surveys, which determine people's preferences between one group of products or services compared to another group of products and services at a different price.

Other benefit assessment methods include:

- **Administratively established values –** the cooperative assignment of benefit values for specific goods and services by water resource agencies.
- **Benefit transfer –** the application of values developed by other studies for similar projects to the project being evaluated.

Table 2-1 summarizes monetary assessment methods and their corresponding WTP.

Table 2-1. Monetary Assessment Methods and Their Corresponding Types of Willingness to Pay (WTP)

Assessment Method (1)	Willingness to Pay (WTP)		
	Revealed (2)	Imputed (3)	Expressed (4)
Alternative costs		●	
Avoided costs/losses		●	
Market prices (water, energy, etc.)	●		
Productivity	●		
Hedonic pricing	●		
Travel cost	●		
Contingent valuation surveys			●
Contingent choice surveys			●

2.3.3 Nonmonetary Descriptions

Although DWR prefers to quantify benefits and express them monetarily, it recognizes that certain areas of fundamental State interest (such as public safety and environmental stewardship) may be difficult to capture solely in monetary terms. In those instances, appropriate nonmonetary evaluation methods must be used.

Because nonmonetary methods do not value project benefits monetarily, it is not possible to conduct a traditional B-C analysis. However, if physical products (end or intermediate) of the plans can be estimated, it may be possible to conduct a cost-effectiveness (CE) analysis, which describes the cost to produce a specified unit of output (for example, $/acre-foot or $/habitat unit). A CE analysis can be combined with an incremental cost analysis, which describes changes in costs associated with changes in outputs.

Combining these methods (i.e., an incremental CE analysis) permits decision makers to compare progressive levels of project output and ask if the next level is “worth it”—that is, whether the additional output in the next attainable level is worth the additional cost. For a multiple purpose project, cost-effectiveness analyses can be combined with monetized benefits in a B-C analysis using a trade-off analysis, as described in Chapter 11. Other nonmonetized benefits and costs shall be qualitatively described: what it is, when it occurs, who receives it, and why it is important.

Another method to combine monetized and nonmonetized benefits and costs is multiple criteria analysis, also described in Chapter 11.

2.4 Benefit Categories

The California Department of Water Resources (DWR) recognizes that projects that integrate multiple benefits, including flood risk management, water supply, recreation, ecosystem restoration, and commercial fisheries, may be more prudent investments than single-purpose projects. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

Benefit categories potentially attributable to integrated flood risk management projects include:

- Flood risk management
- Water supply and quality
- Ecosystem restoration
- Recreation and open space
- Hydropower
- Navigation
- Commercial fisheries
- Reduced long-term system maintenance costs

Table 2-2 compares FRM project benefit categories described in this HAV with the DWR integrated water management goals described in Chapter 1 and the FloodSAFE goals, the 1983 P&G accounts, and the proposed 2013 P&G coequal goals, all described in Chapter 1 of this handbook. Note that this is a fairly broad list and not all categories will apply to a given project or study, and if applicable, may not warrant detailed analysis.

Each of these benefit categories can be evaluated using a variety of methods. However, for FloodSAFE analyses, it is desired that, to the extent practicable, DWR and other parties use the same recommended method for each benefit category to obtain consistent results.

Table 2-3 summarizes whether the DWR water resource benefit categories are described quantitatively, monetarily, or qualitatively, and what method is recommended for their evaluation or description. Benefits that can be monetized can be included in a B-C analysis, as described in Chapter 11. That chapter also describes other methods (such as cost effectiveness/ incremental cost analysis and multiple criteria analysis) that can be used to evaluate nonmomentary benefits.

DWR recognizes that other methods are available besides those recommended in this handbook, and professional judgment must always be used. The use of other methods must be approved in advance by DWR Economic Analysis Section staff.

Table 2-2. Comparison of Flood Risk Management Benefit Categories with DWR Foundational Goals for Integrated Water Management, FloodSAFE Goals, 1983 P&G Accounts, and Proposed 2013 P&G Coequal Goals

	DWR Foundational Goals for Integrated Water Management			FloodSAFE Goals					1983 P&G Accounts				Proposed 2013 P&G Coequal Goals		
Benefit Category	Improve public safety	Foster environmental stewardship	Support economic stability	Reduce chance of flooding	Reduce consequences of flooding	Sustain economic growth	Protect and enhance ecosystems	Promote sustainability	National economic development	Environmental quality	Regional economic development	Other social effects	Economic	Environmental	Social
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Flood risk management[1]	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓
Water supply and quality[2]	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ecosystem restoration		✓	✓			✓	✓	✓		✓	✓	✓	✓	✓	✓
Recreation and open space		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hydropower			✓			✓		✓	✓		✓		✓	✓	✓
Navigation			✓			✓		✓	✓		✓		✓		
Commercial fisheries			✓			✓	✓	✓	✓	✓	✓		✓		
Reduced project O&M[3]			✓			✓		✓	✓		✓		✓		

Notes:

[1] DWR captures all relevant forms of flood damage reduction here, including developed "urban" and agricultural resources. The 1983 P&G NED benefit evaluation categories corresponding to this category are "Urban Flood Damage" and "Agriculture." The P&Gs and the USACE use the terms "urban" and "urbanizing areas" in a generic sense; however, DWR has them legislatively defined for its Urban Level of Flood Protection Criteria and related efforts.

[2] DWR captures all relevant forms of water supply here. The 1983 P&G NED benefit evaluation categories corresponding to this category are "Municipal and Industrial Water Supply" and "Agriculture." Water quality is addressed within the 1983 P&G accounting although not titled specifically.

[3] This DWR benefit category is not specifically described in the 1983 P&G; however, the P&G describe NED benefits as including "increases in the economic value of the national output of goods and services of a plan." From DWR's perspective, a reduction in project O&M costs increases the economic value of national (state) output.

Table 2-3. DWR Water Resource Project Benefits Categories and Recommended Evaluation Methods

Potential DWR Multiobjective Flood Risk Management Project Benefits (1)	How Described (2)	Recommended Evaluation/Description Method (3)
FRM: improved public health and safety	#	Expected lives lost
FRM: reduced economic flood damages	$	Avoided costs
FRM: benefits to local and regional economies	$	Income and employment
Water supply	$	Alternative and/or avoided costs; willingness to pay
Water quality	$	Alternative and/or avoided costs
Ecosystem restoration	⌘,#	Cost effectiveness/incremental cost analysis
Recreation and open space	$	Administrative unit-day values
Hydropower	$	Electricity prices
Navigation	$	Avoided costs
Commercial fisheries	$	Productivity
Reduced long-term flood system management costs	$	Avoided costs

Key:
FRM = flood risk management
WM = water management
# = described quantitatively
$ = described quantitatively and monetarily
⌘ = described qualitatively

2.5 How Costs Are Described

Project costs generally can be classified as either capital or annual operating costs. All costs necessary to obtain project benefits over the period of analysis must be included in an economic analysis. Conceptually, all costs in the economic analysis should reflect the opportunity costs of using resources to construct and operate the project. In other words, using the resources for the proposed project means that value is lost somewhere else in the economy. In practical terms, the cost information used in the economic analysis is often limited to the actual purchase expenditures (i.e., financial costs), including:

- **Capital costs** – Capital costs are all expenditures necessary to complete the project so operations can commence. Capital costs (also called initial, construction, fixed, or first costs) include expenditures for planning and design, land, structures, materials, equipment, and labor, as well as allowances for contingencies. If capital costs occur in one year, then these would be included in the base year; but if they are spread over several years (most likely), the future value of these costs must be determined, as described below.

- **Operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs –** OMRR&R costs include the project's annual administrative and maintenance costs, as well as periodic replacement and rehabilitation costs. Repair costs are incurred when facilities are damaged due to unforeseen events (for example, costs to repair a damaged levee after a flood event).

- Other project costs such as –

  - Associated costs: These are the costs of additional measures, over and above plan components, that would be needed to achieve benefits claimed for some plan. For example, associated costs might include expenditures for boat ramps necessary to fully realize claimed recreation benefits. Note that all costs, including associated costs, shall be included in the cost estimate to satisfy the US Army Corps of Engineers (USACE) "completeness" criterion.
  - Opportunity costs: Opportunity cost is the productivity forgone by not investing in the next optimal project or in using resources differently. For example, if an agency proposes to use land that it already owns, no out-of-pocket costs are incurred to secure project lands. Nevertheless, there is still an economic (opportunity) cost of using the land for project purposes that must be accounted for in the evaluation of costs, reflecting the net benefits forgone by not using the land in its best alternative use.
  - Externalities: Often the activities of producers or consumers have effects on others that impose costs (or sometimes benefits) for which no compensation is received. Unfortunately, many externalities are difficult to identify, quantify, and ultimately assign monetary values. But qualitative descriptions of these costs must be included at a minimum. Examples include increased downstream flood damages that are caused by channel modifications and loss of recreation values from reduced in-stream flows due to use of water for agriculture.

To achieve consistency among different projects, cost estimates shall be developed consistent with the Association for the Advancement of Cost Engineering (AACE) Recommended Practice No. 18R-97. At a minimum, Class 4 (or higher) estimates are required. This estimate class defines the requiemenrts for costs developed for study or feasibility purposes. More information can be found at:

http://www.aacei.org/non/rps/18R-97.pdf

2.6 Life Cycle Cost Analysis

Life cycle cost (LCC) analysis is a method for assessing and comparing the total costs of alternatives. It takes into account all costs of acquiring, owning, and disposing of facilities and related equipment. LCC analysis is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared to identify the one that maximizes net cost savings. The three key variables in an LCC analysis are identifying and evaluating for each alternative (1) all pertinent costs, (2) the period of time over which these costs can be compared, and (3) the discount rate to be applied. DWR shall conduct LCC analyses.

2.7 Benefit-Cost Analysis Defined

DWR's policy is to complete a B-C analysis in support of the State's decision-making process for water resource projects. A B-C analysis is a procedure in which the different benefits and costs of proposed projects are identified and measured (usually in monetary terms) and then compared with each other to determine if the benefits of the project exceed its costs. In the context of a B-C analysis, benefits are defined as the value of the goods and services provided by a project or program. Net benefits are the difference between costs and benefits. The plan with maximum net benefits is selected for further evaluation. The quotient of benefits to costs (the B/C ratio) is also displayed for information purposes, but the primary decision criterion is the plan that maximizes net benefits.

B-C analysis examines the difference between existing and future conditions without the project (sometimes called baseline) and with the project. The analysis is conducted for a planning horizon that usually extends from the beginning of construction to the end of the project's useful life. Normally, the useful life is measured in years. An annual time step is used to display costs and benefits for each future year until the end of the planning horizon, and costs and benefits are discounted to net present value terms using an established discount rate.

B-C analysis is used to determine whether a project is economically justified and to rank those that are found to be feasible. A project is economically justified when all of the following criteria are satisfied (DWR 2008a):

- Estimated total benefits exceed estimated total economic costs.
- Each separable purpose (for example, water supply, hydropower, flood risk reduction, and ecosystem restoration) provides benefits at least equal to its costs.
- The scale of development provides maximum net benefits (in other words, no smaller or larger projects provide greater net benefits).
- No more-economical means of accomplishing the same purpose exist.

Although these criteria are easier to evaluate when the projects benefits and costs are monetized, they do not preclude the consideration of nonmonetary information, when applicable.

2.8 Benefit-Cost Analysis Inputs and Issues

Topics that are especially relevant for DWR B-C analyses are summarized below.

2.8.1 Study Area

The study area defines the extent of the B-C analysis so that all significant benefits and costs of the proposed project are evaluated.

DWR FRM programs may affect regions differently within the State (or even within the Central Valley). These differences shall be identified and evaluated. An example is hydraulic impacts, whereby FRM improvements in one region can adversely affect upstream or downstream flood conditions. To evaluate benefits among different regions, a systemwide benefit analysis is required. Systemwide benefits are the “sum of economic, life-safety, social, and environmental improvements in a geographic area that would result from flood risk management plan implementation and successful operation and maintenance… When evaluating systemwide benefit, the geographic area of influence (the system) must be defined” (DWR 2011b).

Critical to this definition is describing the “geographic area of influence (the system).” The broadest interpretation of “geographic area of influence (the system)” is the State of California. Projects may result in impacts in different parts of the state. For example, the state and federal water projects transfer water supplies from northern California to many other regions (i.e., watersheds) within the state for urban and agricultural uses. Project impacts beyond the state’s borders may not be important to the state, but may be important nationally.

However, for most water resource studies, a more limited system (i.e., study area) must be defined, taking into account potential project hydraulic, economic, social, and environmental impacts. Because the geographic boundaries of evaluating hydraulic, economic, and social impacts are not likely to coincide, it may be necessary to define multiple (overlapping) study areas. For example, the 2012 Central Valley Flood Protection Plan (CVFPP) evaluated flood inundation-reduction benefits for the Sacramento and San Joaquin river systems, but regional economic impacts were evaluated for groups of counties. Thus, two study areas were defined, as shown in Figure 2-2.

2.8.2 Analysis Perspective

A benefit assessment must identify who receives the benefits and where they are located—sometimes called the “analysis perspective” or “accounting stance.” For most DWR programs, the overall analysis perspective is the State of California. However, this analysis perspective is difficult to implement in a modern global economy. Thus, the “California accounting perspective should try and count benefits to residents, plus benefits to businesses operating in the state, plus benefits to property located in the state, regardless of the residence of their owners” (DWR 2011a).

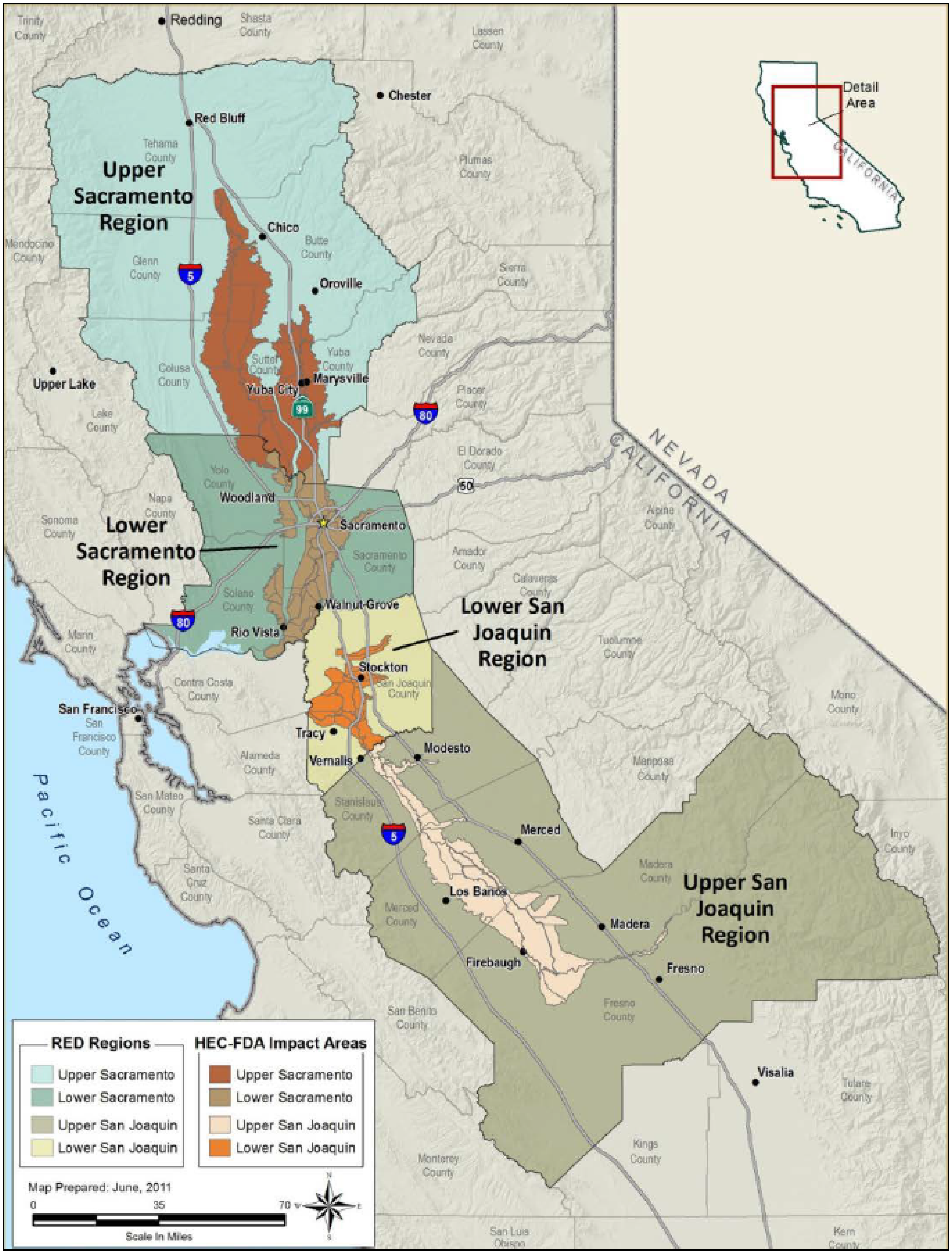

Figure 2-2. Study Regions Used for the 2012 Central Valley Flood Protection Plan

2.8.3 Planning Time Horizon and Analysis Period

The planning time horizon extends from the beginning of the study to the end of the project life, as shown in Figure 2-3. The planning horizon includes planning and design, construction, and project life after construction.

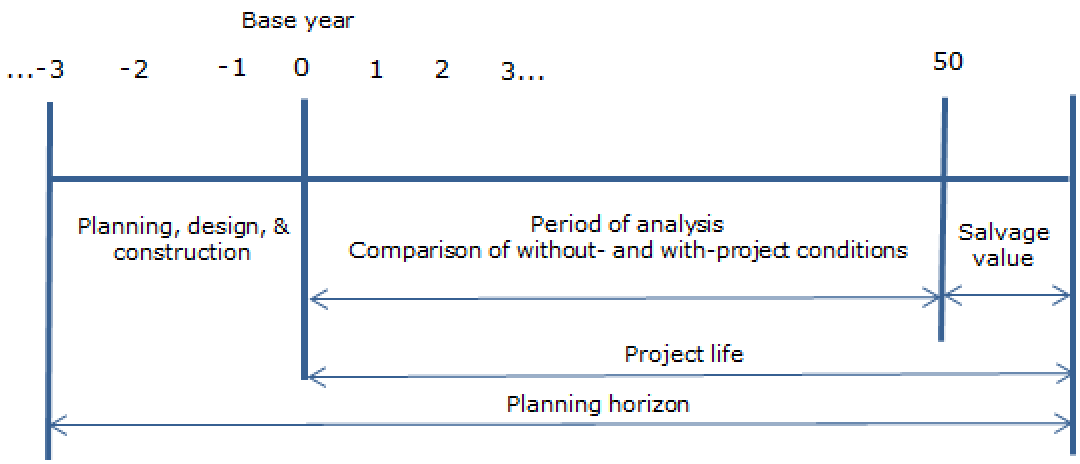

Figure 2-3. Planning Time Horizon

Segments of the project's planning time horizon are described as follows (DWR 2008a, DWR 2010):

- **Economic life –** The period in which the project is economically viable, which means that the incremental benefits of continued use exceed the incremental costs of that use.
- **Project life –** The period in which the project physically performs its intended function; also known in some contexts as "design life." Economic life may be shorter than project life but not vice versa.
- **Period of analysis –** The length of time over which a project's consequences are included in a study. In most cases, typical analysis periods are 50 to 100 years for structural water resource projects and 5 to 25 years for nonstructural measures.

Within the analysis period, a base year must be identified which is when project construction/implementation occurs, and project outputs (that is, benefits) occur after the base year. The base year is usually called year 0 and subsequent years are numbered 1 through the end of the analysis period. If project construction occurs over several years, these are included in the analysis period prior to the base year, and these are numbered -1, -2, -3, etc. Analysis years prior to the base year are treated differently in the discounting process than years occurring after the base year, as described below.

If the analysis period is shorter than the project life, it may be possible to deduct a salvage value, but often this is not warranted because of discounting (described below) since this adjustment occurs at the end of the analysis period. Also, in order to have salvage value, it would have value for non-project use, which would be difficult to estimate for many water resource projects. For example, what would be the salvage value of a levee? Thus, in practice, salvage value is often not estimated in a B-C analysis.

2.8.4 With-Project and Without-Project Conditions

B-C analysis (as well as all aspects of project evaluation) must focus on the change in conditions expected to occur "without" the project compared to conditions "with" the project (DWR 2008a). The without-project conditions, which include not only existing conditions but also future without-project conditions, become the baseline from which all project effects (positive and negative) are compared. Thus, the estimation of the existing and future without-project conditions is a critical step in the economic analysis. It not only involves the projection of key socioeconomic variables (such as population, employment, and housing), but also other related projects that may become operational in the study period without the proposed project. Often the without-project and with-project comparison is confused with a "before" and "after" comparison; this is not correct because some of the benefits forecasted to occur in the future with the project may also have occurred even without the project, and should not be attributed to the project.

2.8.5 Adjustments for Time Value of Money

A project's benefits and costs typically accrue over time. For most projects or programs, construction or implementation costs occur up front in a project's life, followed by smaller recurring annual OMRR&R costs. In contrast, project benefits occur after construction is completed, but can increase over time if a "build-out" period is required (for example, increasing water demand caused by population growth). Because costs and benefits occur at different times, they cannot directly be summed and compared to each other but instead must be made comparable through a present worth analysis.

In a present worth analysis, the future values of annual costs and benefits are discounted using the same discount rate, and total discounted benefits and costs can then be summed for the entire analysis period and directly compared to each other using a net benefit analysis. The discounting occurs by multiplying the present value (discount) factor by the appropriate benefit and cost data for each year. No discounting occurs for the base year (year 0), and decreasing present value factors are applied for succeeding years in the analysis period.

At the conclusion of the present worth analysis, benefits, costs, and net benefits can be described in terms to total present worth or annualized values. Annualized values are computed by multiplying the total present worth value by a capital recovery factor, based on the discount rate and number of years in the analysis period. The USACE reports annualized values; thus, DWR shall also report annual values. However, because the information is readily available, DWR may also report the total present worth values.

Discount Rate

The selection of discount rate is critical for the analysis because the larger the discount rate, the greater the reduction in future monetary values. This tends to affect benefits more than costs because the majority of costs is incurred early in the analysis period (for example, construction costs), whereas benefits typically occur later in the analysis period. DWR currently (2013) uses a 6% discount rate, which approximates a real rate of return in the private sector. The DWR Economic Analysis Section should be consulted for the most recent discount rate being used. The US Treasury Department annually sets the discount rate used by the USACE, available (with other USACE planning guidance) from the USACE planning toolbox (planners' library) website. The current (2014) USACE discount rate is 3.5%.

The discount rate is different from the bond repayment interest rate that is used in a financial analysis.

Forgone Investment Value

If capital costs are incurred prior to the base year, the future value of these expenditures must be determined by multiplying these monetary costs by a future value factor (which is the reciprocal of the present value factor). An example present worth analysis with construction costs prior to the base year is included in DWR guidance (Table A-1, DWR 2008a). This procedure shall be used for DWR projects.

Often this future value adjustment for expenditures prior to the base year is called "interest during construction," as is done by the USACE, to represent the opportunity cost of capital incurred during the construction period. This terminology is not used by DWR because it implies that this adjustment reflects actual interest charges incurred prior to construction, which are accounted for differently in a financial analysis. However, despite the difference in terminology, the approaches by both agencies are measuring the opportunity cost of capital during construction. Prior capital expenditures must be reviewed and approved by DWR economic analysis staff before inclusion in the B-C analysis.

Figure 2-4 illustrates a present worth analysis, including discounted benefits and costs occurring after the base year and the foregone investment value of costs occurring prior to the base year.

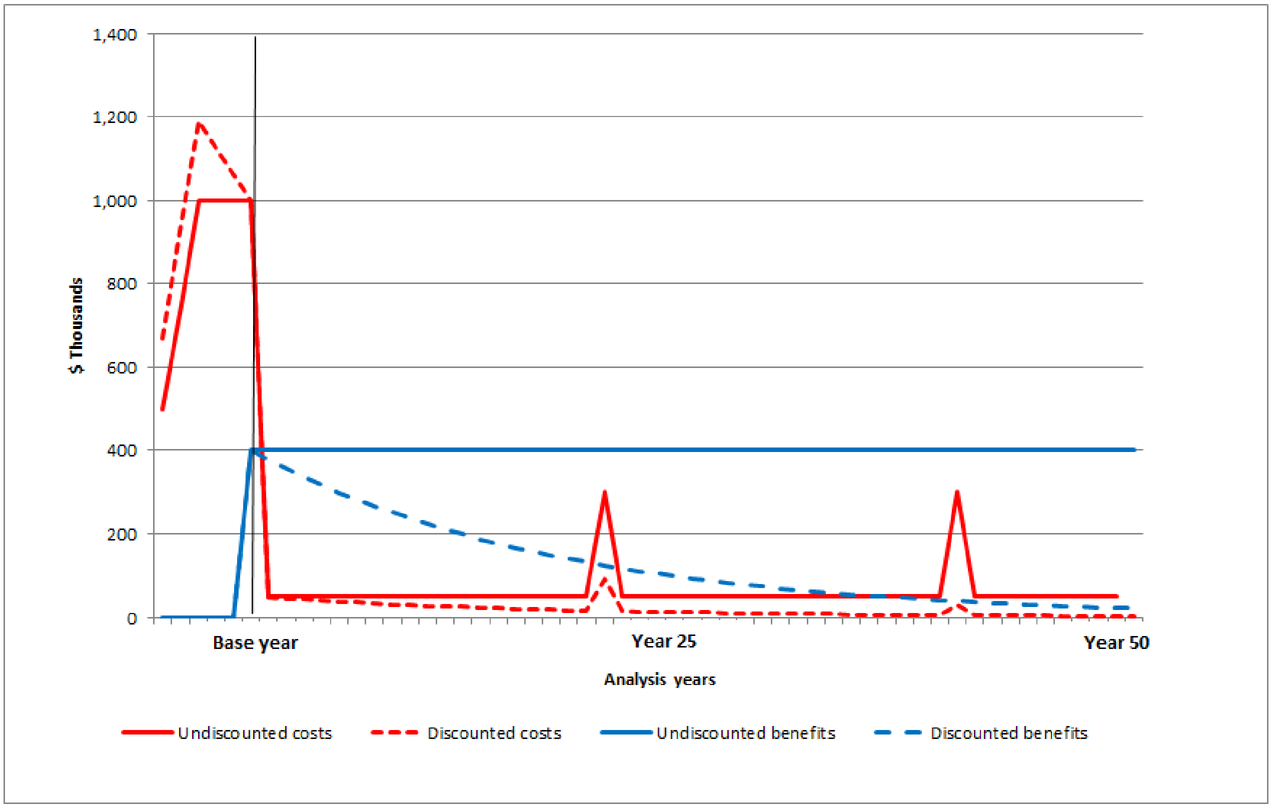

Figure 2-4. An Example Present Worth Analysis

Dollar Base Year

All benefits and costs will be expressed in current year dollars. If dollar estimates are only available from prior years, these can be updated using cost indices available online, including:

- US Bureau of Reclamation Construction Cost Indices
- Engineering News-Record Construction Cost Index
- USACE Civil Works Construction Cost Index System (EM 1110-2-1304)

To update building stock construction costs, Marshall & Swift (or a similar appraisal services company) comparative cost multipliers can be used (www.marshallswift.com). The analysis shall identify which cost index is used.

2.8.6 Multiyear Analysis

Benefits and costs could vary over time if future conditions without and with the project are considered, as described above. For example, a flood inundation-reduction analysis could include increased housing stock (and other building types) as a result of population growth. The same population growth may also affect a proposed project's delivery of water supplies or recreation opportunities. When conditions change over the analysis period, it is necessary to estimate the stream of benefits and costs over time. This will require (a) different estimates of the benefits and costs over many years reflecting the changed conditions and (b) a procedure to compute present value of those changing values over the analysis period. This is described in Appendix H.

2.8.7 Adjustments for Inflation

For DWR B-C analyses, benefits and costs shall be expressed in real, or constant, dollar terms, to indicate they are free of inflation. They shall also be expressed in terms of price levels from a recent year, including applicable month or quarter (e.g., "all dollar values are provided in October 2013 dollars"). If benefits and/or costs are estimated to increase at a rate greater than the inflation rate, then escalation (above the general inflation rate) may be calculated. A useful "all-purpose" index is the Gross Domestic Product Implicit Price Deflator (available online).

2.8.8 Depreciated and Full Replacement Structural Values

For FRM project analyses, physical assets such as structures, automobiles, and infrastructure that are potentially inundated with flood water must be valued using depreciated replacement costs and not full replacement costs. This includes values of structures and their contents. The use of depreciated replacement costs takes into account that structures may have a portion of their economic lives "used up." Typically depreciated replacement values are calculated as:

Depreciated replacement value = structure area (sq ft) x current replacement costs ($/sq ft) x depreciation factor (% remaining life)

2.8.9 Equity Effects

B-C analysis develops information concerning the economic justification of a project; however, it does not address the distribution of benefits and costs among different groups in society. To the extent that such effects can be identified, they should at least be described qualitatively. (Qualitative description can provide the basis for quantification at a later time.) Some of the other effects described in Chapter 10 (especially social effects) can provide the basis for describing equity effects.

2.8.10 Double Counting

Double counting is a common problem in benefits analysis and should be avoided, but it can be difficult to identify in projects of complex operations and multiple, related products. For example, if the project is providing an ecosystem service of improved water quality, the benefit derived from that service could be valued either by the greater agricultural productivity or the avoided costs of providing similar quality water from another source, but not both (Fisher, Bateman, and Turner 2011).

2.9 How Values Are Defined

Above, benefits were defined as the value of the goods and services provided by a project or program, as measured by willingness to pay. Value includes more than commercial or financial value; it includes all values, tangible as well as intangible, that contribute to human satisfaction or welfare. The National Research Council defines this as total economic value, which includes use and nonuse values (NRC 2004):

- **Use values –** those values associated with current or potential future use of a resource by an individual.
- **Nonuse values –** those values associated with the continued existence of a resource, but unrelated to the use of that resource, sometimes referred to as existence, bequest, or passive values.

Typically use values involve some interaction with the resource but nonuse values do not.

Use values are further categorized as consumptive and nonconsumptive uses:

- **Consumptive use –** involves the extraction or harvesting of a resource, thus reducing the quantity of the resource available for use.

- **Nonconsumptive use –** does not involve the extraction or harvesting of a resource, thereby reducing the quantity of the resource, but it may affect the quality of the resource because of pollution or other external effects.

Finally, use values may also be classified whether they are direct or indirect:

- **Direct –** the value associated with some form of direct physical interaction with a resource, such as extraction or harvesting.

- **Indirect –** the value derived from support and protection activities that have measurable values without physical interaction with a resource (for example, changes in property values from close proximity to a park or other open space).

2.10 How Risk and Uncertainty Are Considered in Benefit-Cost Analysis

Risk and uncertainty are intrinsic in water resources planning and design. All measured or estimated values in project planning and design are to various degrees inaccurate due to errors in sampling, measurement, estimation, forecasting, and modeling. Invariably the "true" values are different from any single point value that may be used in a planning study. Federal planning guidance requires that planners characterize, to the extent possible, the different degrees of risk and uncertainty inherent in water resources planning and describe them clearly so decisions can be based on the best available information. Plans can be compared in terms of the variability of their physical performance, economic success, and residual risks.

Risk is the probability that a defined set of events will result in adverse (or beneficial) consequences. A risk analysis accounts explicitly for uncertainty in the contributing factors by first determining the best estimate of each of the functions used for the risk computation, and then describing the confidence in each with a statistical distribution about that best estimate. If descriptions of the statistical distributions of these functions cannot be developed, then uncertainty can be evaluated with sensitivity analysis.

The USACE has developed a substantial body of guidance and tools for risk analysis of FRM projects. USACE risk-based guidance includes ER 1105-2-100, *Planning Guidance Notebook*; ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*; and Engineer Manual (EM) 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies*. The *Flood Damage Analysis* (HEC-FDA) software application developed by the USACE Hydrologic Engineering Center (HEC) incorporates hydrologic, hydraulic, geotechnical, and economic uncertainties in a flood damage analysis.

2.11 Similarities and Differences between State and Federal Benefit-Cost Analysis

Both the federal government and the State of California have developed extensive guidelines and procedures on how to conduct economic analyses. (Federal guidance was summarized in Chapter 1 of this handbook.) Use of these guidelines is essential to ensure that appropriate and consistent procedures are being followed. Because DWR often partners with federal agencies (especially the USACE for flood risk management improvements), and is the non-federal sponsor of the SPFC (primarily through the Central Valley Flood Protection Board), it is critical that DWR be in compliance with federal guidelines. DWR's policy is to be fundamentally consistent with federal procedures when either (1) partnering with a federal agency and seeking federal funding or (2) seeking approval to modify federal facilities such as the State Plan of Flood Control (SPFC). In some cases, in addition to conducting the economic analysis consistent with federal procedures, the State will perform additional analysis to assess the State perspective in addition to the federal perspective. This could include a different discount rate and the endorsement of "innovative methods and tools when appropriate" (DWR 2008a). Table 2-4 summarizes key differences in USACE and DWR B-C analyses.

2.12 Differences between Financial Analysis and Economic Analysis

The objective of economic analysis is to determine if a project represents the best use of resources over an analysis period (that is, whether the project is economically justifiable) (DWR 2008a). The test of economic justifiability is passed if the total benefits that result from the project exceed those which would accrue without the project by an amount in excess of the project costs. This can be expressed mathematically as either net benefits (preferred) or the B/C ratio.

Table 2-4. Comparison of Federal and State Aspects of Benefit-Cost Analysis

Aspect of Economic Analysis (1)	Federal (2)	California (3)
Analysis perspective	Federal funds to be invested to achieve greatest national benefit.	State funds to be invested to achieve greatest benefit to Californians.
B-C analysis objective	NED objective is to maximize the difference between monetized benefits and costs (1983 *P&G*). “Coequal” goals (2013 *P&G*).	Same.
Cost	P&G defines NED costs as the opportunity costs of the resources required or displaced to achieve plan purposes, but in practice, financial costs are usually used.	Same.
Discount rate	Published yearly by the US Treasury.	Available from DWR Economic Analysis Section.
Crops	When changes in acreage are anticipated, an agricultural evaluation is limited to basic crops (rice, cotton, corn, soybeans, wheat, milo, barley, oats, hay, and pasture).	Basic crops may not be distinguished from other types of crops.
Ecosystem benefits	USACE uses cost-effectiveness analysis/incremental cost analysis.	When partnering with a federal agency, uses cost-effectiveness analysis/ incremental cost analysis. When not partnering with a federal agency, may use monetized ecosystem values.

The objective of financial analysis is to determine financial feasibility; that is, whether someone is willing to pay for a project and has the capability to raise the necessary funds. The test of financial feasibility is passed if (a) beneficiaries are able to pay reimbursable costs for project outputs over the project's repayment period, (b) sufficient capital is authorized and available to finance construction to completion, and (c) estimated revenues are sufficient to cover allocated capital and OMRR&R costs over the repayment period (DWR 2008a).

It is possible for projects to be economically justifiable but financially infeasible, or vice versa. For example, a project can be shown to have economic benefits that exceed costs at the statewide level, but sponsors may not be willing or able to finance it. On the other hand, it may not be possible to demonstrate positive net economic benefits for a project, but a sponsor may still be willing to finance and implement the project. A comparison of economic and financial analyses is provided in Table 2-5.

Table 2-5. Comparison of Economic and Financial Analyses

Factor (1)	Economic Analysis (2)	Financial Analysis (3)
Analysis perspective	Can vary from individuals, communities, state, and/or national. 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	Present values determined using economic discount rate	Present values determined 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 borrowed 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.

Table source: DWR (2008a). Economic Analysis Guidebook, Sacramento, CA.

2.13 Other Types of Economic Analyses Used in Lieu of or in Combination with Benefit-Cost Analysis

When it is not possible to describe all of a project's benefits in monetary terms, other economic analysis tools can supplement a B-C analysis, including cost effectiveness analysis, socioeconomic impact analysis, and multiple criteria analysis. These tools are summarized below, with references to specific applications within this HAV. Other tools may also be applicable; contact DWR economics staff for further guidance.

> **Monetary vs. Nonmonetary Benefits**
>
> A benefit's value is measured by the willingness to pay (WTP) of those who benefit from the goods and services produced by a project, expressed in monetary terms. If a monetary WTP cannot be estimated, then other methods can be used to evaluate benefits, which will be called nonmonetary methods herein. One of these nonmonetary methods is cost effectiveness/ incremental cost (CE/IC) analysis. Although CE/IC analysis uses monetary cost information, it does not (by itself) establish a monetary WTP for the project output (benefits). Rather, a CE/IC analysis allows decision makers to compare progressive levels of project output and associated costs and ask if the next level is "worth it." However, sometimes alternative project cost information can be used as an imputed, or proxy, value of benefits.

2.13.1 Cost-Effectiveness Analysis/ Incremental Cost Analysis

Cost-effectiveness (CE) analysis focuses on costs of achieving or exceeding an objective that can be expressed in specific, nonmonetary terms such as acre-feet, milligrams per liter, and habitat units (DWR 2008a). For example, if the objective of the project is to deliver *y* acre-feet of water to a service area per year, then a cost-effectiveness analysis would compare the costs of alternative plans that meet or exceed that objective. Other things being equal, the plan that delivers the specified water quantities at the lowest cost would be the preferred plan. Although B-C analysis is the primary method used to determine economic justification of a project, cost-effectiveness analysis can often provide additional information that can serve as a "reality check" for the B-C analysis and has implications for the financial analysis. CE analysis is particularly important when the objective cannot be expressed in monetary terms and therefore cannot be included in a traditional B-C analysis. A good example of this in water resources planning is ecosystem restoration; many projects now include ecosystem restoration either as their primary purpose or as part of a multiobjective project.

USACE planning guidance, such as ER 1105-2-100, *Planning Guidance Notebook*, describes the use of cost-effectiveness (combined with an incremental cost analysis) to evaluate changes in costs and outputs among plans with ecosystem benefits—basically, determining which ecosystem alternative gives the "most bang for the buck" and combining this information (through a trade-off analysis) with flood damage reduction benefits of the proposed project. This method requires a cost allocation of the project costs between ecosystem restoration and other project purposes, often using the SCRB method. After the cost allocation, project costs allocated to flood damage reduction can be compared to flood damage reduction benefits, ecosystem restoration costs can be compared to ecosystem restoration benefits, and so on. This type of analysis is described further in Chapter 11.

2.13.2 Socioeconomic Impact Analysis

Whereas B-C analysis measures changes in resource costs and benefits to primary beneficiaries, socioeconomic impact analysis (SEIA) focuses on changes in regional population and economic activity as well as fiscal impacts on local governments (changes in public services and revenues). SEIAs are particularly relevant in evaluating the effects on local communities where water resource projects are constructed and operated as well as within the service areas where project supplies are delivered. The results of SEIAs are typically displayed either in the federal regional economic development (RED) or other social effects (OSE) accounts, and may be incorporated into environmental impact reports and environmental impact statements (EIR/EIS). This type of analysis is described further in Chapter 10.

2.13.3 Multiple Criteria Analysis

Multiple criteria analysis (MCA) is a complementary approach to B-C analysis. It is a two-stage decision procedure. The first stage identifies a set of goals or objectives and then seeks to identify the trade-offs between those objectives for different policies or for different ways of achieving a given policy. The second stage seeks to identify the “best” policy by attaching weights (scores) to the various objectives. It involves judging the expected performance of each development option against a number of criteria or objectives. These techniques can deal with complex situations, involving uncertainty as well as the preferences of many stakeholders. This is particularly highlighted when the problem presents conflicting objectives and when these objectives cannot be easily expressed in monetary terms.

There are several variants of the MCA technique. These techniques do not necessarily rely on monetary variables even though monetary variables can also be accommodated in them. MCA involves judging the expected performance of each development option against a number of criteria or objectives and taking an overall view on the basis of a pre-assigned importance to each criterion. The essence of MCA lies in the preparation of a performance matrix with several rows and columns in which each row describes one of the options and each column describes criterion or performance dimension. Thereafter, scores for each option with respect to each criterion are assigned. These scores are supposed to represent performance indicators and are worked out through specific graphs or value functions for each criterion as based on scientific knowledge. Generally a scale of 1 to 10 or 1 to 100 is adopted. In the more sophisticated versions of MCA, weights are assigned to each criterion. Thereafter, a weighted average of scores is worked out. This average provides the overall indicator of performance of each option; the higher the weighted average of scores, the better the option (APFM 2007).

As described in Chapter 11, MCA can be used to inform the decision-making process regarding projects with monetary and nonmonetary benefits and costs.

2.14 Consultation with DWR Economic Analysis Staff Required

This handbook describes the tools, methods, software applications, and analysis result templates applicable for integrated flood risk management benefit evaluations. However, because of the complexity of many of these analyses, the DWR Economic Analysis Section member of the team shall be consulted prior to commencing any of these analyses to select the most appropriate methods and software applications given the study’s objectives and available resources. DWR Economics Analysis staff will also facilitate bringing in a subject matter expert if the project manager is requesting an alternate method or software application (e.g., ecosystem benefits).

HAV provides analysis result display templates. For each of these templates, a spreadsheet has been created that contains the necessary formulas to do the computations. Thus, these spreadsheets provide a consistent method of doing (and displaying) the computations and also provide a measure of “quality assurance.” The file containing these spreadsheets can be requested from DWR Economics Analysis staff. In addition, the team shall work with DWR Economics Analysis staff for guidance on quality assurance/quality control and/or developing Quality Management Plans.

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3.0 Flood Risk Management Benefits

In this chapter:

- The conceptual basis for measuring flood risk management benefits
- USACE methods for computing flood risk management benefits
- Recommended DWR approaches to computing flood risk management benefits
- Consistency between USACE and DWR approaches to computing flood risk management benefits
- Recommended templates for displaying analysis results
- What to do if DWR-recommended procedures are not to be used

3.1 Conceptual Basis for Measuring Flood Risk Management Benefits

Flood risk is the probability of flooding combined with negative outcomes that could result when flooding occurs (DWR 2012n). Flood risk commonly is expressed as a consequence-probability function. The consequence-probability function can be integrated to compute an expected value of the consequence. If the probabilities are annual values, this is called the expected annual value. If the consequence considered is economic loss, this is called the expected annual damage (EAD). EAD reduction is often used as a standard for measuring the effectiveness of proposed flood risk management (FRM) measures. However, risk can also be measured with other indices, such as life loss or impacts to habitat.

The five components of flood risk are hazard, performance, exposure, vulnerability, and consequence (DWR 2013a). They are summarized below and further described in Appendix A.

- **Hazard** – The hazard is what causes the harm, in this case, a flood. The flood hazard is described in terms of frequency of water surface elevation (stage), velocity, extent, depth, and other flood properties.
- **Performance** – Performance is the system's reaction to the hazard. For example, performance can be described by levee fragility curves and interior/exterior functions for leveed areas; unregulated/regulated transforms for reservoirs and diversions; and rating curves for channels.

- **Exposure** – Exposure is who and what may be harmed by the flood hazard. It incorporates a description of where the flooding occurs at a given frequency, and what exists in that area. Tools such as flood inundation maps provide information on the extent and depth of flooding; and structure inventories, crop data, habitat acreage, and population data provide information on the people and property that may be affected by the flood hazard.

- **Vulnerability** – Vulnerability is the susceptibility to harm of people, property, and the environment exposed to the hazard. Depth-percent damage functions, depth-percent mortality functions, and other similar relationships describe vulnerability.

- **Consequence** – Consequence is the harm that results from a single occurrence of the hazard. It is measured through indices such as economic damage, acreage of habitat lost, crop values damaged, and lives lost.

Flood risk reduction is achieved by altering the hazard, performance, exposure, and/or vulnerability, thus reducing adverse consequences. The relationships of the flood risk components are illustrated in Figure 3-1.

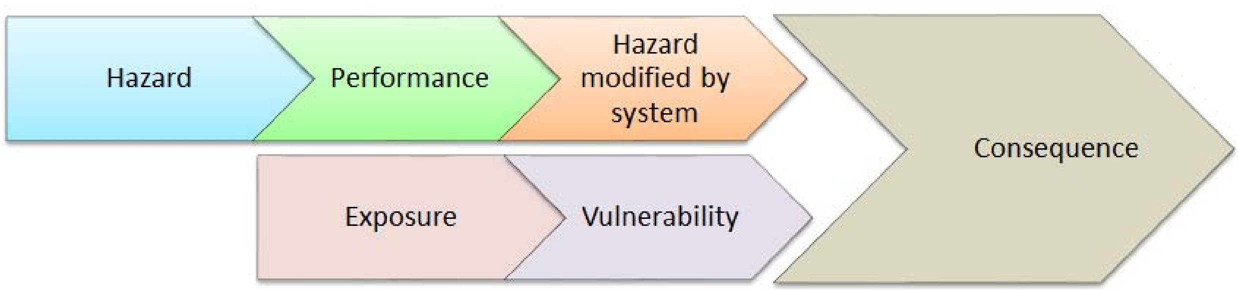


Figure 3-1. Conceptual Illustration of the Relationship among Flood Risk Analysis Components

3.1.1 How Flood Risk Management Fits into Multiobjective Projects

The California Department of Water Resources (DWR) recognizes that projects that integrate multiple benefits, including water supply, recreation, and ecosystem restoration, may be more prudent investments and provide more sustainable and resilient FRM solutions than single-purpose projects that address only public safety. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

For multiobjective projects, the benefit and cost (B-C) analysis shall combine monetized benefits and costs for all project objectives.

Nonmonetized benefits and costs shall be quantifiably assessed, when possible. Otherwise, they shall be qualitatively described. This process is described in Chapter 11.

3.1.2 How Flood Risk Management Benefits Are Categorized

Flood risk management benefits result from protecting existing and future development from flood damage and making flood-prone land more suitable for appropriate uses. The measurement standard and conceptual basis for benefits associated with flood risk management are the willingness to pay (WTP) for each increment of output from a plan.

In general, FRM primary benefits can be grouped into three subcategories:

- Inundation-reduction (IR) benefits
- Intensification benefits
- Location benefits

IR benefits are reduced or modified flood damage, costs, and/or losses, to existing or future economic activity. Their computation is the main focus of an FRM B-C analysis. On the other hand, intensification and location benefits are not often included in FRM B-C analyses.

3.2 How Inundation-Reduction Benefits Are Computed

IR benefits are the reduction in damages associated with existing or future land use. Damages and damages reduced are reported in annualized terms (expected annual damage). EAD is calculated as the integral of the damage-probability function which weights the damage for each event by the probability of that event happening in any given year and then sums across all possible events.

The damage-probability function is derived commonly by transformation of available hydrologic, hydraulic, and economic information, as illustrated in Figure 3-2. A discharge-probability function (Figure 3-2a) and a discharge-water surface elevation (rating) function (Figure 3-2b) are developed using principles of hydrology and hydraulics. An elevation-damage function (Figure 3-2c) is developed from information about location and value of damageable property in the floodplain, which can be transformed to yield the required damage-probability function (Figure 3-2d). Finally, to compute the expected damage, the damage-probability function can be integrated.

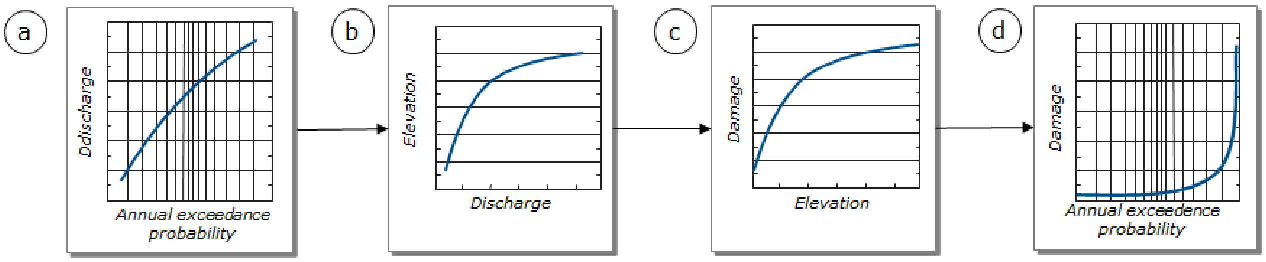


Figure 3-2. Computation of Expected Annual Damage

(USACE 1996a)

The IR benefit is the value of damage prevented: damage incurred without the project less damage incurred with the project. For example, if EAD is $1 million in damage to property without the project, but reduced to $0.4 million with the project, then the IR benefit (the EAD losses avoided due to the project) is $0.6 million.

IR benefits can be realized from a wide range of projects, including those that are structural as well as nonstructural. Structural projects are traditionally used to keep flood waters away from area by modifying the flow, velocity, or direction of a river (i.e., they modify the hazard). Examples of structural measures included reservoirs, levees, floodwalls, and channel modifications). In contrast, nonstructural projects alter human development and behavior (i.e., they modify exposure and vulnerability). Examples of nonstructural management projects include moving or elevating structures, building barriers around structures, and flood-proofing. Both types of projects are addressed in USACE guidance (USACE 1975, 1978, 1995a).

Examples of IR benefits include reductions in:

- Physical flood damage to structures, infrastructure, crops, and ecosystem resources
- Loss of functions of structures and infrastructure
- Emergency response costs
- Disruptions to water supplies and deterioration of water quality and resulting economic losses in Southern California resulting from flooding in the Delta
- Loss of life

Because DWR often partners with federal agencies (especially the USACE) for FRM improvements, it is important that DWR follow procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Following is a summary of USACE FRM planning requirements (methods, software, and analysis results templates), followed by recommended DWR procedures to estimate FRM benefits. For most FRM benefits, DWR-recommended procedures are the same as for the USACE. Where they are different, those differences are noted, along with the reasons why the procedures are different, and the potential implications of those differences.

3.3 USACE Approach to Computing Inundation-Reduction Benefits

The USACE approach to computing inundation-reduction benefits is described below. Specific step-by-step instructions, with examples, can be found in USACE on-line NED manuals.

3.3.1 Method

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), the USACE describes the following evaluation steps for urban FRM benefits based on the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G, US Water Resources Council 1983):

1. Delineate affected area. Identify the affected area which consists of the floodplain plus all other nearby areas likely to serve as alternative sites for any major type of activity that might use the floodplain if it were protected.

2. Determine floodplain characteristics. Describe existing physical and socioeconomic attributes of the floodplain, including an inventory of existing types, numbers, and values of structures and contents.

3. Forecast activities in affected areas. Prepare projections of economic and demographic activities in the affected areas, assuming that new development complies with National Flood Insurance Program (NFIP) requirements (i.e., is outside of the regulatory 100-year [annual p = 0.01] floodplain). This has been further modified by State legislation described below.

What are urban benefits?

As used in this handbook to describe various benefit computations, “urban” broadly refers to all non-agricultural land uses (such as residential, commercial, industrial, and public) which can occur in cities, small communities, or even rural areas. However, this usage is not to be confused with the California legislatively defined terms “urban areas” and “urbanizing areas” as described below.

4. Estimate potential land use. Convert demographic projections to acres.

5. Project land use. Allocate land use demand to floodplain and non-floodplain lands for the without-project condition for each alternative flood management plan.

6. Determine existing flood damages. Estimate existing condition average annual losses by using standard damage-frequency integration techniques and computer programs that relate hydrologic flood variables such as discharge and stage to damages and to probabilities of occurrence of such variables.

7. Project future flood damages. Estimate future flood damages to activities that might use the floodplain in the future without (Step 3) and with the plan (Step 5).

8. Determine other costs of using the floodplain. The impact of flooding on existing and potential future occupants is not limited to flood losses. Some of these are intangible, but others can be translated into national economic development (NED) losses such as flood proofing costs, NFIP administrative costs, and modified use of structures.

9. Collect land market value and related data. If land use is different with and without the project, compute the difference in income for land using land market value data.

10. Compute NED benefits. Compute IR benefits if existing and future land use is the same without and with the project. If land use is the same but more intense with the project, compute intensification benefits. If land use is different, compute location benefits.

USACE NED Manuals Are Available Online

Manuals include flood risk management, coastal storm management, and deep draft navigation, as well as a benefits overview and economics primer. Each manual provides step-by-step descriptions and examples of the benefit evaluation process, including example computation files and audio tutorials. Links are provided to USACE FRM policies and guidance (for example, economic guidance memorandums, including depth-damage functions) and other important resources.

These steps are shown in Figure 3-3.

The USACE evaluation of FRM benefits, especially IR benefits, is evolving. Most importantly, these procedures now explicitly account for uncertainty in the hydrologic, hydraulic, geotechnical, and economic information used to compute EAD. USACE guidance that addresses risk analyses includes the following:

- Engineer Manual (EM) 1110-2-1419 (1995a) describes hydrologic engineering analyses required for planning and design of flood damage reduction measures, both structural and nonstructural.

- Engineer Manual (EM) 1110-2-1619 (1996y) describes risk and uncertainty procedures to be used for USACE flood damage reduction studies, presents templates for display of results, and suggests how risk and uncertainty can be taken into account in plan selection.

- ER 1105-2-101 (2006) defines risk-based analysis as a decision-making framework that comprises three tasks: risk assessment, risk management, and risk communication. It is an approach to evaluation and decision making that explicitly, and to the extent practical, analytically incorporates considerations of risk and uncertainty. It recognizes that the “true” values of planning and design variables and parameters are frequently not known with certainty and can take on a range of values. However, it is possible to describe the likelihood of a parameter taking on a particular value using a probability distribution.

- The US Water Resources Development Act (WRDA) of 1990 (Section 308, Floodplain Management) provided additional guidance concerning how to account for projections of growth in the analysis: “The Secretary [of the Army] shall not include in the benefit base for justifying Federal flood damage reduction projects ‘Any new or substantially improved structure… built in the 100-year flood plain with a first floor elevation less than the 100-year flood elevation after July 1 1991’” (WRDA 1990). Also, “in practice,” new growth within existing 100-year (annual p = 0.01) floodplains or project growth in areas that have been declared in the 100-year (annual p = 0.01) floodplain prior to construction have been excluded from the benefit analysis and are only accounted for as residual risk (i.e., flood risk to these structures is not reduced because of the project). Finally, “in practice,” the USACE no longer counts NFIP administrative costs as benefits (Step 8), nor does it collect land market data (Step 9); most of the forecasting can be accomplished with steps 3 and 5.

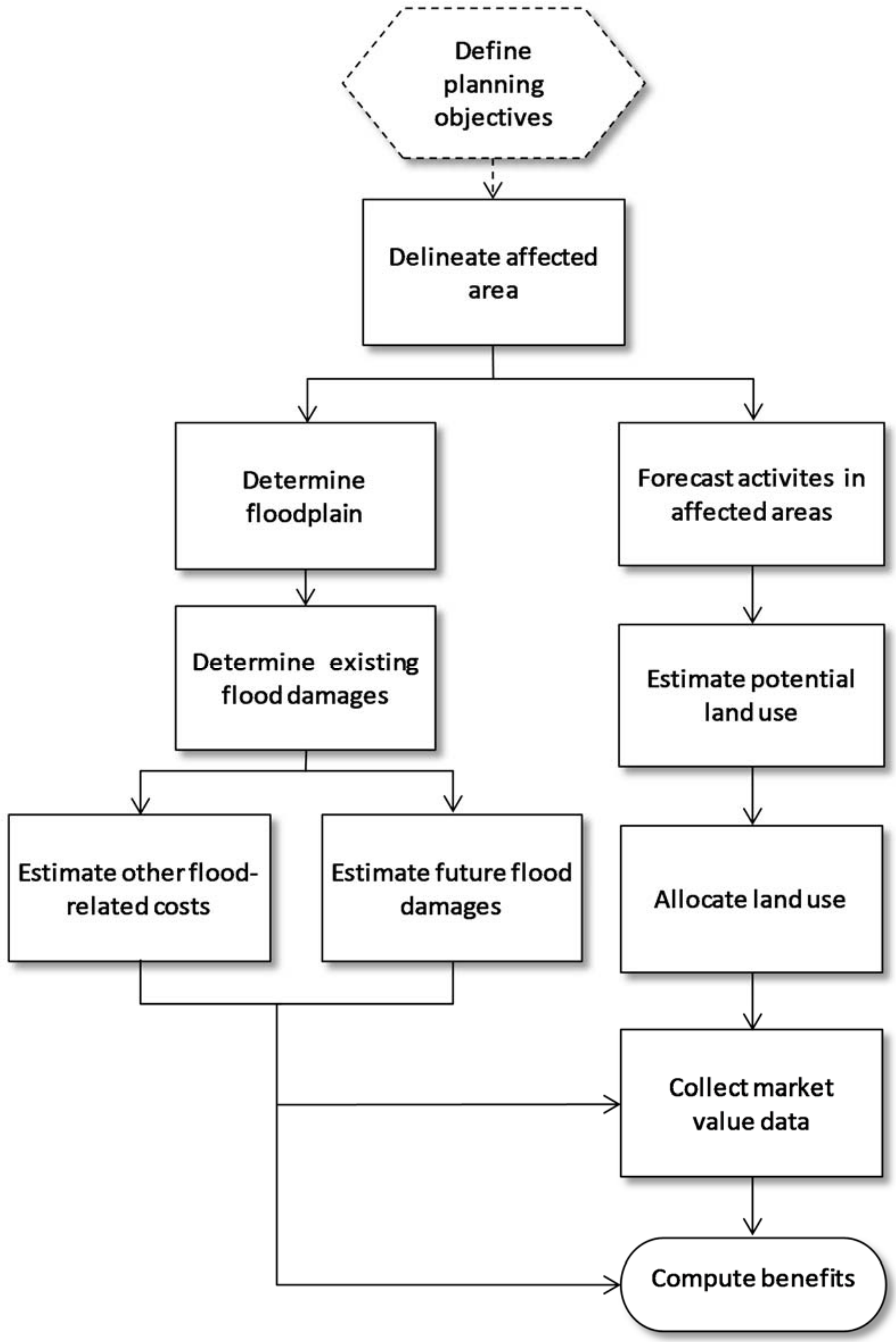


Figure 3-3. USACE Urban Flood Damage Evaluation Method

(Adapted from ER 1105-2-100, Appendix E)

3.3.2 Software Application

HEC-FDA (“Flood Damage Reduction Analysis”) (USACE 2008a) is the USACE certified program for conducting risk-based flood damage reduction analyses (see text box for description of USACE certified and approved models). HEC-FDA is based on the concept that the average of damages that are incurred over a very long period will approach the true EAD. It uses a statistical model to generate a long sequence of flood elevations, uses the elevation-damage transformation to create an equally long record of annual damages, and averages those while explicitly accounting for uncertainty. Thus, it replicates the process shown in Figure 3-2, while accounting for uncertainty in each of the functions.

> **USACE Certified and Approved Models**
>
> A certified model is a planning model that has been reviewed and certified by the appropriate USACE Planning Center of Expertise (PCX) and Headquarters (HQ) in accordance with the rules and procedures specified in EC 1105-2-4142. Model certification is a determination that the model is a technically and theoretically sound and functional tool that can be applied during the planning process by knowledgeable and trained staff for purposes consistent with the model’s purposes and limitations. Other models may be approved on a one-time basis for a specific study or project, if approval is obtained in advance. This process can take up to a year to complete.

To run HEC-FDA, the steps described below are followed, which reflect the USACE FRM benefit assessment procedure shown in Figure 3-3. Although specific to HEC-FDA, the analyst would follow similar steps in most FRM studies:

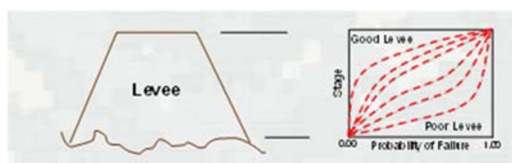
1. Describe the study configuration. In this step, the physical study layout and analysis plans (without-project and with-project) are defined. This includes defining the streams, impact areas (also called damage reaches), and index points to be analyzed. This is a crucial step, because consideration must be given to the systemwide implications of projects being evaluated, including actions that might be taken upstream by others that would affect the project, as well as effects of the proposed project on communities downstream (i.e., hydraulic impacts). Systemwide implications may also extend beyond the study stream system. For example, a flood may damage a water supply pipeline, thereby disrupting water deliveries to a different part of the State and causing socioeconomic impacts. Although these other areas may not be included as an impact area in the “study area,” methods are available to import externally-derived stage (or probability) damage functions into HEC-FDA.
2. Provide the hydrology and hydraulics (H&H) information. In this step, the analyst identifies and obtains the H&H information needed to evaluate plans, including channel water surface profiles, exceedance probability-functions, and water surface elevation (stage)-discharge

functions. H&H information is developed for existing and future without-project and with-project conditions, and shall take into account climate change. The H&H modeling also produces floodplains, which define the frequency, extent, and variation in depth of flooding for without-project and with-project conditions. Floodplains are used in conjunction with channel water surface elevations to develop interior (floodplain)-exterior (channel) relationships within HEC-FDA that define depths in the floodplains. Floodplains are also used to help delineate the impact areas described above, which then define the extent of the economics information that must be obtained, described below. H&H information (including uncertainty) describes the natural hazard (Figure 3-1).

3. Provide levee failure information. This information describes top of levee and levee failure probabilities associated with specified channel water surface elevations for without- and with-project conditions (see text box). Levee failure information describes the performance component of a risk analysis (Figure 3-1) and may be available from other studies and/or reports, or obtained directly from geotechnical specialists. [Note: another input into HEC-FDA is a flow transform relationship which defines a relationship between unregulated and regulated flows when reservoirs or other structures that modify channel flow are present. Flow transform relationships are also descriptors of the performance component of a risk analysis.]

Levee Failure Probability vs. Water Surface Elevation

This graphic illustrates the relationship between the probability of levee failure and water surface elevation (stage). In general, a “good” levee has less probability of failure at a specified water surface elevation (stage) than a “poor” levee. This relationship is sometimes called the levee failure (or fragility) function.



(USACE South Pacific Division)

4. Provide the economics information. In this step, the analyst identifies and obtains the economic data and information needed to evaluate plans, including damage categories (for example, residential, commercial, and industrial), structure occupancy types (for example, single-family and multiple-family residential), and structure inventory data (for example, numbers and values of structures and their contents) for without- and with-project existing and future conditions. The best source of structural inventory information is geo-referenced county assessor data, combined with construction cost and depreciation factors

obtained from a recognized valuation service. Structures are assigned ground elevations using digital elevation models (DEMs) or LiDAR information. Field work is required to verify published information and to collect additional information, such as foundation heights, construction materials, number of stories, condition of structures, etc. If proposed plans include nonstructural measures (for example, raising structures), then the inventory information (for example, foundation heights) would be modified accordingly for with-project conditions. The USACE has published guidance on developing structural inventories (1995c). Economics information (including uncertainty) describes the exposure component of a risk analysis (Figure 3-1). In addition, standard depth-percent damage functions by structure type must also be obtained from the USACE and/or the Federal Emergency Management Agency (FEMA). This information (including uncertainty) describes the vulnerability component of a risk analysis (Figure 3-1).

5. Evaluate the benefit. In this step, the analyst runs HEC-FDA to compute EAD, the consequences component of a risk analysis. To compute EAD, a water surface elevation (stage)-damage relationship is developed based on the H&H and economics information. HEC-FDA can generate this relationship automatically, or the user can enter it manually if water surface elevation (stage)-damage is computed external to HEC-FDA (for example, water disruption impacts in another region). Summary reports are generated to display expected annual damage without and with a plan by impact area. Project performance statistics (annual exceedance probability, long-term risk, and conditional nonexceedance probability) are also generated by HEC-FDA. Annual exceedance probability (AEP) is the probability that flooding will occur in any given year considering the full range of possible annual floods. Long-term risk is the probability of flooding over 10-, 30-, and 50-year periods. Conditional nonexceedance probability (now called assurance by the USACE) is the probability that inundation will not occur if an event of specified annual chance exceedance occurs (e.g., 10%, 4%, 2%, 1%, 0.4%, and 0.2% annual chance exceedance events). EAD and project performance statistics are computed incorporating uncertainty and are included in USACE required risk analysis displays described below.

Appendix A provides additional descriptions and graphics of the flood risk analysis concepts underlying these steps.

3.3.3 Analysis Results Display Templates

Required USACE analysis display templates of EAD and project performance statistics are shown in Table 3-1 through Table 3-3; the values for these tables are obtained from HEC-FDA outputs.

The residual risk must also be described. Residual risk is the flood risk that remains after all efforts to reduce the risk are completed. In other words, residual risk is the amount of EAD remaining after the project is implemented, as shown in Column 3 of Table 3-1. For example, after a levee is constructed, a hydrologic event with discharge rates that raise water elevations above the top of the levee may occur. In that case, water reaches the floodplain and property is damaged, albeit less frequently. The average over the long term of damage not prevented is the residual risk for an impact area.

In practice, when estimating urban IR benefits, the USACE often focuses on physical property damage benefits because traditionally these are likely to provide the “most benefits for the buck.” However, other types of flood damage are increasingly being evaluated, including displacement costs, emergency response costs, and clean-up costs. Because these benefits may not make a significant difference in comparing alternatives, the USACE may only evaluate them once the final alternative is selected. Loss of life is another type of IR benefit receiving significant attention by the USACE and DWR and is described below.

The USACE also focuses on reducing flood damage to existing land uses rather than future land uses (i.e., the benefit to cost ratio for existing condition must be greater than 1.00).

Additional display templates which combine FRM benefits with other benefits and total project costs for multiobjective projects are described in Chapter 11. Non-economic IR benefits (such as loss of life, described below) shall be described clearly, either quantitatively or qualitatively, in text, tables, and charts, as appropriate.

Table 3-1. Example USACE Risk Analysis Display Template for Expected Value and Probabilistic Values of Expected Annual Damage (EAD) and EAD Reduced

Plan (1)	EAD ($1000)		Damage Reduced ($1000)		EAD Reduced That Is Exceeded with Specified Probability ($1000)		
	W/out plan (2)	W/plan (3)	Mean (4)	SD[1] (5)	0.75 (6)	0.50 (7)	0.25 (8)
20' levee	575	220	355	57	316	353	393
25' levee	575	75	500	77	451	503	555
30' levee	575	5	570	98	502	573	628
Channel	575	200	375	65	328	370	415
Detention basin	575	250	325	93	263	325	388
Relocation	575	220	355	61	313	353	396

Table source: ER 1105-2-101
Note:
[1] Standard deviation.

Table 3-2. Example USACE Risk Analysis Display Template for Annual Exceedance Probability (AEP) and Long-Term Risk Project Performance Statistics

Plan (1)	Annual Exceedance Probability (AEP) (2)	Long-Term Risk: Chance of Exceedance[1] (Long-Term Risk)[2]		
		10 years (3)	30 years (4)	50 years (5)
Without	0.250 (1 in 4)	0.94 (1 in 1.1)	1.00 (1 in 1.0)	1.00 (1 in 1.0)
20' levee	0.020 (1 in 5)	0.18 (1 in 5.5)	0.45 (1 in *2.2*)	0.64 (1 in 1.6)
25' levee	0.010 (1 in 100)	0.10 (1 in 10.0)	0.26 (1 in 3.8)	0.39 (1 in 2.5)
30' levee	0.001 (1 in 1000)	0.01 (1 in 100)	0.03 (1 in 33.8)	0.05 (1 in 20.5)
Channel	0.015 (1 in 67)	0.14 (1 in 7.1)	0.36 (1 in 2.7)	0.53 (1 in 1.9)
Detention basin	0.030 (1 in 33)	0.26 (1 in 3.8)	0.60 (1 in 1.7)	0.78 (1 in 1.3)
Relocation	0.020 (1 in 50)	0.18 (1 in 5.5)	0.45 (1 in 2.2)	0.64 (1 in 1.6)

Table source: ER 1105-2-101
Notes:
[1] Chance of exceedance over indicated time period.
[2] Alternative description of risk.

Table 3-3. Example USACE Risk Analysis Display Template for Conditional Nonexceedance Probability (Assurance)

Plan (1)	Conditional Nonexceedance Probability by Events					
	10% (2)	4% (3)	2% (4)	1% (5)	0.4% (6)	0.2% (7)
Without	0.6628	0.2157	0.0956	0.0349	0.0057	0.0006
Plan A	1.0000	0.9957	0.9624	0.8368	0.4914	0.1661
Plan B	0.9994	0.9632	0.8101	0.5283	0.1991	0.0585

Note: This is an optional display that shows the probability that inundation will not occur if an event of specified annual chance exceedance (ACE) occurs (USACE 2008a). The USACE now calls this “assurance.”

3.4 DWR-Recommended Approach to Computing Inundation-Reduction Benefits

Figure 3-4 summarizes the major steps to be followed by DWR in estimating urban inundation reduction benefits. These steps are consistent with USACE guidance.

The DWR-recommended procedure includes these requirements:

- DWR shall follow USACE procedures for displaying urban IR benefits (Table 3-1 through Table 3-3).
- DWR shall use HEC-FDA to estimate urban IR benefits.
- DWR shall describe uncertainty about inputs to all economic analyses.
- When using HEC-FDA for economic risk analysis, uncertainty about inputs should be described with one of the available distributions. In the absence of support for another selection, the normal distribution should be used.
- Parameters for these distributions shall be selected consistent with guidance in USACE Engineer Manual 1110-2-1619.

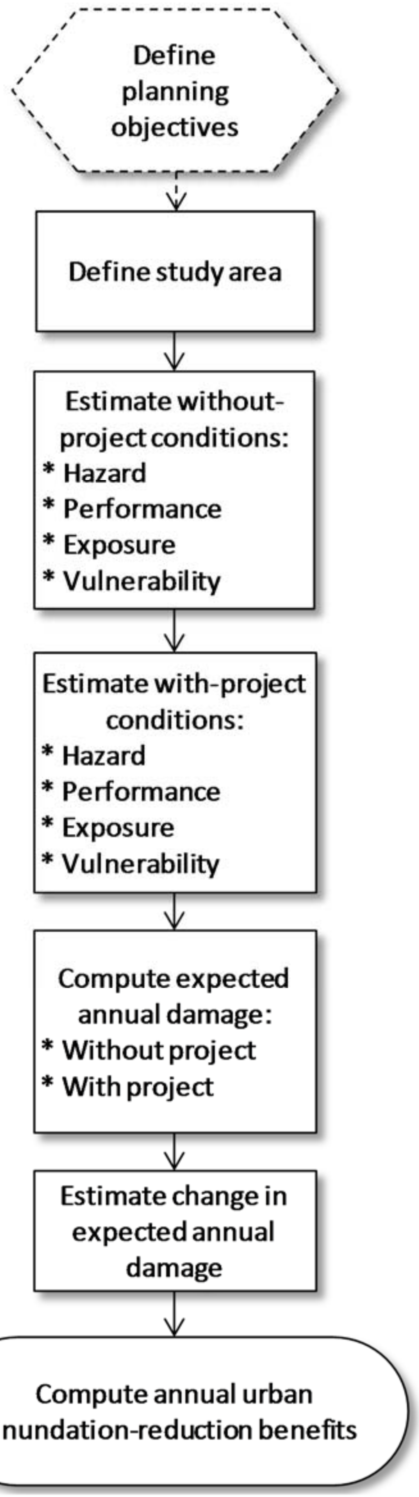


Figure 3-4. DWR Urban Inundation Reduction Benefits Analysis Method

As mentioned above, the USACE often focuses on a subset of urban IR benefits (physical property damage benefits) because these are likely to be the most significant benefits. However, ignoring other benefits may be "leaving benefits on the table" that could potentially affect the economic justification of the proposed project.

Accordingly, to illustrate interest in a potential project, DWR shall evaluate and include, where significant, other damage such as the loss of functions of assets inside and outside of the flooded area, emergency response costs, community disruption, and loss of life (described below).

Example studies that evaluate some additional types of benefits include the following:

- The Sacramento Area Flood Control Agency's Natomas Levee Improvement Program economic analysis, which includes monetized estimates of displacement and temporary housing costs (SAFCA 2007).
- The USACE American River watershed project (Folsom dam modification/raise projects), which includes emergency costs/humanitarian assistance, dewatering costs, emergency levee repair costs, and debris removal costs (USACE 2008b).
- DWR's 2012 Central Valley Flood Protection Plan, which estimated business losses associated with decreased business activity caused by flooding (DWR 2012g). [Note: an analysis of potential business activity losses caused by flooding should also account for the possibility of increased business activity outside of the flood zone as businesses respond to the flood event and its consequences.]

In addition, FEMA's guidance, *What Is a Benefit? Guidance on Benefit-Cost Analysis of Hazard Mitigation Projects (Draft), Revision 2.0* (2001), has information on computing benefits for FEMA hazard mitigation programs, including loss of function impacts for buildings (including critical facilities such as police, fire, and medical buildings), utilities (loss of electric power, potable water, and wastewater services), and roads and bridges.

Step 3 of the USACE evaluation steps listed above includes the requirement that future development included in the B-C analysis will be assumed to comply with NFIP requirements and be located outside the regulatory 100-year (annual $p = 0.01$) floodplain. However, the State has enacted more stringent requirements. In 2007, State FRM legislation was passed (Senate Bill 5) requiring a 200-year (annual $p = 0.005$) "urban level of flood protection" (ULOP) for urban areas and urbanizing areas protected by facilities of the SPFC in the Central Valley. These urban areas and urbanizing areas areas must demonstrate “adequate progress” towards meeting this objective by 2015, with full compliance by 2025. Outside of the Central Valley these requirements are voluntary for urban areas (DWR 2012j). Thus, this additional requirement must be accounted for when including future development in the economic analysis, which will usually reduce benefits of proposed projects because the future without-project condition damages will be reduced as a result of the greater level of protection attributed to future development.

If significant changes in the hazard, performance, exposure, or vulnerability are expected to occur over the analysis period, then these must be accounted for in the IR analysis. Appendix H describes how these changes can be directly incorporated into the HEC-FDA analysis.

3.5 How Intensification and Location Benefits Are Computed

Improved flood protection can make flood-prone land more suitable for development resulting in intensification and/or location benefits. When the land use is the same without or with a project but the intensity of land use changes, an intensification benefit may accrue to the project. The change in intensity of usage must be directly and solely due to the project and it must result in an increase in the net income. Examples of intensification benefits include:

- Vacant lots interspersed among existing developed land that can be developed.
- Buildings with unusable lower floors (due to the flood hazard) that can be fully utilized.
- Land that can shift from lower-value crops to higher value crops.

When the land use changes between the without-project and with-project conditions because of a new economic use, a location benefit may accrue to the project. The change of usage must be directly and solely due to the project and it must result in an increase in the net income. Examples of location benefits include:

- Vacant land that is developed for residential purposes.
- Agricultural land that is converted to industrial purposes.

3.6 USACE Approach to Computing Intensification and Location Benefits

The USACE approach to computing intensification and location benefits is described below.

3.6.1 Methods

For intensification and location benefits, the USACE uses either change in net income or land values between the without-project and with-project conditions (Step 9 in the above evaluation steps). Specific procedures (and examples) for estimating both types of benefits are provided in the USACE FRM on-line NED manual (land use changes).

3.6.2 Software Application

No specific software is required to compute these benefits, which can be accomplished using spreadsheet analyses.

3.6.3 Analysis Results Displays

An example USACE intensification benefits analysis is shown in Table 3-4. Risk and uncertainty is addressed using sensitivity analysis.

Table 3-4. Example USACE Analysis Display Template for Intensification Benefits

(1)	Without-Project (2)	With-Project (3)
(a) Gross income	$25,000	$75,000
(b) Expected annual damages	$1,000	$5,000
(c) Other costs	$23,000	$60,000
(d) Net income (a)-[(b)+(c)]	$1,000	$10,000
(e) Intensification benefits 3(d)-2(d)	$0	$9,000

Table source: USACE on-line flood risk management manual: land use changes

In practice, although guidance is provided how to compute intensification and location benefits, USACE policy is not to estimate these benefits except in limited circumstances, because, according to ER 1105-2-100, *Planning Guidance Notebook* (2000), they “do not reduce actual flood damages.” In fact, rather than a benefit, encouraging land development within the floodplain may be interpreted by the USACE to be in conflict with the federal objective included in the recently proposed federal principles and requirements regarding “unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used” as well as other federal directives regarding floodplain management.

(See, for example, P&G 2013 and Executive Order 11988). Thus, such development may require mitigation.

3.7 DWR-Recommended Approach to Computing Intensification and Location Benefits

Figure 3-5 summarizes the major steps to be followed by DWR in estimating urban intensification and location benefits, based on the change in net income associated with the different land use. These steps are consistent with USACE guidance, as shown in Figure 3-3.

If feasible to compute, DWR shall include both of these benefits if the proposed land use is consistent with the flood risk. Consistent uses would exclude critical facilities, such as schools, hospitals, utilities, transportation facilities, and/or storage of hazardous materials, etc. However, if different uses are being introduced to the floodplain, it is necessary to determine if it is really a "new" use or one transferring from another region in the study area or the State. If transferred from somewhere else in the study area or the State, a net income is computed taking into account the gain in one region and the offsetting loss in the other region. If it is transferring from another state, then it would be considered a "new" use and a net income analysis would not be required.

Key assumptions and variables must be described, along with sources of uncertainty, and subjected to a sensitivity analysis. As described above, future development must be modeled so that it complies with NFIP requirements and ULOP requirements. However, because the USACE only allows these benefits in limited circumstances, it may disallow these benefits if computed by DWR to support federal funding requests or permit approvals.

Whenever these benefits are included, the analyst must demonstrate that the proposed economic activities "facilitate continuing opportunities for prudent economic development that supports robust regional and statewide economies *without creating additional flood risk*" as required by the FloodSAFE goals described in Chapter 1 (emphasis added). [Note: At the time of this writing, DWR does not have a policy regarding the inclusion of intensification and location benefits. Thus, DWR Economic Analysis Section staff should be consulted prior to including these benefits.]

No software applications are recommended. DWR shall follow USACE procedures for displaying urban intensification and location benefits (Table 3-4).

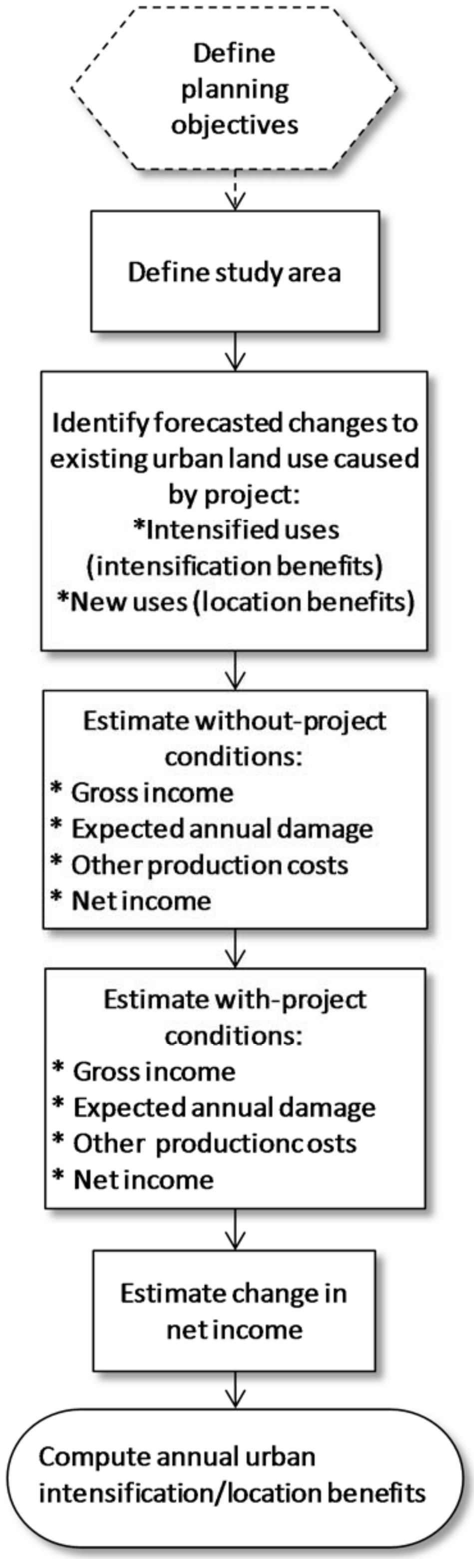


Figure 3-5. DWR Urban Intensification and Location Benefits Evaluation Method

If significant land use changes are expected to occur over the analysis period, then the intensification and location benefits must be computed as many times as necessary to reflect those changes and reported for each time period using the format shown in Table 3-4, where applicable. Appendix H describes how to do the present value analysis when the benefits (and costs) change over the analysis period.

3.8 How Agricultural Flood Risk Management Benefits Are Computed

Agricultural FRM primary benefits result from protecting agricultural development from flood damage and the value of increased agricultural production resulting from improved flood protection. Although agricultural production includes both crops and livestock, typically only crop benefits are computed.

Crop FRM benefits can be grouped into two subcategories, depending on whether the cropping pattern changes:

- **Damage reduction benefits –** These benefits accrue on lands where no change in cropping pattern occurs between the without-project and with-project conditions. Benefits result from the reduction in damage costs from floods (similar to urban IR benefits).

- **Intensification benefits –** These benefits accrue on lands where the cropping pattern changes, with benefits measured by the change in the value of production resulting from improved flood protection.

Location benefits are not estimated for crops.

3.9 USACE Approach to Computing Agricultural Flood Risk Management Benefits

For agricultural FRM B-C analyses (and water supply benefit analyses described in Chapter 5), the USACE distinguishes between basic and other (non-basic) crops:

- **Basic crops –** Basic crops are crops that are grown throughout the country in quantities such that no water resources project would affect the price and thus cause transfers of crop production from one area to another. The production of basic crops is limited primarily by the availability of suitable land. Basic crops include rice, cotton, corn, soybeans, wheat, milo, barley, oats, hay, and pasture.

- **Other crops –** On a national basis, production of crops other than basic crops is seldom limited by the availability of land. Rather, production is generally limited by market demand, risk aversion, and supply factors other than suitable land. Thus, production from increased acreage of crops other than basic crops in the project area would be offset by a decrease in production elsewhere, and therefore these would be excluded from the benefit analysis. However, if it can be shown that the production of other crops is limited by the availability of suitable land, they may be considered as basic crops and included in the analysis.

As discussed below, this distinction between basic crops and other crops has important implications for analyses conducted by the USACE compared with DWR, because many specialty (non-basic) crops are grown in California. In practice, crop benefits are not significant benefits in most USACE FRM B-C analyses.

3.9.1 Method

ER 1105-2-100, *Planning Guidance Notebook* (2000) describes the following evaluation steps for agricultural flood damage benefits based on the 1983 P&G:

1. Identify land use and cropping patterns without and with a plan. Separate project area land into two categories: lands on which the cropping pattern is the same without and with the project and lands on which there would be a change in cropping pattern. To estimate crop production benefits on lands where there would be a change in cropping pattern, go to Step 3. To estimate crop production benefits on lands where there would not be a cropping pattern change, go to Step 2.

2. Determine damage reduction benefit. For lands on which cropping pattern does not change, determine the change in net income without and with a plan using farm budget analysis. Income increases may result from increased crop yields and decreased production costs/losses using farm budget analysis. This is the damage reduction benefit.

3. Select evaluation method for estimating intensification benefits. For land on which cropping pattern would change, use either farm budget analysis (Step 4) or land value analysis (Step 9).

4. Determine whether other crops are to be treated as basic crops. If it can be shown that the production of the other crops is constrained by the availability of suitable land, they can be treated as basic crops. Go to Step 5. Otherwise, go to Step 8.

5. Determine the limit on acreage of other crops that may be treated as basic crop acreage. If other crops are determined to be basic crops, the number of acres that may be claimed for that crop is limited. This is the maximum acreage of other crops that may be analyzed as basic crops in steps 6 and 7. For any acres in excess of the maximum allowable acres, go to Step 8.

6. Project net value of agricultural (basic crop) production without and with the plan. Use farm budget analysis to estimate the net value of agricultural production under without-project and with-project conditions.

7. Compute intensification benefits for acreage of basic crops and other crops treated as basic crops. Compute intensification benefits as the change in net income between the without-project and with-project conditions, completing the analysis for basic crops.

8. Determine efficiency benefits. Compute efficiency benefits for acreage producing other crops not treated as basic crops as the sum of (a) the difference between the cost of producing the crops in the project area and the cost of producing them on other lands and (b) the net income that would accrue from production of an "appropriate mix of basic crops on those other lands."

9. Land value analysis. When estimating intensification benefits based on land value analysis, use appraisals of current market values of lands that would benefit and compare them with appraisals of non-project lands, adjusted for improvements not found on the project lands. Subtract the project land appraisals from the adjusted non-project land appraisals to determine intensification benefits. Damage reduction may also be computed for "other agricultural properties" such as equipment, improvements, and agricultural enterprises (economic activities that may be affected by changed water management conditions, such as a delay in spring planting).

These steps are shown in Figure 3-6.

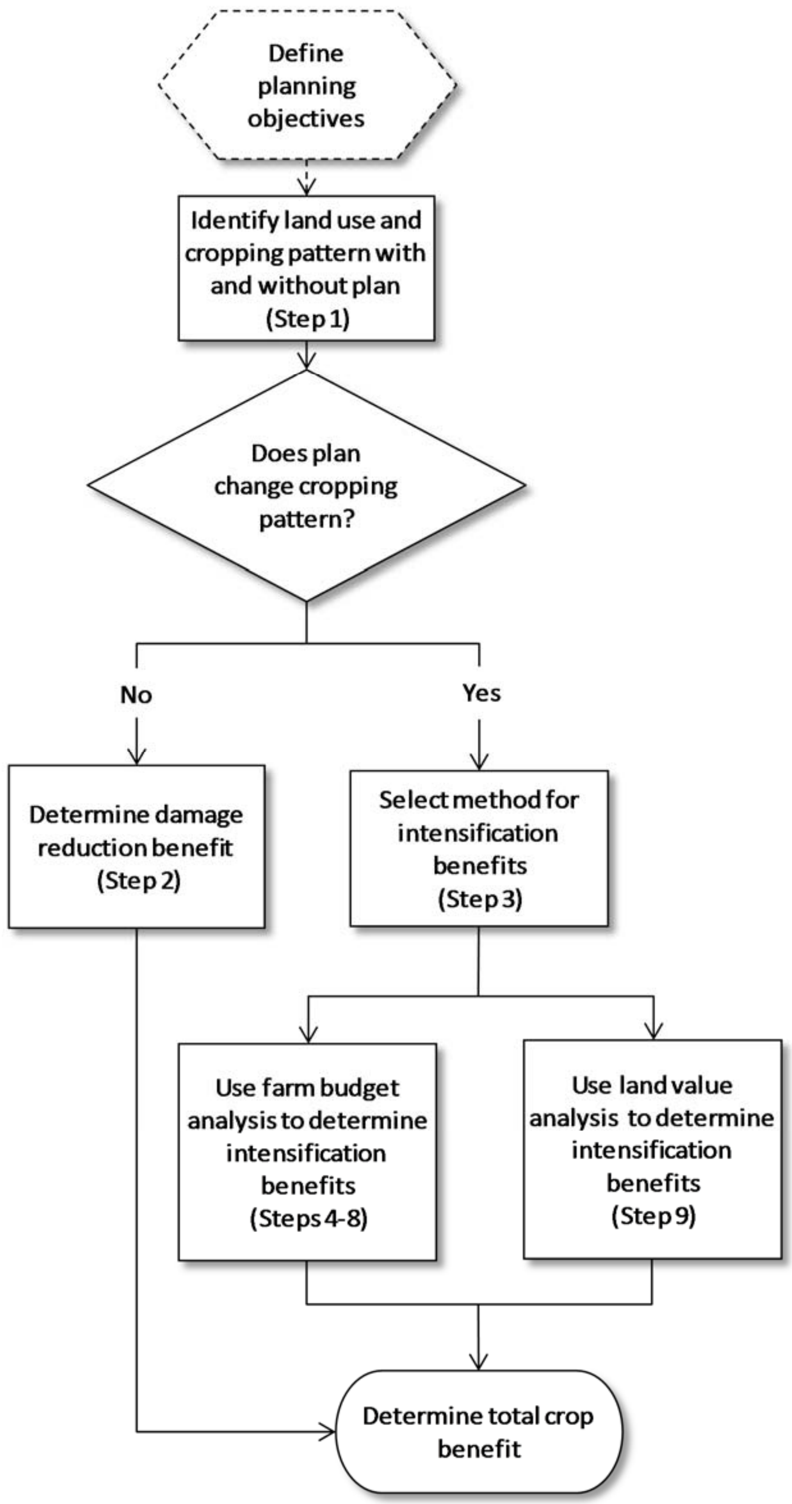


Figure 3-6. USACE Agricultural Flood Damage Evaluation Method

(Adapted from ER 1105-2-100, Appendix E)

3.9.2 Software Applications

The USACE does not have a “certified” software application to estimate expected annual crop flood damage, although spreadsheets can be used to develop crop stage (or probability)-damage functions for input into HEC-FDA. HEC-FDA was designed primarily for urban flood damage analyses, but can be adapted for crop analyses as described below. HEC-FIA (“flood impact analysis”) computes crop damage taking into account cropping patterns, crop budget information, season of the year flooding occurs, duration of flooding, previous flooding, and crop loss functions, but on an *event* basis.

3.10 DWR-Recommended Approach to Computing Agricultural Flood Risk Management Benefits

Crop flood damage reduction and/or intensification benefits are likely to be important for DWR FRM analyses, especially in the Central Valley. Figure 3-7 summarizes the major steps to be followed by DWR in estimating crop inundation reduction benefits. The estimation of crop inundation reduction benefits does not require a distinction between basic and other crops.

Figure 3-8 summarizes the major steps to be followed by DWR in estimating crop intensification benefits.

If intensification benefits are anticipated to occur because of a projected change in cropping pattern resulting from improved flood protection, and the analysis is part of a federal feasibility study, then the distinction in basic and other crops must be applied, as shown in Figure 3-8. Uncertainty shall be addressed with sensitivity analyses for crop inundation reduction and intensification benefits analyses.

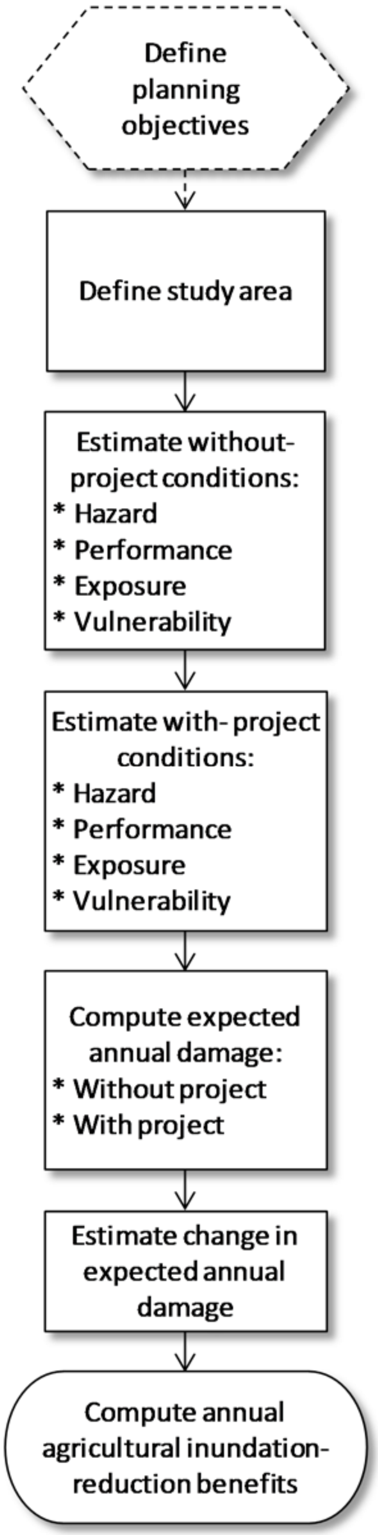


Figure 3-7. DWR Crop Inundation Reduction Benefit Evaluation Method

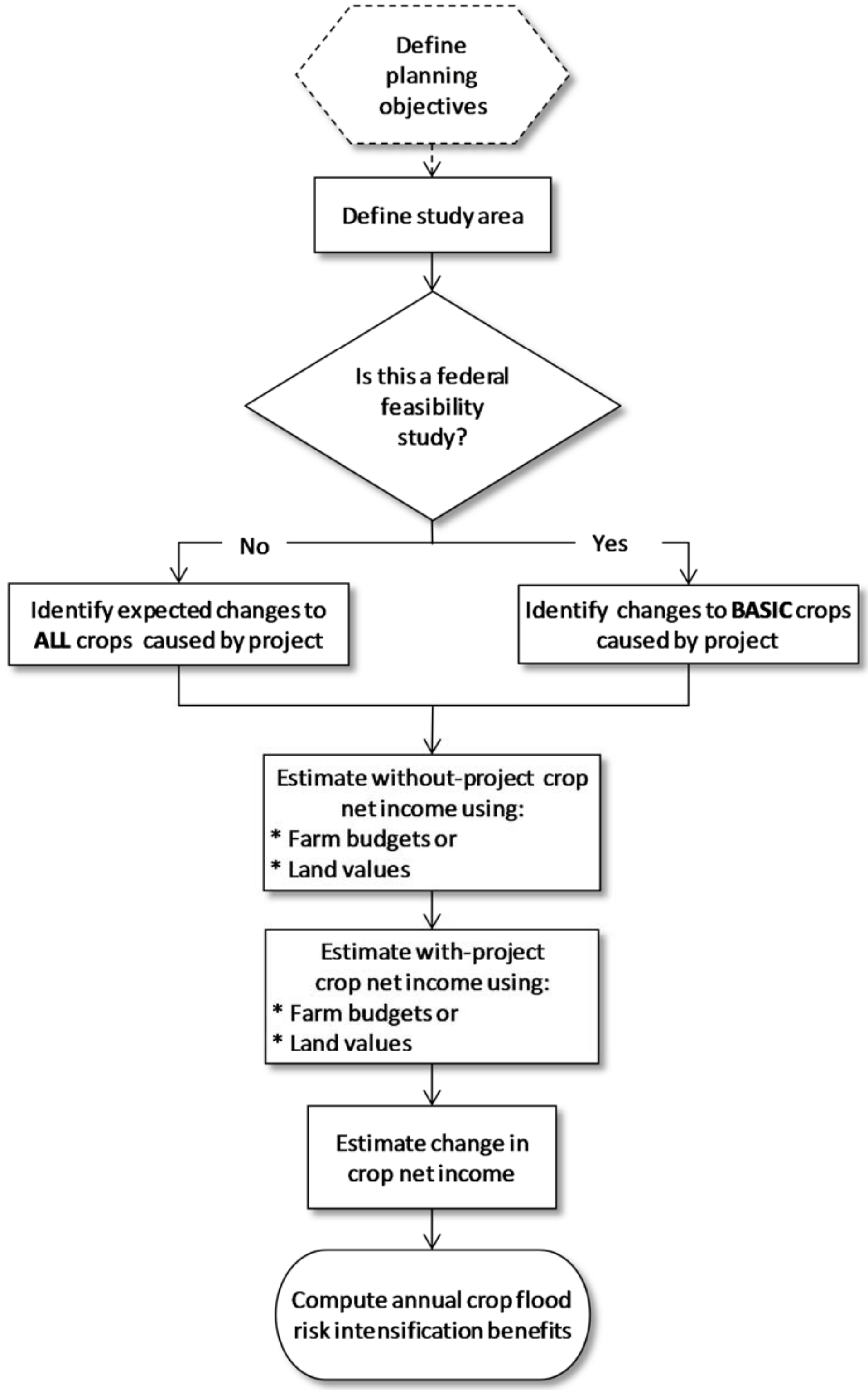


Figure 3-8. DWR Crop Intensification Benefit Evaluation Method

HEC-FDA can be adapted for crop flood damage analyses using the HEC-FDA evaluation steps described above for an urban inundation-reduction analysis, with these changes in Step 4:

Provide economic information – Instead of developing a geo-referenced structural inventory, the analyst develops a geo-referenced crop inventory (i.e., crop polygons) using DWR geographic information system (GIS) county land use files, which describe crop exposure (Figure 3-1). The crop polygons are assigned average ground elevations using DEMs or LiDAR information. Instead of providing structural depth-damage functions, the analyst provides crop damage/acre values for representative crops. These crop damage/acre estimates are based on monthly estimates of:

- Cultivation costs (growing costs).
- Harvest costs.
- Gross income (a function of yield and price).

These monthly data are then combined with the probability of a flood in a particular month and the percent damage that would occur for each crop if there were a flood in that month to obtain a weighted average annual crop damage/acre estimate. The crop damage/acre values also take into account duration of flooding: short-term (less than five days of inundation) and long-term (greater than five days of inundation). Duration of flooding is important for permanent crops with potential re-establishment costs, which are added to the weighted average annual damage estimate. A final adjustment is to add land clean up and rehabilitation costs for all crops. Table 3-5 shows the crop weighted average annual crop damage estimates developed for the 2012 CVFPP, which were originally developed for the Sacramento and San Joaquin river basins comprehensive study and price updated for the 2012 CVFPP flood damage analysis (USACE and CA Reclamation Board 2002, DWR 2012e). An example crop/damage/acre spreadsheet is shown in Table 3-6.

For all depths greater than zero, crops are assigned the appropriate weighted crop damage/acre value from Table 3-5, which essentially serves the same purpose as a structural depth-damage function. However, unlike structures, crop flood damage is not significantly affected by depth, but rather when the flood occurs, which is taken into account in the weighted annual damage values described above.

This procedure of using HEC-FDA to compute crop flood damage reduction benefits was used by DWR to evaluate the benefits of potential SPFC levee repairs (DWR 2012i).

As with the DWR loss of life analysis using HEC-FDA described below, advantages of this approach are that:

- The same HEC-FDA models developed for the urban IR analysis can be used, only with changes in the structural inventory and depth-damage information (i.e., the structural inventory is replaced with the crop inventory and depth-damage functions are replaced with the crop damage/acre values). The study configuration, H&H, and levee failure information remains the same.
- HEC-FDA will incorporate uncertainty into the analysis, including the H&H and levee failure information. Uncertainties have not yet been developed for the DWR county land use information or crop damage/acre relationships, but they could be developed.

Crop flood damage reduction benefit results shall be reported using the format shown in Table 3-1. Crop intensification benefits shall be reported using the format of Table 3-4, distinguishing between basic and other crops.

If cropping patterns are expected to change significantly over the analysis period, then the crop flood damage reduction benefits must be computed as many times as necessary to reflect those changes and reported for each time period using the format shown in Table 3-1 and Table 3-4, where applicable. Appendix H describes how to do the present value analysis when the benefits (and costs) change over the analysis period.

Table 3-5. 2012 Central Valley Flood Protection Plan Weighted Average Annual Crop Damage/Acre Estimates

Crop Types (1)	Products (2)	Sacramento Valley[1]		San Joaquin Valley[1]	
		Short-Term[2] (3)	Long-Term[3] (4)	Short-Term[2] (5)	Long-Term[3] (6)
Citrus	Oranges	222	3,463	222	3,463
Fruit and nuts	Almonds	1,320	4,819	1,320	4,819
	Walnuts	739	4,120	820	4,176
	Peaches	1,257	6,181	1,381	6,425
	Pears	2,514	9,777	2,619	9,917
	Prunes	594	4,819	684	4,889
Field	Cotton	497	497	654	654
	Beans	342	363	397	448
	Safflower	337	373	387	427
	Wheat	489	508	506	511
	Corn	361	361	391	391
Pasture and alfalfa	Pasture	419	698	394	752
	Alfalfa	547	1,057	608	1,085
Rice	Rice	323	323	372	376
Truck	Melons	652	652	700	700
	Tomatoes	947	947	1,205	1,205
Vine	Wine grapes	824	6,076	905	6,285
Other	Idle	291	291	291	291
	Semi-agricultural	291	291	291	291
	Native vegetation	145	145	145	145

Table source: DWR 2012a

Notes:

1 These were originally computed for the Sacramento and San Joaquin river basins comprehensive study and price updated for the 2012 CVFPP flood damage analysis (DWR 2012e).

2 Inundation shorter than five days.

3 Inundation longer than five days.

Table 3-6. Example Spreadsheet for Computing Walnut Weighted Crop Damage/Acre Originally Developed for Sacramento and San Joaquin River Basins Comprehensive Study ($1998)

(1)	OCT (2)	NOV (3)	DEC (4)	JAN (5)	FEB (6)	MAR (7)	APR (8)	MAY (9)	JUN (10)	JUL (11)	AUG (12)	SEP (13)	Total (14)
Cultural costs	$9	$18	$9	$66	$9	$9	$172	$81	$211	$61	$90	$31	$766
Harvest/post-harvest costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$511	$511
Total variable costs	$9	$18	$9	$66	$9	$9	$172	$81	$211	$61	$90	$542	$1,277
Accumulated variable costs	$9	$27	$36	$102	$111	$120	$292	$373	$584	$645	$735	$1,277	
Variable costs not expended	$1,268	$1,250	$1,241	$1,175	$1,166	$1,157	$985	$904	$693	$632	$542	$0	
Gross income	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,724	$1,724
Gross income – variable costs not expended	$456	$474	$483	$549	$558	$567	$739	$820	$1,031	$1,092	$1,182	1,724	
Probability of flooding	0.058	0.124	0.177	0.200	0.170	0.132	0.082	0.030	0.010	0.002	0.002	0.013	1
% damage	100	100	100	100	100	100	100	100	100	100	100	100	
Expected damage	$26.45	$58.78	$85.49	$109.80	$94.86	$74.84	$60.60	$24.60	$10.31	$2.18	$2.36	$22.41	$572.69
	Long Duration[1]		**Short Duration**										
Weighted annual average damage	$573		$573										
Establishment costs[2] x 0.50	$4,516		$0										
Land cleanup	$208		$208										
Total loss per failure	$5,297		$781										

Notes:
1 Long duration of flooding is greater than five days.
2 Establishment costs are 50% of total estimated establishment costs, or $9,031 for walnuts (USACE and CA Reclamation Board 2002).

3.11 How Loss of Life Benefits Are Computed

Public safety has always been DWR's primary goal. In the context of flood risk management, public safety incorporates a number of factors, including loss of life and injuries/illnesses due to flood water depth and velocity and/or exposure to hazardous materials released during floods. Although all of these are important, the focus herein is on one key indicator of public safety—loss of life.

Flood loss of life estimation requires consideration of these complex factors (Needham, et al., undated):

- Dam (or levee) failure event: including capacity exceedance or the dam (or levee) breach location, geometry and rate of breach development, reservoir pool level, the time of day, detection time, and the extent, velocity, depth, and arrival times throughout the downstream inundation area. These factors describe hazard and flood management system performance as shown in Figure 3-1.

- Number and location of people exposed to the flood event: including the initial spatial distribution of people throughout the downstream inundation area, the effectiveness of warnings, the response of people to warnings, the opportunity and effectiveness of evacuation, and the degree of shelter provided by the setting where people are located at the flood arrival time (for example, in structures, vehicles, or on foot). These factors describe exposure and warning system performance as shown in Figure 3-1.

- Loss of life among threatened population: including loss of life for those remaining in the inundation area at the time of arrival of the flood wave. Loss of life takes into account the physical character of the flood event and the degree of shelter provided by the setting where people are located at the flood arrival time and after the flood wave has passed for those who survive it. The degree of shelter is a description of vulnerability as shown in Figure 3-1.

3.12 USACE Approach to Computing Loss of Life Benefits

The USACE is developing detailed guidance and software applications to estimate loss of life from flood events, based on an in-depth review of case studies (McClelland and Bowles 2002). Specific software applications being developed include:

- LifeSim, which is a modular, spatially distributed, dynamic simulation system for estimating potential loss of life from natural and dam/levee failure flood events. LifeSim considers detailed flood dynamics, evacuation, loss of shelter, and historically based life loss (Aboelata and Bowles 2009). LifeSim is still under development by HEC.

- HEC-FIA ("Flood Impact Analysis") (USACE 2012), which is a stand-alone software application that provides techniques for calculating flood impacts for a user-specified event. In addition to estimating urban and crop damage, HEC-FIA also estimates loss of life using methods similar to LifeSim and, in fact, includes a simplified version of LifeSim. The current version of HEC-FIA does not incorporate uncertainty, but this capability is being added to future versions. HEC-FIA is available from HEC. HEC-FIA is not certified for FRM planning studies at the time of publication of this handbook, but it is currently under review.

Each of these software applications has rigorous data requirements. For example, LifeSim requires digital elevation model (DEM) information, time series of depth and velocity grids (for each event being evaluated), census and structure data, and road network and vehicle information. HEC-FIA also requires DEM information and census and structure data, but uses maximum depth and arrival time grids or hydrographs (for each event being evaluated). Both models quantify loss of life for a single flood event and would have to be run for multiple events to generate an expected annual loss of life statistic similar to EAD. In practice, the USACE does not place monetary values on loss of life.

3.13 DWR-Recommended Approach to Computing Loss of Life Benefits

The recommended DWR approach to computing loss of life benefits is based on the flood life risk assessment for the 2012 CVFPP (DWR 2012f). There, life risk was assessed by modifying the HEC-FDA economic risk inputs in the 2012 CVFPP economic risk models to include information on the exposure and vulnerability of population within the floodplains, including:

- Replacing structure economic values with persons/structure, adjusted to take into account the efficiency of existing flood warning systems.

- Replacing structure depth-damage functions with empirically-derived depth-mortality functions based on loss of life during Hurricane Katrina in New Orleans (Jonkman 2009).

Results were reported as expected annual lives lost. The life risk analysis method provided estimates of relative flood risk, allowing comparison of the 2012 CVFPP approaches. However, it was recognized that these life risk estimates were not forecasts of deaths expected to occur from flood events that could be used for emergency planning purposes.

Figure 3-9 summarizes the major steps to be followed by DWR in estimating life risk benefits.

This is the recommended approach for DWR life risk analyses because it:

- Incorporates commonly used procedures for assessing life risk, as influenced by flood hazard, system performance, and vulnerability and exposure of people.
- Is generally consistent with USACE methods.
- Uses the same HEC-FDA models developed for the urban IR analysis, with changes in the structural inventory (replacing economic values with persons/structure) and depth-damage information (i.e., replacing depth-damage with depth-mortality functions). The study configuration, H&H, and levee failure information remains the same.
- Computes uncertainty, although it will be a partial uncertainty because uncertainty information has not yet been developed for the warning times and persons/structure values.
- Was reviewed by USACE Hydrologic Engineering Center (HEC) staff, which recognized its advantages and limitations.

Loss of life analysis (IR) results shall be reported using the format shown in Table 3-1 except EAD will be replaced with “life risk values” (DWR 2012f).

If housing and/or population are expected to change significantly over the analysis period, then the life risk analysis benefits must be computed as many times as necessary to reflect those changes and reported for each time period using the format shown in Table 3-1. Appendix H describes how to do the present value analysis when the benefits (and costs) change over the analysis period.

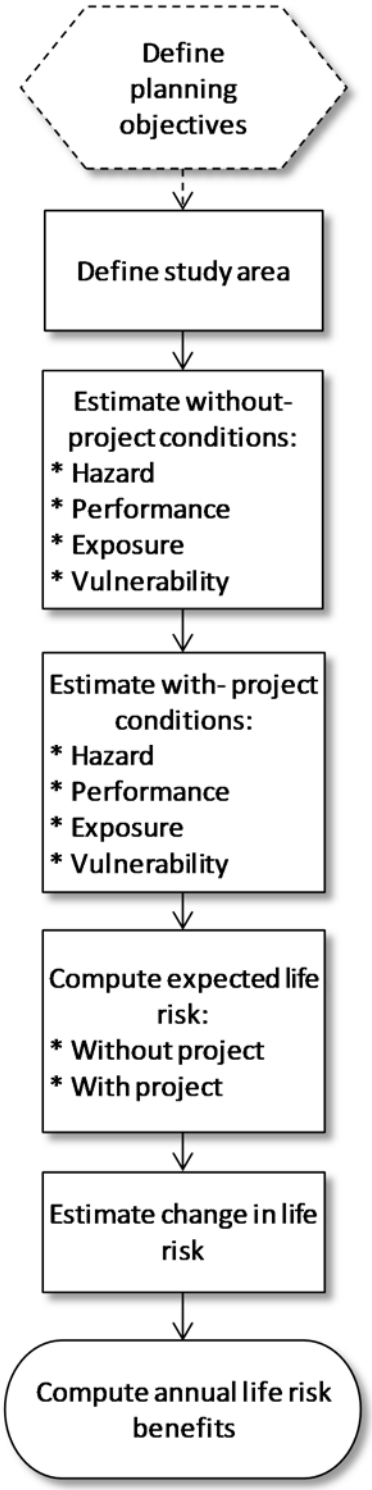


Figure 3-9. DWR Life Risk Benefit Evaluation Method

3.14 Consistency between USACE and DWR-Recommended Flood Risk Management Benefit Evaluation Approaches

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 3-7 compares recommended DWR procedures with USACE FRM procedures. The DWR-recommended method is mostly consistent with that of the USACE.

Table 3-7. Comparison of USACE and DWR-Recommended Flood Risk Management Benefit Assessment and Risk Analysis Methods

FRM Benefit (1)	DWR Method (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Urban			
Inundation-reduction	●	●	●
Intensification/location	○	NA	○
Loss of life			
Inundation-reduction	●	◒	◒
Crops			
Flood damage reduction	◒	◒	◒
Intensification	◒	NA	◒

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

This comparison is summarized below:

- The DWR-recommended urban IR benefit risk analysis method is consistent with that used by the USACE.

- DWR-recommended urban intensification and location benefit methods, although computationally consistent with USACE procedures, may be inconsistent with USACE applications, because these benefits (a) are often not applicable from the USACE national economic development perspective and (b) may be in conflict with the “wise use of floodplains” federal objective prescribed by the proposed 2013 P&G

(CEQ 2013). Nonetheless, they may be important from a State perspective.

- DWR-recommended loss of life (IR) benefit evaluation methods are generally consistent with those used by the USACE because they incorporate commonly used procedures for assessing life risk. Use of HEC-FDA to estimate loss of life is suitable for planning study purposes. HEC-FDA incorporates uncertainty for all major variables, although it currently provides only partial uncertainty for a loss of life computation because uncertainty information has not yet been developed for the warning times and persons/structure values.

DWR-recommended crop flood damage reduction and intensification methods are generally consistent with those used by the USACE. Although the USACE does not have a “certified” software application to estimate crop flood damage reduction benefits, use of HEC-FDA will be consistent with the USACE urban IR benefit analyses. HEC-FDA incorporates uncertainty in all of the major variables, although it currently provides only partial uncertainty for a crop flood damage computation because uncertainty information has not yet been developed for land use and crop damage/acre values. Crop intensification benefits shall be estimated with spreadsheet analyses and uncertainty accounted for with sensitivity analysis.

3.15 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods and software applications will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff must be contacted in advance for further guidance and approval prior to initiation of the study. Fortunately, the use of avoided damage/costs/losses for flood damage reduction benefits is standard practice, and other benefit assessment practices (such as alternative costs) are typically not used.

It should be noted that for planning studies, one software application is recommended for computation of DWR urban IR, loss of life (IR), and crop flood damage reduction benefits—HEC-FDA. When using HEC-FDA to estimate each of these benefits, the study configuration, H&H, and geotechnical inputs can be retained. However, the consequences inputs are changed depending on the type of benefit, as shown in Table 3-8.

Essentially, once an HEC-FDA model has been configured for an impact area for an economic analysis, it can be copied and used for the loss of life or crop flood damage reduction benefit analyses, with the appropriate changes in the economics information shown in Table 3-8.

Using the same software application (HEC-FDA) to estimate urban, crop, and loss of life benefits has several advantages. It:

- Reduces staff training requirements because only one software application will be used.
- Facilitates data collection and model configuration, because the same models and data inputs can be used to estimate different types of IR benefits, with appropriate changes in the consequence information.
- Integrates loss of life and crop flood damage reduction benefits with the economic benefit calculations.
- Estimates benefits in terms of reductions in expected annual losses, comparable to traditional EAD calculations.
- Provides comparable benefit estimates attributable to proposed alternatives due to:
  - Reduced flood depth.
  - Reduced flood frequency.
  - Reduced exposure of people to flooding.

  For example, changes in levee failure probabilities associated with a proposed levee modification can be input into the respective urban IR, crop flood damage reduction, and loss of life HEC-FDA models, keeping other inputs constant, to generate comparable changes in expected annual losses (compared to the without-project condition) suitable for planning study purposes.
- Complies, to the extent practicable, with USACE risk-computation requirements.

Table 3-8. Summary of Required Inputs for Urban Inundation-Reduction, Loss of Life, and Crop Flood Damage Reduction Benefit Analyses Using HEC-FDA

HEC-FDA Inputs (1)	Type of Benefit		
	Urban IR (2)	**Loss of Life (3)**	**Crop FDR (4)**
Study configuration	• Study plans • Streams • Impact areas • Index points	Same	Same
Hydrology and hydraulics	• Stage/discharge-probability • Water surface elevations • Regulated/ unregulated transforms • Interior/ exterior relationships	Same	Same
Geotechnical	• Top of levee elevation • Levee failure probabilities	Same	Same
Consequences	• Structure inventory ($) • Depth-damage functions	• Structure inventory (people) • Depth-mortality functions	• Crop inventory ($) • Crop damage/ acre values

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4.0 Ecosystem Restoration Benefits

In this chapter:

- The conceptual basis for measuring ecosystem restoration benefits
- The USACE approach to computing ecosystem restoration benefits
- The recommended DWR approach to computing ecosystem restoration benefits
- Consistency between USACE and DWR approaches to computing ecosystem restoration benefits
- What to do if the DWR-recommended method is not to be used

4.1 Conceptual Basis for Measuring Ecosystem Restoration Benefits

Ecosystem restoration benefits result from improving the structure and/or functions of ecosystems, which not only provide basic biological support for plants and animals, but also valuable goods and services to society.

The California Department of Water Resources (DWR) defines ecosystem restoration as "a process where an ecosystem that has been degraded or disturbed is restored to mimic, as closely as possible through the restoration of critical natural processes, conditions which would naturally occur in an area" (DWR 2012n). An ecosystem is defined in more detail as consisting "of all the organisms in a given area interacting with the physical environment. The biotic and physical components in an ecosystem are interdependent, frequently with complex feedback loops. The physical components that sustain the biota of an ecosystem include the soil or substrate, topographic relief and aspect, atmosphere, weather and climate, hydrology, geomorphic processes, nutrient regime, and salinity regime" (DWR 2012n).

Ecosystem benefits may also occur if damage to ecosystem resources is reduced by a proposed project. This is an inundation-reduction (IR) benefit described in Chapter 3.

4.1.1 How Ecosystem Restoration Fits into Multiobjective Projects

DWR recognizes that projects that integrate multiple benefits, including flood risk management, water supply, recreation, and ecosystem restoration, may be more prudent investments than single-purpose projects (DWR 2009, DWR 2012j).

For multiobjective projects, the benefit and cost (B-C) analysis shall combine monetized benefits and costs when they can be estimated for project objectives. If benefits cannot be monetized, they can be evaluated using other tools such as cost effectiveness/incremental cost analysis and multiple criteria analysis. This process is described in Chapter 11.

4.1.2 How Ecosystem Restoration Benefits Are Categorized

What Are Ecosystem Services?

Ecosystem services emanate from a functioning ecosystem and are the beneficial outcomes for the natural environment or for people that result from ecosystem functions. Some examples of ecosystem services are support of the food chain, harvesting animals or plants, clean water, or scenic views. In order for an ecosystem to provide services to humans, some interaction with, or at least some appreciation by, humans is required (DWR 2012n).

For most benefit categories associated with water resource projects, monetary benefits can be incorporated directly into a B-C analysis (for example, water supply and quality, flood damage reduction, recreation, and hydropower). However, for ecosystem restoration, the estimation of monetary values is more challenging for a variety of reasons. Thus, a fundamental decision must be made whether or not to monetize ecosystem benefits.

If ecosystem restoration benefits are not monetized, then they must be evaluated using methods supplemental to a B-C analysis, including cost effectiveness/incremental cost analysis. These methods are used by the US Army Corps of Engineers (USACE), as described below. However, methods are being researched by the National Research Council (NRC) and others to monetize ecosystem outputs (NRC 2004). As with other benefits, the measurement standard and conceptual basis of ecosystem restoration benefits is the willingness to pay for each increment of output (i.e., services) from a plan.

Many of these monetary valuation methods focus on the services that ecosystems provide for humans, such as groundwater recharge, water and air quality purification, recreation, and flood water storage (Task force on the natural and beneficial functions of the floodplain 2002; NRC 2004; APFM 2006; ASFPM 2008; DWR 2008a).

The proposed 2013 P&G include a "healthy and resilient ecosystems" guiding principle that recognizes that "[e]cosystems provide important services to humans both directly and indirectly" (CEQ 2013). Expressing ecosystem services in monetary terms facilitates a multiobjective B-C analysis described in Chapter 11. Figure 4-1 illustrates examples of ecosystem services.

Regardless of whether ecosystem benefits are monetized or not, it is important to quantify physical outputs of ecosystem restoration plans. These outputs may be expressed as intermediate products (such as the numbers of acres or habitat units) or preferably as end products (such as the numbers of animals or species and ecosystem services provided to humans).

What Are Ecosystem Structure and Functions?

Ecosystem structure refers to the composition (i.e., its various parts) and the physical and biological organization defining how those parts are organized. Ecosystem function describes a process that takes place in an ecosystem as a result of the interaction of plants, animals, and microorganisms in the ecosystem with each other or their environment that serves some purpose. Ecosystem structure and function provide various goods and services to humans that have value (NRC 2004).

4.2 How Ecosystem Restoration Benefits Are Computed

Following is a description of computing ecosystem restoration benefits using the ecosystems services approach, which monetizes these benefits, and the USACE approach, which does not.

4.2.1 Ecosystems Services Approach

Ecosystems perform many complex and interrelated functions which not only provide basic biological support, but also provide valuable goods and services to society. If these societal goods and services can be identified and measured, then that may provide an opportunity to monetize them. The DWR *Economic Analysis Guidebook* encourages the investigation of "emerging methods of performing economic analysis, particularly those involving benefit assessment for project outputs not usually assigned monetary values" (DWR 2008a).

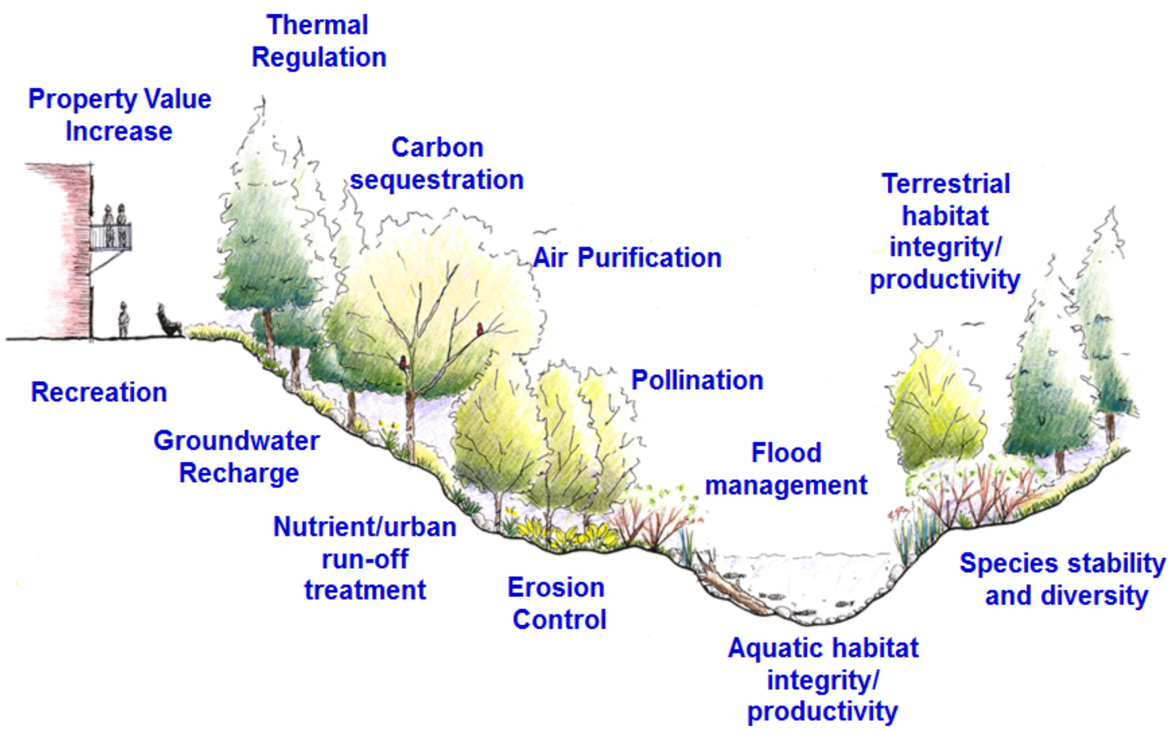

Figure 4-1. Example Ecosystem Services

(USACE Sacramento District, 2008)

To value ecosystem services monetarily requires translating ecosystem services (i.e., end products) into monetized benefits realized by society. The NRC identifies the following steps to value ecosystem services (NRC 2004):

1. Estimate the changes in ecosystem structure and function resulting from the implementation of a policy.
2. Estimate the changes in ecosystem services that result from the changes in structure and function.
3. Estimate the economic value of these changes in ecosystem services.

Essentially, this process "requires an integration of ecological and economic methods and models" (NRC 2004). Figure 4-2 shows the relationships among ecosystem function and structure, services, human actions, and the use and nonuse values that can result.

For FloodSAFE programs, most of the ecosystem services and values identified in Figure 4-2 are directly related to the natural and beneficial functions of floodplains: "Floodplains perform a variety of essential functions including floodwater conveyance and storage, groundwater recharge, wave attenuation, stream bank erosion control, reduction in sedimentation rates, water quality maintenance, and support of highly productive ecosystems. Benefits to humans are also provided in the form of sites for various types of water dependent development and recreational opportunities…Protecting and restoring floodplain functions will reduce flood losses, preserve wildlife habitat, improve the water quality of our Nation's waterways, and improve the quality of life in our communities" (Task Force on the natural and beneficial functions of the floodplain 2002).

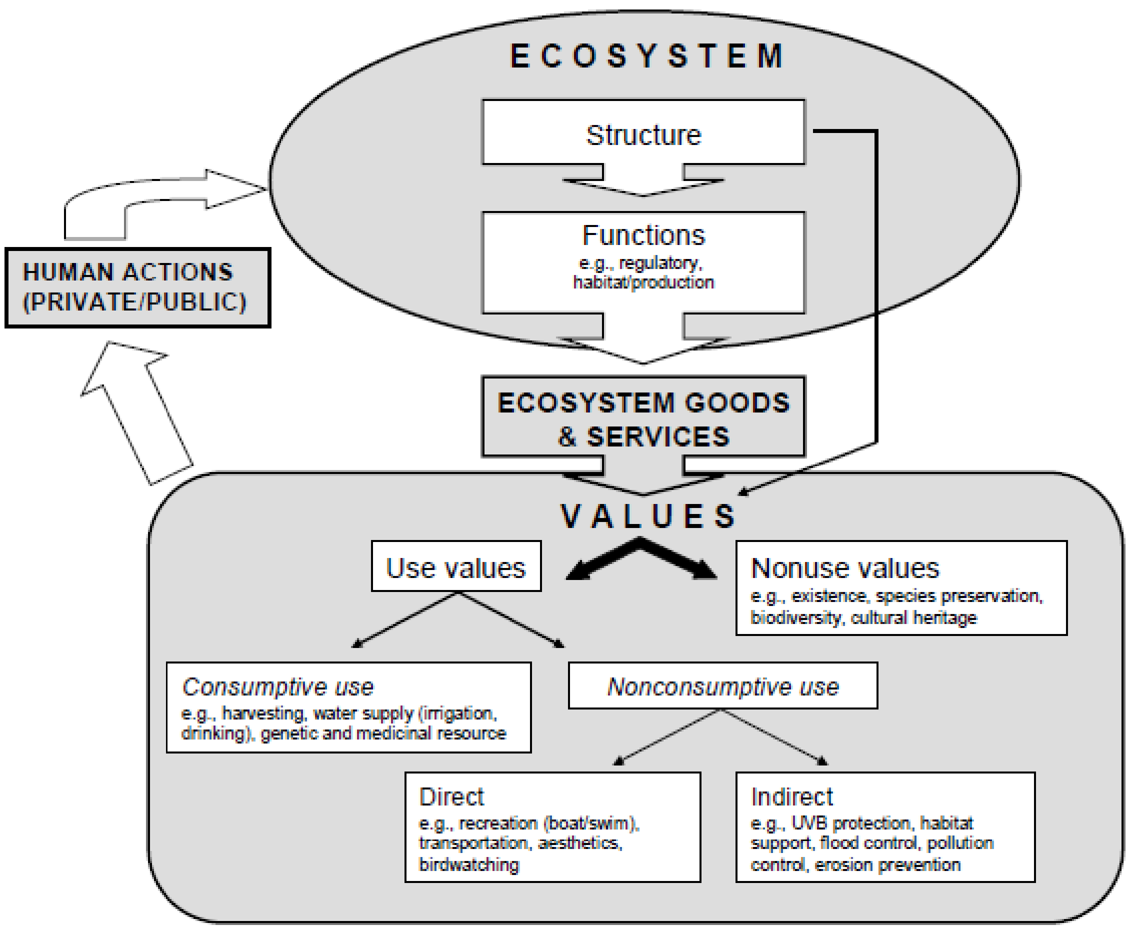

Figure 4-2. Relationships among Ecosystem Structure and Function, Ecosystem Services, Human Actions, and Values

(NRC 2004)

Building on the ecosystem services concept, DWR has developed a framework for assessing the potential economic benefits of the CVFPP conservation strategy (DWR 2011c):

- **Provisioning services –** physical material benefits obtained from ecosystems. Examples include:
  - Food
  - Water supply
  - Fiber and fuel
  - Biochemical resources
  - Genetic materials
- **Regulating services –** regulation of ecosystem processes that affect the production of other ecosystem services. Examples include:
  - Climate regulation
  - Water regulation
  - Waste treatment
  - Erosion regulation
  - Disturbance regulation
  - Pollination
  - Biological control
- **Cultural services –** nonmaterial benefits provided by ecosystems. Examples include:
  - Recreational benefits
  - Aesthetic benefits
  - Educational benefits
  - Cultural, spiritual, and religious benefits
  - Existence
- **Supporting services –** ecosystem processes and conditions necessary for the production of other ecosystem services. Examples include:
  - Soil formation
  - Nutrient cycling
  - Habitat provision

These potential CVFPP conservation strategy ecosystem services and associated valuation approaches are further described in Appendix B.

The DWR *Economic Analysis Guidebook* (2008a) describes various ecosystem services valuation methods, organized according to willingness to pay (revealed, imputed, and expressed), as well as benefit transfers. Additional resources concerning ecosystem valuation methods and societal values associated with natural floodplain functions can be found on the DWR economic analysis website.

The NRC also describes economic valuation methods classified depending on whether the valuation method is based on observed economic behavior (i.e., revealed preferences) or on responses to survey questions (i.e., stated preferences) (NRC 2004).

4.3 USACE Approach to Computing Ecosystem Restoration Benefits

Current USACE policy does not monetize ecosystem benefits, based on the 1983 P&G: "Increments that do not provide net NED [national economic development] benefits may be included…*if they are cost effective*" (USACE 1999, WRC 1983, emphasis added). Thus, USACE procedures focus on cost-effectiveness and incremental cost analyses (CE/IC) that evaluate the change in costs to achieve various levels of ecosystem outputs. Using CE/IC analysis avoids placing a monetary value on those outputs. Following is a summary of USACE ecosystem restoration planning requirements (methods, decision making, software, and analysis results templates).

4.3.1 Methods

The USACE recommended ecosystem restoration plan "should be the justified alternative and scale having the maximum excess of monetary and nonmonetary beneficial effects over monetary and nonmonetary costs. This plan occurs where the incremental beneficial effects just equal the incremental costs, or alternatively stated where the extra environmental value is just worth the extra costs. This plan should be called the NER [National Ecosystem Restoration] plan. In making these value and cost comparisons it is assumed that each plan and scale is the minimum cost way of achieving that level of output; i.e., that an appropriate least cost or cost effectiveness algorithm was used in their development" (USACE 2000). Evaluation of the single-purpose NER plan is summarized below.

For plans that have both economic benefits (for example, flood damage reduction or water supply benefits) and restoration benefits, the plan "with the greatest net sum of economic and restoration benefits is to be selected, consistent with protecting the Nation's environment" (USACE 2000). Evaluation of a restoration plan combined with other monetized benefits is described in Chapter 11 (multiobjective analysis).

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), the USACE describes the following planning process steps for ecosystem restoration benefits in the context of the 1983 P&G, as summarized below:

- Planning steps 1-3 comprise plan formulation. They include:
  - Delineating the study area (a watershed perspective is recommended for ecosystem-based restoration planning).
  - Assessing problems and opportunities.
  - Assessing current and future without-project ecological conditions using habitat evaluation procedures or similar methods that take into account habitat quantity and quality.
- Planning Step 4 compares the with-project and without-project plan conditions for each alternative plan on the basis of CE/IC analysis. This step is described in more detail below
- Planning Step 5 compares alternative plans, with emphasis on the important effects and trade-offs that influence the decision-making process. This step concludes with a ranking of plans.
- Planning Step 6 selects an ecosystem restoration plan that "meets planning objectives and constraints and reasonably maximizes environmental benefits while passing tests of cost effectiveness/ incremental cost analyses, significance of outputs, acceptability, completeness, efficiency, and effectiveness."

4.3.2 CE/IC Analysis Procedure

The following steps are required to conduct the CE/IC analysis needed for planning Step 4 above (USACE 2000):

1. Identify the potentially implementable solutions (i.e., management measures) for achieving desired ecosystem outputs and describe their costs and outputs. All costs should be calculated in terms of present worth using the appropriate discount rate and then annualized. However, ecosystem restoration outputs are not discounted, but should be computed on an average annual basis, taking into consideration that the outputs are likely to vary over time. [Note: this is a significant difference from traditional resource cost/unit calculations, which discount the project outputs as well as project costs. For example, to compute the cost/acre-foot of water delivered, the present worth of costs is divided by the present worth of water deliveries over the analysis period. See the example water supply discounting example, Table A-1, in the DWR *Economic Analysis Guidebook* (2008a).]

2. Formulate all possible combinations of management measures and scales (i.e., sizes of plans). Each possible combination becomes an alternative plan. By definition, scales within a management measure are mutually exclusive; they represent the application or

implementation of different amounts of a given management measure. Formulating all possible combinations requires choosing one scale from each of the management measures to combine in turn with one scale from each of the other management measures, until all possible permutations have been combined. The “No Action” possibility for each management measure should also be included in the permutations. When the measures and scales are combined, the cost and output of each constituent part of the combination is summed. Each combination (i.e., alternative plan) thus has an associated total cost and total output.

3. Sort all plans in terms of increasing output as a prelude to the cost effectiveness analysis.

4. Conduct cost-effectiveness analysis to determine that (a) for a particular level of output, no other plan costs less, and (b) no plan yields more output for the same or less cost. Graph cost-effective plans in terms of their respective costs and outputs to display visually the relationship between the increasing financial investments required for increasing environmental outputs. Each of the cost effective plans produces its associated level of output at the least cost; no other plan can provide as much output for the same level of investment. This is an important point in ecosystem restoration evaluations and an important criterion in qualifying plans for further evaluation. Figure 4-3 shows an example cost effectiveness analysis.

5. Conduct incremental cost analysis to identify which cost-effective plans are the most efficient in producing environmental outputs. These plans, known as “best buy” plans, provide the greatest increase in output for the least increase in cost, i.e., they have the lowest incremental costs per unit of output. The concept of incremental changes in costs and outputs is analogous to the concept of marginal changes—the differences in cost or output between one alternative plan and the next one in succession.

   The decision rule in incremental analysis is to select the plan with the lowest cost per unit, i.e., the first best buy from a production perspective that produces output at the lowest unit cost, and then remove from consideration any plans that provide a smaller output than the selected plan, i.e., that are less efficient in production.

   To conduct incremental cost analysis, start with the subset of cost effective plans ranked by increasing output. Beginning with the No Action alternative, compute the incremental cost, incremental output, and incremental cost per unit of incremental output advancing from the No Action alternative to each successive alternative plan. The incremental cost is the additional cost incurred in selecting one plan over another, or in this case the difference in cost between each alternative and No Action. Similarly, the incremental output is the additional output gained in selecting one plan over another, or in this case the difference in output between each alternative and No Action. The incremental cost per unit of incremental output is the incremental cost divided by the incremental output. It shows the change in cost from No Action to each other alternative plan on a per-unit basis. Figure 4-3 illustrates cost effectiveness/incremental cost analyses.

6. Recalculate the incremental cost per unit of incremental output of implementing each remaining plan instead of the last selected plan.

   The same decision rule still applies: of the remaining plans (all larger than the first best buy plan), select the plan with the lowest incremental cost per unit of incremental output, then remove from consideration any plans that provide a smaller output than the selected plan.

   This process of recalculating incremental cost per incremental output unit for each remaining plan over the last selected best buy plan is reiterated until the incremental unit cost for the last remaining plan has been recalculated. The number of iterations is dependent on the number of plans and on the respective cost and output of each. The purpose of this iterative process is not to eliminate plans but rather to identify those plans (and their corresponding level of output) which show a marked increase in production costs. This knowledge can assist decision makers in determining the desirable project scale.

   Situations may arise where the most efficient plan produces such a large quantity of output that its total cost makes it infeasible due to cost constraints. However, because the plan is the most efficient in production, all plans that produce smaller output levels (possibly at lower and acceptable cost levels) would be eliminated from consideration in the iterative process. In such situations, it may be useful to remove such a large plan from consideration and repeat the best buy iterative process.

7. The final step in the CE/IC analysis is to tabulate and graph the incremental costs and outputs. Develop a table that summarizes the pertinent incremental cost and output information associated with the increasing size (in terms of output) of the best buy plans. Graph the best buy plans to display visually the relationship between the increasing financial investments required for increasing environmental outputs. Figure 4-4 shows an example incremental cost analysis, with

costs (in $1000) on the y-axis and the average annual environmental benefits (in habitat units) on the x-axis.

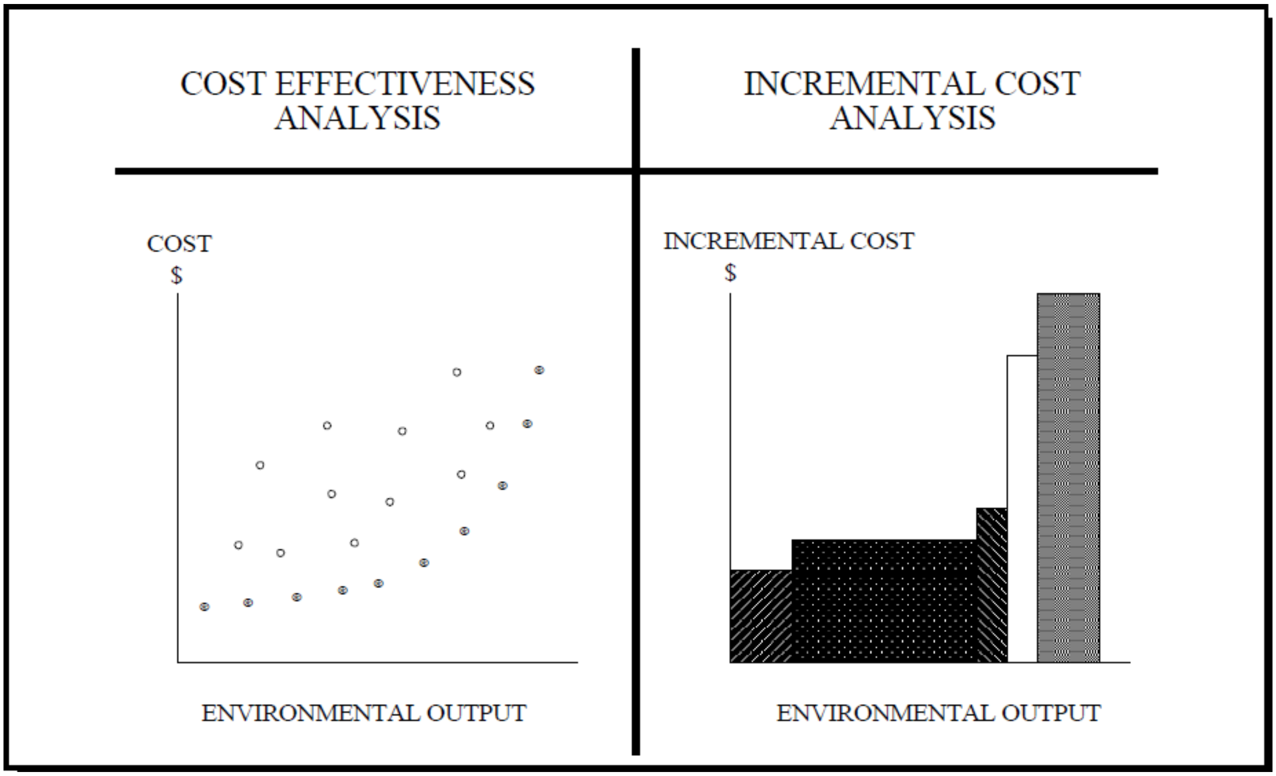

Figure 4-3. Cost Effectiveness/Incremental Cost Analyses

(Source: USACE, 1995b)

4.3.3 Role of CE/ICA in Decision Making

CE/IC analysis will not identify a unique or "optimal" solution and thereby dictate what choice to make, although it will identify inferior alternatives. However, the information developed by CE/IC analysis can inform decision-making by progressively proceeding through the available levels of output to ask whether the next level is "worth it;" that is, whether the environmental benefit of the additional output in the next level is worth the additional cost. In the example shown in Figure 4-4, the first question is whether the first increment (Plan A) of 22 habitat units is worth $1,500 per unit. At the next level (Plan B), there are a total of 33 habitat units or 11 additional habitat units over the last level, at a cost of $2,600 for each additional habitat unit. If the case can be made that the additional 11 habitat units are worth $2,600 each, the analysis proceeds to the next increment, and so on.

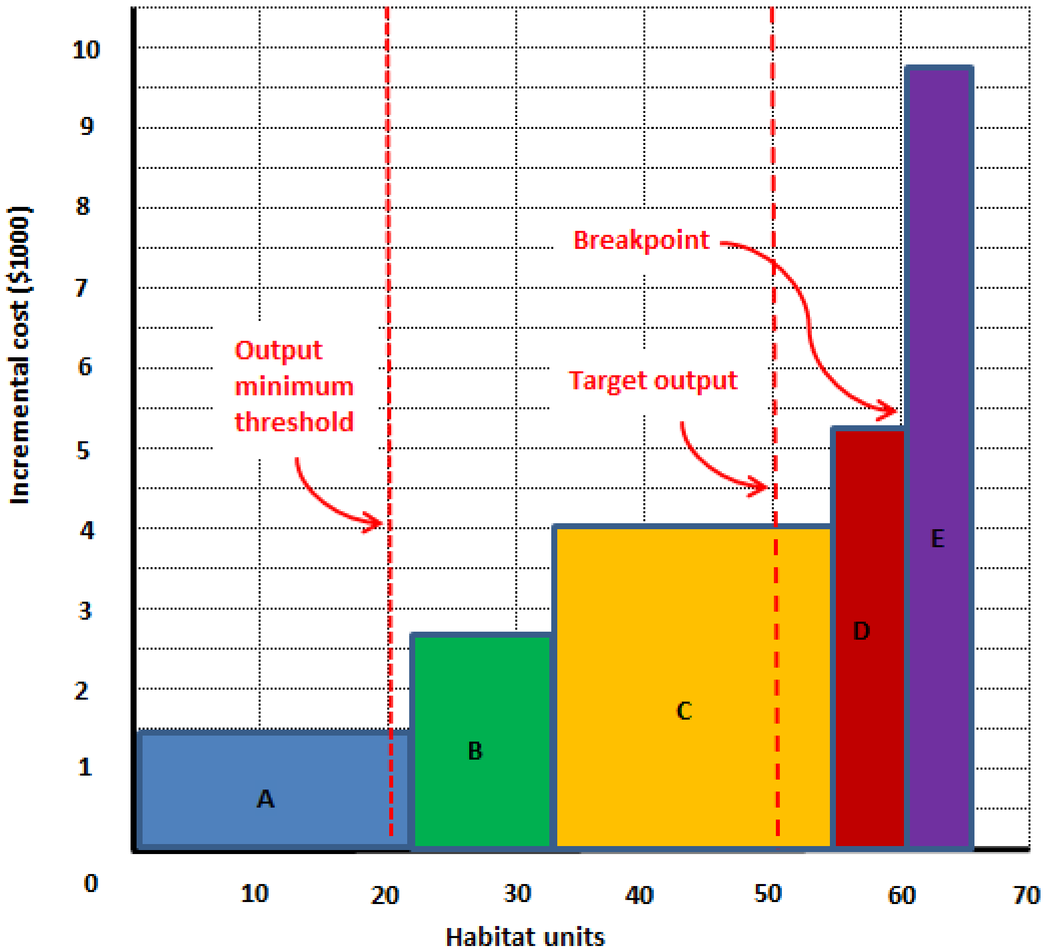

Figure 4-4. Example Incremental Costs and Outputs of Alternative Plans, Including an Output Minimum Threshold, Target Output, and Breakpoint in Incremental Costs

Often the questioning process will continue to conclude that successive levels of output are "worth it" until an unusual increase in incremental costs, beyond the general range of preceding costs, is encountered. In Figure 4-4, the last increment represents a jump in incremental costs of $9,700 per habitat unit for each of the last five habitat units. This represents almost a doubling of unit cost for the additional output (compared with the preceding increment) that should be explained, supported, or otherwise considered in detail.

The USACE identifies the following guidelines to be applied to the CE/IC analysis to assist with the “is it worth it” decision process:

- **Anomalies –** Identify abrupt breakpoints, spikes, peaks, jumps, inflection points, etc., that provide decision-makers with reasons to examine the causes of the changes and whether additional incremental costs are worth it. A breakpoint in incremental cost between plans D and E is shown in Figure 4-4.

- **Output target –** If a study has identified a specific resource output target to be met, then a decision rule can be developed to meet some portion of that target. For example, a habitat unit target could be marked on an incremental cost bar graph to display the relationship between the target and possible solutions. Such a display may be useful in focusing on whether the incremental costs of the solutions leading to the target are worth it. An output target (50 habitat units) is shown in Figure 4-4.

- **Output thresholds –** In some cases it may be necessary to first produce a minimum base amount of output because any lesser amount would not be successful. Similarly, there may also be a maximum threshold level of output where production beyond that output would no longer contribute to the achievement of planning objectives. If minimum or maximum output thresholds exist, they can be used to bracket the range of acceptable solutions. An output minimum threshold (20 habitat units) is shown in Figure 4-4.

- **Cost affordability –** If implementation funds are constrained, then decision makers can review the CE/IC analysis cost curve shown in Figure 4-4 to help them judge the best investment for the funds available.

- **Unintended results –** In addition to the cost considerations captured in a CE/ICA analysis, other factors may also influence the decision process, such as land ownership, effects on other outputs, and effects on nearby stakeholders.

Finally, in addition to CE/IC analysis, other criteria that the USACE applies in the environmental decision-making process include:

- **National significance –** Under the current USACE budget process, priority for including a project in the President’s budget is based on whether that project is nationally significant and the degree to which it addresses scarce habitats, habitat connectivity, and restoration of natural hydrology and geomorphic processes; would be self-sustaining;

and would address special status species and existing resource management plans. National significance is based primarily on habitat scarcity and connectivity, as well as on special status species and plan recognition.

- **Acceptability, completeness, effectiveness, and efficiency –** These are the overall evaluation criteria included in the 1983 P&G described in Chapter 1.

- **Risk and uncertainty –** When the costs and outputs of alternative restoration plans are uncertain and/or there are substantive risks that outcomes will not be achieved, it is essential to document the assumptions made and uncertainties encountered during the planning analyses.

4.3.4 Software Applications

CE/IC analysis can be conducted in a number of ways, including relatively simple calculations performed "with hand and paper," more complex user-built spreadsheet models, and software applications specifically designed for CE/IC analysis, such as IWR Planning Suite (formerly called IWR-PLAN). IWR Planning Suite assists with the formulation and comparison of alternative plans for ecosystem restoration because it:

- Generates solutions with two options:
  - The user can provide specific alternatives, costs, and outputs.
  - IWR Planning Suite can combine user-provided measures, costs, and outputs to generate all possible alternatives.
- Conducts the CE/IC analysis.
- Displays results.

IWR Planning Suite is available online.

4.3.5 Analysis Results Display Templates

USACE CE/ICA result displays from IWR Planning Suite include Figure 4-4 plus the tables and figures shown in Appendix C.

4.3.6 CE/IC Analysis Resources

An example CE/IC analysis is included in Appendix C. More detailed descriptions (and examples) of the USACE CE/ICA process can be found in these resources:

- IWR Report 94-PS-2, *Cost Effectiveness Analysis for Environmental Planning: Nine Easy Steps* (USACE 1994).

- IWR Report 95-R-1, *Evaluation of Environmental Investments Procedures Manual Interim: Cost Effectiveness and Incremental Cost Analyses* (USACE 1995b).
- IWR Report 02-R-5, *Lessons Learned from Cost Effectiveness and Incremental Cost Analyses* (USACE 2002c).

4.4 DWR-Recommended Approach to Computing Ecosystem Restoration Benefits

Figure 4-5 summarizes the DWR recommended ecosystem restoration benefit evaluation procedure. The critical question that must be answered is whether DWR is partnering with the USACE. If YES, then DWR must conduct a CE/IC analysis as described above, resulting in the identification of the least cost plan, consistent with federal guidance. As noted above and in Appendix C, CE/IC analysis can be conducted in a number of ways. However, for most DWR applications, the “relative production efficiency” approach described in Appendix C shall be sufficient for planning studies.

The CE/IC “relative production efficiency” approach can be accomplished using spreadsheet models. However, if the scale of the project warrants a more thorough identification and analysis of alternative plans, then IWR Planning Suite may be used. No software applications are recommended for an ecosystem services approach, at this time.

CE/IC analysis results will be displayed using figures and tables included above and in Appendix C.

The CE/IC process is shown on the left side of Figure 4-5.

If DWR is not partnering with the USACE, then it may want to evaluate ecosystem restoration benefits using the ecosystem services approach. Or, even if DWR is partnering with the USACE, it may still wish to conduct an ecosystem services benefit evaluation to (a) supplement the CE/IC analysis to help identify a locally preferred plan and (b) better position itself if the ecosystem services approach is ultimately used by the USACE.

At this time, it is not possible to identify specific steps and the level of effort/timing required to prepare a services approach. This is an evolving field and many approaches are likely to be identified. In general, Figure 4-5 includes these steps for the ecosystem services approach:

- The first step in using the ecosystem services approach is to consult with the DWR Economic Analysis Section concerning the use of this approach. Next, this approach requires the evaluation of changes in ecosystem structure(s) and function(s) and associated changes in ecosystem services for the plans being evaluated. Such an evaluation can be a challenge because of the difficulties in establishing relationships among ecosystem structures, functions, and ultimately, human services. The completion of these two steps will result in quantified estimates of ecosystem services.

- Next, DWR must decide if it wants to assign monetary values to these services. If NO, then changes in quantified ecosystem services could be used in a CE/IC process, although the units described in the ecosystem services approach may be different than the habitat units generally used by the USACE for a CE/IC analysis. In addition, quantified estimates of ecosystem services could also be used in a MCA analysis or other type of analysis.

- If DWR decides to monetize ecosystem services, the last step is to compute monetized benefits for the quantified ecosystem services. Different methods are available to assign monetary values to ecosystem services which are described in the DWR *Economic Analysis Guidebook* (DWR 2008), including the advantages and disadvantages of each. Many of these methods can be relatively complex to implement and interpret; thus, the selection of a particular method will depend upon the study objectives and available resources.

The ecosystem services benefit evaluation approach is shown on the right side of Figure 4-5.

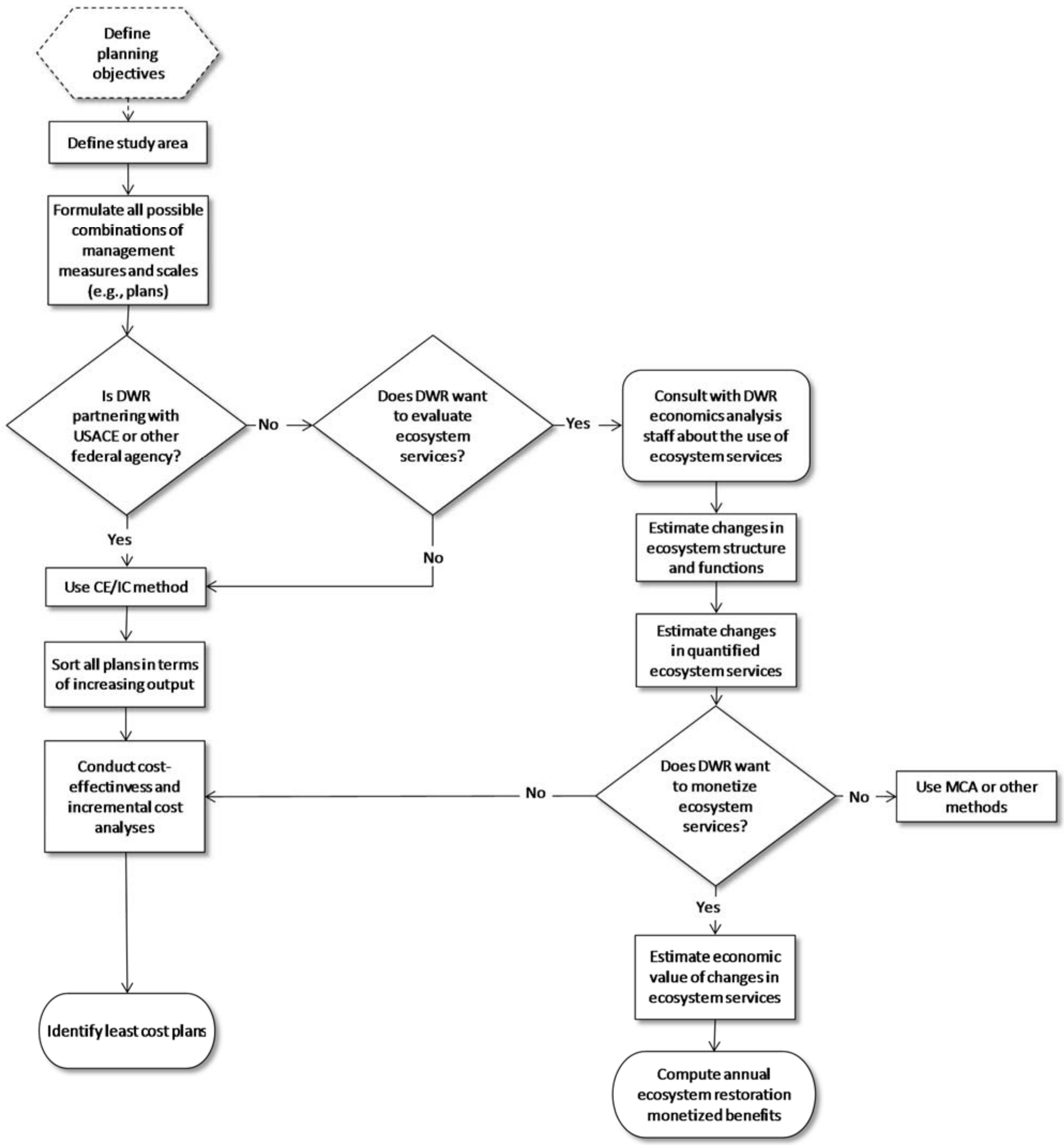

Figure 4-5. DWR Ecosystem Restoration Benefit Evaluation Method

4.5 Consistency between DWR and USACE Ecosystem Restoration Benefit Evaluation Approaches

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 4-1 compares recommended DWR methods with those used by the USACE. The DWR-recommended CE/IC evaluation method is consistent with USACE methods; the DWR-recommended ecosystem services approach is not.

Another potential source of inconsistency between USACE and DWR ecosystem restoration approaches involves discounting. The USACE does not discount ecosystem restoration outputs (e.g., habitat units), but rather computes them on an average annual basis, taking into consideration they are likely to change over time (USACE 2000). Thus, if DWR is using the USACE CE/IC approach, this policy must be followed. However, if DWR is using the ecosystem services approach (resulting in either quantified or monetized ecosystem services), then it may elect to discount ecosystem services over time.

For both methods, uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

Table 4-1. Comparison of USACE and DWR-Recommended Ecosystem Restoration Benefit-Cost Analysis and Risk Analysis Methods

Benefit (1)	DWR Method (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Ecosystem Restoration			
CE/IC Evaluation	●	●	●
Ecosystem Services	○	NA	○

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

4.6 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods and software applications will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff should be contacted in advance for further guidance and for approval prior to initiation of the study.

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5.0 Water Supply and Water Quality Benefits

In this chapter:

- The conceptual basis for measuring water supply and water quality benefits
- The USACE approach to computing water supply and water quality benefits
- The recommended DWR approach to computing water supply and water quality benefits
- Consistency between USACE and DWR approaches to computing water supply and water quality benefits
- Recommended templates for displaying analysis results
- What to do if DWR-recommended procedures are not to be used

5.1 Conceptual Basis for Measuring Water Supply and Water Quality Benefits

Water supply benefits result from providing improved volume, timing, and certainty of supply to sustain economic activities. Water quality benefits result from providing water of improved quality for water users or ecosystems.

5.1.1 How Water Supply and Water Quality Fit into Multiobjective Projects

The California Department of Water Resources (DWR) recognizes that projects that integrate multiple benefits, including flood risk management, water supply and quality, recreation, and ecosystem restoration, may be more prudent investments than single-purpose projects. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

For multiobjective projects, the benefit and cost (B-C) analysis shall combine monetized benefits and costs for all project objectives. Nonmonetized benefits and costs shall be quantifiably assessed, when possible. Otherwise, they will be qualitatively described. This process is described in Chapter 11.

5.1.2 How Water Supply and Water Quality Benefits Are Categorized

The measurement standard and conceptual basis of water supply and/or water quality benefits are the willingness to pay (WTP) for each increment of output from a plan. Where prevailing prices approximately reflect the cost of providing the next increment of water supply service, these can be used as a measure of WTP for the additional water supply and/or quality. However, because water supply and quality improvements are not usually traded in competitive markets, useful price information is not likely to be available. Therefore, the benefits of additional water supply typically are measured by the cost of the least costly alternative most likely to be implemented without the proposed project. For example, for communities located in the Central Valley, the least cost alternative (in lieu of a proposed project) may be additional ground water pumping. However, for a coastal community, the least costly alternative may be recycling. In some cases, water supply benefits may also be measured using revealed or expressed WTP. For water quality, assessment methods typically include avoided damages and methods based on revealed or expressed WTP.

In general, water supply benefits can be grouped into these subcategories:

- **Urban water supply benefits –** These benefits result from providing additional supplies for urban use, including residential, commercial, industrial, and public uses. Residential water supply is used for single family or multiple family indoor use and outdoor use; commercial water use includes water use for light industry and business establishments, including retail services, office buildings, restaurants, dry cleaners, and other consumer-oriented services or businesses; industrial water use is primarily for processing and manufacturing purposes; and public water use includes facilities such as schools, prisons, and parks. Urban water use is also called municipal and industrial (M&I) water use.

- **Agricultural water supply benefits –** These benefits result from the introduction of additional supplies for any use with on-farm production of agricultural commodities that result in more intensive use of existing land, or an increase in total irrigated acreage (DWR 1977). Agricultural water supply benefits may also occur from avoided groundwater pumping costs or avoided leaching costs.

- **Environmental water supply benefits –** These benefits result from introducing additional supplies to meet environmental water requirements. Environmental water is defined as the “minimum flows of a specific quality that [are] needed in order to assure the continued viability of fish and wildlife resources for a particular water body. This is water that is used to maintain and enhance the beneficial uses related to the preservation and enhancement of fish, wildlife, and other aquatic resources or preserves as specified in the Porter/Cologne Water Quality Control Act, 2008" (DWR 2009).

In general, water quality benefits can be grouped into the same three subcategories as water supply benefits, although the details of those subcategories differ somewhat from water supply benefits:

- **Urban water quality benefits –** These benefits result from providing water supplies of improved quality for urban use, such as avoided damage to appliances and equipment, or improved productivity.
- **Agricultural water quality benefits –** These benefits result from providing water supplies of improved quality for agricultural use, such as improved yields, or avoided leaching costs.
- **Environmental water quality benefits –** These benefits result from water supplies of improved quality for environmental use, such as improvements in water temperature and salinity.

5.2 USACE Approach to Computing Water Supply and Water Quality Benefits

The USACE uses the same approach to computing water supply benefits and water quality benefits, as described below.

5.2.1 Method

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), the US Army Corps of Engineers (USACE) describes the following evaluation steps for M&I (i.e., urban) water supply benefits based on the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (WRC 1983). These steps do not distinguish between water supply and quality benefits. Rather, the USACE acknowledges that "[b]ecause water quality is a critical factor in water supply, it should be specified in any consideration or presentation related to water quantity. The degree of detail used to describe water quality should be suitable to permit differentiation among water sectors (e.g., residential, commercial, agricultural, etc.) or available water supplies." The evaluation steps for M&I water supply are (USACE 2000):

1. Identify the study area. The study area is the area within which significant project impacts will accrue from the use of M&I water supplies, including areas that will receive direct benefits and/or incur costs from the provision of M&I water supply.
2. Estimate future M&I water supplies. Prepare an analysis of all sources of supply expected to be available to the M&I water user. This analysis should be by time period and include existing water supplies, institutional arrangements, additional water supplies, probability of water supply, and water quality.
3. Project future M&I water use. Project future water use by sector in consideration of seasonal variation. Base projections on an analysis of those factors that may determine variations of water use by sector (e.g., residential indoor and outdoor uses). Aggregate water use projections for all sectors by time period.
4. Identify the deficit between future water supplies and use. Compare projected M&I water use with future water supplies to determine whether any deficits exist in the study area. Make an analysis of the intensity, frequency, and duration of the expected deficits. Address deficits with three basic options:
   - Reduce projected water use by implementation of nonstructural conservation measures that are not part of the without-project condition.
   - Increase and/or more efficiently use water supplies through structural measures.
   - Accept and plan to manage water supply shortages.

   Plans generally are formulated to include some or all of these options, described in the next step.
5. Identify alternative plans without the federal plan. Identify alternative plans that are likely to be implemented by communities and/or industries in the absence of any federal alternative. Plans should be identified through analysis of the total water resources of the region, allowing for present and expected competing uses. Plans do not have to eliminate completely the projected difference between supply and demand. Include in such plans measures to minimize and allocate shortages when they occur (drought management measures). Balance the increased risk of occasional shortages against the savings from lesser investments that would increase the probability of occasional shortages. The costs of shortages include the costs of implementing drought management measures and the costs of related public health and safety measures.

6. Rank and display the alternative plans based on a least cost analysis. Rank all of the alternatives in order from the highest cost alternative to the lowest. Calculate the annualized costs of the alternatives on the basis of the life of the facility or period of analysis, whichever is less.
7. Identify the most likely alternative. Begin identification of the most likely alternative with the least costly. If an alternative with a lesser cost is passed over for a more expensive one, justify the selection of the more expensive plan.
8. Compute M&I water supply annualized benefits. Annualized benefits of the federal water supply are equal to the annualized costs of the most likely alternative. When applicable, the evaluation should reflect differences in treatment, distribution, and other costs compared to the most likely alternative.

These steps are shown in Figure 5-1.

To evaluate the benefits of agricultural water supplies, the same steps are followed as described for agricultural flood damage benefits (Figure 3-6, Chapter 3), excluding flood damage reduction described in Step 2. Because water supply benefits are likely to result in changes in cropping patterns (i.e., intensification benefits), they are reported using a format similar to Table 3-6. This table computes the change in net income between the without- and with-project conditions, although flood damage would be excluded from the water supply benefit computation.

5.2.2 Software Application

The USACE has developed IWR-MAIN Water Demand Management Suite, which (DWR 2008a):

- Uses demographic, housing, and business statistics of service areas to estimate the existing and future per unit water demands.
- Uses projections of population, housing, employment, or other demographic unit to derive baseline forecasts of water use.
- Provides an analysis of existing and projected water demands at the end use (i.e., final consumer) level, including the estimation of conservation savings from emergency demand reduction measures.
- Allows the user to select least-cost combinations of demand side alternatives, through B-C analysis, to formulate the optimal cost-effective long-term water management plan.

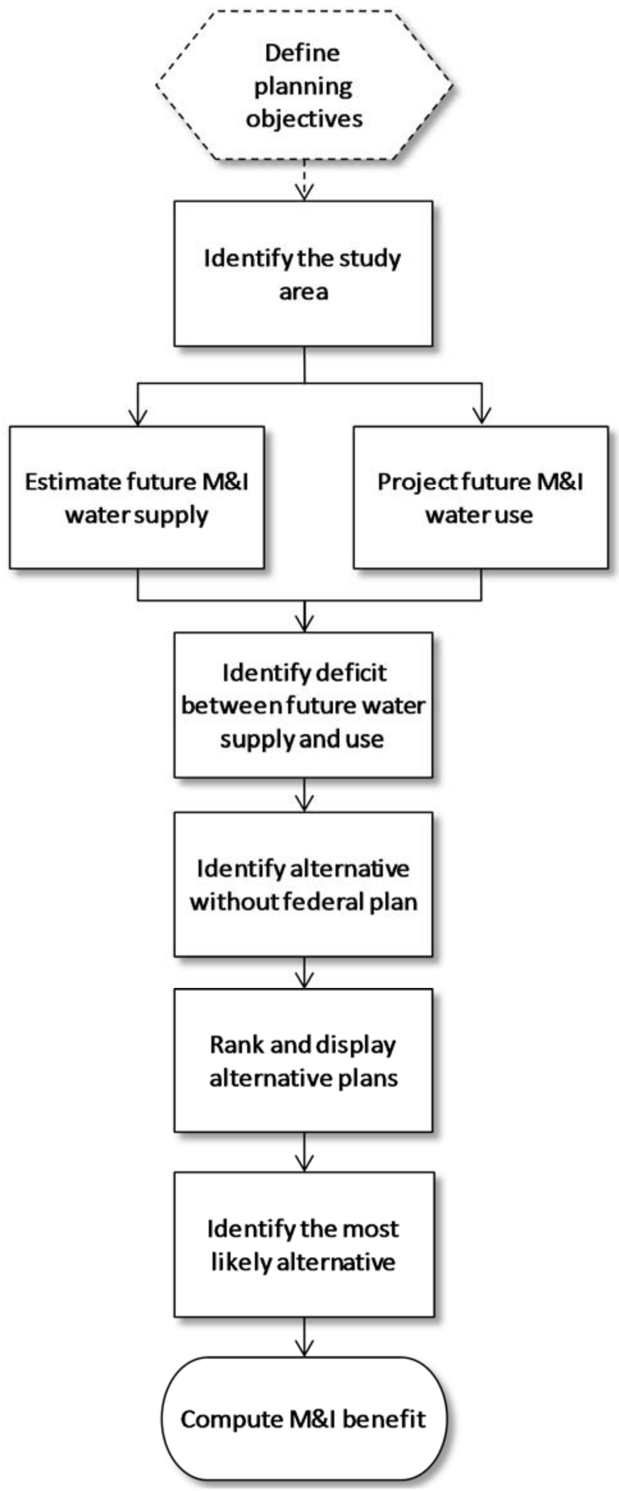

Figure 5-1. USACE M&I (Urban) Water Supply Evaluation Method

(Adapted from ER 1105-2-100, Appendix E)

Although IWR-MAIN can be used for the above analyses, it does not compute benefits and costs for structural water supply alternatives. IWR-MAIN is further described in Appendix I.

5.2.3 Analysis Results Display Templates

Required USACE analysis display templates for the M&I water supply benefit computation are shown in Table 5-1 and Table 5-2.

Table 5-1. Example USACE Analysis Display Template for Municipal and Industrial (M&I) Water Uses and Supplies Without-Project Water Use (mgd=million gallons/day)

Projected Average Day Water Use[1,2] (1)	Time Period[3]			
	P1 (2)	P2 (3)	P3 (4)	PN (5)
Residential (mgd)	0	0	0	0
Commercial (mgd)	0	0	0	0
Industrial (mgd)	0	0	0	0
Additional (public services and unaccounted for losses)(mgd)	0	0	0	0
Total	0	0	0	0
Average day water supply capacity without a plan:				
Source 1 (mgd)	0	0	0	0
Source 2 (mgd)	0	0	0	0
Source 3 (mgd)	0	0	0	0
Source x (mgd)	0	0	0	0
Total	0	0	0	0
Difference between projected average day water use and supply without a plan (mgd)	0	0	0	0

Table source: ER 1105-2-100, Appendix E

Notes:

[1] Include effects of nonstructural and conservation measures.

[2] Complete separate tables for average day and maximum day use capacity.

[3] Show by time period and season where seasonal variations occur.

Table 5-2. Example USACE Analysis Display Template for Municipal and Industrial (M&I) Water Supply Alternatives

Alternative (1)	Annualized Cost ($1000) (2)	Quantity Supplied (mgd) [1]			
		P1 (3)	P2 (4)	P3 (5)	PN (6)
Most likely alternative	$0	0	0	0	0
Recommended plan	$0	0	0	0	0
Other plans	$0	0	0	0	0

Table source: ER 1105-2-100, Appendix E

Note:

[1] Show by time period and season where seasonal variations occur.

5.3 DWR-Recommended Approach to Computing Water Supply and Water Quality Benefits

The recommended approaches to computing water supply and water quality benefits are similar, as explained below.

5.3.1 Water Supply Benefits

DWR has developed two different approaches to evaluating urban (M&I) water supply benefits: the Common Assumptions approach and the proposal solicitation package (PSP) developed for the Integrated Regional Water Management (IRWM) implementation grants funded under Proposition 84 (the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006):

- **Common Assumptions –** Common Assumptions was an effort initiated in 2002 to develop consistency and improve efficiency among proposed surface storage investigations. One objective of this process was to "[d]evelop and refine a common analytical framework including tools and methods for integrated hydrologic and economic analyses." Common Assumptions was a joint effort by DWR, US Bureau of Reclamation, and the California Bay-Delta Authority. More information on the Common Assumptions methods and models is included in Appendix E.

- **IRWM implementation grants PSP –** Guidance was developed for applicants requesting IRWM implementation grants, including step-by-step instructions, methods, and formats to be followed in estimating water supply benefits. Other benefits were also included, such as water quality, recreation and public access, power cost savings and power production, and ecosystem restoration (DWR 2012k).

Both approaches are applicable to FloodSAFE programs. The study team shall first discuss the choice of procedures with the DWR Economic Analysis Section member of the team who, in turn, may ask for guidance from the Chief of the Economic Analysis Section to determine if the Common Assumptions approach is more appropriate to use. The DWR Economic Analysis Section can also assist in applying Common Assumptions procedures to compute water supply benefits.

If the IRWM approach is agreed upon, then the set of benefit evaluation procedures adapted from IRWM shall be used, as described below. [Note: These procedures will result in a much less rigorous water supply benefit evaluation compared to procedures contained in Common Assumptions. For example, no distinction is made between the benefits of drought year compared with average year water supplies.]

IRWM defines urban water supply benefits as avoided water supply purchase costs, including those for environmental purposes; avoided costs of water supply projects; avoided water shortage costs; avoided operations and maintenance costs; or water revenue from water sales to another purveyor or third party. Only one of these can be claimed for each unit of water supply benefit (DWR 2012k). This DWR definition is consistent with the USACE definition.

The following steps are adapted from those described in the IRWM implementation grant PSP, modified (where necessary) to meet the USACE procedures described above.

1. Identify the study area, as described in Step 1 of the USACE procedure above.
2. Estimate existing and future urban water supply/demand balances, as described in steps 2, 3, and 4 of the USACE procedures above. The objective is to determine existing and projected differences between demand and supply. Include descriptions of all assumptions used to develop the water supply/demand balances, including population projections, per capita use, implementation of other water supply projects, water quality considerations, etc. The water supply/demand balances can be displayed in a table similar to Table 5-1 above, except reported in units of acre-feet (AF) rather than million gallons/day (mgd). [Note: 1 AF = 325,851 gallons.]

3. Identify alternative plans likely to be implemented by communities in the absence of a proposed project, as described in Step 5 of the USACE procedure above. Include descriptions of plan outputs and costs. Alternative plans should have similar outputs (e.g., quantity and quality of water deliveries). If alternative plans do not completely alleviate deficits, costs of shortages must also be included. Differences in water quality among plans are discussed below.
4. Compute annualized cost/AF of alternative plans. If an alternative's costs and/or annual deliveries are expected to remain constant over the analysis period, use the "short method" shown in Table 5-3 to compute cost/AF. If an alternative's costs and/or annual deliveries are expected to vary significantly over the analysis period, use the "long method" shown in Table 5-4 to compute cost/AF. Repeat this computation for each alternative plan being evaluated and summarize the results of these computations in Table 5-5.
5. Compute annual urban water supply benefits. Use Table 5-5 to compute water supply benefits of alternative plans. If the project is a single-purpose water supply project, these benefits could be compared with costs to determine the plan with the maximum net benefits. However, if the project is a multiobjective project with water supply as one of the components, then the information in Table 5-5 must be combined with potential benefits (and costs) from other project purposes, as described in Chapter 11.

The foregoing steps are shown in Figure 5-2.

If agricultural water supply benefits are expected to occur, DWR shall use the procedures described in Appendix E for Common Assumptions. Because agricultural water supply benefits are likely to result in changes in cropping patterns (i.e., intensification benefits), the distinction in basic and other crops must be applied, as shown in Figure 3-8, if the study includes federal partners.

For most FloodSAFE programs, water supply benefits can be computed using spreadsheet analyses. No software applications are recommended. Use Table 5-3, Table 5-4, and Table 5-5 to display water supply benefit computations and results.

5.3.2 Water Quality Benefits

Water quality benefits occur from the provision of better water quality for water users (e.g., urban and agricultural) and ecosystems. IRWM defines water quality benefits as reduced costs of protecting, restoring, or enhancing beneficial uses; avoided water quality project costs; avoided water treatment costs; avoided wastewater treatment costs; water supply benefits caused by water quality improvements (if not already captured as a water supply benefit); and willingness to pay for water quality improvements for drinking water, impaired water bodies, and sensitive habitats (DWR 2012k). This DWR definition is consistent with the USACE definition.

To compute water quality benefits, the steps described above for water supply benefits shall be followed, with these changes:

- Step 3 above requires that alternatives be evaluated that provide similar quantities and *qualities* of urban water supplies. If water quality is significantly different among alternatives, then appropriate treatment costs (i.e., associated costs described in Chapter 2) must be added to the alternative's cost estimate. Thus, water quality will be included implicitly in the urban water supply (quantity) benefit computation.

- If a project provides only water quality benefits (urban or agricultural), DWR economics staff shall be contacted for further guidance using avoided damage, change in production costs, or other method.

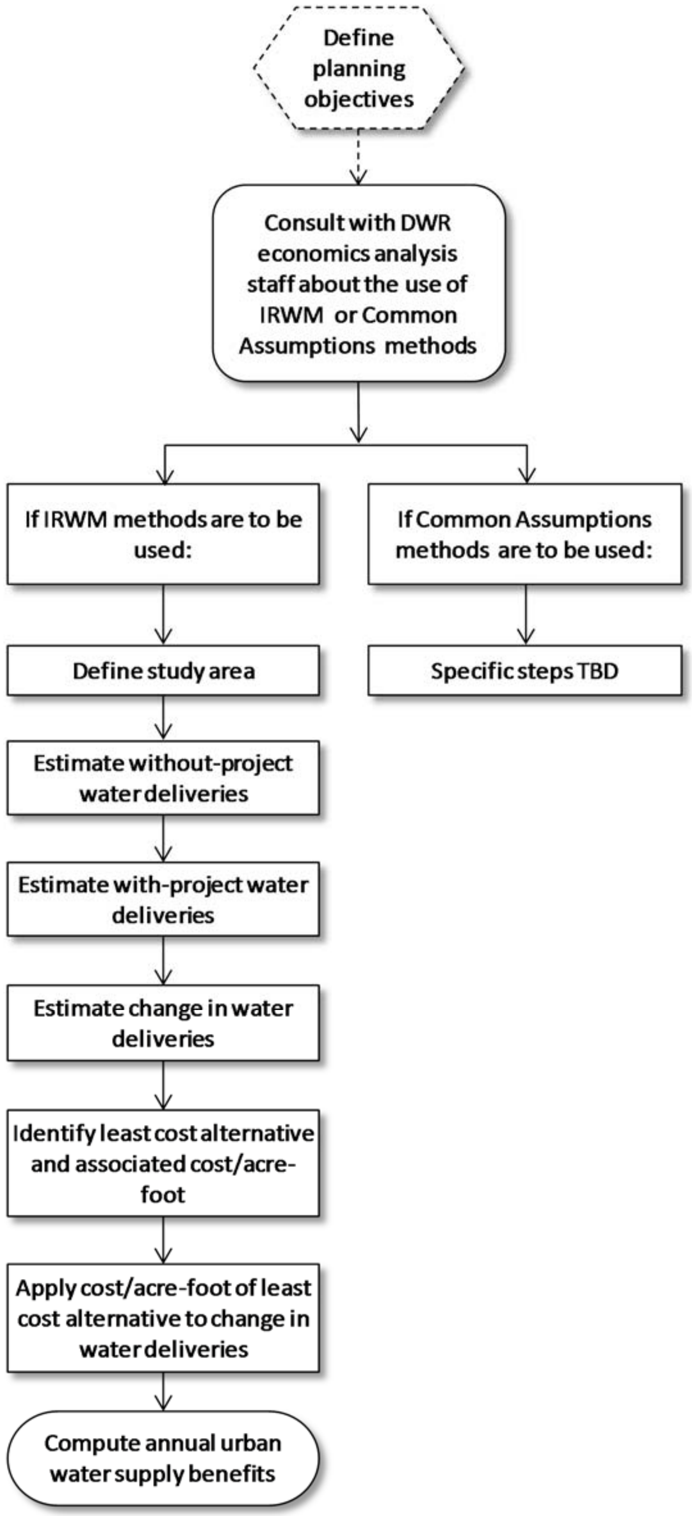

Figure 5-2. DWR Urban Water Supply Benefit Evaluation Method

These steps are summarized in Figure 5-3.

For most FloodSAFE programs, water quality benefits can be computed using spreadsheet analyses. No software applications are recommended. Water quality benefits shall be displayed using Table 5-6.

[Note: Common Assumptions water quality models are described in Appendix E.]

5.4 Consistency between DWR and USACE Water Supply and Water Quality Benefit Evaluation Approaches

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 5-7 compares recommended DWR methods with those used by the USACE. DWR-recommended water supply and quality benefit evaluations include IRWM or Common Assumptions procedures, depending on DWR analysis requirements. Both are consistent with USACE guidance. (Common Assumptions was developed in consultation with the US Bureau of Reclamation). Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

5.5 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods and software applications will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff must be contacted for further guidance and approval prior to initiation of the study.

Table 5-3. DWR-Recommended Template for Calculating Alternative Water Supply Plan Cost/AF: Short Method[1]

Costs and Deliveries (1)	Value (2)
(a) Project capital costs	
(b) Discount rate	0%
(c) Capital recovery factor (50 year analysis period)	0.0xxx
(d) Annual capital costs [(a)*(c)]	
(e) Annual OMRR&R[2] costs	
(f) Annual total costs [(d)+(e)]	
(g) Annual deliveries	
(h) Annual total costs/annual deliveries ($/AF) [(f)/(g)]	

Notes:
[1] Use this method if alternative project costs and water deliveries do NOT vary significantly over 50-year analysis period.
[2] Operations, maintenance, power, repair, replacement, and rehabilitation

Table 5-4. DWR-Recommended Template for Calculating Alternative Water Supply Plan Cost/AF: Long Method[1]

Year (1)	Costs ($1000)			Water Deliveries (1000 AF)		
	Capital and OMRR&R Costs[2] (2)	Discount Factor[3] (3)	Discounted Costs (4)	Annual Deliveries (5)	Discount Factor[3] (6)	Discounted Water Deliveries (7)
			[(2)*(3)]			[(5)*(6)]
0		1.0000			1.0000	
1		0.xxxx			0.xxxx	
2		0.xxxx			0.xxxx	
3		0.xxxx			0.xxxx	
4		0.xxxx			0.xxxx	
…		0.xxxx			0.xxxx	
50		0.xxxx			0.xxxx	
(a) Total discounted costs						
(b) Total discounted water deliveries						
(c) Total discounted costs/total discounted water deliveries ($/AF) [4a/7b]						

Notes:
[1] Use this table if alternative project costs and/or water supply deliveries vary significantly over 50-year analysis period.
[2] Operations, maintenance, repair, replacement, and rehabilitation costs.
[3] x% discount rate for 50 years.

Table 5-5. DWR-Recommended Template for Calculating Annual Urban (Municipal and Industrial, or M&I) Water Supply Benefits for Alternative Plans

Alternative Plans (1)	Annual Water Deliveries (AF)			$/AF Value (5)	Annual Benefit ($) (6)
	Without Project (2)	With Project (3)	Change (4)		
			[(3)-(2)]		[(4)*(5)]
Plan A					
Plan B					
Plan C					
…					

Table 5-6. DWR-Recommended Template for Calculating Annual Water Quality Benefits for Alternative Plans

Alternative Plans (1)	Measure of Physical Benefit[1] (Units) (2)	Annual Physical Benefits			$/unit Value (6)	Annual Benefit ($) (7)
		Without Project (3)	With Project (4)	Change (5)		
				[(4)-(3)]		[(5)*(6)]
Plan A						
Plan B						
Plan C						
…						

Note:
[1] Total dissolved solids (TDS) or other appropriate measure of water quality.

Table 5-7. Comparison between USACE and DWR-Recommended Water Supply/Quality Benefit-Cost Analysis Methods

Benefit (1)	DWR Methods (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Water Supply and Quality			
Urban			
IRWM	●	NA	●
Common Assumptions	●	●	●
Crops			
Common Assumptions	●	●	●

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

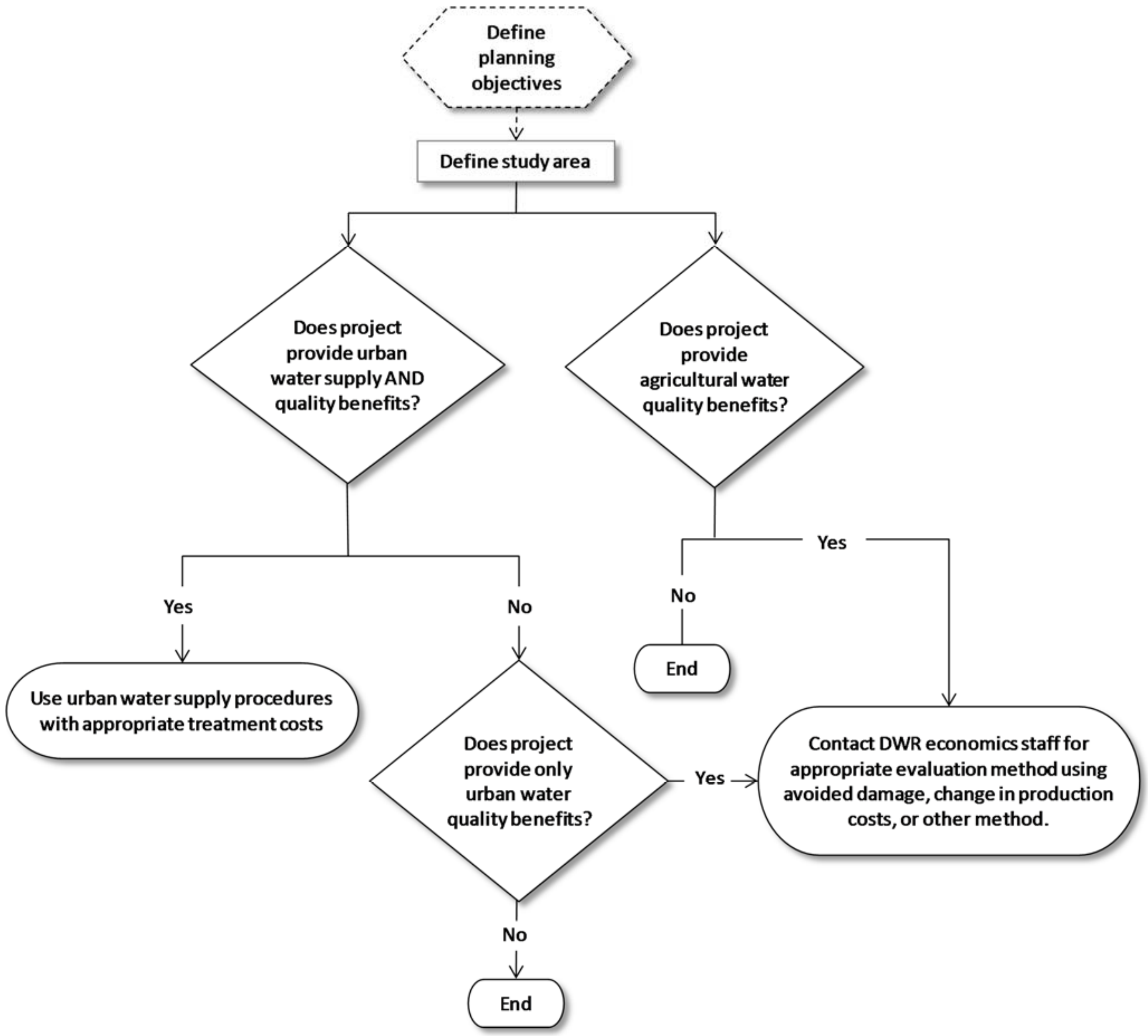

Figure 5-3. DWR Water Quality Benefit Evaluation Method

6.0 Recreation and Open Space Benefits

In this chapter:

- The conceptual basis for measuring recreation and open space benefits
- The USACE approach to computing recreation benefits
- The recommended DWR approach to computing recreation benefits
- Consistency between USACE and DWR approaches to computing recreation benefits
- The USACE approach to computing open space benefits
- The recommended DWR approach to computing open space benefits
- Consistency between USACE and DWR approaches to computing open space benefits
- Recommended templates for displaying analysis results
- What to do if DWR-recommended procedures are not to be used

6.1 Conceptual Basis for Measuring Recreation and Open Space Benefits

Recreation benefits result from providing new leisure-time activities or improving the quality of existing ones. Recreational opportunities provided by FloodSAFE programs may include nature-based activities, such as fishing, hunting, hiking, and wildlife viewing. Open space is areas of land without human-built structures. These areas include areas protected from development by legislation or other public policies, such as parks and greenbelts, as well as privately-owned working farmland. Open space opportunities provided by FloodSAFE programs may include developing and/or expanding existing bypasses, implementing levee setbacks, and protecting existing agricultural development.

6.1.1 How Recreation and Open Space Fit into Multiobjective Projects

The California Department of Water Resources (DWR) recognizes that projects that integrate multiple benefits, including flood risk management, water supply and quality, recreation/open space, and ecosystem restoration, may be more prudent investments than single-purpose projects. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

For multiobjective projects, the benefit and cost (B-C) analysis shall combine monetized benefits and costs for all project objectives. Nonmonetized benefits and costs shall be quantifiably assessed, when possible. Otherwise, they will be qualitatively described. This process is described in Chapter 11.

6.1.2 How Recreation Benefits Are Categorized

The measurement standard and conceptual basis of recreation benefits (more specifically, water-oriented recreation) are the willingness to pay (WTP) for each increment of output from a plan. Where prevailing prices approximately reflect the cost of providing the next increment of recreation services, these can be used as a measure of WTP for additional recreation activities. However, because many forms of recreation are not usually traded in competitive markets, useful price information may not be available. Therefore, in the absence of useful price information, recreation benefits are typically measured by other methods, including travel cost surveys (another form of revealed WTP), user surveys (expressed WTP), and administrative unit-day values.

Recreation benefits can be classified as either general or specialized recreation (DWR 1977):

- **General recreation –** These activities attract the majority of outdoor recreationists and, in general, require the development and maintenance of convenient access and adequate facilities. This category includes the great majority of recreational activities associated with water projects, including swimming, picnicking, boating, and most warm-water fishing.

- **Specialized recreation –** Opportunities for these activities generally are limited, intensity of use is low, and a high degree of skill, knowledge, and appreciation of the activity may often be involved. Examples include white water boating and canoeing, big game hunting, salmon fishing, and wilderness pack trips.

Proposed recreation improvements may involve recreation gains and losses. For example, constructing a dam and reservoir may create surface water recreation opportunities where none existed before. However, the reservoir may also inundate a stream segment that previously provided white water rafting and other recreation activities. The values of these activities must be deducted from the recreation benefits computed for the reservoir. In addition, the new reservoir may attract boaters from other reservoirs. Since this is a transfer of benefits from one reservoir to another, they also must be deducted from recreation benefits computed for the new reservoir, if they are expected to occur. All of these effects must be accounted for in the analysis of recreation benefits.

Following is a summary of US Army Corps of Engineers (USACE) recreation planning requirements (methods, software, and analysis results templates), followed by recommended DWR procedures to estimate recreation benefits. For most recreation benefits, DWR recommends the same approach that the USACE uses. Where they are different, those differences are noted, along with the reasons why the approaches are different, and the potential implications of those differences.

6.2 USACE Approach To Computing Recreation Benefits

The USACE approach to computing recreation benefits is described below.

6.2.1 Method

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), the USACE describes the following evaluation steps for recreation benefits based on the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (WRC 1983). A summary of the evaluation steps for recreation follows (USACE 2000):

1. Define the study area. The study area should include the geographical recreation “market” defined by the location of actual and potential user population, accounting for the characteristics and quality of the proposed site and the availability of similar alternative recreation opportunities in the study area.
2. Estimate recreation resource capacity of all existing sites that provide recreation activities similar to those provided (or displaced) by the project:
   - Inventory recreation sites in the study area, including federal, State, county, local, and private sites and those that are authorized and likely to be developed in the forecast period.
   - Estimate the resource capacity (e.g., visitation) of these recreation sites.
   - Identify alternative recreation sites and the types and qualities of activities at those sites.

3. Forecast potential recreation use in the study area. Potential use is the expected visitation at prevailing prices unconstrained by supply. Forecast total study area recreation use for each activity currently provided at the project site and for each activity proposed in the plan or project. The potential use for a specified recreation activity will depend on: (a) the attributes of the site, (b) its proximity to population centers, and (c) the availability of similar or complementary types of recreation in the study area. Estimate recreation use with one of the forecasting methods described below.
4. Determine the without-project condition. Determine the without-project condition for the study area by comparing the available recreation resources' capacity, as determined in Step 2, and the recreation resources' use, as determined in Step 3, for each activity currently provided at the project site and each activity proposed in the plan or project.
5. Forecast recreation use with the project. Forecast recreation use with one or more of the following methods for the with-project condition (see ER 1105-2-100 for more information concerning these methods):
   - Regional use estimating models. These are statistical models that relate use to the relevant determinants based on data from existing sites in the study area.
   - Site-specific use-estimating models. These are use-estimating models that relate use per 1,000 of origin population to distance traveled, socioeconomic factors, and characteristics of the site as alternative recreation opportunities.
   - Application of information from a similar project. This method estimates recreation demand for a proposed project based on observations of visitation patterns at one or more existing projects with similar resource, operations, and use characteristics.
   - Capacity method. This method equates use with site recreation capacity.
6. Estimate the value of use with the project. Three alternative methods can be used to estimate the economic value of recreation benefits:
   - Travel cost method. This method derives a demand function for recreation by using the variable costs of travel and the value of time as proxies for price. The basic premise is that per capita use of a recreation site will decrease as out-of-pocket and time costs of traveling to the site increase, other variables being constant.
   - Contingent valuation method. This method estimates recreation benefits by directly asking individual households their willingness to pay (WTP) for changes in recreation opportunities at a given site.

Individual values may be aggregated by summing WTP for all users in the study area.

- Unit day value method. These values estimate the average WTP of recreational users, based on expert or informed opinion and judgment. By applying a carefully thought-out unit day value to estimated use, an approximation of recreation benefits is obtained. Unit day values can be adjusted using a point rating method to reflect quality, relative scarcity, ease of access, and aesthetic features. General recreation unit day values range from $3.80 to $15.43, and for specialized recreation, $15.43 to $45.09. Unit day values can be obtained from a USACE economics guidance memorandum located on the USACE planning toolbox website. See ER 1105-2-100 for more information concerning these methods.

7. Forecast recreation use diminished with the project. Using the appropriate method described in Step 5 above, forecast the recreation resource uses that would be diminished due to physical displacement expected because of the project or plan.
8. Estimate value of recreation use diminished with the project. Using the appropriate method described in Step 6 above and the appropriate selection criteria, estimate the economic value of the recreation uses that would be diminished due to physical displacement expected because of the project or plan. In addition, account for changes in recreation use of an existing resource and/or project as a result of transfers to the plan under study.
9. Compute net project benefits. Compute the project benefit as the value of diminished recreation value as determined in Step 8 subtracted from the gross value of recreation as estimated in Step 6. However, if excess capacity for any activity exists in the study area, benefits are the user cost savings plus the value of any qualitative difference in recreation.

These steps are shown in Figure 6-1.

6.2.2 Analysis Results Display Templates

Required USACE analysis display templates for recreation benefit computations are shown in Table 6-1 and Table 6-2 (USACE 2000).

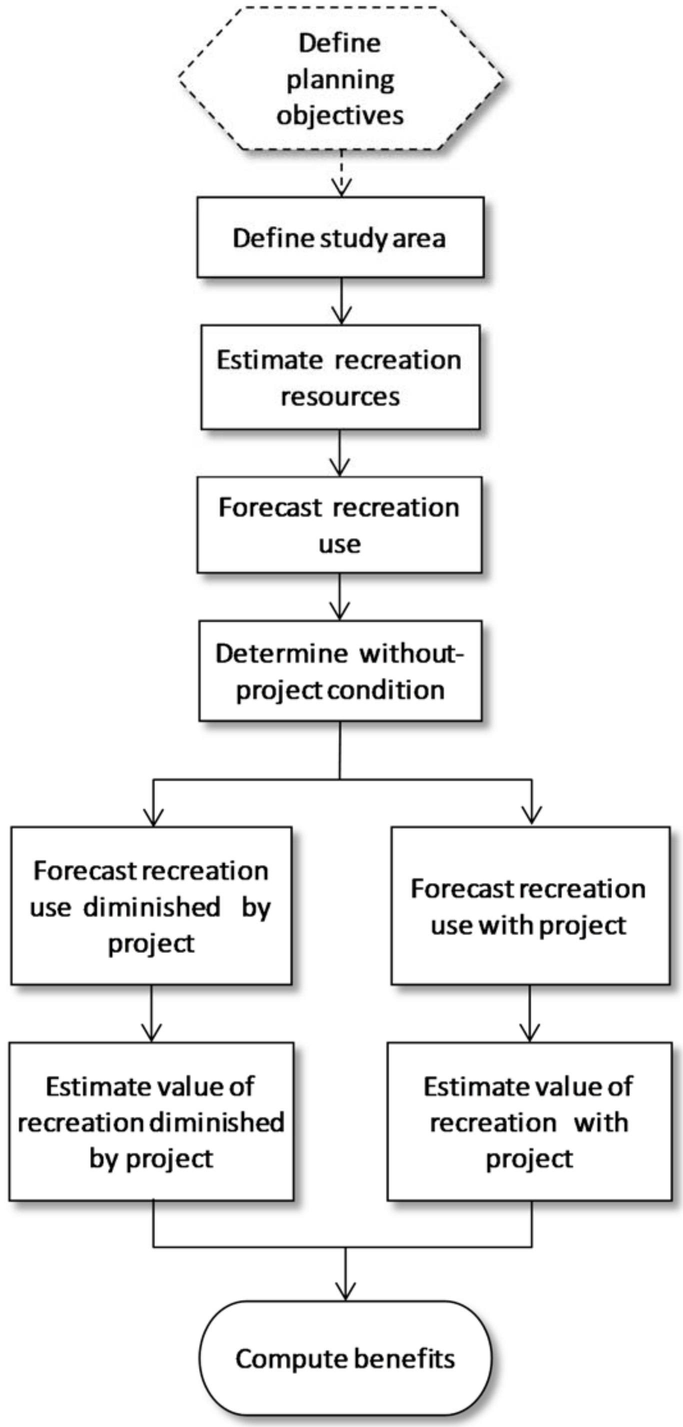

Figure 6-1. USACE Recreation Evaluation Method

(Adapted from ER 1105-2-100, Appendix E)

Table 6-1. Example USACE Analysis Display Template for Recreation Capacity and Use

Alternative Plans (1)	Without Project			With Project		
	Capacity (2)	Use (3)	Surplus/Deficit (4)	Capacity (5)	Use (6)	Surplus/Deficit (7)
Plan A	0	0	0	0	0	0
Plan B	0	0	0	0	0	0
Plan C	0	0	0	0	0	0
Plan D	0	0	0	0	0	0

Table source: ER 1105-2-100, Appendix E

Table 6-2. Example USACE Analysis Display Template for Annualized Recreation Benefits, Recommended Plan

(1)	Value of Gross Use (2)	Value of Displaced Use (3)	Net Value (4)
Specialized	0	0	0
General	0	0	0

Table source: ER 1105-2-100, Appendix E

6.3 DWR-Recommended Approach to Computing Recreation Benefits

The recommended DWR approach to compute recreation benefits is based on the USACE approach, although with some simplifications. The recommended steps are as follows:

1. Define the study area. As described above, define the study area the same as for a USACE analysis.
2. Estimate without-project recreation use. Inventory existing (including authorized, but not yet constructed) recreation sites at the project location, as well as comparable recreation sites in the study area. Estimate annual use (e.g., visitation) at these sites based on (a) the capacity of the sites, (b) site-specific use estimates obtained from annual reports and/or discussions with local recreation officials, or (c) estimates of use transferred from other sites providing similar recreation activities. Document why a particular method was used.
3. Estimate the with-project recreation use. Estimate types and amounts of annual recreation use created at the project site, with deductions for recreation (a) displaced by the project and/or (b) likely to be transferred from other recreation sites in the study area (or statewide). Estimate annual use with one of the above methods.

4. Compute the annual recreation benefit. Estimate the net change in annual recreation use between the without- and with-project conditions (accounting for displaced and transferred recreation uses). Although different methods are available to estimate the economic value of recreation benefits, unit day values are most likely to be applicable for DWR analyses. Unit day values can be obtained from the USACE economics guidance memorandum located on the USACE planning toolbox website.

These steps are shown in Figure 6-2.

Recreation benefits shall be calculated using Table 6-3.

If recreation activities are expected to change significantly over the analysis period, then the recreation benefits must be computed as many times as necessary to reflect those changes and reported for each time period using the format shown in Table 6-3. Appendix H describes how to do the present value analysis when the benefits (and costs) change over the analysis period.

No software applications are recommended.

6.4 How Open Space Benefits Are Described

The measurement standard and conceptual basis of open space benefits are the WTP for each increment of output from a plan. Where prevailing prices approximately reflect the cost of providing the next increment of open space services, these can be used as a measure of WTP for additional recreation activities. However, because open space is not usually traded in competitive markets, useful price information may not be available. Therefore, in the absence of useful price information, open space benefits are typically measured by other methods, described below.

Open space can provide a wide variety of benefits, including (Economy League of Greater Philadelphia, et al. 2011):

- Improved residential property values for properties in close proximity to open space.
- Naturally provided environmental services, such as water supply, water quality, air quality, flood mitigation, wildlife habitat, and carbon sequestration.
- Improved recreational opportunities.

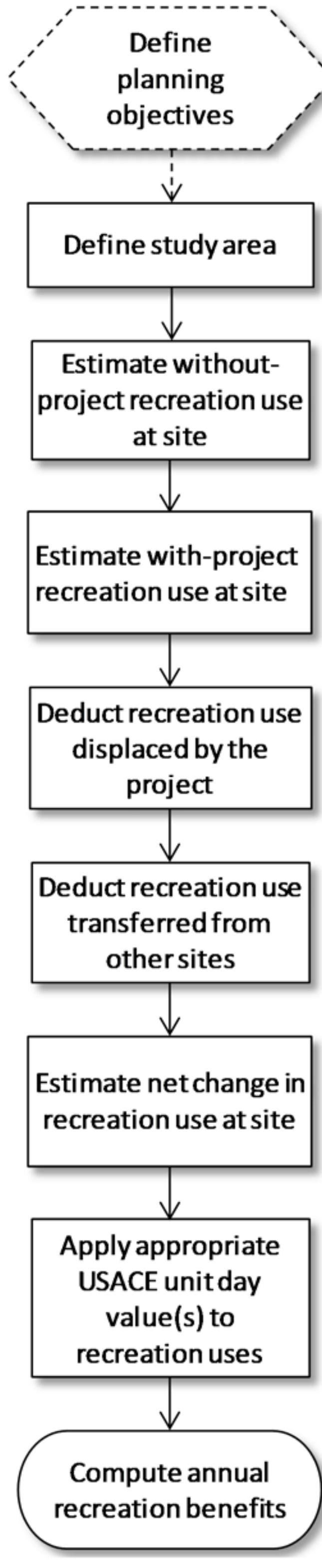

Figure 6-2. DWR Recreation Benefit Evaluation Method

Table 6-3. DWR-Recommended Template for Calculating Annual General and Specialized Recreation Benefits at the Location of Project, Taking into Account Recreation Displaced at that Location and Recreation Transferred from Other Sites in the Study Area or Elsewhere in the State

Alternative Plans and Type of Recreation (1)	Annual Visitor Days							USACE Unit Day $ Value (9)	Annual Benefit ($) (10)
	Without Project (2)	With Project[1] (3)	Change (4)	Displaced Use[1] (5)	Transferred Use[2] (6)	Total Displaced or Transferred Use (7)	Net Change (8)		
			[(3)-(2)]			[(5)+(6)]	[(4)-(7)]		[(8)*(9)]
Plan A									
General									
Specialized									
Total									
Plan B									
General									
Specialized									
Total									
Plan C									
General									
Specialized									
Total									
…									
General									
Specialized									
Total									

Notes:

[1] Recreation displaced at project location.

[2] Recreation transferred from other recreation sites in study area or from other areas of the state.

- Reduced health-related costs for those participating in physically-active recreational activities associated with open space.

These are primary benefits that could be included in a B-C analysis. However, some of these benefits may be evaluated for other project purposes (for example, ecosystem services or recreation); thus, care must be taken to avoid double-counting.

In addition, the following types of "economic activity" benefits have also been evaluated, although most of these should be included as secondary impacts described in Chapter 10 (Economy League of Greater Philadelphia, et al. 2011):

- Annual expenditures associated with open space preservation, including government spending for management and maintenance activities, spending for the purchase of goods made on preserved farmland, and spending related to tourism associated with protected open space.
- Job creation (numbers of jobs and salaries) associated with public maintenance workers; park administrators and rangers; farmers, distributors, and suppliers associated with protected farmland; and guides and hospitality professionals catering to tourists.
- Changes in state and local taxes generated from economic activity that takes place on and because of protected open space.

6.5 USACE Approach to Computing Open Space Benefits

Open space is not an authorized USACE mission objective; thus, evaluation procedures for this benefit category are not included in USACE guidance (2000). However, some of the specific benefits (recreation or flood mitigation, for example) are included in USACE guidance and could be applied, provided the same benefits are not being claimed for other project objectives.

6.6 DWR-Recommended Approach to Computing Open Space Benefits

For recreation or flood mitigation benefits associated with open space, the DWR recommended methods (which are consistent with USACE procedures) shall be used as described above, provided the same benefits are not being claimed for other project objectives.

Property value, environmental services, and health-related benefits associated with open space shall be described qualitatively and quantified, and where possible, monetized. Open space benefits shall be displayed using Table 6-4.

Methods are available to monetize many of these benefits (DWR 2008a, NRC 2004, Economy League of Greater Philadelphia, et al. 2011). Thus, monetization may be done optionally if it (a) improves the decision-making process, and (b) sufficient data and other resources are available. However, monetization of ecosystem services may not be acceptable to the USACE, which does not currently monetize ecosystem services benefits as described in Chapter 4.

6.7 Consistency between DWR and USACE Recreation and Open Space Benefit Evaluation Approaches

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 6-5 compares recommended DWR methods, software applications, and risk analysis procedures with those used by the USACE. DWR-recommended recreation benefit evaluations are based on USACE unit day values, with annual use based on the USACE capacity approach and/or additional information from local officials and published reports. However, if the significance of recreation benefits (relative to other project benefits) warrants a more rigorous analysis of alternative plans, then these other methods can be used. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

Open space is not an authorized USACE mission objective; thus recommended DWR procedures for this benefit cannot be compared to USACE procedures. However, evaluation of potential open space benefits (for example, recreation or flood mitigation) is included in USACE guidance and also described above for DWR procedures. Thus, DWR procedures for these specific benefits are consistent with the USACE, taking care to avoid double-counting of benefits. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

Table 6-4. DWR-Recommended Template for Calculating Open Space Benefits

Alternative Plans/Types of Benefits (1)	Measure of Physical Benefit (Units) (2)	Annual Physical Benefits			$/Unit Value[1] (6)	Annual Benefit ($) (7)	Comments (8)
		Without Project (3)	With Project (4)	Change (5)			
				[(4)-(3)]		[(5)*(6)]	
Plan A							
Property values							
Environmental services							
Health costs							
Other							
Plan B							
Property values							
Environmental services							
Health costs							
Other							
Plan C							
Property values							
Environmental services							
Health costs							
Other							
…							
Property values							
Environmental services							
Health costs							
Other							

Note:
[1] Some benefits may not be monetized.

Table 6-5. Comparison of USACE and DWR-Recommended Recreation Benefit-Cost Analysis and Risk Analysis Methods

Benefit (1)	DWR Methods (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Recreation			
Unit day value evaluation	●	NA	●

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

6.8 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods and software applications will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff must be contacted in advance for further guidance and approval prior to initiation of the study.

7.0 Hydropower Benefits

In this chapter:

- The conceptual basis for measuring hydropower benefits
- The USACE approach to computing hydropower benefits
- The recommended DWR approach to computing hydropower benefits
- Consistency between DWR and USACE approaches to computing hydropower benefits
- What to do if DWR-recommended procedures are not to be used

7.1 Conceptual Basis for Measuring Hydropower Benefits

Hydropower benefits result from the generation of electrical energy using flowing water. Water resource projects can generate hydropower in a number of ways, including single-purpose hydropower projects, multipurpose projects that include hydropower facilities, and the addition of power generating facilities to existing water resource projects.

If they occur, hydropower benefits are likely to be incidental to California Department of Water Resources (DWR) FloodSAFE projects. In some instances, hydropower generating capability of existing facilities may be adversely affected by FloodSAFE projects, such as when reservoir operation rules are modified to allow additional flood reservation space at the expense of water supply and hydropower capability. Adverse effects on existing hydropower production would be included in a benefit and cost (B-C) analysis as a cost of the proposed project.

7.1.1 How Hydropower Fits into Multiobjective Projects

DWR recognizes that projects that integrate multiple benefits, including flood risk management, water supply, recreation, ecosystem restoration, and hydropower, may be more prudent investments than single-purpose projects. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

For multiobjective projects, the B-C analysis shall combine monetized benefits and costs for all project objectives. Nonmonetized benefits and costs shall be quantifiably assessed, when possible. Otherwise, they will be qualitatively described. This process is described in Chapter 11.

7.1.2 How Hydropower Benefits Are Described

The conceptual basis for evaluating the benefits from energy produced by hydroelectric power plants is society's willingness to pay (WTP) for these energy outputs. Although utility pricing of electricity is complex and usually based on average cost rather than marginal cost, in cases where it can be determined that market price to the final consumer is based on marginal production costs, this may be used as a measure of benefits. Market prices should only be used as a measure of benefits when the incremental change in supply is relatively small compared to total supply (thereby avoiding changes in prices due to the change in supply). An alternative approach to measuring hydroelectric power benefits is the resource cost of the most likely alternative to be implemented in the absence of the proposed project.

Following is a summary of US Army Corps of Engineers (USACE) methods, software, and analysis results templates to estimate hydropower benefits, followed by recommended DWR procedures to estimate hydropower benefits. For most hydropower benefits, DWR recommended procedures are the same as for the USACE. Where they are different, those differences are noted, along with the reasons why the procedures are different, and the potential implications of those differences.

7.2 USACE Approach to Computing Hydropower Benefits

The USACE approach to computing hydropower benefits is described below.

7.2.1 Method

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), the USACE describes the following evaluation steps for hydropower benefits based on the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (WRC 1983). The evaluation steps for hydropower depend on whether the proposed project is to be federally cost-shared or not (USACE 2000).

If the project is to be federally cost-shared, USACE guidance includes the following steps to evaluate hydropower benefits:

1. Identify the system for analysis.
2. Estimate future demand for electric power.

3. Define base system generating resources.
4. Evaluate the load/resource difference.
5. Determine the most likely non-federal alternative.
6. Compute benefits.

These steps, which are shown in Figure 7-1, describe a rigorous analysis to support a hydropower feasibility study.

However, USACE guidance also recognizes that for "[T]he purpose of ensuring efficiency in the use of planning resources, simplifications of the procedures set forth in this section are encouraged in the case of single-purpose, small-scale hydropower projects (25 MW or less), if these simplifications lead to a reasonable approximation of NED [national economic development] benefits and costs." These simplified procedures (called a financial evaluation) can be used to evaluate single-purpose projects that are (a) to be 100 percent non-federally financed and (b) do not have significant incidental costs (USACE 2000).

This simplified approach uses market data based on long-run (10 or more years) utility wholesale prices as an estimate of the cost of producing equivalent power from the most likely alternative. These prices may be used to evaluate and compare the financial feasibility of alternative plans, provided they are consistently applied to all alternatives. Through this process, the most financially attractive alternative is identified as the federal NED plan.

7.2.2 Analysis Results Display Templates

No specific USACE analysis display templates are required for the simplified financial evaluation approach.

7.2.3 Software Applications

No specific USACE software application is required for the simplified financial evaluation approach.

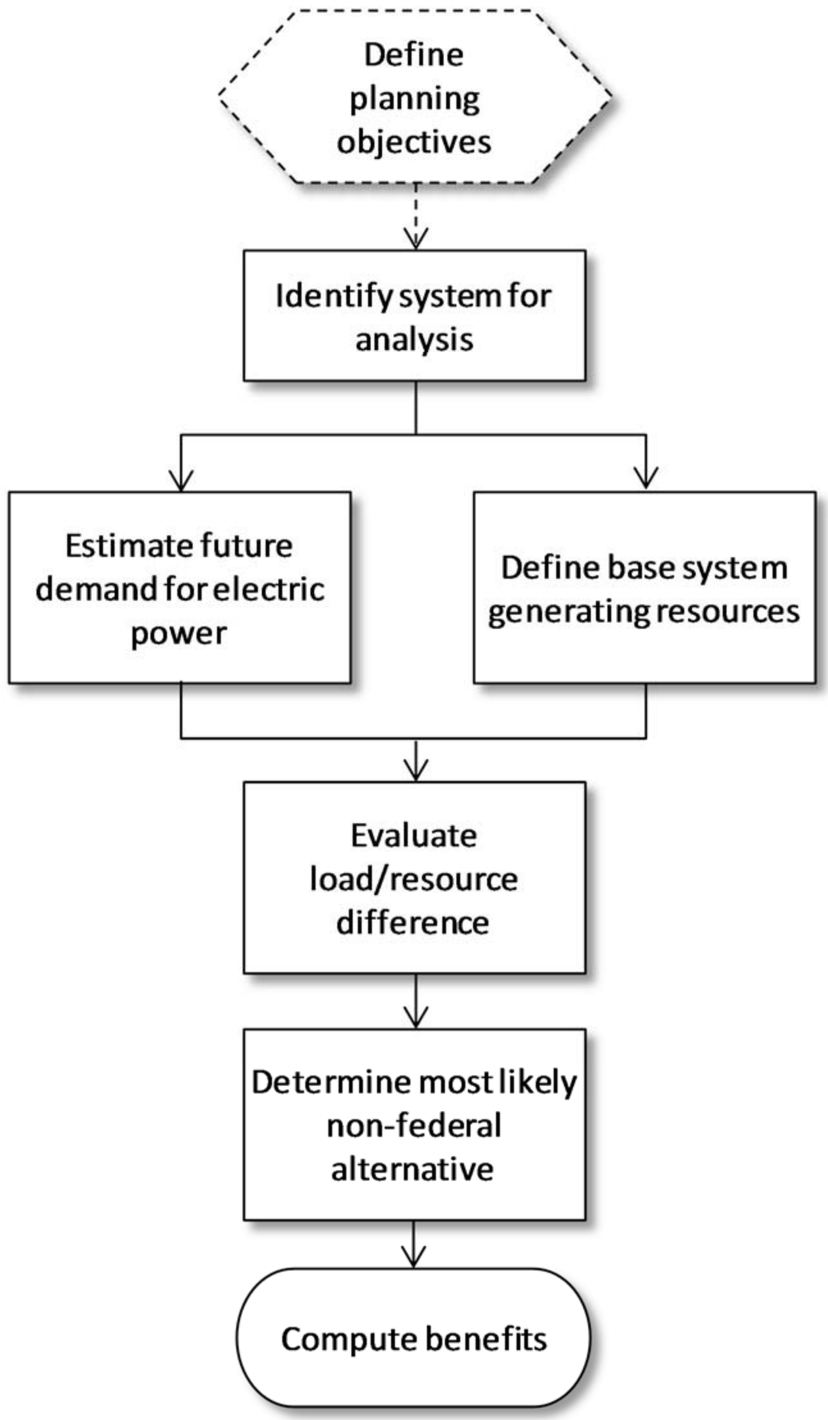

Figure 7-1. USACE Hydropower Evaluation Method

(Adapted from ER 1105-2-100, Appendix E)

7.3 DWR-Recommended Approach to Computing Hydropower Benefits

Although FloodSAFE projects are not likely to include single-purpose hydropower projects, hydropower facilities associated with multiobjective projects are likely to be "small scale" and not federally funded. Thus, the simplified USACE financial evaluation procedure is recommended for DWR projects involving hydropower benefits. However, if the hydropower facility is not "small scale" and/or is to be federally funded, then the more detailed procedures may need to be followed (USACE 2000).

The DWR procedure for computing hydropower benefits is shown in Figure 7-2. Table 7-1 shall be used to display hydropower benefits based on the simplified procedure. No software applications are recommended.

If hydropower generation is expected to change significantly over the analysis period, then the hydropower benefits must be computed as many times as necessary to reflect those changes and reported for each time period using the format shown in Table 7-1. Appendix H describes how to do the present value analysis when the benefits (and costs) change over the analysis period.

Table 7-1. DWR-Recommended Template for Calculating Hydropower Benefits Based on Simplified USACE Financial Evaluation Procedure Using Long-Run Information on Wholesale Electricity Prices

Alternative Plans (1)	Annual Kilowatt-Hours (kwh)			$/kwh Value (5)	Annual Benefit ($) (6)
	Without Project (2)	With Project (3)	Change (4)		
			[(3)-(2)]		[(4)*(5)]
Plan A					
Plan B					
Plan C					
…					

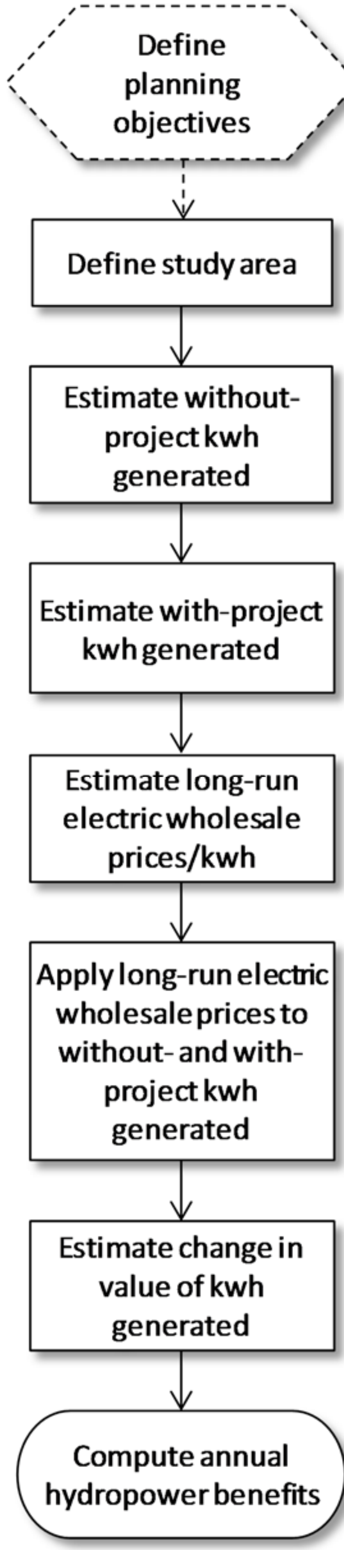

Figure 7-2. DWR Hydropower Benefit Evaluation Method

7.4 Consistency between DWR and USACE Hydropower Benefit Evaluation Approaches

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 7-2 compares recommended DWR methods with those used by the USACE. DWR-recommended hydropower benefit evaluation is based on the USACE financial evaluation method. Other more rigorous USACE hydropower benefit evaluation methods are available that are more appropriate for a full hydropower feasibility analysis; however, such an analysis is not anticipated with most FloodSAFE projects. If the significance of hydropower benefits (relative to other project benefits) warrants a more rigorous analysis of alternative plans, then these other methods can be used. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

Table 7-2. Comparison of USACE and DWR-Recommended Hydropower Benefit-Cost Analysis and Risk Analysis Methods

Benefit (1)	DWR Methods (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Hydropower			
Financial evaluation	●	NA	●

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

7.5 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff must be contacted in advance for further guidance and approval prior to initiation of the study.

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8.0 Navigation Benefits

In this chapter:

- The conceptual basis for measuring navigation benefits
- The USACE approach to computing navigation benefits
- The recommended DWR approach to computing navigation benefits
- Consistency between DWR and USACE approaches to computing navigation benefits
- Recommended templates for display of analysis results
- What to do if DWR-recommended procedures are not to be used

8.1 Conceptual Basis for Measuring Navigation Benefits

Navigation benefits result from improving the transportation of freight and passengers on inland or coastal waterways.

8.1.1 How Navigation Fits into Multiobjective Projects

The California Department of Water Resources (DWR) recognizes that projects that integrate multiple benefits, including flood risk management, water supply, recreation, ecosystem restoration, and navigation may be more prudent investments than single-purpose projects. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

For multiobjective projects, the benefit and cost (B-C) analysis shall combine monetized benefits and costs for all project objectives. Nonmonetized benefits and costs shall be quantifiably assessed, when possible. Otherwise, they will be qualitatively described. This process is described in Chapter 11.

8.1.2 How Navigation Benefits Are Categorized

The measurement standard and conceptual basis of navigation benefits are the willingness to pay (WTP) for each increment of output from a plan. However, navigation benefits are typically measured by the reduction in commodity or passenger transportation costs and/or the increase in the value of output for goods and services.

The US Army Corps of Engineers (USACE) distinguishes between inland and deep-draft navigation benefits. Inland navigation benefits occur from transportation improvements on inland waterways (such as the Mississippi River). Deep draft navigation benefits occur from improvements to harbors and channels to meet the requirements of ocean-going (and Great Lakes) shipping. Although FloodSAFE projects are not anticipated to include navigation facilities, they may affect operations of the ports of Sacramento and Stockton, as well as the Sacramento deep water ship channel. Therefore, USACE deep-draft navigation benefit procedures are probably more applicable for FloodSAFE applications and are summarized below. [Note: FloodSAFE projects may also adversely affect existing port and other shipping facilities. If this occurs, the procedures summarized below would be used to estimate additional *costs* for these projects, not benefits.]

Deep draft navigation benefits include (USACE 2000):

- **Cost reduction benefits –** If neither the origin nor the destination of a commodity changes, the benefit is the reduction in transportation costs of the commodity quantities that would move with and without the plan resulting from the proposed improvement. Cost reduction benefits apply in the following situations:
  - Same commodity, origin-destination, and harbor. This situation occurs where commodities now move or are expected to move via a given harbor with or without the proposed improvement.
  - Same commodity and origin-destination, different harbor. This situation occurs where commodities that are now moving or are expected to move via alternative harbors without the proposed improvement would, with the proposed plan, be diverted through the subject harbor.
  - Same commodity and origin-destination, different mode. This situation occurs where commodities that are now moving or are expected to move via alternative land transportation modes without the proposed improvement would, with the proposed plan, be diverted through the subject harbor.
- **Shift of origin benefits –** If the origin of a commodity changes because of a proposed plan but the destination does not change, the benefit is the reduction in the total cost of producing and transporting quantities of the commodity that would move with and without the plan.
- **Shift of destination benefits –** If the destination of a commodity changes because of a proposed plan but the origin does not change, the benefit is the change in net revenue to the producer for quantities that would move with and without the plan.

- **Induced movement benefits –** If a commodity or additional quantities of a commodity are produced and consumed as the result of lowered transportation costs, the benefit is the value of the delivered commodity less production and transportation costs.

8.2 USACE Approach to Computing Navigation Benefits

The USACE approach to computing navigation benefits is described below.

8.2.1 Method

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), the USACE describes the evaluation steps for deep-draft navigation benefits based on the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (WRC 1983). Because navigation is an important mission of the USACE, especially in other regions of the country, this guidance is very detailed and is probably beyond the requirements for potentially limited FloodSAFE applications. USACE guidance also acknowledges the complexity of this guidance: "The level of effort expended on each step depends on the nature of the proposed improvement, the state of the art for accurately refining the estimate, and the sensitivity of project formulation and justification to further refinement" (USACE 2000). Steps in the USACE computation method for navigation benefits are summarized below:

1. Determine the economic study area. Delineate the economic study area that is tributary to the proposed harbor and channel improvement. Assess the transportation network functionally related to the proposed improvement, including the types and volumes of commodities being shipped, in order to determine the area that can be served more economically by the improvement.
2. Identify types and volumes of commodity flow. Estimate the types and volumes of commodities that now move on the existing project or that may be attracted to the proposed improvement.
3. Project waterborne commerce. Develop projections of the potential use of the waterway for 10-year intervals during the analysis period. The usual procedure for constructing commodity projections is to relate the traffic base to some type of index over time, such as those made by the US Bureau of Economic Analysis.

4. Determine vessel fleet composition and cost. Obtain data on past trends in vessel size and fleet composition and on anticipated changes in fleet composition over the project life. Obtain deep-draft vessel operating costs for various types and classes of domestic and foreign vessels expected to benefit from the proposed improvement.
5. Determine current cost of commodity movement. Determine transportation costs prevailing at the time of the study for all tonnage identified in Step 2. Transportation costs include the full origin-to-destination cost, including necessary handling, transfer, storage, and other accessory charges. Develop costs for the with- and without-project condition.
6. Determine current cost of alternative movement. Determine transportation costs prevailing at the time of study for all tonnage identified in Step 2 that is using alternative movements (i.e., competing harbors and facilities).
7. Determine future cost of commodity movement. Estimate relevant shipping costs during the period of analysis and future changes in the fleet composition, port delays, and port capacity under the with- and without-project conditions for each alternative improvement being studied.
8. Determine use of harbor and channel with and without the project. Estimate the proposed harbor use over time with and without the project based on the estimated types and tonnages of commodities that potentially might use the proposed improvement, transportation costs, and fleet composition.
9. Compute NED benefits. Once the tonnage moving with and without a plan is estimated and the cost via the proposed harbor and via each competing harbor are known, compute the appropriate total NED navigation benefits:

   - **Cost reduction benefits** -

     Same commodity, origin-destination, and harbor. For traffic now using the harbor or expected to use it, both with and without the proposed project, the transportation benefit is the difference between current and future transportation cost for the movement by the existing project (without-project condition) and the cost with the proposed improvement (with-project condition).

     Same origin-destination, different harbor. For commerce shifted to the proposed improvement from other harbors or alternatives, the benefit is any reduction in current and future costs when movement via the proposed improvement is compared with each alternative.

Same origin-destination, different mode. For commerce shifted to the proposed improvement from other modes of transportation, the benefit is any reduction in current and future costs to the producer or shipper.

- **Shift of origin benefits -** For commerce that originates at a new point because of the proposed improvement, the benefit is the difference between the total cost of producing and transporting the commodity to its destination with and without the plan.

- **Shift of destination benefits** - For commerce that is destined to a new point because of the proposed improvement, the benefit is the difference in net revenues to producers with and without the plan.

These steps are shown in Figure 8-1.

8.2.2 Software

The USACE uses HarborSym for deep draft navigation economic analyses. HarborSym is a certified planning-level simulation model designed to assist in economic analyses of coastal harbors. HarborSym incorporates risk analysis using Monte Carlo simulation.

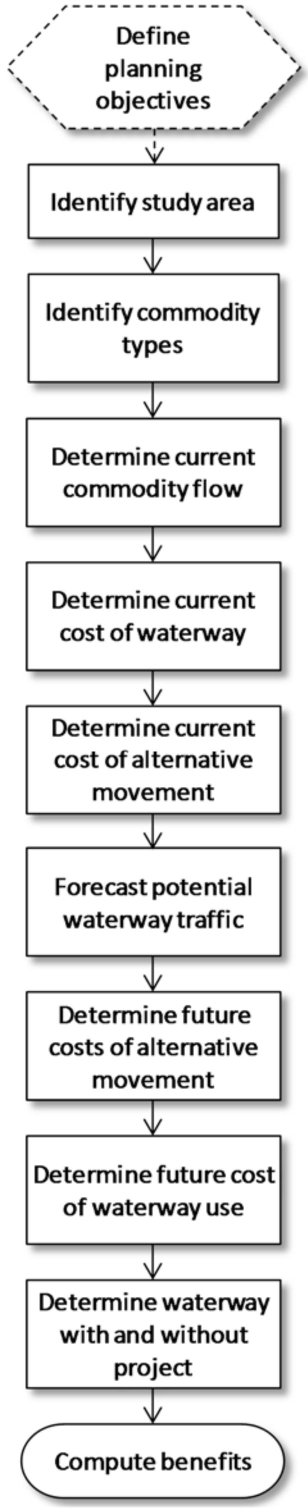

Figure 8-1. USACE Navigation Benefits Evaluation Method

(Adapted from ER 1105-2-100, Appendix E)

8.2.3 Analysis Results Displays

An example USACE navigation analysis result display template is shown in Table 8-1. Uncertainty is addressed using sensitivity analysis.

Table 8-1. Example USACE Analysis Display Template for Navigation Benefits

Navigation Benefits (1)	Alternatives			
	A (2)	B (3)	C (4)	X (5)
Cost reduction				
Shift of mode				
Shift in origin-destination				
New movement				
Total navigation benefits				

Table source: ER 1105-2-100, Appendix E

8.3 DWR-Recommended Approach to Computing Navigation Benefits

Although FloodSAFE projects are not anticipated to include navigation facilities, they may affect operations of the ports of Sacramento and Stockton, as well as the Sacramento deep water ship channel. Thus, the USACE deep-draft navigation benefit procedures are probably more applicable for FloodSAFE applications. Of these benefits, the cost reduction (same commodity, origin-destination, and harbor) benefits are likely to be the most applicable. In those instances where FloodSAFE projects have adverse effects on existing navigation facilities, then these benefit procedures can be used to estimate increases in transportation costs.

The DWR navigation benefit evaluation procedure is shown in Figure 8-2. Cost reduction benefits (or increases in shipping costs) shall be displayed using Table 8-2. No software applications are recommended.

If shipping activity is expected to change over significantly the analysis period, then the navigation benefits must be computed as many times as necessary to reflect those changes and reported for each time period using the format shown in Table 7-1. Appendix H describes how to do the present value analysis when the benefits (and costs) change over the analysis period.

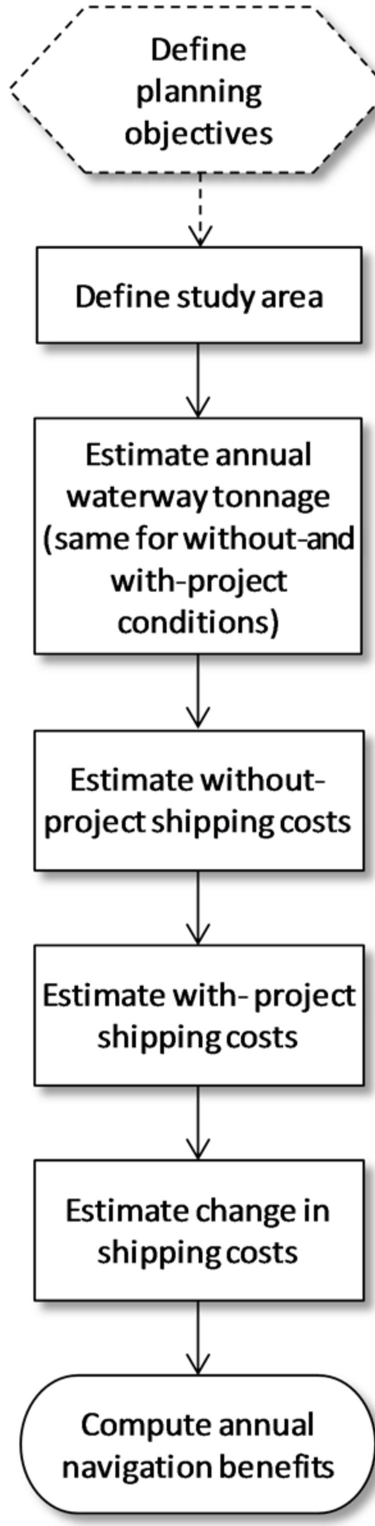

Figure 8-2. DWR Navigation Benefits Evaluation Method

Table 8-2. DWR-Recommended Template for Calculating Navigation Cost Reduction Benefits

Alternative Plans (1)	Annual Tonnage[1,2] (2)	Shipping Cost ($/ton) Without Project (3)	With Project (4)	Change (5)	Annual Benefit (or Cost) ($) (6)
				[(4)-(3)]	[(2)*(5)]
Plan A					
Plan B					
Plan C					
…					

Notes:

[1] Same for without- and with-project conditions.

[2] Annual tonnage is assumed to remain constant over without-project and with-project conditions, with the only change (increase or decrease) occurring to shipping costs.

8.4 Consistency between DWR and USACE Navigation Benefit Evaluation Approaches

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 8-3 compares recommended DWR methods and risk analysis procedures with those used by the USACE. DWR-recommended navigation benefit evaluation is based on the USACE cost reduction method, which computes a benefit based on a reduction in transportation cost. This method does not allow for changes in mode, origin, and/or destination of transported goods. Other more rigorous USACE navigation benefit evaluation methods are available that do account for changes in these other factors, but these situations are not anticipated with most FloodSAFE projects. However, if the significance of navigation benefits (relative to other project benefits) warrants a more rigorous analysis of alternative plans, then these other methods can be used. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

Table 8-3. Comparison of USACE and DWR-Recommended Navigation Benefit-Cost Analysis and Risk Analysis Methods

Benefit (1)	DWR Method (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Navigation			
Cost reduction	●	NA	●

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

8.5 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff must be contacted in advance for further guidance and approval prior to initiation of the study.

9.0 Commercial Fisheries Benefits

In this chapter:

- The conceptual basis for measuring commercial fishing benefits
- The USACE approach to computing commercial fisheries benefits
- The recommended DWR approach to computing commercial fisheries benefits
- Consistency between DWR and USACE approaches to computing commercial fisheries benefits
- Recommended templates for displaying analysis results
- What to do if DWR-recommended procedures are not to be used

9.1 Conceptual Basis for Measuring Commercial Fisheries Benefits

Fisheries benefits result from improving opportunities for commercial fishing, including marine, estuarine, and fresh water fish and shellfish.

9.1.1 How Commercial Fisheries Fit into Multiobjective Projects

The California Department of Water Resources (DWR) recognizes that projects that integrate multiple benefits, including flood risk management, water supply, recreation, ecosystem restoration, and commercial fisheries, may be more prudent investments than single-purpose projects. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

For multiobjective projects, the benefit and cost (B-C) analysis shall combine monetized benefits and costs for all project objectives. Nonmonetized benefits and costs shall be quantifiably assessed, when possible. Otherwise, they will be qualitatively described. This process is described in Chapter 11.

9.1.2 How Commercial Fisheries Benefits Are Categorized

Fisheries benefits result from improving opportunities for commercial fishing, including marine, estuarine, and fresh water fish and shellfish. The measurement standard and conceptual basis of fisheries benefits is the willingness to pay (WTP) for each increment of output from a plan.

However, fisheries benefits are typically measured by the differences in the value of the increased catch after deducting associated costs from gross income at dockside.

Fisheries benefits include (US Water Resources Council 1983):

- **No change in catch** - When no change in aggregate fish catch is expected as a result of a plan, benefits may be measured as cost savings to existing fish harvests (that is, avoided costs).

- **Change in fish catch** - When a change in aggregate fish catch is expected as a result of a plan, benefits may be measured by the change in net revenue associated with the change in catch.

9.2 USACE Approach to Computing Commercial Fisheries Benefits

The USACE approach to computing commercial fisheries benefits is described below.

9.2.1 Method

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), the US Army Corps of Engineers (USACE) describes the evaluation steps for commercial fishing benefits based on the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (WRC 1983). These steps are summarized below (USACE 2000):

1. Identify the affected areas. Identify the areas in which the proposed alternative plans will have biological impacts. Identify the areas in which the proposed alternative plans will have economic impacts. Describe the process by which the biological and economic study areas are linked.
2. Determine the without-project condition. Estimate the harvest of the relevant species in physical terms if a plan is not undertaken. Include a detailed description of the stock and institutional conditions that would exist without a project. Estimate the total cost of harvesting the relevant species in each of the relevant years if a plan is not undertaken. For each relevant species, determine the current weighted ex-vessel price corrected for seasonal fluctuations. [Note: ex-vessel prices are those received by fisherman for fish landed at the dock.]

3. Determine conditions that would exist with an alternative plan. Estimate the harvest of the exploited stocks if an alternative plan is undertaken. Estimate the seasonally corrected current price of the harvested species and the total cost of harvesting if a plan is undertaken. This will require an understanding of the economics of entry and exit for the fish harvesting industry, as well as the effects of a change in harvest rates on the catch per unit of effort.
4. Estimate national economic development (NED) benefits. Calculate the ex-vessel value of the harvest (output) for each alternative plan and for the without-project condition. Determine the harvesting costs, including non-project operation, maintenance, and replacement, for the level of catch (output) identified by each alternative plan and the without-plan condition. Compute the NED benefit from an alternative plan as the value of the change in harvest less the change in harvesting cost from the without-plan condition to the with-plan condition.

These steps are shown in Figure 9-1.

No specific risk-based procedures have been developed for commercial fishing evaluations. In studies where fishing benefits constitute a significant portion of NED effects, sensitivity analysis of key variables such as harvest costs, harvest rates, and/or ex-vessel prices provides a description of uncertainty.

9.2.2 Software

No specific software is required to compute commercial fisheries benefits.

9.2.3 Analysis Results Displays

An example analysis result display template for commercial fisheries benefits is shown in Table 9-1.

Table 9-1. Example USACE Analysis Display Template for Commercial Fisheries Benefits

Commercial Fisheries Benefits (1)	Alternatives			
	A (2)	B (3)	C (4)	X (5)
Change in output				
Value of change in output				
Change in costs				
NED benefit				

Table source: ER 1105-2-100, Appendix E

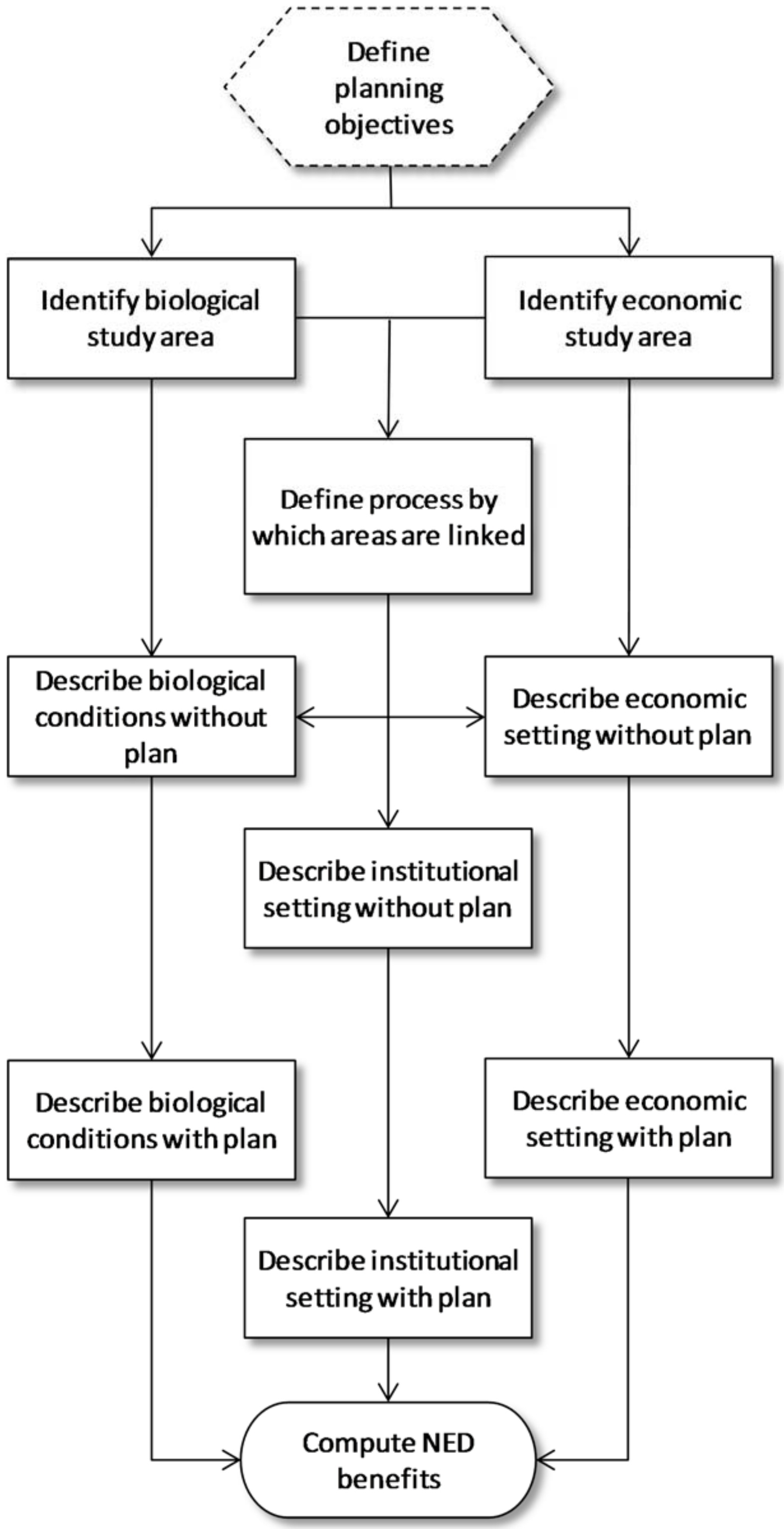

Figure 9-1. USACE Commercial Fisheries Benefit Evaluation Method

(Adapted from ER 1105-2-100, Appendix E)

9.3 DWR-Recommended Approach to Computing Commercial Fisheries Benefits

The recommended DWR approach to compute commercial fishing benefits is based on USACE procedures, although with some simplifications. The DWR approach for computing commercial fishing benefits is shown in Figure 9-2.

Table 9-2 shall be used to display commercial fishing benefits based on the simplified procedure for each alternative plan. No software applications are recommended.

If commercial fishing activity is expected to change significantly over the analysis period, then the commercial fishing benefits must be computed as many times as necessary to reflect those changes and reported for each time period using the format shown in Table 9-2. Appendix H describes how to do the present value analysis when the benefits (and costs) change over the analysis period.

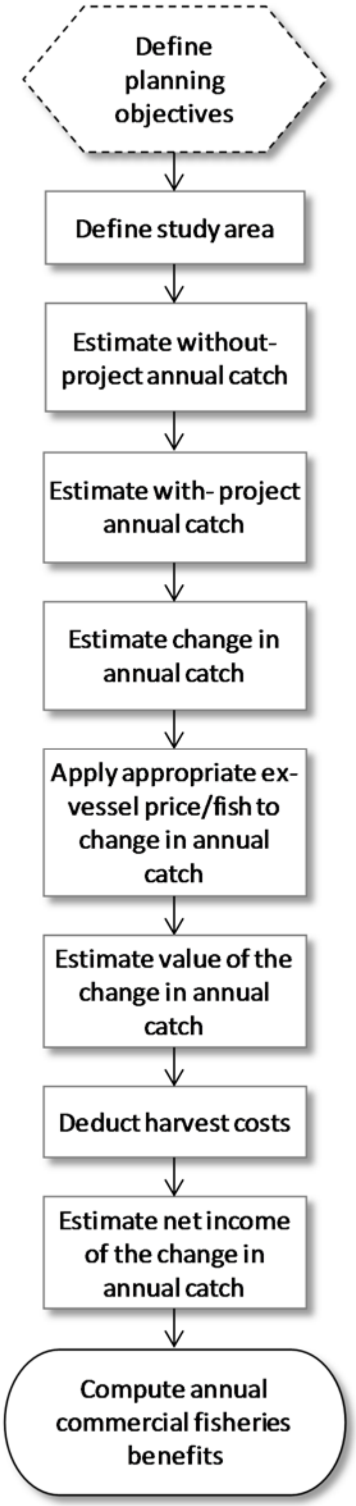

Figure 9-2. DWR Commercial Fishing Benefit Evaluation Method

Table 9-2. DWR-Recommended Template for Calculating Commercial Fisheries Benefits Based on Changes in Annual Catch, Ex-Vessel Prices, and/or Harvest Costs

Alternative Plans (1)	Annual Catch (# of Fish)			Ex-Vessel Value[1]		Harvest Costs		Annual Benefit ($) (9)
	Without Project (2)	With Project (3)	Change (4)	$/Fish Value (5)	Total Value ($) (6)	$/Fish Cost (7)	Total Cost ($) (8)	
			[(3)-(2)]		[(4)*(5)]		**[(4)*(7)]**	[(6)-(8)]
Plan A								
Plan B								
Plan C								
…								

Note:
[1] Prices received by fisherman at the dock.

9.4 Consistency between DWR and USACE Commercial Fishing Benefit Evaluation Approaches

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 9-3 compares recommended DWR methods with those used by the USACE. DWR-recommended navigation benefit evaluation is based on the USACE change in catch method. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

Table 9-3. Comparison of USACE and DWR-Recommended Commercial Fisheries Benefit-Cost Analysis and Risk Analysis Methods

Benefit (1)	DWR Method (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Commercial fisheries			
Change in catch	●	NA	●

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

9.5 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods and software applications will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff must be contacted in advance for further guidance and approval prior to initiation of the study.

10.0 Other Effects

In this chapter:

- Introduction to other effects
- Conceptual basis of measuring secondary (regional economic) effects
- USACE approach to computing secondary (regional economic) effects
- Recommended DWR approach to computing secondary (regional economic) effects
- Conceptual basis of measuring social effects
- USACE approach to computing social effects
- Recommended DWR approach to computing social effects
- Consistency between USACE and DWR approaches to computing other effects
- What to do if the DWR-recommended approach is not to be used

10.1 Introduction to Other Effects

The preceding chapters focus on primary economic benefits, which are compared with primary costs in a benefit and cost (B-C) analysis to evaluate the economic justification of a project. However, there are other beneficial and adverse effects that should also be considered in a complete assessment of the benefits and costs of a proposed project. These other effects include secondary effects, which are the changes in regional economic activity resulting from the construction and operation of the project. Primary and secondary impacts are included in an economic impact analysis (Figure 2-1). In addition, projects may also have social effects, which are the changes in social "well-being" as a result of the project. These other effects are described in this chapter.

Although these other effects have always been a part of federal and state water resource planning, to various degrees, the importance of considering them was elevated following Hurricane Katrina and its lasting impacts:

"Hurricane Katrina caused a significant economic hardship to not just the immediate Gulf Coast but for entire counties, watersheds, and the State of Louisiana. Besides the devastating damage to homes (which [is] captured by the NED account), hundreds of thousands lost their jobs, property values fell, and tourism and tax revenues declined significantly and moved to other parts of the U.S. In this example, the RED [regional economic development] account provided a better story of the overall impact to the region" (USACE IWR 2011).

10.2 A Note About Terminology

In this chapter, the terms "effects" and "impacts" are used interchangeably for the most part. Both terms refer to beneficial and/or adverse changes resulting from an action, project, or program.

10.3 Conceptual Basis for Measuring Secondary Effects

Secondary effects are the changes in regional economic activity from subsequent rounds of re-spending of dollars as a result of constructing and operating a project (USACE IWR 2011). For example, the expenditure of state and/or federal funds in a region to construct and operate a water resource project will stimulate subsequent rounds of spending in a local or regional economy. Regional economic activity may also be stimulated by the project's delivery of primary benefits. For example, urban and agricultural development (intensification benefits) resulting from improved flood protection, or additional water supplies, may also stimulate the local or regional economy. Or, secondary effects may also be described in terms of potential regional economic losses resulting from a flood or other catastrophic disaster without a project.

10.3.1 How Secondary Effects Fit into Multiobjective Projects

The California Department of Water Resources (DWR) recognizes that projects that integrate multiple benefits, including flood risk management, water supply, recreation, ecosystem restoration, and commercial fisheries, may be more prudent investments than single-purpose projects. Thus, to the greatest extent possible, multi-benefit projects are encouraged (DWR 2009, DWR 2012j).

For multiobjective projects, the B-C analysis combines the primary benefits and costs for all project objectives, as described in Chapter 11. But, each primary benefit will have its own set of secondary effects, which are not included in that B-C analysis. In addition, secondary effects may also be associated with project costs. For example, the use of funds for public investment excludes those funds from being used for private investment, thus forgoing secondary benefits resulting from such investment.

The forgoing of these secondary benefits in the private sector is a secondary cost not captured in the proposed project's B-C analysis.

10.3.2 How Secondary Effects Are Described

Secondary effects are the changes in regional economic activity from subsequent rounds of re-spending of dollars as a result of constructing and operating a project. Secondary effects can occur from (a) project construction and operation and (b) the "ripple" effects resulting from the values of goods and services produced by the project (the primary benefits). Secondary effects can also be described in the context of avoided economic losses within a community, if catastrophic flooding or another disaster were to occur without a project.

> **Who Developed I-O Analysis?**
>
> Wassily Leontief (1905-1999) received the 1973 Nobel Prize in Economics for his development of the I-O economics model. His example for an I-O model: "When you make bread, you need eggs, flour, and milk. And if you want more bread, you must use more eggs. There are cooking recipes for all the industries in the economy" (USACE IWR 2011).

To evaluate secondary effects requires a model of the regional economy. The most common approach is to use input-output (I-O) analysis, which measures the flow of commodities and services among industries, institutions, and final consumers within an economy or study area. An I-O model uses a matrix representation of a region's economy to predict the effect that changes in one industry will have on others as well as consumers, government, and foreign suppliers in the economy. I-O models capture all monetary market transactions in an economy, accounting for inter-industry linkages and availability of regionally produced goods and services. The resulting mathematical formulas allow I-O models to simulate the economic impacts of a change in one or several economic activities on an entire economy. It is a static, linear model of all purchases and sales, or linkages, between sectors of an economy (DWR 2012g).

The measurement of linkages within a regional economy is based on the concept of a multiplier. A multiplier is a single number that quantifies the total economic effect resulting from initial spending, or output in a sector. For example, an output multiplier of 1.7 for the "widget" production sector indicates that every $100,000 of widgets produced (the initial spending, or output in this industry) supports a total of $170,000 in business sales throughout the economy (total output of all linked industries), including the initial $100,000 in widget output. A multiplier must also account for "leakages"—subsequent rounds of spending which occur outside of the study area and the portion of consumer spending (induced effects) that is not spent (i.e., saved).

Many types of multipliers can be produced by an I-O model, including specific multipliers for estimating impacts on industry output, employment, and value added—the main metrics of I-O analysis results. These metrics are summarized below and illustrated in Figure 10-1 (DWR 2012g).

- **Industry output –** The value of goods and services produced in a region, which includes the value of intermediate inputs (i.e., goods and services used in the production process) and value added. Intermediate goods may or may not originate from a region. For example, direct industry output for construction refers to the value of construction, although some of the intermediate inputs used in the construction process may be imported into the region.

- **Value added –** The difference between industry output and the cost of intermediate inputs, which consists of four components: (1) employee compensation, (2) proprietor income, (3) other property income, and (4) indirect business tax (sales and excise taxes). Labor income is the sum of employee compensation and proprietor income.

- **Employment –** The number of annual full-time, part-time, and temporary positions. Estimated changes in employment are tied to economic relationships between industry output and labor productivity, regardless of availability and fluidity in the local labor force.

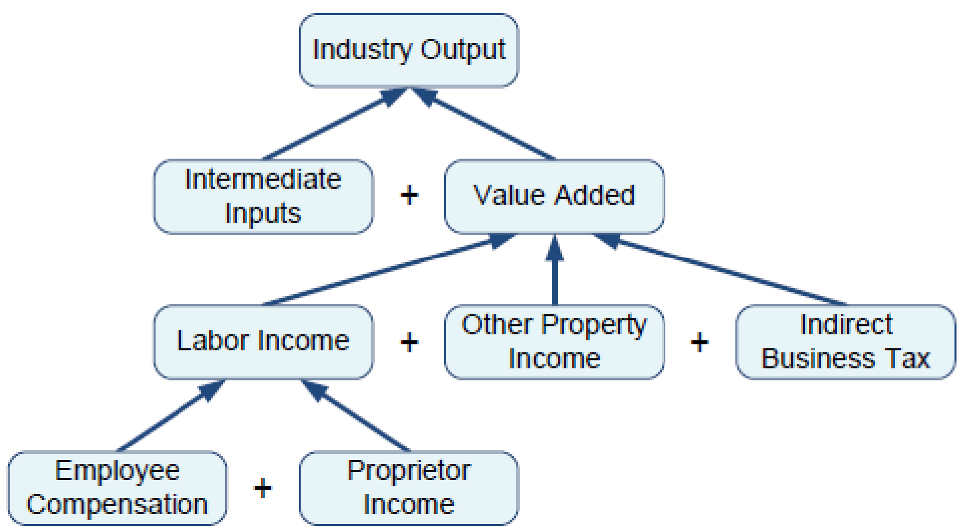

Figure 10-1. Relationships of Input-Output Analysis Metrics

(DWR 2012g)

Key sources of information for these metrics are (USACE IWR 2009):

- **US Department of Labor's Bureau of Labor Statistics (BLS) –** Provides detailed industry data on employment, hours, and worker's earnings for counties, metropolitan statistical areas, states, and the nation. (This information is available from the BLS website.

- **US Department of Commerce's Bureau of Economic Analysis (BEA) –** Provides quarterly data on state and MSA gross domestic product as well as state and local personal income. (This information is available from the BEA website.)

The multipliers mentioned above account for these types of economic effects (DWR 2012g):

- **Direct effects –** The response of a given industry (i.e., changes in output, value added, and employment) based on final demand for that industry.

- **Indirect effects –** The changes in output, value added, and employment resulting from the iterations of industries purchasing from other industries caused by the direct economic effects.

- **Induced effects –** The changes in output, value added, and employment caused by the expenditures associated with changes in household income generated by direct and indirect economic effects.

Total effects are the sum of direct, indirect, and induced effects.

A number of off-the shelf software applications are available to do I-O analysis, but one of the more commonly used is IMPLAN (IMpact analysis for PLANning), formerly Minnesota IMPLAN Group. IMPLAN contains multiplier models of economies at the national, state, county, or ZIP-code levels (IMPLAN Group). Other software applications include those used by the US Bureau of Economic Analysis' Regional Input-Output Modeling System (RIMS II) available from BEA's website and Regional Economic Models Inc. (REMI).

10.4 USACE Approach to Computing Secondary Effects

The USACE includes the evaluation of secondary effects in the Regional Economic Development (RED) account established by the 1983 P&G (*Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*). The RED account displays changes in the distribution of regional economic activity that result from alternative plans, as measured by regional income and regional employment (WRC 1983). A previous version of the 1983 P&G further described RED as (USACE IWR 2011):

"Through its effects—both beneficial and adverse—on a region's income, employment, population, economic base, environment, social development and other factors, a plan may exert a significant influence on the course and direction of regional development. The regional development account embraces several types of beneficial effects, such as (a) increased regional income; (b) increased regional employment; (c) population distribution; (d) diversification of the regional economic base; and (e) enhancement of environmental conditions of specific regional concern."

Unlike the federal National Economic Development (NED) account, which is required for federal feasibility studies, a RED account analysis is discretionary. Thus, the RED account is often examined in less detail than NED. However, recent USACE guidance (EC 1105-2-409) has strengthened the case for considering RED impacts in the formulation and evaluation of projects. This guidance encourages evaluation of all four P&G accounts: NED, EQ, RED, and OSE (described below). Events surrounding Hurricane Katrina and its aftermath have also increased awareness of the importance of considering non-NED effects (USACE IWR 2011).

The distinction between the NED (primary) and RED (secondary) benefits is a matter of perspective. For example, if a federal project enables a firm to leave one state to locate in the newly protected floodplain of another state, the increase in regional income for the project area may come at the expense of the former state's loss. Thus, these income effects would not influence the nation's output of goods and services (e.g., NED), since the gain in one state is offset by the loss in another. But, these changes in regional income (RED) are important to each state (USACE IWR 2011). Similarly, at a state level, one region could benefit from a project while another one loses.

10.4.1 Method

The following steps for conducting a secondary (RED) analysis were summarized from the USACE regional economic development procedures handbook, and follow the federal planning process (USACE IWR 2011):

1. Identify problems and opportunities. This step defines the functional economic area for the RED economic impact analysis, which may be different than that used for the NED flood damage analysis. Factors to consider when defining the economic study area are: initial impact site, residential location of the labor force (commuters), travel corridors, location of supporting industries and services, and location of consumers. Often, the regional economic study area is defined using one or more counties, because many of the software applications used for a RED analysis rely on county income and employment data (see, for example, Figure 2-2). Once the economic study area has been defined, this step also identifies the RED metrics that should be used for the particular study (such as income, employment, output, etc.).
2. Inventory and forecast conditions. Based on the economic study area and the RED metrics identified in Step 1, collect current and forecasted data. This information should assist the team to understand the potential impact of severe or long-term flooding on the local and regional economies which should be described in the without-project condition.
3. Formulate alternative plans. Plan formulation is the process of building plans (based on specific management measures) that meet planning objectives and address planning constraints. If the team decides that RED should be a significant driver in the overall decision, then the plans should address the local and regional economic needs identified in the previous two steps. For example, if the study area is plagued with high and persistent unemployment, potential management measures could consider economic incentives, perhaps in the form of more labor-intensive construction components, so that RED benefits could be realized in addition to NED benefits.
4. Evaluate alternative plans. Evaluate how each plan affects the RED metrics identified in Step 3, compared to without-project conditions.
5. Compare alternative plans. Display a summary of the effects of each plan on the RED metrics to assist decision makers' recommendations for the preferred plan.

In addition to the metrics shown in Figure 10-1, USACE guidance also includes the metric of "population distribution." This metric focuses on the distribution of benefits to the population. For example, if a group of disadvantaged people are made better off in a local area as a result of a project, then the reduction in the number of people requiring public assistance could arguably be considered a regional economic development benefit (USACE IWR 2011). [Note: Such an analysis addresses the “equity effects” described in Chapter 2.]

The USACE has identified example secondary benefits for flood risk management, water supply, ecosystem restoration, and recreation project objectives, as shown in Table 10-1.

Table 10-1. Example Water Resource Secondary Economic Benefits

Benefit Category (1)	What Is Described (2)
Flood risk management	
Construction*	Additional construction-related activity and resulting spillovers to suppliers.
Revenues	Increased local business revenues as a consequence of reduced flooding, particularly catastrophic floods.
Tax revenues	Increased income and sales taxes from the direct project and spillover industries.
Employment*	Short-term increase in construction employment. With catastrophic floods, the reduction in significant losses in local employment (apart from the debris and repair businesses, which may show temporary gains).
Population distribution	Benefit (often to disadvantaged groups) from the creation of a flood-free zone.
Increased wealth	Potential increase in wealth for floodplain residents as less is spent on damaged property, repairs, etc. Potential increase in property values.
Water supply	
Construction	Regional economic activity relating to construction of water supply features.
Tax revenues	Increased federal and state taxes from workers on the project as well as sales taxes from recreational activities.
Economic output	Boost to local M&I and agricultural industries from additional water supply that is not captured in the primary benefit analysis.
Recreation	Revenues generated from recreational activities dependent on water.
Ecosystem restoration	
Construction	Regional economic activity relating to construction of restoration features.
Increased property values	Potential increase in resale values for homes adjacent to newly-restored areas; higher property values and increased property tax collections.
Tax revenues	Increased federal and state taxes from workers on the project as well as sales taxes from recreational activities.
Recreation	Revenues generated from recreational activities.
Recreation	
Construction	Regional economic activity relating to construction of recreation features.
Tax revenues	Increased federal and state taxes from workers on the project.
Economic output/ business revenues	Visitor spending on recreation-related activities.

Table source: USACE IWR 2011

Note:
* = quantified for the 2012 CVFPP (DWR 2012g).

10.4.2 Analysis Results Display Templates

The USACE South Pacific Division developed a sample template to display RED benefits for feasibility studies. This template, which emphasizes regional income and employment, is shown in Table 10-2. Other example RED analysis display results are provided in the USACE RED procedures handbook (USACE IWR 2011).

Table 10-2. USACE-Recommended Regional Economic Development (RED) Display Template

RED Benefits (1)	Plans A (2)	B (3)	C (4)	X (5)
Employment and labor force				
Business and industrial activity				
Local government finance				

Table source: USACE IWR 2011

10.5 DWR-Recommended Approach to Computing Secondary Effects

The DWR approach to computing regional economic benefits is shown in Figure 10-2. The first step is to identify the regional economic study area, which may differ from the study region used to evaluate, for example, flood risk management benefits. Typically, regional economic analyses are conducted based on county information (for example, see Figure 2-2). Next, the regional economic effects that are to be evaluated are identified (Table 10-1), along with the evaluation metrics (Figure 10-1).

The evaluation of regional economic effects often requires the use of a software application (for example, IWR Planning Suite). DWR economic analysis staff can advise as to which software application to use.

In addition to the USACE handbook for RED analyses, the study team should review these resources before doing a regional economic analysis:

- **2012 CVFPP *Regional Economic Analysis for the State Systemwide Investment Approach* –** This study estimated (a) secondary output and employment effects as a result of constructing measures associated with the State Systemwide Investment Approach and (b) secondary potential business output and employment losses attributable to flooding (DWR 2012g).

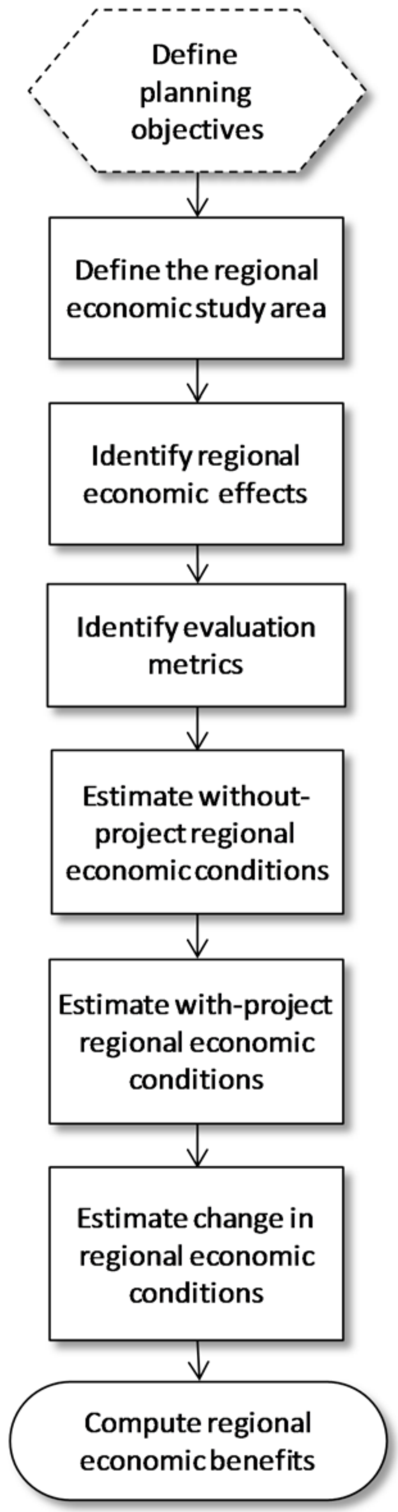

Figure 10-2. DWR Regional Economic Benefits Evaluation Method

- **CA DWR Bulletin 210: *Measuring Economic Impacts: The Application of Input-Output Analysis to California Water Resources Problems* (1980) –** This document describes multiregional economic impact analyses for several California water resource projects considered in the early 1980s, as well as for the 1977 California drought. The report provides detailed descriptions of the 1976 statewide and multiregional (i.e., hydrologic region) input-output models developed for these analyses (DWR 1980). [Note: electronic copies of Bulletin 210 are available from the DWR Economic Analysis Section and David Ford Consulting Engineers.]

10.6 How Social Effects Are Defined

Social effects refers to how the constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness are affected by some condition or proposed intervention. The importance of social effects was recognized by the Flood Control Act of 1936: "the Federal Government should improve or participate in the improvement of navigable waters or their tributaries including watersheds thereof, for flood control purposes if the benefits to whomever they may accrue are in excess of the estimated costs, *and if the lives and social security of people are otherwise adversely affected*" (emphasis added) (USACE IWR 2009).

10.7 How Social Effects Are Categorized

The USACE has identified a list of factors that describe social "well-being" (USACE IWR 2009):

- **Health and safety –** The basic human need for personal and group safety.
- **Economic vitality –** The economy's ability to provide a good standard of living for residents now and into the future.
- **Social connectedness –** The pattern of social networks within which individuals interact, which largely provides meaning and structure to life.
- **Identity –** The sense of self as a member of a group, distinct from and distinguished from other groups by values, beliefs, norms, roles, and culture.

- **Social vulnerability and resiliency –** Social vulnerability refers to the capacity for being damaged or negatively affected by hazards or impacts, which is associated with characteristics of the population. Certain groups of the population are more vulnerable than others (e.g., the aged and those that may not have the means to evacuate). Resiliency is the capability to cope with and recover from a traumatic event.

- **Participation –** The ability to interact with others to influence social outcomes.

- **Leisure and recreation –** Having leisure time and the ability to spend it in preferred recreational pursuits.

10.8 USACE Approach to Computing Social Effects

The USACE includes the evaluation of social effects in the Other Social Effects (OSE) account established by the 1983 P&G, which displays beneficial and adverse effects on social well-being. The categories of effects in the OSE account include urban and community impacts; life, health, and safety factors; displacement; long-term productivity; and energy conservation (USACE 2000).

Similar to the RED account, an OSE account analysis is discretionary. Thus, the OSE account is often examined in less detail than NED. However, recent USACE guidance (EC 1105-2-409) encourages evaluation of all four P&G accounts: NED, EQ, RED, and OSE. Events surrounding Hurricane Katrina and its aftermath have also increased awareness of the importance of considering non-NED effects.

The USACE has published a handbook that provides indicators, tools, methods, and case studies for developing OSE information and a framework for using such information in the planning process. In this handbook, social effects are defined as "how the constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness are affected by some condition or proposed intervention" (USACE IWR 2009).

10.8.1 Indicators

The USACE has identified indicators (i.e., metrics) to be used for the "well-being" factors listed above. These are shown in Table 10-3 through Table 10-10 (USACE IWR 2009).

10.8.2 Tools

The USACE has identified various tools to evaluate social effects, including workshops, interviews, surveys, focus groups, charrettes, and quality of life indices (USACE IWR 2009).

Table 10-3. USACE Other Social Effects (OSE) Indicators: Basic Social Statistics

Indicators (1)	Sources of Information (2)
Population	
Total population	Census quick facts; Census profiles; American Fact Finder
Population % change	Census quick facts; Census profiles; American Fact Finder
Population projections	CA Department of Finance; DWR Economic Analysis Section (demographics)
Race and ethnicity	Same as population
Age	
Median age	Same as population
% 65 and above	Same
% under 18	Same
Education	
% high school graduates	Same as population
% college graduates	Same
Income and poverty status	
Median household income	Same as population
% persons below poverty	Same
Housing	
Housing mix and values	Same as population
Housing units	Same
Homeownership rate	Same
% housing units in multiunit structures	Same
Median value of owner occupied housing units	Same
Employment and industry	
Major industries	Chamber of Commerce
Unemployment rate	US Bureau of Labor Statistics
Key questions • Who lives in the area? • How do residents make a living? • How can the area's housing stock be described? • What are the patterns of wealth and poverty? • How educated are the area's residents?	

Table source: USACE IWR 2009

Table 10-4. USACE Other Social Effects (OSE) Indicators: Social Vulnerability

Indicators[1] (1)	Sources of Information (2)
Vulnerability	
% population 65 and above	Census quick facts; Census profiles; American Fact Finder National Oceanic and Atmospheric Administration coastal risk vulnerability tools
% population under 18	Same
% persons below poverty	Same
% population minority residents	Same
% of female head of households	Same
Persons with disabilities	Same
# of mobile homes	Same
# and location of special use facilities (nursing homes, hospitals, schools, day care centers, etc.)	Telephone directories; "Google Map;" FEMA HAZUS-MH databases
Key question Are any groups differentially exposed to hazards or impacts from hazards?	

Note:
[1] These indicators can be combined with hazard information (flood zones, storm surge zones, etc.) and road network information and evacuation routes to create a place vulnerability analysis (USACE IWR 2009).

Table 10-5. USACE Other Social Effects (OSE) Indicators: Social Connectedness

Indicators[1] (1)	Sources of Information (2)
Citizen descriptions or ratings of the community as a good place to live, friendliness, effectiveness, etc.	Community survey conducted as part of comprehensive plan process, chamber of commerce surveys, etc.
# of civic and community organizations/numbers of members	Library and online searches
Community vision and outlook for the future	Community comprehensive plan, interviews
Community improvements underway	Community comprehensive plan; community capital improvements plan
% of voters casting ballots in the last election	City/county clerk's office
Number of citizens attending open municipal government meetings in the past year	City/county clerk's office
Views of quality of life in the community	Community surveys conducted as part of comprehensive plan process; chamber of commerce surveys; etc.
Views on equity and diversity in the community	Surveys conducted by city/county human services office
Key questions • What is the structure of community leadership? • What is the community's vision for the future? • What are the structure and function of community voluntary organizations? • How are community interpersonal networks, leadership, visions for the future, and relationships among voluntary organizations likely to be affected by future without- and future with-project conditions?	

Note:
[1] These indicators refer to patterns of social networks within which individuals interact and that provide meaning and structure to life. Communities having a robust civic infrastructure composed of many and diverse opportunities for connectedness are likely to be more satisfying to individuals and more economically and socially progressive and resilient (USACE IWR 2009).

Table 10-6. USACE Other Social Effects (OSE) Indicators: Economic Vitality

Indicators[1] (1)	Sources of Information (2)
Employment by industry	US Bureau of Labor Statistics; US Census-county business patterns
Top 10 employers	Chamber of Commerce
Wages	US Bureau of Labor Statistics
Average annual cost of living	US Bureau of Labor Statistics-Consumer Price Index
Average number of hours worked per week	US Bureau of Labor Statistics-current employment statistics
Number of homes sold in past year; annual % change	Local Realtors association
% of businesses locally owned	Chamber of Commerce
Unemployment rate	US Bureau of Labor Statistics

Key questions

- What is the economic base of the community?
- Is economic development growing, stagnant, or declining?
- How are jobs, income, and employment opportunities likely to be affected by future without- and future with-project conditions?

Note:
[1] These indicators refer to the capacity of the economy to provide a good standard of living for residents now and into the future (USACE IWR 2009).

Table 10-7. USACE Other Social Effects (OSE) Indicators: Leisure and Recreation

Indicators[1] (1)	Sources of Information (2)
Favorite pastimes	Recreational surveys conducted by university departments or state government agencies
Hours spent in recreation/leisure activities	Recreational surveys conducted by university departments or state government agencies
Average distance travelled in recreation/leisure activities	Recreational surveys conducted by university departments or state government agencies
Inventory of local recreational areas, sizes, features	Library and online research
# of visitor days by season spent at recreational areas	Facility records
Local/nonlocal visitation at recreation sites	Facility records
#/extent of restrictions on use of recreational facilities from advisories, alerts, or weather-related closures	Facility records

Key question

How are leisure and recreational opportunities likely to be affected by future without- and future with-project conditions?

Note:
[1] These indicators refer to the amount of time available to spend in leisure and the opportunities to spend leisure time in preferred recreational pursuits (USACE IWR 2009).

Table 10-8. USACE Other Social Effects (OSE) Indicators: Participation

Indicators[1] (1)	Sources of Information (2)
Voter turnout	City/county clerk
# of special citizens commissions established to address local issues	City/county government
Planning process participation	
Access of public to planning documents and information	Planning team self-assessment; verification with stakeholders
Ability of all stakeholders to actively participate in each stage of the planning process	Same
Ability of stakeholders to influence planning outcomes	Same
Planning process provides regular opportunities to share information with stakeholders	Same
Key question Are opportunities for all affected groups' participation provided for in all phases of the planning process?	

Note:
[1] These indicators refer to the ability of citizens to interact with others to influence social outcomes (USACE IWR 2009).

Table 10-9. USACE Other Social Effects (OSE) Indicators: Identity

Indicators[1] (1)	Sources of Information (2)
Core values	Interviews or consultations with community members and knowledgeable third parties
Key traditions	Same
Language	Same
Sources of group pride and honor	Same
Key question How are communities' sense of cultural security and identity affected by future without- and future with-project conditions?	

Note:
[1] These indicators refer to a community's core values, traditions, and other sources of pride that help define it as distinct from others (adapted from USACE IWR 2009).

Table 10-10. USACE Other Social Effects (OSE) Indicators: Health and Safety

Indicators[1] (1)	Sources of Information (2)
Loss of life associated with hazards	CA Emergency Management Agency; FEMA
Exposure to hazards	Same
Key question What risks and benefits to human health and safety are associated with future without- and future with-project conditions?	

Note:
[1] These indicators refer to perceptions of personal and group safety and freedom from risks associated with natural and social hazards (USACE IWR 2009).

10.8.3 Method

The USACE has identified the following steps for analyzing other social effects (USACE IWR 2009):

1. Identify problems and opportunities. This step defines the "social landscape" or profile—e.g., identifying who lives in the study area, who has a stake in the problem or issue, and why it is important to them. This analysis may identify special circumstances or issues requiring more detailed analysis. For example, in a study which primarily focuses on flood damage reduction, particularly vulnerable populations (e.g., the elderly, low-income groups) would likely be special focuses for analysis.
2. Inventory and forecast conditions. This step describes the current and future state of social conditions of concern to stakeholders in the absence of a water resource project.
3. Formulate alternative plans. This step describes desired future social conditions; rankings and priorities among stated desired future conditions; and specific management measures that may be preferred to achieve a desired social future condition and an understanding of why measures are preferred. It should include an assessment of key underlying interests that management measures and alternatives should address.
4. Evaluate alternative plans. This step describes the plans' effects on social conditions of concern, that is, an evaluation of each plan's adequacy in contributing to desired future social conditions.
5. Compare alternative plans. In this step, a summary of the other social effects of each plan is displayed to assist decision makers' recommendations for the preferred plan.

10.8.4 Analysis Results Display Templates

An example USACE OSE analysis results summary table is shown in Table 10-11. Some of the OSE effects are quantified, whereas others are qualitatively described.

An example USACE plan comparison for all four planning accounts (NED, EQ, RED, and OSE) is shown in Table 10-12.

10.8.5 Loss of Life and Injuries

Because (a) the federal NED planning account describes monetary effects of plans and (b) loss of life and injuries associated with flood events are not monetized by the USACE, these effects are included in the OSE planning account. However, the reduction in loss of life and injuries is an inundation reduction (IR) benefit, monetized or not, and is described in Chapter 3, although the focus is on the key benefit—reduction in loss of life.

Table 10-11. Example Display of Other Social Effects (OSE) among Alternative Plans (Some of the Effects Are Quantified; Others Are Qualitatively Described)

Effects (1)	Plan A (2)	Plan B (3)	Plan C (4)
Exposure			
Population at risk for flooding (500 year/100 year)	30,000 25,000	30,000 25,000	30,000 25,000
Population provided protection	22,000	25,000	17,000
Number to be relocated	1,000	700	500
Businesses to be relocated	30	3	30
Location			
% of 100-year (annual p = 0.01) floodplain protected in CBD Neighborhood A Neighborhood B Neighborhood C	 100 100 100 100	 100 100 100 100	 100 0 100 100
Disruptive effects of plan localized in:	CBD	Few	Neighborhood A
Timing & duration			
Time before flood protection provided	8 – 10 yrs	10 – 12 yrs	5 – 7 yrs
Duration of construction	4 yrs	6 yrs	3 yrs
Risk of loss of life in events exceeding design capacity	Minimal	Minimal	Minimal- moderate
Effects on key interests expressed by stakeholders			
Preservation of commercial space	Somewhat	Yes	Yes
Provide community access to river	Yes, in cooperation with sponsor and other programs	Yes, in cooperation with sponsor and other programs	Yes, in cooperation with sponsor and other programs
Provide space for community events	Potentially, in cooperation with sponsor and other programs	Potentially, in cooperation with sponsor and other programs	Potentially, in cooperation with sponsor and other programs
Consistent with community vision	Somewhat	Yes	No
Addresses special needs of elderly, poor, and disabled	Yes, in cooperation with sponsor and other programs	Yes, in cooperation with sponsor and other programs	No

Table source: USACE IWR 2009

Table 10-12. Example USACE Plan Comparison for All Four Planning Accounts

Effects[1] (1)	Plan A		Plan B	
	Pros (2)	Cons (3)	Pros (4)	Cons (5)
NED	$1.5 M in average annual NED benefits in reduced flood damages	$1 M in average annual cost	$1.7 M in average annual NED benefits in reduced flood damages	$1.5 M in average annual cost
EQ	Preserves 500 acres of riverine habitat	Loss of 5 acres of wetlands	Preserves 600 acres of riverine habitat	Loss of 5 acres of wetlands
RED	Local business income increases by 30%; 5,000 additional jobs created	1% increase in local taxes	Local business income increases by 35%; 6,000 additional jobs created	1.5% increase in local taxes
OSE	Provides the opportunity for continued growth and development of community having robust civic infrastructure and diverse and vibrant neighborhoods	Increased tax burden on all, but greater burden on the community's working poor	Provides the opportunity for continued growth and development of community having robust civic infrastructure and diverse and vibrant neighborhoods, plus a more economically resilient business community, and slightly more recreational access to the river for the community	Increased tax burden on all, but greater burden on the community's working poor

Note:
[1] (National Economic Development [NED], Environmental Quality [EQ], Regional Economic Development [RED], and Other Social Effects [OSE]) (USACE IWR 2011)

10.9 DWR-Recommended Approach to Evaluating Social Effects

The DWR approach to evaluating social effects is shown in Figure 10-3. The first step is to identify the study area for which social effects are to be evaluated. Next, identify the indicators that are most appropriate for the particular study. For example, many of the basic social statistics (Table 10-3) and economic vitality indicators (Table 10-6) would be applicable to most water resource project evaluations, but a flood risk management (FRM) study would also likely consider the social vulnerability (Table 10-4) and health and safety indicators (Table 10-10). In addition, information concerning the proportion of properties that have purchased flood insurance may indicate how quickly a community can recover from a flood emergency, because funds should be available relatively quickly to speed reconstruction and other recovery efforts. Using the indicated data sources, it should be possible to quantify these indicators at least for existing (without-project) conditions. Quantification of these indicators describes the social profile of the study area and is an extension of the structure inventory compiled for an FRM study. This social profile also provides the basis for evaluating equity effects described in Chapter 2.

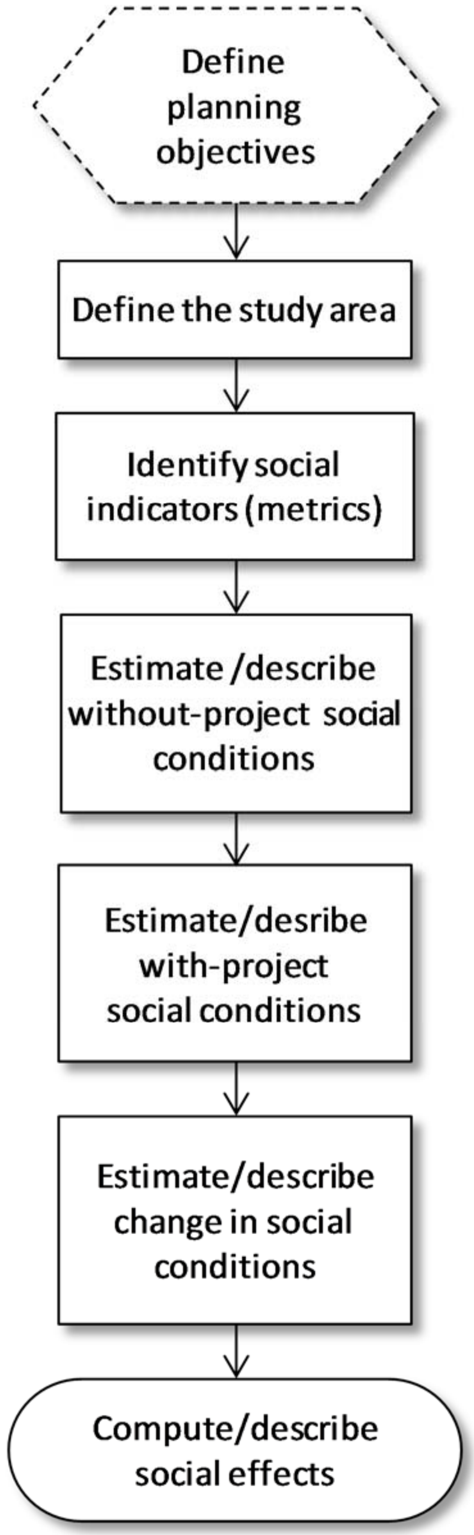

Figure 10-3. DWR Social Effects Evaluation Method

The next steps evaluate and compare the effects of alternative plans on these social indicators (e.g., the without-plan and with-plan comparison). While it may be difficult to quantify the effects of plans on these social indicators, qualitative descriptions of the effects can be displayed, as shown in Table 10-11.

10.10 Consistency between DWR and USACE Secondary Benefit and Social Effects Evaluation Approaches

The recommended DWR secondary (regional economic) benefit and social effects evaluation approaches are consistent with those used by the USACE. However, differences may occur in applying these methods, especially with the secondary regional economic effects. As mentioned above, if a federal project enables a firm to leave one state to locate in the newly protected floodplain of another state, the increase in regional income for the project area may come at the expense of the former state's loss. Thus, these income effects would not influence the nation's output of goods and services (e.g., NED), since the gain in one state is offset by the loss in another. But, these changes in regional income (RED) are important to each state (USACE IWR 2011). Similarly, at a state level, one region could benefit from a project while another one loses.

10.11 What To Do If DWR-Recommended Methods Are Not To Be Used

Following USACE guidance regarding methods and software applications will make analyses conducted by DWR and other agencies comparable and help ensure eligibility for future federal funding and permit approvals. If an evaluation method or analysis tool other than the preferred method or recommended tool is proposed for use, DWR economics staff must be contacted in advance for further guidance and approval prior to initiation of the study.

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11.0 Multiobjective Benefit-Cost Analysis

In this chapter:

- The conceptual basis for multi-objective benefit-cost analysis
- The USACE approach to multi-objective benefit-cost analysis
- The recommended DWR approach for multi-objective benefit-cost analysis
- Consistency between USACE and DWR approaches for computing flood risk management benefits
- Multiple criteria analysis
- How risk and uncertainty are described
- Cost allocation

11.1 Conceptual Basis for Multiobjective Benefit-Cost Analysis

The objective of an economic analysis is to determine if a project represents the best use of resources over the analysis period (i.e., if the project is economically justifiable). To do this, an economic analysis focuses on a comparison of the benefits and costs of proposed projects in a benefit-cost (B-C) analysis. Conceptually, such a comparison includes all (or at least the most significant) benefits and costs attributable to the plans under consideration.

For example, Table 11-1 summarizes the annual benefits (compared to without-project conditions) and costs of a hypothetical comparison of four plans. The annual benefits include:

- Monetized flood damage reduction and water supply benefits, and costs.

- Riparian habitat restored, measured in average annual habitat units (AAHUs).

- Reduction in loss of life, measured in numbers of persons.

- Qualitative water quality benefits (none, low, medium, and high).

Table 11-1. Example Display of Hypothetical Alternative Plans' Benefits and Costs, Including Monetary and Nonmonetary Effects

Alternative Plans	Annual Flood Damage Reduction Benefits ($1000)	Annual Water Supply Benefits ($1000)	Riparian Habitat (AAHUs)	Annual Loss of Life Benefits (Persons)	Annual Water Quality Benefits (Qualitative)	Annual Costs ($1000)
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Plan A	450	73	1,220	12	Medium	475
Plan B	220	12	980	5	Low	225
Plan C	258	60	1,000	9	None	300
Plan D	348	100	1,100	10	High	425

If all of the benefits and costs in Table 11-1 were monetized, the computation of net benefits would be straight-forward. However, because some key benefits are usually not expressed in monetary terms (for example, ecosystem restoration and loss of life), the B-C analysis must be supplemented with other economic analysis tools, described below. When none of these tools can be used, a project's effects can always be described in qualitative terms for decision makers to consider in combination with other information.

Further complicating the comparison of benefits and costs are federal procedures established by the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G, US Water Resources Council 1983) and subsequent guidance published by the US Army Corps of Engineers (USACE) and other federal agencies. Because the California Department of Water Resources (DWR) often partners with federal agencies (especially the USACE), it is important that DWR follow procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Following is a summary of USACE multi-objective planning requirements (methods, software, and analysis results templates), followed by recommended DWR procedures to estimate multi-objective benefits. DWR recommended procedures are mostly the same as for the USACE. But, where they are different, those differences are noted, along with the reasons why the procedures are different, and the potential implications of those differences.

11.2 USACE Approach to Multiobjective Benefit-Cost Analysis

The USACE approach to multiobjective benefit-cost analysis is described below.

11.2.1 Methods

In Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook* (2000), and Engineering Pamphlet (EP) 1165-2-1, *Digest of Water Resources Policies and Authorities* (1999), the USACE describes procedures for evaluating multiobjective projects. Study authorizations are either unique, study-specific authorities or standing, program authorities, usually called continuing authorities. The USACE is authorized to implement projects within these principal project purposes: flood damage reduction (e.g., flood risk management), (commercial) navigation, ecosystem restoration, hurricane and (coastal) storm damage reduction, water supply, hydroelectric power generation, recreation, and multiple purpose studies/projects. The USACE is also authorized for project purposes of streambank (erosion) protection, aquatic plant control and four "other authorities" (refer to Section 3-10 of ER 1105-2-100). The term "mission area" is somewhat synonymous with "project purpose" for the USACE. Recreation cannot be a stand-alone project, but limited recreation features can be added to other purposes, if justified. For the USACE fiscal year 2015 budget, the first three of these missions are identified as the main water resource mission areas of the USACE. The USACE also has eight budget business lines: emergency management, environment, flood risk management, hydropower, navigation, recreation, regulatory, and water supply. The USACE Five Year Development Plan submitted to the Office of Management and Budget and Congress includes funding streams for each business line.

The USACE shall "wherever possible… combine these purposes to formulate multiple purpose projects" that "maximize the net beneficial effects of alternative plans." However, a key distinction is whether the benefits are monetized national economic development (NED) outputs (such as flood risk management, water supply, or hydropower) or nonmonetized national ecosystem restoration (NER) outputs (such as ecosystem restoration). Some projects may result only in NED or NER outputs, and therefore do not give rise to "conflicts of space utilization, water utilization or land use." In these cases, no trading off one output for another is necessary. In other cases, more of one output (for example, NER) can only be obtained by accepting less of another (for example, NED). "[T]radeoffs between NED outputs and NER outputs are permissible, and should be made as long as the value of what is gained

exceeds its implementation cost plus the value of what is forgone."
Table 11-2, Table 11-3, and Table 11-4 illustrate example multiobjective analyses:

- In Table 11-2, the project produces only monetized federal NED outputs (such as flood risk management or water supply), which can be directly compared with project costs to estimate a benefit-cost ratio or net benefits and directly evaluate economic efficiency.

- In Table 11-3, the project produces only nonmonetized NER environmental outputs. In this example, different plan scales are shown that compare incremental changes in outputs and costs among the plans to assist decision makers in the evaluation of whether additional outputs are worth the cost. Since a recommendation depends on a subjective evaluation of worth, which is not readily displayed in the table, no recommended plan is indicated.

- In Table 11-4, the project produces NED and NER outputs at different scales. For the first two plan scales NED and NER outputs do not interact and thus no tradeoff is needed. The third plan scale indicates that the next increment of NER outputs requires an additional environmental implementation cost of $5 and the foregoing of $10 in NED benefits, resulting in incremental adverse effects of $15. (Adverse effects are the cost of NER outputs plus forgone NED benefits.) For this plan to be recommended, the subjective worth of the additional environmental outputs would have to be at least $15. Total project costs are $150 but the benefit-cost ratio is based only on costs attributable to the NED benefits, $110. Any of the displayed plans could be the recommended plan, provided that the economic development plan under consideration maximizes NED benefits or that the restoration plan under consideration is shown to be the most cost effective.

Table 11-2. USACE Example for Project that Produces Only National Economic Development (NED) Outputs

Benefits ($) (1)	Costs ($) (2)	Benefit-Cost Ratio (3)
150	100	1.5

Table source: ER 1105-2-100, Appendix E

Table 11-3. USACE Example for Project that Produces Only National Ecosystem Restoration (NER) Outputs

Environmental Outputs (Units) (1)	Costs ($) (2)	Cost per Unit ($) (3)	Incremental Cost per Unit ($) (4)
40	80	2.00	Not available
50	105	2.10	2.50
60	130	2.25	3.00

Table source: ER 1105-2-100, Appendix E

Table 11-4. USACE Example for Project that Produces National Economic Development (NED) and National Ecosystem Restoration (NER) Benefits

NED Benefits ($) (1)	Costs ($) (2)	B/C (3)	Net Benefits ($) (4)	NER Outputs (Units) (5)	Costs ($) (6)	NED Benefits Forgone ($) (7)	Total Adverse Costs ($) (8)	Cost per Unit ($) (9)	Incremental Cost per Unit ($) (10)	Total Project Costs ($) (11)
140	110	1.3	30	40	30	0	30	0.75	N/A	140
140	110	1.3	30	43	35	0	35	0.81	1.67	145
130	110	1.2	20	50	40	10	50	1.00	2.14	150

Table source: ER 1105-2-100, Appendix E

Plans that are formulated to produce both economic and environmental benefits are called the combined NED/NER plan. These plans produce both types of benefits such that "no alternative plan or scale has a higher excess of NED plus NER benefits over total project costs."

The first step in developing a combined NED/NER plan is to identify the NED plan or NER plan for the primary problem under consideration (e.g., flood damage reduction). Alternative plans that address ecosystem restoration are then considered and compared to the optimal plan to identify the tradeoffs and determine the recommended combined NED/NER plan. In many situations, maintenance or restoration of natural processes may be at the expense of net NED benefits and increases in NED benefits may be at the expense of NER output. The objective is to identify "the best reasonable mix of benefits at a reasonable cost" (USACE 2003).

As with the evaluation of flood risk management benefits, USACE procedures for conducting multi-objective analyses are also evolving. EC 1105-2-404 describes more specific procedures for formulating and evaluating combined NED/NER plans, based on the USACE's environmental operating principles (USACE 2002a). A combined plan also requires the identification of a primary purpose and a plan that optimizes benefits for that purpose (NED or NER). In most instances, the primary purpose will be flood damage reduction, navigation, or storm damage prevention and the formulation process will identify an NED plan that "reasonably maximizes economic development benefits consistent with protecting the environment" (USACE 2003).

In general, formulation of the combined plan requires compliance with the following principles (USACE 2003):

- Formulation of alternatives to meet opportunities.
- Identification of cost-effective plans with multiple benefits.
- Identification of the highest ranked plan based on trade-off analysis.
- Justification of the recommended plan, as described below.

Specific procedures to formulate and evaluate combined plans, based on the P&G planning process, include:

1. Define problems and opportunities. Clearly define the problems, opportunities, objectives, and constraints for both economic development and ecosystem restoration. Identify the potential for addressing national economic development opportunities and for restoring significant ecosystems or resources.

2. Inventory and forecast. Clearly define the future without-project conditions.

3. Formulate plans. Identify all reasonable management measures (structural and nonstructural) that will contribute to the objectives and avoid constraints of the study. The emphasis of the formulation process is on formulating alternatives that take advantage of the synergies created by the plans that address both the primary problem and the relevant secondary problems. If the primary problem is flood damage reduction, other plans will be formulated to address both flood damage reduction and ecosystem restoration opportunities. If the primary problem is ecosystem restoration, other plans will be formulated to address both ecosystem restoration and economic development opportunities. Specific sub-steps include:

    a. Formulate plans that address the primary purpose (e.g., flood damage reduction, navigation, or ecosystem restoration).

    b. Identify the NED or the NER plan.

    c. Formulate plans that address other problems and opportunities as well as the primary objective under study.

4. Evaluate plans. Evaluation requires assessing benefits across different project purposes and, in some cases, performing trade-off analyses between different types of benefits. Specific sub-steps include:

    a. Identify decision criteria. The decision criteria for the cost-effectiveness and trade-off analysis are total national benefits and total cost. Total national benefits are subdivided into national economic development benefits and national ecosystem restoration outputs. The national economic development benefits and national ecosystem restoration outputs can be subdivided into more specific criteria to represent the different types of benefits or outputs produced by the alternative plans under consideration. Criteria that do not enable planners to discriminate among plans can be safely eliminated from the analysis. An example of a nondiscriminating criterion would be one for which all plans have exactly the same measured effect. The best criteria are those that can be quantified.

    b. Identify cost-effective plans. Applying the decision criteria developed above, the total number of plans under consideration would be screened to identify a set of cost-effective plans. Cost-effective plans are not dominated by any other plan that has been formulated. A dominated plan is not cost-effective because another plan costs the same or less than this plan and accomplishes at least as much or more than the dominated plan. The result of this sub-step is the identification of a set of cost-effective plans, none of which is dominated by any other plan. When no one plan is clearly the best, a preferred plan can only emerge from this set as the result of a trade-off analysis (described below).

c. Analyze trade-offs. Assessing the trade-offs among the various cost-effective plans' effects can be done in several different ways to help identify the best combined plan for further consideration. No single trade-off method will be adequate or appropriate for all situations. A good trade-off procedure will be transparent, understandable, and replicable, and will use valid data transformations and algorithms. Once a trade-off approach is selected, the most difficult issue to address related to a combined plan is that the metrics for the benefits/outputs produced, such as the monetized NED outputs and nonmonetized NER outputs, are not interchangeable. Thus, the trade-off analysis must often be conducted using indexes and normalization procedures (USACE 2002b). Trade-off analysis requires the implicit or explicit assignment of preferences (weights) to each decision criterion; this is a subjective process that reflects the relative importance assigned to each criterion. Various techniques are available to determine preferences, and whichever technique is used must be documented. Sensitivity analyses will be conducted to demonstrate the impact of using different sets of preferences. The final set of preferences should reasonably reflect the relative importance of each purpose to the overall plan.

d. Rank plans. The final outcome of the trade-off analysis is a ranking of plans. The highest ranked plan performs the best relative to all of the other formulated plans, based on the identified criteria and set of preferences. The highest ranked plan is the combined plan.

e. Justify plans. The next step is to determine if the combined plan is justified, which occurs when the benefits of each purpose included in the plan exceed the separable costs of the purpose plus the joint allocated costs. This is accomplished using a separable cost-remaining benefit (SCRB) procedure, described in Appendix F.

Steps 5 and 6: Compare, analyze trade-offs, and select a plan. The NED or NER plan is the benchmark for comparison to the combined plan. Benefits forgone, benefits gained, and differences in total cost shall be quantified, displayed, and documented. Other important decision-making criteria may also be considered in support of the selection of the combined plan. Finally, the benefit/cost ratio for the combined plan must be reported. If the combined plan is not justified as result of the analysis, the NED or NER plan shall be recommended for implementation.

An example combined plan analysis is described in Appendix D. This is the Hamilton City flood damage reduction and ecosystem restoration feasibility study conducted by the USACE and State Reclamation Board (now Central Valley Flood Protection Board) in 2004. This project improved flood protection for the Glenn County community of Hamilton City (and surrounding agricultural land) and restored riparian habitat along the Sacramento River. The primary purpose of the combined plan was ecosystem restoration.

11.2.2 Software Applications

The USACE has certified a software application, IWR Planning Suite, to conduct cost-effectiveness/incremental cost analysis (CE/ICA) for ecosystem restoration projects. In addition, because the combined plan analysis often requires a trade-off analysis between NED and NER benefits, at the time of this writing the USACE is also developing a Multiple Criteria Decision Analysis (MCDA) Module to facilitate the trade-off analysis that is included with IWR Planning Suite. (Multiple criteria analysis is described in a later section of this chapter.)

11.2.3 Analysis Results Display Templates

Example USACE analysis display templates are provided below. These are from recent USACE studies in the Central Valley, including the American River Watershed Project: Folsom Dam Modification and Folsom Dam Raise Projects Final Economic Reevaluation Report (NED benefits) and for the Hamilton City Flood Damage and Ecosystem Restoration Final Feasibility Study (Combined Plan).

11.2.4 NED Benefits

The American River Watershed Project Economic Reevaluation Report estimated potential damages associated with flood risk and the economic benefits associated with four alternative flood damage reduction alternatives (in addition to the No Action alternative) at Folsom Dam on the American River. Estimated benefits and costs for this project were displayed in a table similar to Table 11-5. Because this is an NED analysis, an alternative that maximizes net benefits is considered the most efficient in terms of NED analysis, which is Alternative C in Table 11-5 (USACE 2008b). Although this project focused on flood damage reduction benefits, other NED benefits (and costs) could also be included if applicable.

Table 11-5. Example USACE Benefit and Cost Display: American River Watershed Economic Reevaluation Report (ERR) National Economic Development (NED) Benefits Only (2007 $millions)

Item (1)	Alternative A (2)	Alternative B (3)	Alternative C (4)	Alternative D (5)
Total project first costs	$650.4	$918.1	$1,042.1	$1,555.6
Annual FDR costs	$46.6	$47.0	$52.7	$82.9
Annual FDR benefits	$130.7	$143.2	$173.7	$199.1
Net benefits	$84.1	$96.2	$121.0	$116.2
B/C ratio	2.8	3.0	3.3	2.4

Table source: USACE 2008b

Note: Not shown above, but which were also included in the overall B-C analysis, were (i) avoided annual dam safety costs that were deducted from annual project costs for applicable alternatives and (ii) FDR benefits that occurred during project construction and included in the annual FDR benefits. The B-C analysis conducted with a 50-year analysis period and federal discount rate of 4.875%.

11.2.5 NED and NER Benefits (Combined Plan)

The Hamilton City Flood Damage and Ecosystem Restoration Final Feasibility Study combined flood damage reduction (NED) and ecosystem restoration (NER) benefits. As described further in Appendix D, the B-C analysis procedures to develop a combined plan were as follows:

- A primary project purpose—ecosystem restoration—was identified. [Note: the primary purpose of FloodSAFE projects will be flood risk management, not ecosystem restoration.]
- A preliminary and then a final array of single-purpose ecosystem restoration alternative plans (different levee setback alignments) were formulated and evaluated to identify the plan that reasonably maximized the NER net benefits.
- A preliminary and then a final array of multi-purpose (combined) plans were formulated and evaluated to identify a plan that reasonably maximizes total net NER benefits and NED benefits.

Essentially, the B-C analysis allocates total project first and operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs to the flood damage reduction and ecosystem restoration project purposes, and the monetized net benefits are estimated only for flood damage reduction annual benefits and compared to costs allocated to flood damage reduction. The most cost-effective ecosystem restoration plan is determined using CE/IC analysis based on costs allocated to ecosystem restoration. The B-C analysis for the Hamilton City combined plan is shown in Table 11-6.

Table 11-6. Example USACE Benefit and Cost Display: Hamilton City Feasibility Study National Economic Development (NED) and National Ecosystem Restoration (NER) Benefits (2003 $1,000s)

Item	FDR		Ecosystem		Total Costs and Benefits	
	Allocated Costs	Benefits	Allocated Costs	Benefits	Allocated Costs	Benefits
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Investment cost						
First cost[1]	$4,260		$40,446		$44,706	
Interest during construction	$271		$3,066		$3,337	
Total	$4,531		$43,512		$48,043	
Annual cost						
Interest and amortization	$272		$2,615		$2,887	
OMRR&R	$47		$8		$55	
Subtotal	$319		$2,623		$2,942	
Annual benefits						
Monetary (FDR[2])		$577				$577
Nonmonetary (Ecosystem)				888 AAHUs		888 AAHUs
Net annual FDR benefits		$258				$258
FDR B/C ratio[3]		1.8				1.8

Table source: USACE and CA Reclamation Board 2004

Notes:

1 Also called capital, construction, initial, or fixed costs.

2 Flood damage reduction.

3 50-year analysis period and federal discount rate of 5.625%.

11.3 DWR-Recommended Approach to Multiobjective Benefit-Cost Analysis

Because DWR often partners with federal agencies for water resource projects, it is important that DWR follow procedures consistent with federal guidelines, to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

To be consistent with federal guidance, DWR's comparison of benefits and costs for multi-purpose projects will depend on whether all benefits can be monetized (i.e., the federal NED benefits), or if nonmonetized benefits are also included, such as loss of life or ecosystem benefits (the USACE does not monetize loss of life or ecosystem benefits). Thus, a comparison of benefits and costs of alternative plans under consideration for a proposed project begins with a summary of a proposed project's benefits and costs.

11.3.1 Summary of Benefits and Costs

The summary of a proposed project's benefits and costs shall include a narrative description of the project's expected physical benefits, including (adapted from DWR 2012k):

- Recent and historical conditions that provide background for benefits to be claimed (for example, recent flood events and associated damage and loss of life, recent water shortages, loss of habitat or ecosystem function, and water supply and/or quality problems).
- Estimates of without-project conditions such as levels of the physical benefits in the future, without the project, but with other projects that might be planned.
- A description of the project in relationship to other projects planned in the study area, including potential cumulative effects.
- Acknowledgement of all new facilities, policies, and actions required to obtain the physical benefits.
- Uncertainty of the benefits and factors contributing to that uncertainty.
- Description of any potential adverse physical effects.

11.3.2 Monetized Benefits Summary

Monetized benefits (such as flood risk management, water supply and quality, or recreation) can be summarized using Table 11-7. For alternative plans that are under consideration, this table displays the:

- Units of the physical benefits (for example, property damage, acre-feet, visitor days, and kilowatt hours).
- Without- and with-project conditions and the change between these conditions.
- Dollar unit/value to be applied to the physical benefits (where applicable; property damage is already expressed in monetary terms).
- Annual monetized benefit, based on procedures described in above chapters.

11.3.3 Nonmonetized Benefits Summary

Nonmonetized benefits (such as loss of life and ecosystem restoration) can be summarized using Table 11-8. For alternative plans that are under consideration, this table displays similar information as Table 11-7, excluding the monetary computations.

11.3.4 Cost Summary

Project capital and OMRR&R costs can be summarized using Table 11-9. For alternative plans under consideration, this table computes annualized capital and costs and adds those to annual OMRR&R costs to obtain total annual costs.

11.3.5 Benefit and Cost Comparison

The comparison of benefits and costs depends on whether all (or, at least the most significant) benefits can be monetized.

If all benefits can be monetized, then a comparison of benefits and costs for the alternative plans shall be accomplished using Table 11-10. This table displays the annual benefits and costs of all alternative plans under consideration. The plan with the maximum net benefits is selected for further evaluation, pending the results of cost-allocation analyses to determine if the benefits allocated to each project purpose exceed the costs allocated to that purpose (described in Appendix F). The quotient of benefits to costs (the B/C ratio) is also displayed for information purposes, but the primary decision criterion is the selection of the plan that maximizes annual net benefits. Table 11-10 is consistent with federal guidance. [Note: To derive maximum net benefits, alternative sizes, or scales, of the proposed plan may have to be evaluated, as described in the box below. This box also illustrates the difference between maximum net benefits and B/C ratios.]

Table 11-10 is a template to compute the present worth of average annual benefits and costs over a 50-year analysis period, taking into account multiple benefits. Implicitly, this table assumes that benefits and costs do not vary significantly over the analysis period, which is appropriate if the benefit and cost comparison is based only on existing conditions (or some other arbitrary point in time). However, benefits and costs could vary over time if future conditions without and with the project are considered. For example, a flood inundation reduction analysis could include increased housing stock (and other building types) as a result of population growth. The same population growth may also affect a proposed project's delivery of water supplies or recreation opportunities. When conditions change over the analysis period, those benefits must be evaluated over multiple time periods as described in the previous sections and another method is required to do the present worth analysis of benefits and costs, as described in Appendix H.

Table 11-7. Recommended DWR Template for Summarizing Monetized Benefits for Alternative Plans

Alternative Plans/ Types of Benefits (1)	Measure of Physical Benefit (Units) (2)	Annual physical benefits			$/Unit Value (6)	Annual Benefit ($) (7)
		Without Project (3)	With Project (4)	Change (5)		
				[(4)-(3)]		[(5)*(6)]
Plan A						
Flood risk management						
Inundation-reduction						
Intensification						
Location						
Water supply and quality						
Recreation and open space						
Hydropower						
Navigation						
Commercial fisheries						
Plan B						
Flood risk management						
Inundation-reduction						
Intensification						
Location						
Water supply and quality						
Recreation and open space						
Hydropower						
Navigation						
Commercial fisheries						
…						

Table 11-8. DWR-Recommended Template for Summarizing Nonmonetized Benefits

Alternative Plans/ Types of Benefits (1)	Measure of Physical Benefit (Units) (2)	Annual Physical Benefits			Comments (6)
		Without Project (3)	With Project (4)	Change (5)	
				[(4)-(3)]	
Plan A					
Loss of life (FRM)					
Ecosystem restoration					
Other					
Plan B					
Loss of life (FRM)					
Ecosystem restoration					
Other					
Plan C					
Loss of life (FRM)					
Ecosystem restoration					
Other					
…					

Table 11-9. DWR-Recommended Template for Summarizing Costs for Alternative Plans

Alternative Plans (1)	Capital Cost ($) (2)	Capital Recovery Factor[1] (3)	Annual Capital Cost ($) (4)	Annual OMRR&R Cost ($) (5)	Total Annual Cost ($) (6)
			[(2)*(3)]		[(4)+(5)]
Plan A		0.xxxx			
Plan B		0.xxxx			
Plan C		0.xxxx			
…		0.xxxx			

Note:
[1] Based on 50-year analysis period and discount rate of *y*%

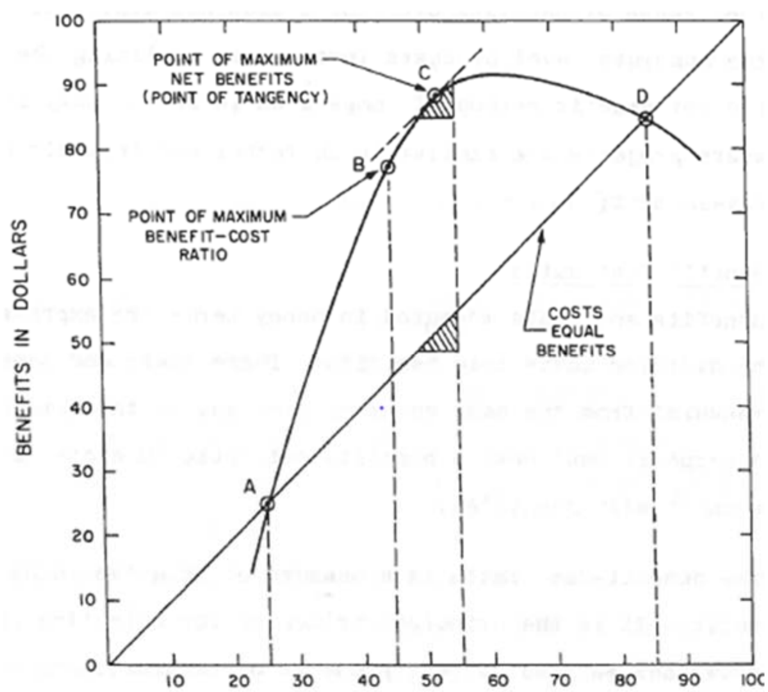
Table 11-10. DWR-Recommended Template for Summarizing Monetized Benefits and Costs

Benefits and Costs[1] (1)	Alternative Plans A (2)	B (3)	C (4)	… (5)
Annual benefits				
(a) Flood risk management				
(b) Inundation				
(c) Intensification				
(d) Location				
(e) Total FRM benefits [(a)+(b)+(c)+(d)]				
(f) Water supply and quality				
(g) Recreation and open space				
(h) Hydropower				
(i) Navigation				
(i) Commercial fisheries				
(k) Ecosystem restoration				
(l) Other				
(m) Total annual benefits [(e)+(f)+(g)+(h)+(i)+(j)+(k)+(l)]				
Annual costs				
(n) Capital				
(o) OMRR&R				
(p) Total annual costs [(n)+(o)]				
Annual net benefits [(m)-(p)]				
B/C ratio [(m)/(p)]				

Note:
[1] Annual benefits and costs computed with a 50-year analysis period and applicable DWR discount rate. A separate table may also be required using the applicable federal discount rate, if different from the DWR discount rate.

Maximum Net Benefits and Project Scale

Net benefits are at a maximum when the benefits added by the last increment of a project are equal to the cost of adding that increment (e.g., marginal benefit = marginal cost). Maximum net benefits are not obtained by a scale of development that maximizes the B/C ratio, nor where the ratio is equal to one. This is illustrated in the figure below, in which maximum net benefits occur at point C, which is different than the maximum B/C ratio (point B) or when that ratio equals one (points A and D), for an example analysis (DWR 1977).



If ecosystem benefits are identified and DWR is partnering with the USACE on the project, then according to USACE guidance, these are not to be monetized. Instead, they shall be evaluated using the format of a combined plan described above and illustrated in Table 11-6. However, if DWR is not partnering with the USACE, it may use the ecosystem services method described above, which will result in monetized ecosystem benefits. These could then be directly included as an "Other" benefit. Although these monetized ecosystem benefits would not be accepted by the USACE (under current guidance), they could supplement the CE/IC analysis included in Table 11-6 and help DWR identify the "locally preferred plan."

The proposed project may also result in other nonmonetized benefits. One of the more critical no-monetized benefits is the reduction in loss of life attributable to flood risk management projects. Although these can be displayed in Table 11-8, they cannot be combined with other benefits and costs to determine net benefits because they are not expressed in the same metric (dollars). [Note: Some agencies do place monetary values on loss of life, most notably the Federal Emergency Management Agency (FEMA) (FEMA 2001). However, the USACE and DWR do not place monetary values on loss of life.]

Thus, in order to evaluate loss of life (or other nonmonetized benefits) in combination with the monetized benefits, they can be described and subjectively considered with the other benefits, but this is not likely to be a systematic and repeatable process. However, an optional method may be used to evaluate monetized and nonmonetized benefits (and costs)—multiple criteria analysis, or MCA, described below.

11.4 Reduced Long-Term System Maintenance Costs

Another benefit not described above is the reduction in long-term maintenance costs of *existing* systems. For example, certain improvements (e.g., changes in operating rules or the addition of specialized equipment) may reduce long-term operation, maintenance, power, repair, replacement, and rehabilitation (OMRR&R) costs, without changing the footprint of the existing system. This reduction in long-term OMRR&R costs can be claimed as a benefit. To do so, use Table 11-11 to (a) compute the difference (benefit) in total long-term OMRR&R costs for the without-project and with-project conditions and convert to an annual benefit value; (b) compute annual capital cost of the improvement, if any; and (c) subtract the annual capital cost from the annual benefit to obtain the net benefit.

Reduced long-term system OMRR&R costs may also occur from system improvements. For example, implementation of flood risk management projects should reduce flood emergency and response and recovery activities, flood fighting costs, and associated costs. Or, the expansion of floodway corridors and realignment of levees to reduce the erosive force of floodwaters on levees can improve their reliability and reduce maintenance and repair costs. However, these reductions in OMRR&R costs shall be included in the B-C analyses for those projects, making sure the without-project and with-project conditions capture the different operating costs.

Table 11-11. Recommended DWR Template for Calculating Reduction in Long-Term Operations, Maintenance, Replacement, Rehabilitation, and Repair (OMRR&R) Costs from Improvements to Existing Facilities

Year (1)	Without-Project OMRR&R[1] Costs			With-Project OMRR&R[1] Costs		
	Costs (2)	Discount Factor[2] (3)	Discounted Costs (4)	Costs (5)	Discount Factor[2] (6)	Discounted Costs (7)
			[(2)*(3)]			[(5)*(6)]
1		0.xxxx			0.xxxx	
2		0.xxxx			0.xxxx	
3		0.xxxx			0.xxxx	
4		0.xxxx			0.xxxx	
…		0.xxxx			0.xxxx	
50		0.xxxx			0.xxxx	
(a) Total discounted costs						
(b) Total benefit [4a-7a]						
(c) Capital recovery factor[3]					0.0xxx	
(d) Annual benefit [(b) * (c)]						
(e) Capital cost of improvement						
(f) Capital recovery factor[3]					0.0xxx	
(g) Annual capital cost [(e) * (f)]						
(h) Net benefit [(d) – (g)]						

Notes:
[1] Operations, maintenance, power, replacement, rehabilitation, and repair costs.
[2] x% discount rate for 50 years.
[3] Capital recovery factor for 50 years using x% discount rate.

11.5 Multiple Criteria Analysis

Multiple criteria analysis (MCA) is a complementary approach to B-C analysis. It is a two-stage decision procedure. The first stage identifies a set of goals or objectives and then seeks to identify the trade-offs between those objectives for different policies or for different ways of achieving a given policy. The second stage seeks to identify the "best" policy by attaching weights (scores) to the various objectives. It involves judging the expected performance of each development option against a number of criteria or objectives. These techniques can deal with complex situations, including those involving uncertainty as well as the preferences of many stakeholders. MCA is particularly applicable when the problem presents conflicting objectives and when these objectives cannot be easily expressed in monetary terms (for example, ecosystem or loss of life benefits).

There are several variants of the MCA technique. These techniques do not necessarily rely on monetary variables even though monetary variables can also be accommodated in them. MCA involves judging the expected performance of each development option against a number of criteria or objectives and taking an overall view on the basis of a pre-assigned importance to each criterion. The essence of MCA lies in the preparation of a performance matrix with several rows and columns in which each row describes one of the options and each column describes a criterion or performance dimension. Thereafter, scores for each option with respect to each criterion are assigned. These scores are supposed to represent performance indicators and are worked out through specific graphs or value functions for each criterion as based on scientific knowledge. Generally a scale of 1 to 10 or 1 to 100 is adopted. In the more sophisticated versions of MCA, weights are assigned to each criterion. Thereafter, a weighted average of scores is worked out. This average provides the overall indicator of performance of each option; the higher the weighted average of scores, the better the option (APFM 2007).

The example comparison of benefits and costs for alternative plans shown in Table 11-1 provides the basis to do an MCA. The plans are arranged in the table rows and the criteria by which the plans are to be compared (the different benefits and costs) are shown in the columns. This is the performance matrix. It does not matter that the benefits and costs are expressed in different units (e.g., dollars, lives, or AAHUs), because the MCA translates these to a common unit using a variety of techniques. For example, one technique computes the proportion of each measurement compared with the highest value for each criterion. Once all measurements are expressed as “proportions of the maximum” for each criterion, they can then be summed across all criteria (for each plan) and the total scores compared against each other. The criteria can also be weighted to reflect subjective preferences.

The USACE has developed guidance describing how to use MCA to conduct trade-off analyses (USACE 2002b). It is also developing a Beta version Multiple Criteria Decision Analysis (MCDA) Module which is available on the USACE IWR Planning Suite website.

An example MCA analysis is described in Appendix G.

11.6 Describing Uncertainty

As described in Chapter 2, risk and uncertainty are intrinsic in water resources planning and design. Risk is the probability that a defined set of events will result in adverse (or beneficial) consequences. A risk analysis accounts explicitly for uncertainty in the contributing factors by first determining the best estimate of each of the functions used for the risk computation, and then describing the confidence in each with a statistical distribution about that best estimate. If descriptions of the statistical distributions of these functions cannot be developed, then uncertainty can be evaluated with sensitivity analysis.

Ideally, DWR should conduct risk analyses for all benefits and costs, with results displayed as shown in Table 3-1 for flood risk management benefits. However:

- The tools to do risk analyses for benefits other than flood risk management, and in particular, inundation-reduction benefits, are not yet available.
- The tools to do risk analyses of costs are not yet available. [Note: the USACE Walla Walla District has developed *Cost and Schedule Risk Analysis Guidance* and a tool to incorporate uncertainties in USACE project cost estimates (USACE 2009). However, these cost uncertainties are computed differently than flood damage reduced uncertainties; thus, they are not recommended for DWR B-C analyses at the present time.]

Given these limitations, benefits and costs that are displayed in Table 11-7 through Table 11-10 shall be characterized as “best estimates.” However, the critical variables and associated uncertainties underlying these benefits and costs shall, at a minimum, be identified and qualitatively described. To the extent possible, these variables shall be evaluated by DWR using a sensitivity analysis to compare the analysis results against changes in those variables.

If projects include flood risk management benefits, then those benefits shall not only be included in Table 11-7 through Table 11-10 as “best estimates,” but also displayed separately using the format of Table 3-1. The USACE has developed a substantial body of guidance and tools for risk analysis of flood risk management projects specifically. USACE risk-based guidance includes ER 1105-2-100, *Planning Guidance Notebook*; ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*; and Engineer Manual (EM) 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies*. The *Flood Damage Analysis* (HEC-FDA) software application developed by the USACE Hydrologic Engineering Center (HEC) incorporates hydrologic, hydraulic, geotechnical, and economic uncertainties in a flood damage analysis.

11.7 Consistency between DWR and USACE Multiobjective Benefit-Cost Analysis Methods

Because DWR often partners with federal agencies for water resource improvements, it is important that DWR follow project benefit estimation procedures consistent with federal guidelines to the extent practicable. Noncompliance could jeopardize future federal funding and permit approvals.

Table 11-12 compares recommended DWR methods with those used by the USACE. DWR-recommended methods are mostly consistent with those of the USACE. This comparison is summarized below for specific benefits:

- Flood risk management
  - DWR-recommended urban IR benefit risk analysis methods are consistent with those used by the USACE.
  - DWR-recommended urban intensification and location benefit methods, although computationally consistent with USACE procedures, may be inconsistent with USACE applications, because these benefits (a) are often not applicable from the USACE national economic development perspective and (b) may be in conflict with the "wise use of floodplains" federal objective prescribed by the 2013 P&G (CEQ 2013). Nonetheless, they may be important from a State perspective.
  - DWR-recommended loss of life (IR) benefit evaluation methods are generally consistent with those used by the USACE because they incorporate commonly used procedures for assessing life risk. Use of HEC-FDA to estimate loss of life is suitable for planning study purposes. HEC-FDA incorporates uncertainty for all major variables, although it currently provides only partial uncertainty for a loss of life computation because uncertainty information has not yet been developed for the warning times and persons/structure values.
  - DWR-recommended crop flood damage reduction and intensification methods are generally consistent with those used by the USACE. Although the USACE does not have a "certified"

software application to estimate crop flood damage reduction benefits, use of HEC-FDA will be consistent with the USACE urban IR benefit analyses. HEC-FDA incorporates uncertainty in all of the major variables, although it currently provides only partial uncertainty for a crop flood damage computation because uncertainty information has not yet been developed for land use and crop damage/acre values. Crop intensification benefits shall be estimated with spreadsheet analyses and uncertainty accounted for with sensitivity analysis.

- Ecosystem restoration
  - If DWR is partnering with the USACE, then ecosystem restoration alternative plans shall be evaluated using CE/IC analysis as applied by the USACE. Although CE/IC analysis can be conducted in a number of ways, for most DWR applications, the USACE "relative production efficiency" spreadsheet-based approach described in Appendix C should be sufficient for planning studies. However, if the scale of the project warrants a more thorough identification and analysis of alternative plans, then IWR Planning Suite may be used. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.
  - If DWR is not partnering with the USACE, then, when possible, ecosystem benefits may be evaluated and monetized using an ecosystem services approach described in Chapter 4. Or, even if DWR is partnering with the USACE, it may still wish to conduct an ecosystem services benefit evaluation to (a) supplement the CE/IC analysis to help identify a locally preferred plan and (b) better position itself if the ecosystem services approach is ultimately used by the USACE. However, monetizing ecosystem benefits is not consistent with current USACE policy. Uncertainty shall be addressed with sensitivity analysis.
- **Water supply and quality –** DWR-recommended water supply and quality benefit evaluations include IRWM or Common Assumptions procedures, depending on DWR analysis requirements. Both are consistent with USACE guidance. (Common Assumptions was developed in consultation with the US Bureau of Reclamation). Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

- Recreation and open space
  - DWR-recommended recreation benefit evaluations are based on USACE unit day values, with annual use based on the USACE capacity approach and/or additional information from local officials and published reports. However, if the significance of recreation benefits (relative to other project benefits) warrants a more rigorous analysis of alternative plans, then these other methods can be used. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.
  - Open space is not an authorized USACE mission objective; thus recommended DWR procedures for this benefit cannot be compared to USACE procedures. However, evaluation of potential open space benefits (for example, recreation or flood mitigation) is included in USACE guidance and also described above for DWR procedures. Thus, DWR procedures for these specific benefits are consistent with the USACE, taking care to avoid double-counting of benefits. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.
- **Hydropower –** DWR-recommended hydropower benefit evaluation is based on the USACE financial evaluation method. Other more rigorous USACE hydropower benefit evaluation methods are available that are more appropriate for a full hydropower feasibility analysis; but, such an analysis is not anticipated with most FloodSAFE projects. However, if the significance of hydropower benefits (relative to other project benefits) warrants a more rigorous analysis of alternative plans, then these other methods can be used. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

- **Navigation –** DWR-recommended navigation benefit evaluation is based on the USACE cost reduction method, which computes a benefit based on a reduction in transportation cost. This method does not allow for changes in mode, origin, and/or destination of transported goods. Other more rigorous USACE navigation benefit evaluation methods are available that do account for changes in these other factors, but these situations are not anticipated with most FloodSAFE projects. However, if the significance of navigation benefits (relative to other project benefits) warrants a more rigorous analysis of alternative plans, then these other methods can be used. Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

- **Commercial fisheries –** DWR-recommended navigation benefit evaluation is based on the USACE change in catch method.

> Uncertainty shall be addressed with sensitivity analysis, consistent with USACE guidance.

Although these methods have been identified to be consistent with USACE guidance to the extent practicable, differences in the benefit evaluations approach (or the rigor of the approach) may still occur. These differences can be identified—and resolved—working directly with the USACE district, the South Pacific Division, and local and regional stakeholders.

Additional USACE resources include its Planning Centers of Expertise (PCX) for topics such as flood risk management, ecosystem restoration, inland navigation, coastal storm damage reduction, and water management reallocation. Each PCX is led by a team of experts specialized in plan formulation, environmental sciences, economics, and related technical disciplines.

Table 11-12. Comparison of USACE and DWR-Recommended Benefit-Cost Analysis and Risk Analysis Methods

Benefit (1)	DWR Method (2)	Software Application Used by DWR (3)	Risk Analysis Method Used by DWR (4)
Flood risk management			
Urban			
Inundation-reduction	●	●	●
Intensification/location	○	NA	○
Loss of life			
Inundation-reduction	●	◒	◒
Crops			
Flood damage reduction	◒	◒	◒
Intensification	◒	NA	◒
Ecosystem restoration			
CE/IC evaluation	●	●	●
Ecosystem services	○	NA	○
Water supply and quality			
Urban			
IRWM	●	NA	●
Common Assumptions	●	●	●
Crops			
Common Assumptions	●	●	●
Recreation and open space			
Unit day value evaluation	●	NA	●
Hydropower			
Financial evaluation	●	NA	●
Navigation			
Cost reduction	●	NA	●
Commercial fisheries			
Change in catch	●	NA	●

● = consistent with USACE procedures and/or applications.
◒ = partially consistent with USACE procedures and/or applications (i.e., minor inconsistencies exist).
○ = not consistent with USACE procedures and/or applications.
NA=not applicable (no software application available).

12.0 Glossary

Annual exceedance probability (AEP)	A measure of the likelihood of exceeding a specified target in any year. Comparing a proposed plan's AEP to the without-project condition will indicate the change in the likelihood of flooding. AEP is a project performance statistic computed by the USACE software application HEC-FDA. (USACE 2008a)
Benefit	The values of goods and services produced by a project or program. (DWR 2008a)
Benefit transfers	A method used to estimate benefit values in a current study based on values developed by other studies.
Benefit-cost (B-C) analysis	A procedure where the different benefits and costs of proposed projects are identified and measured (usually in monetary terms) and then compared with each other to determine if the benefits of the project exceed its costs. (DWR 2008a)
Benefit-cost ratio	The quotient of benefits to costs (B/C ratio). The B/C ratio is displayed for information purposes, but the primary decision criterion is the plan that maximizes net benefits.
CALFED	A collaborative effort among 25 State and federal agencies to improve California water supply and the ecological health of the Sacramento-San Joaquin Delta. This program has been transferred to the Delta Stewardship Council.
CALSIM II	A computer model developed by DWR and US Bureau of Reclamation that simulates much of the water resource infrastructure in the Central Valley and Delta region of California. CALSIM II models all areas that contribute flow to the Delta. The geographical coverage includes the Sacramento River Valley, the San Joaquin River Valley, the Delta, the Upper Trinity River, and the CVP and SWP service areas. CALSIM II simulates operation of the CVP-SWP system using a monthly time step.
Central Valley Flood Management Planning (CVFMP) Program	A program begun in 2008 to implement integrated flood management actions for the Sacramento and San Joaquin valleys required by passage of legislation in 2007. The CVFMP is now implementing actions identified by the 2012 Central Valley Flood Protection Plan and preparing the 2017 CVFPP. (2012 CVFPP)

Central Valley Flood Protection Plan (CVFPP) A State plan that describes the challenges, opportunities, and vision for improving integrated flood management in the Central Valley. The CVFPP describes current and future risks associated with flooding and recommends improvements to the State-federal flood protection system to reduce the occurrence of major flooding and the consequences of flood damage that could result. The plan is to be updated every five years. (2012 CVFPP)

Central Valley Flood Protection Board (CVFPB) A board created by the California legislature in 1911 to carry out a comprehensive flood control plan for the Sacramento and San Joaquin rivers. The Board has jurisdiction throughout the Sacramento-San Joaquin Valley, which is synonymous with the drainage basins of the Central Valley and includes the Sacramento-San Joaquin Drainage District. (2012 CVFPP)

Central Valley Project (CVP) A water storage and transport system operated by the US Bureau of Reclamation which has 22 reservoirs and a combined storage of 11 million acre-feet, of which 7 million acre-feet are delivered in an average year. CVP water irrigates more than 3 million acres of farmland and provides drinking water to nearly 2 million consumers. (DWR 2009)

Common Assumptions An effort initiated by DWR in 2002 with the US Bureau of Reclamation and the California Bay-Delta Authority to develop a common analytical framework, including tools and methods, for surface storage investigations. (DWR Commons Assumptions website)

Conditional nonexceedance probability (CNP) The probability that flood inundation will not occur if an event of specified annual chance exceedance occurs. CNP (which is now called “assurance” by the USACE) is a project performance statistic computed by the USACE software application HEC-FDA. (USACE 2008a)

Consequence The harm that results from a single occurrence of the hazard. It is measured through indices such as economic damage, acreage of habitat lost, crop values damaged, and lives lost.

Contingent valuation/ choice methods Survey methods used to determine people’s willingness to pay for goods and services in the absence of market data. Contingent valuation surveys ask how much people would be willing to spend for specific goods and services, or alternatively, how much they would be willing to accept to give up a specified amenity or benefit. Contingent choice surveys ask people to state preferences for different goods and services based on their costs. (DWR 2008a)

Costs — All expenditures necessary to obtain project benefits over the analysis period. Conceptually, all costs in the economic analysis should reflect the opportunity costs of using resources to construct and operate the project. Practically, however, the costs are often limited to the actual purchase expenditures which are used in the financial analysis:

- Capital: expenditures necessary to complete the project so operations can commence. Capital costs, also called construction, "fixed," or "first" costs, include expenditures for land, structures, materials, equipment, and labor, as well as allowances for contingencies and forgone investment value. Financial costs such as interest during construction and long-term debt service interest are not included, although they are important in a financial analysis.
- Operation, maintenance, and replacement: the project's annual administrative, maintenance, energy, and replacement costs are often called variable costs because they vary with different levels of project output.

(DWR 2008a)

Cost allocation — A systematic distribution of costs among the project purposes of a multipurpose project. A common cost-allocation method is Separable Costs-Remaining Benefits (SCRB), which distributes costs among the project purposes by identifying separate costs and allocating joint costs or joint savings in proportion to each purpose's remaining benefits. (USACE 2000 and DWR 2008a)

Cost apportionment — The process of dividing allocated project costs into federal and non-federal costs. (USACE 2000)

Cost sharing — The sharing of costs among various parties. Multiple-purpose studies and projects are cost shared by the USACE in accordance with the cost sharing policies applicable to each project purpose under consideration. (USACE 2000)

Cost-effectiveness (CE) analysis — A type of economic analysis that identifies the least costly method for achieving specific physical objectives. Cost-effectiveness analysis is often used to evaluate projects in which the outputs cannot easily be expressed in monetary terms (for example, projects that produce ecosystem benefits). Cost-effectiveness analysis can also be combined with incremental cost analysis to measure changes in costs and outputs among alternative plans. (DWR 2008a)

Discounting A process used to adjust for the time value of money. Even in the absence of inflation, a dollar received today is worth more than one received in the future because a dollar received today can be put to immediate use. Adjusting for different time periods is accomplished by estimating the present value of each benefit and cost in the future. Present values are calculated with a simple formula ($PV = FV/(1+r)^n$), which involves dividing the future dollar amount of benefit or cost by a discount factor ($1+r$) raised to the n^{th} power. In this equation, P is the present value of the future cash flow, F is the future cash flow, r is the discount rate, and n is the number of time periods into the future that the benefit or cost occurs. Alternatively, present value "factors" for different discount rates and analysis years may be found in financial tables. All annual costs and benefits are discounted using the same discount rate and total discounted benefits and costs can then be summed for the entire analysis period and directly compared to each other. (DWR 2008a)

Discount rate The rate used to adjust dollars received or spent at different times to dollars of a common value, usually present day dollars ("present worth" or "present value"). Although determining discount rates can be done using several different methods, generally the value to use for this rate for an economic analysis is the real (i.e., excluding inflation) rate of return that could be expected if the money were instead invested in another project. In other words, the discount rate is a measure of forgone investment (i.e., opportunity cost) if the money allocated to the project were instead invested elsewhere. (DWR 2008a)

Economic analysis A type of analysis used to determine if a project represents the best use of resources over the analysis period and is therefore economically justifiable. The economic analysis addresses questions such as: should the project be built at all, should it be built now, or should it be built to a different configuration or size? A project is economically justifiable if its expected total discounted benefits exceed project discounted costs over the analysis period. The comparison of benefits and costs is done using the with- and without-project conditions. (DWR 2008a)

Ecosystem All the organisms in a given area interacting with the physical environment. The biotic and physical components in an ecosystem are interdependent, frequently with complex feedback loops. The physical components that sustain the biota of an ecosystem include the soil or substrate, topographic relief and aspect, atmosphere, weather and climate, hydrology, geomorphic processes, nutrient regime, and salinity regime. (2012 CVFPP)

Ecosystem functions	A process that takes place in an ecosystem as a result of the interaction of plants, animals, and other microorganisms in the ecosystem with each other or their environment that serves some purpose. (NRC 2004)
Ecosystem restoration	A process where an ecosystem that has been degraded or disturbed is restored to mimic as closely as possible, through the restoration of critical natural processes, conditions which would naturally occur in an area. (2012 CVFPP)
Ecosystem services	Services emanating from a functioning ecosystem that are beneficial outcomes for the natural environment or for people. Some examples of ecosystem services are support of the food chain, harvesting animals or plants, clean water, or scenic views. In order for an ecosystem to provide services to humans, some interaction with, or at least some appreciation by, humans is required. (2012 CVFPP).
Ecosystem structure	The various parts of an ecosystem and the physical and biological organization defining how those parts are organized. (NRC 2004)
Ecosystem valuation methods	Methods to estimate consumers' "willingness to pay" for ecosystem goods and services not normally found in the marketplace. Four general types of methods can be used: • Revealed willingness to pay: measures value of ecosystem goods and services based on actual prices paid for these products or related goods and services (using hedonic pricing and travel cost methods). • Imputed willingness to pay: measures value of ecosystem goods and services based on the (1) cost of avoiding damage caused by the loss of these services, (2) cost of replacing ecosystem services, or (3) cost of providing substitute services. • Expressed willingness to pay: measures value of ecosystem goods and services based on consumer surveys (using contingent valuation/choices methods). • Benefit transfers: measures value of ecosystem goods and services by transferring available information from studies already completed in another location and/or context. (DWR 2008a)
Environmental justice	The fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. (California Government Code Section 65040.12(c))

Exposure Who and what may be harmed by the hazard.

Externalities Costs (or benefits) imposed on others from the activities of producers or consumers for which no compensation is received. (DWR 2008a)

Feasible Capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors. (2012 CVFPP)

Federal decision criteria The four broad decision criteria identified in the federal *P&G* for the evaluation of all federal plans:

- Completeness: the extent to which a given plan has all the necessary investments and other actions to ensure the realization of the planned effects.
- Effectiveness: the extent to which an alternative plan accomplishes its planning objectives.
- Efficiency: the extent to which an alternative plan is the most cost-effective means of accomplishing its planning objectives and is the criteria which is addressed by the economic analysis.
- Acceptability: the workability and viability of the alternative plans with respect to acceptance by state and local entities and the public as well as compatibility with existing laws, regulations, and public policies.

Project feasibility is determined by how well a proposed project meets all four criteria. (DWR 2008a)

Federal objective "[T]o contribute to national economic development (NED) consistent with protecting the Nation's environment, in accordance with national environmental statutes, applicable executive orders, and other federal planning requirements." (1983 P&G)

Federal planning accounts

The four planning accounts established in the federal *P&G* to facilitate project planning:

- National Economic Development (NED): displays contributions to national economic development which are increases in the net value of the national output of goods and services, expressed in monetary units, and which are the direct net benefits that accrue in the planning area and the rest of the nation.
- Environmental Quality (EQ): displays nonmonetary effects on ecological, cultural, and aesthetic resources including the positive and adverse effects of ecosystem restoration plans.
- Regional Economic Development (RED): displays changes in the distribution of regional economic activity such as income and employment.
- Other Social Effects (OSE): displays plan effects on social aspects such as community impacts, health and safety, displacement, energy conservation, and other effects.

Display of the national economic development and environmental quality accounts is required whereas display of the other two accounts is discretionary. (1983 P&G)

Federal planning process

The six steps of the federal planning process described in the federal P&G: (1) specification of water and related land resources problems and opportunities; (2) inventory, forecast, and analysis of water-related land resources within the study area; (3) identification of alternative plans; (4) evaluation of the effects of alternative plans; (5) comparison of the alternative plans; and (6) selection of the recommended plan based on the comparison of the alternative plans. Plan formulation consists of the third, fourth, and fifth planning steps. It is a highly iterative process that involves cycling through the formulation, evaluation, and comparison steps many times to develop a reasonable range of alternative plans and then narrow those plans down to a final array of feasible plans from which a single plan can be identified for implementation. (1983 P&G)

Federal plans

The four types of plans for which the USACE has authority to implement:

- National economic development (NED) plan. For single project purposes, such as water supply or flood damage reduction where project outputs can be measured in dollars, project selection is based on maximizing net national economic development consistent with the federal objective.
- National ecosystem restoration (NER) plan. The USACE incorporated ecosystem restoration as a project purpose in response to the increasing national emphasis on environmental restoration and preservation; however, the USACE does not place monetary values on ecosystem benefits.
- Combined NED/NER plan. USACE projects that produce both NED and NER benefits will result in a "best" recommended plan so that no alternative plan has a higher excess of NED monetary benefits plus NER nonmonetary benefits over project costs. This plan shall attempt to maximize the sum of net NED and NER benefits and to offer the best balance between two federal objectives.
- Locally preferred plan (LPP). Projects may deviate from the NED, NER, or combined NED/NER plans if requested by the non-federal sponsor. For example, if the sponsor prefers a more costly plan and the increased scope of the plan is not sufficient to warrant full federal participation based on the NED analysis, the LPP may be approved as long as the sponsor pays the difference in costs between the NED (or NED/NER) plans and the LPP.

(USACE 2000)

Federal *Principles and Guidelines* (P&G)

The Environmental Principles and Guidelines for Water And Related Land Resources Implementation Studies published by the Water Resources Council in March 1983. Economic analyses conducted by federal agencies working with water and related land resource problems (such as the USACE and the Bureau of Reclamation) must follow the P&G. The "principles" part of the P&G establishes project planning policies to be followed; the "guidelines" part describes "how to" procedures. (DWR 2008a)

Financial analysis — A type of analysis that determines if project beneficiaries are willing and able to raise sufficient funds to construct and operate a project over its repayment period. The financial analysis addresses questions such as: who benefits from a project, who will repay project costs and will they be able to meet repayment obligations? A project is financially feasible if beneficiaries are able to pay for reimbursable costs over the repayment period, sufficient capital is authorized and available to finance construction to completion, and estimated revenues are sufficient to cover reimbursable costs over the repayment period. (DWR 2008a)

Flood — An overflow of water onto normally dry land; the inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch; ponding of water at or near the point where the rain fell. Flooding is a longer term event than flash flooding; it may last days or weeks. (NWS website)

Flood damages — All damages caused by a flood including loss of life, physical damage (structures, infrastructure, crops, ecosystems, etc.) and loss of functions of structures and other physical assets. (DWR 2008b)

Flood risk — The probability of flooding combined with negative outcomes that could result when flooding occurs. (DWR 2012n)

Forgone investment value — The value of other investments that could have been pursued if the project were not undertaken ("opportunity costs"). If construction occurs over several years, then the future value of these expenditures is determined in an economic analysis by multiplying these monetary costs by a future value factor (which is the reciprocal of the present value factor). Forgone investment value is often erroneously called "interest during construction." (DWR 2008a)

HarborSym — A USACE-developed software application for risk analysis of deep draft navigation plans.

Hazard — The hazard is what causes the harm.

HEC-FDA — A software application developed by the USACE Hydrologic Engineering Center for risk analysis of flood risk management plans.

HEC-FIA — A software application developed by the USACE Hydrologic Engineering Center to estimate economic damage to structures and crops and the loss of life on a single flood event basis.

Hedonic pricing method	A method to estimate economic benefits associated with environmental amenities (such as aesthetic views or proximity to recreational sites) or environmental costs (such as the effects of air, water, or noise pollution). Most hedonic pricing applications use differences in residential housing prices to estimate the value of the environmental amenities. (DWR 2008a)
Incremental cost (IC) analysis	An analysis method that computes the change in cost per unit of output resulting from different sizes of project alternatives, thus determining which alternative has (a) the greatest increase in output for the least cost increase and (b) the lowest incremental costs per unit of output relative to other cost-effective plans. (DWR 2008a)
Integrated flood management	A comprehensive approach to flood management that considers land and water resources at a watershed scale within the context of integrated water management; employs both structural and nonstructural measures to maximize the benefits of floodplains and minimize loss of life and damage to property from flooding; and recognizes the benefits to ecosystems from periodic flooding. (DWR 2009)
Integrated regional water management	A multi-objective approach that encourages using a mix of resource management strategies to provide benefits to regions.
Input-output analysis	A quantitative description of the relationship among industries within an economy which shows the interdependence among various sectors of the economy as they combine to meet a given final demand for goods and services. (DWR 2008a)
Interest during construction	The financial compound interest paid on borrowed funds during construction. (DWR 2008a)
IWR PLAN	A software application developed by the USACE Institute for Water Resources to conduct cost effectiveness/incremental cost analyses of environmental restoration plans.
Least Cost Planning Simulation model (LCPSIM)	A DWR PC-based simulation/optimization model that assesses the economic benefits and costs of increasing urban water reliability at the regional level. LCPSIM, which can be applied for major urban regions within State and federal project water supply contract areas, is included in Common Assumptions. (DWR 2012m)
Life cycle cost (LCC) analysis	A method of analysis that assesses and compares the total costs of alternatives. It takes into account all costs of acquiring, owning, and disposing of facilities and related equipment over the physical life of the asset. LCC analysis is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to identify the one that maximizes net cost savings. (DWR 2008a)

LifeSIM	A modular, spatially-distributed, dynamic simulation model being developed by the USACE Hydrologic Engineering Center to estimate loss of life from flood events. (Aboelata 2009).
Long-term risk	The chance of exceedance over specified time periods. Long-term risk is a project performance statistic computed by the USACE software application HEC-FDA. (USACE 2008a)
Management measure	A feature or an activity that can be implemented at a specific geographic site to address one or more planning objectives. It may be a "structural" feature that requires construction or assembly on-site, or it could be a "nonstructural" action. Management measures are the building blocks of alternative plans. (USACE IWR 2009)
Multiple criteria analysis (MCA)	A decision support framework that facilitates the evaluation and selection of alternatives based on multiple criteria that reflect planning objectives and other significant attributes of a plan. (USACE 2002b)
Multiple-purpose studies	Studies that examine more than one type of water resources problem or opportunity and recommend projects with more than one purpose (e.g., flood risk management, water supply, ecosystem restoration). (USACE 2000)
Net benefits	The difference between costs and benefits. Net benefits are the primary decision criterion, but the benefit-cost ratio is usually displayed for informational purposes.
Nonstructural management measures	Instead of trying to control water, nonstructural measures focus on altering the development and human behavior that is exposed to flood damage. Examples include moving or elevating structures, building barriers around structures, dry-flood proofing (sealing building to ensure flood water does not get inside), and wet flood-proofing (allowing water to enter building with minimal damage to building and its contents). (ASFPM 2003)
Opportunity costs	The value of productivity forgone by not investing a resource in the next optimal project. (DWR 2008a)
Other Municipal Water Economics Model (OMWEM)	A DWR spreadsheet-based model to estimate water supply benefits to smaller State and federal water contractors not included in LCPSIM. OMWEM is included in Common Assumptions. (DWR 2012m)
Performance	The system's reaction to the hazard.
Planning area	Synonym for project area, study area, and study region. These terms are used interchangeably. *See* Study area.

Planning time horizons	Different planning time periods that may be used for feasibility analyses (DWR 2008a): • Economic life: The period in which the project is economically viable, which means that the incremental benefits of continued use exceed the incremental costs of that use. • Physical life: The period that ends when the project can no longer physically perform its intended function. Economic life may be shorter than physical life but not vice versa. • Analysis period: The length of time over which a project's consequences are analyzed. Typical analysis periods for structural water resource projects are 50 to 100 years and 5 to 25 years for nonstructural projects. • Financing period: The length of time required for bond repayment or other required paybacks, which may be shorter or longer than the economic period of analysis. This time horizon is only relevant for financial analyses. • Short-term vs. long-term: Short-term is the period of time in which capital investments cannot be changed, compared to the long-term in which new capital investments can be undertaken.
Primary benefits	The increased values of goods and services attributable to a project; that is, increases in products or services and/or reductions in costs, damage, or losses to those directly affected by the project. (DWR 2008a)
Primary beneficiaries	Parties (producers and consumers) who directly use the project's outputs. (DWR 2008a)
Project area	Synonym for planning area, study area, and study region. These terms are used interchangeably. *See* Study area.
Project objective	A project may provide benefits from other objectives that are incidental to the project purposes for which benefits can also be estimated, but for which no cost allocation occurs.
Project purpose	A project purpose is one included in the plan formulation process for which benefits are estimated and to which costs are allocated.
Public benefits	Benefits that encompass environmental, economic, and social goals, include monetary and nonmonetary effects, and allow for the inclusion of quantified and unquantified measures. (P&G 2013)
Public good	Goods or services in which, once they are made available to one person, others cannot be excluded from making use of the same goods or services. In addition, consumption by one does not reduce the consumption by others. In other words, public goods are characterized by nonexcludability and nonsubtractability. (APFM 2007)

Residual risk	The flood risk that remains if a flood risk management project is implemented. Residual risk includes the consequences of capacity exceedance. (USACE 2006)
Resiliency	The capability to cope with and recover from a traumatic event. (USACE IWR 2009).
Risk	The probability that a defined set of events will result in adverse (or beneficial) consequences. (David Ford Consulting Engineers, Inc.)
Risk analysis	A method of analysis that accounts explicitly for uncertainty in the contributing factors by first determining the best estimate of each of the functions used for the risk computation, and then describing the confidence in each with a statistical distribution about that best estimate. If descriptions of the statistical distributions of these functions cannot be developed, then uncertainty can be evaluated with sensitivity analysis. (David Ford Consulting Engineers, Inc.)
Risk-based water deliveries	An analysis approach that balances increasing deliveries in a given year with the risk of not meeting full deliveries in a subsequent dry year. (DWR 2009)
Secondary effects	The changes in economic activity from subsequent rounds of re-spending of dollars as a result of constructing and operating a project. (USACE 2011)
Social effects	The constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness and how they are affected by some condition or proposed intervention. (USACE 2009)
Social vulnerability	The capacity for being damaged or negatively affected by hazards or impacts. Vulnerability is associated with certain characteristics of a portion of the population—e.g., people with mobility difficulties, language barriers, and those who lack means of transportation are generally more vulnerable than others. (USACE IWR 2009)
Socioeconomic impact analysis	A type of economic analysis that focuses on changes in regional population, and secondary economic and fiscal effects expected to occur from proposed projects. Results from socioeconomic impact analyses are often included in environmental impact studies/reports and, for federal studies, are included in the Regional Economic Development and/or Other Social Effects planning accounts. (DWR 2008a)

State Plan of Flood Control (SPFC) The State and federal flood control works, lands, programs, plans, policies, conditions, and mode of maintenance and operations of the Sacramento River Flood Control Project described in Section 8350 of the California Water Code (CWC), and of flood control projects in the Sacramento River and San Joaquin River watersheds authorized pursuant to Article 2 (commencing with Section 12648) of Chapter 2 of Part 6 of Division 6 for which the CVFPB or DWR has provided the assurances of nonfederal cooperation to the United States, and those facilities identified in CWC Section 8361. (California Water Code Section 9110(f))

State Water Project (SWP) A water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. Its main purpose is to store water and distribute it to 29 urban and agricultural water suppliers in northern California, the San Francisco Bay Area, the San Joaquin Valley, the central coast, and southern California. Of the contracted water supply, 70 percent goes to urban users and 30 percent to agricultural users. The project delivers water supplies to two-thirds of the State's population and is maintained and operated by the California Department of Water Resources. (DWR 2009)

Statewide Agricultural Production Model (SWAP) A DWR model that optimizes agricultural production by adjusting crop mix, water sources and quantities, and other inputs. It focuses on the Central Valley, but does include coverage in other areas of the State. SWAP is included in Common Assumptions. (DWR 2012m)

Structural measures These measures have traditionally been used by communities to keep flood waters away from an area by modifying the flow, velocity, or direction of a river or other water source. Examples include reservoirs; levees, floodwalls, seawalls, or other barriers; channel modifications; bridge and culvert improvements; groins; dredging; and diversions. (ASFPM 2003)

Study area Synonym for planning area, project area, study region, and the like. These terms are used interchangeably. A geographic area large enough to ensure that plans will address the problems and opportunities in the area under study and encompass areas that are potentially affected by or that could affect candidate solutions so the solutions can be examined appropriately. Often the study area can be defined by hydrologic interaction (i.e., the watershed). (USACE 2010)

Study region Synonym for planning area, project area, study area, and the like. *See* Study area.

Sustainable The creation and maintenance of conditions under which humans and nature can coexist in the present and into the future. (CEQ 2013)

Tradeoff analysis	An analysis method that displays all monetary and nonmonetary effects of a project such that the "gains and losses" among different plans can be identified. (DWR 2008a).
Travel cost method	An analysis method used to estimate the value of recreational and/or ecosystem benefits assuming that the time and travel costs people incur to visit sites can be used as indicators of their willingness to pay for benefits obtained at those sites. (DWR 2008a)
Uncertainty	Situations without sureness, whether or not described by a probability distribution. Two key sources of uncertainty arise in a planning study—model specification and data collection/ measurement. (DWR 2008a)
Unwise use of floodplains	Any action or change that diminishes public health and safety, or an action that is incompatible with or adversely impacts one or more floodplain functions that leads to a floodplain that is no longer self-sustaining. (CEQ 2013)
Urban	Broadly includes all non-agricultural land uses, such as residential, commercial, industrial, and public which can occur in cities, small communities, or even rural areas.
Urbanizing area	A developed area or an area outside a developed area that is planned or anticipated to have 10,000 residents or more within the next 10 years. (California Government Code Section 65007(k))
Urban levee design criteria (ULDC)	The levee and floodwall design criteria developed by DWR for providing the urban level of protection. (California Government Code Section 65007(k) and CWC Section 9602(i))
Urban level of protection (ULOP)	Level of protection that is necessary to withstand flooding that has a 1-in-200 chance of occurring in any given year using criteria consistent with, or developed by, DWR. (California Government Code Section 65007(l) and CWC Section 9602(i))
Vulnerability	The susceptibility to harm of people, property, and the environment exposed to the hazard.
Watershed	The land area from which water drains into a stream, river, or reservoir. (California Water Plan Update 2009 Glossary)
Willingness to accept	The amount of money that an individual would be willing to accept as payment in order to forego a good or service. (DWR 2008a)
Willingness to pay	The amount of money that an individual would be willing to pay for a good or service, which indicates the benefit of that good to that individual. (DWR 2008a)

With-project and without-project conditions

Without-project: The condition that includes not only historical and existing conditions but also the future without-project condition. This condition becomes the baseline from which all project effects (positive and negative) are compared.

With-project: The condition with the project.

Often the without-project and with-project comparison is confused with a "before" and "after" comparison, but this is not correct because some of the benefits forecasted to occur in the future with the project may also have occurred without the project and therefore should not be attributed to the project. (DWR 2008a)

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WRC. *See* U.S. Water Resources Council.

14.0 Abbreviations

AAHU	Average annual habitat unit
AEP	Annual exceedance probability
AF	Acre-feet
B/C	Benefit to cost ratio
B-C	Benefit-cost analysis
CE	Cost effectiveness
CEA	Cost effectiveness analysis
CE/IC	Cost effectiveness/incremental cost (analysis)
CEQA	California Environmental Quality Act
CVFMP	Central Valley Flood Management Planning (program)
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project
DEM	Digital elevation model
DWR	California Department of Water Resources
EAD	Expected annual damage
EIR/EIS	Environmental impact report/environmental impact statement
EM	Engineer Manual (US Army Corps of Engineers)
ER	Engineer Regulation (US Army Corps of Engineers); Environmental restoration
EQ	Environmental quality
FEMA	Federal Emergency Management Agency
FRM	Flood risk management
GIS	Geographic information system
HAV	Handbook for Assessing Value of State Flood Management Projects (this document)
HEC	USACE Hydrologic Engineering Center
H&H	Hydrology and hydraulics
IR	Inundation-reduction (benefit)
IRWM	Integrated regional water management
LCC	Life cycle cost
MCA	Multiple criteria analysis

M&I .... Municipal and industrial
NED .... National economic development
NEPA .... National Environmental Policy Act
NER .... National ecosystem restoration
NFIP .... National Flood Insurance Program
NRC .... National Research Council
OMRR&R .... Operation, maintenance, repair, replacement, and rehabilitation
OSE .... Other social effects
P&G .... Economic and environmental principles and guidelines for water and land related resources implementation studies, US Water Resources Council (1983)
PS .... Public safety
PSP .... Proposal solicitation package
RED .... Regional economic development
R&U .... Risk and uncertainty
SCRB .... Separable cost-remaining benefit
SEIA .... Socioeconomic impact analysis
SPFC .... State Plan of Flood Control
TDS .... Total dissolved solids
ULOP .... Urban level of protection
USACE .... US Army Corps of Engineers
WRC .... Water Resources Council
WTP .... Willingness to pay

Appendix A: Flood Risk Concepts

June 2014

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Appendix A: Flood Risk Concepts

A goal of flood risk management (FRM) is to protect lives, property, and other resources in a cost-effective manner. FRM studies are intended to identify measures and plans that achieve this goal by reducing risk. A flood risk analysis, the concepts for which are described in this attachment, is a critical input to a flood risk management study.

A.1 Definition of Risk and Risk Analysis

Risk is the probability that a defined set of events will result in adverse (or beneficial) consequences. A risk analysis accounts explicitly for uncertainty in the contributing factors by first determining the best estimate of each of the functions used for the risk computation, and then describing the confidence in each with a statistical distribution about that best estimate. If descriptions of the statistical distributions of these functions cannot be developed, then uncertainty can be evaluated with sensitivity analysis.

A.2 Definition of Flood Risk

Flood risk is the probability of adverse consequences for the entire range of hydrologic events for a given impact area with a specified climate condition, land use condition, and flood management system (existing or planned) in place. Flood risk is not the loss of life or damage incurred from a single catastrophic event. Rather, it accounts for the probability of each of many outcomes.

Flood risk commonly is expressed as a consequence-probability function. The consequence-probability function can be integrated to compute an expected value of the consequence. If the probabilities are annual values, this is called the expected annual value. If the consequence considered is economic loss, this is called expected annual damage (EAD). EAD reduction is often used as a standard for measuring the effectiveness of proposed FRM measures. However, risk can also be measured with other indices, such as life loss or impacts to habitat.

The five components of flood risk are hazard, performance, exposure, vulnerability, and consequence. These components are defined below.

A.2.1 Hazard

The hazard is what causes the harm, in this case, a flood. The flood hazard is described in terms of probability of stage, velocity, extent, depth, and other properties of the flood.

A.2.2 Performance

Performance is the system's reaction to the hazard. Performance can be described for engineered systems (such as levees or reservoirs) which directly affect the hazard. Performance can also be described for non-engineered systems, such as flood warning systems, in terms of the efficiency of delivering critical information to the public, taking into account the time of day and people's activities when the warning is received.

A.2.3 Exposure

Exposure is a measure of who and what may be harmed by the flood hazard. It incorporates a description of where the flooding occurs at a given frequency, and what exists in that area. Tools such as flood inundation maps provide information on the extent and depth of flooding; and structure inventories, crop data, habitat acreage, and population data provide information on the people and property that may be affected by the flood hazard.

A.2.4 Vulnerability

Vulnerability is the susceptibility to harm of people, property, and the environment exposed to the hazard. Depth-percent damage functions, depth-percent mortality functions, and other similar relationships describe vulnerability.

A.2.5 Consequence

Consequence is the harm that results from a single occurrence of the hazard. It is measured in terms of indices such as structure damage, acreage of habitat lost, crops damaged, and lives lost.

The relationships of the flood risk components are conceptually illustrated in Figure A-1. Flood risk reduction (e.g., benefits) is achieved by altering the hazard, performance, exposure, and/or vulnerability, thus reducing adverse consequences.

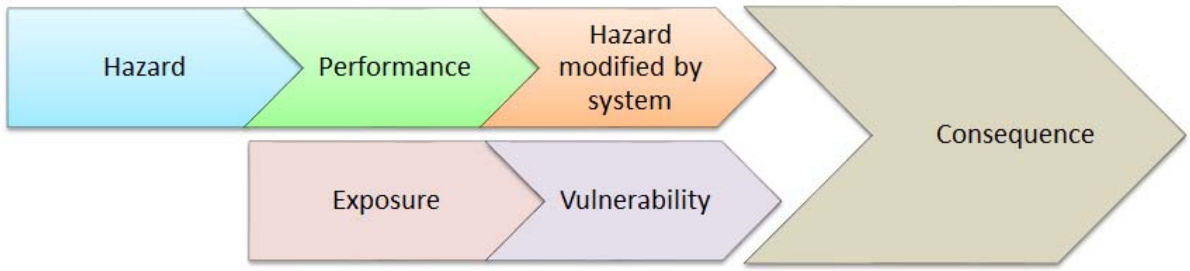


Figure A-1. Conceptual Illustration of Flood Risk Analysis Components

A.3 Note About Terminology

This attachment uses the following terminology wherever appropriate:

- "Function" instead of "curve."
- "Probability" instead of "frequency."
- "Discharge" instead of "flow."
- "Water surface elevation" instead of "stage."

For example, a flow-frequency curve is referred to herein as a discharge-probability function.

In this attachment, "water surface elevation" is used to indicate a vertical distance to a selected vertical datum. That datum may be an accepted standard datum, such as the USACE standard, which is the North American Vertical Datum of 1988 (NAVD88). Alternatively, the datum used may be another convenient datum selected for the study, but constant throughout the study. "Water surface elevation" is not used to mean depth at a site measured relative to a local site datum.

A.4 Types of Flood Risk Management Benefits

Flood risk management benefits result from protecting existing and future development from flood damage and making flood-prone land more suitable for appropriate uses. In general, FRM primary benefits can be grouped into three subcategories:

- Inundation-reduction (IR) benefits
- Intensification benefits
- Location benefits

IR benefits are reduced or modified flood damage, costs, and/or losses to existing or future economic activity. Their computation is the main focus of a FRM risk analysis described in this attachment. Examples of IR benefits include reductions in:

- Physical flood damage to structures and contents, infrastructure, crops, and ecosystem resources
- Loss of functions of structures and infrastructure
- Emergency response costs
- Loss of life

Intensification benefits are the value of intensifying existing land use as a result of implementing an FRM project (for example, development of vacant lots interspersed among existing land uses). Location benefits are the value of making floodplain land available for a new economic use through FRM (for example, shifting from agricultural to residential land uses). Current US Army Corps of Engineers (USACE) policy is not to estimate either of these benefits, except in limited circumstances, because they "do not reduce actual flood damages." Thus, these benefits are not described herein, but information concerning how (and when) to compute them can be found in the USACE *Planning Guidance Notebook*.

A.5 How Economic Inundation-Reduction Benefits Are Computed

Although IR benefits can be estimated for different indices, in this document, the focus is on economic IR benefits—an economic flood risk analysis. Economic IR benefits are the reduction in damages associated with existing or future land use, based on a comparison of without- and with-project conditions. Damages and damages reduced are reported in annualized terms: expected annual damage (EAD). For example, if EAD is $1 million in damage to property without the project, but reduced to $0.4 million with the project, then the annual IR benefit (the EAD losses avoided due to the project) is $0.6 million.

EAD is calculated as the integral of the damage-probability function which weights the damage for each event by the probability of that event happening in any given year and then sums across all possible events. The damage-probability function is derived commonly by transformation of available hydrologic, hydraulic, and economic information, as illustrated in Figure A-2. A water discharge-probability function (Figure A-2a) and a water surface elevation (stage)-discharge (rating) function (Figure A-2b) are developed using principles of hydrology and hydraulics. A water surface elevation-damage function (Figure A-2c) is developed from information about location and value of damageable property in the floodplain. With this, the elevation-probability function can be transformed to yield the required damage-probability function (Figure A-2d). Finally, to compute the expected damage, the resulting damage-probability function can be integrated.

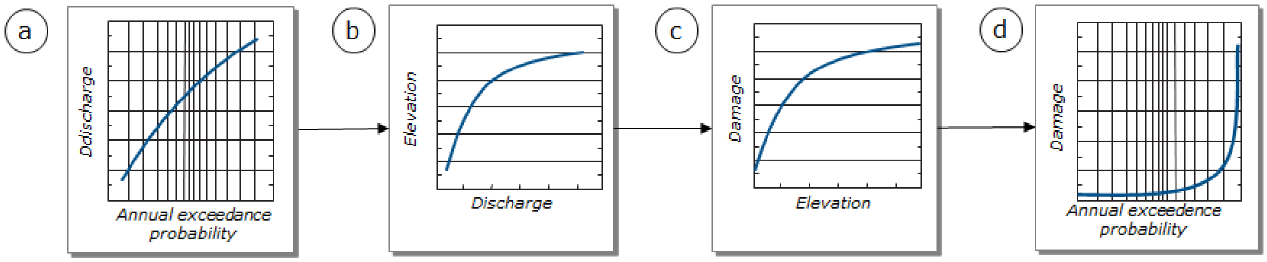


Figure A-2. Computation of Expected Annual Damage (EAD)

In mathematical terms, EAD is computed as follows:

The expected value of annual flood damage (EAD) can be determined by developing and integrating an annual damage probability function, computing the expected value of annual damage, $E[X]$, as

$$E[X] = \int_{-\infty}^{\infty} x \, f_X(x) \, dx \qquad (1)$$

in which $E[\ ]$ = the standard notation for expected value; X = annual maximum flood damage; x = the random value of annual maximum damage; $f_X(x)$ = probability density function of annual damage.

This integration task is completed using the USACE computer program Hydrologic Engineering Center (HEC)-Flood damage reduction analysis (FDA) (USACE 2008).[1] This program is based on the concept that the average of damages that are incurred over a very long period will approach the true EAD. It uses a statistical model to generate a long sequence of flood elevations, uses the water surface elevation-damage transformation to create an equally long record of annual damages, and averages those. It also assigns uncertainties to these functions, as described below.

A.6 Flood Risk Analysis Concepts

Flood risk is the probability of adverse consequences for the entire range of hydrologic events for a given impact area with a specified climate condition, land use condition, and flood management system (existing or planned) in place. The consequence may be direct or indirect economic loss, loss of life, environmental impact, or other specified measure of flood effect. Only impact as measured by economic cost (sometimes called an economic flood risk analysis) is described in the remainder of

[1] Other software applications are also available to compute flood risk, including HEC-Flood Impact Analysis (FIA) and the Federal Emergency Management Agency's (FEMA) HAZUS-MH (Hazards US Multi Hazard). However, HEC-FDA is currently the standard application for USACE flood risk analyses.

this document. However the concepts described below can be used generally to describe life safety, environmental, and other consequences.

The flood risk assessment analysis, which takes into account hazard, performance, exposure, vulnerability, and consequences, can vary in complexity depending on existing and proposed flood risk management facilities. Thus, concepts underlying the flood risk analysis will be described below using three example systems:

- System without engineered structures
- System with upstream reservoirs
- System with upstream reservoirs and levees

But, first, the geographic extent of the study area must be determined.

A.6.1 Define Study Area, Impact Areas, and Index Points

The study area is defined based on the stream system and extent of potential flooding. In addition, the study area must account for potential changes upstream (or downstream) that will affect the potential inundated area. Thus, a systemwide flood risk analysis is required.

The potential inundated area is divided into impact areas (sometimes called damage reaches). An impact area is land subject to inundation from a nearby body of water, such as a creek, stream, river, lake, reservoir, sea, or ocean. Risk analysis procedures are similar in most aspects for all these water bodies. The remainder of this text focuses on an impact area subject to inundation from a nearby channel, as shown in Figure A-3.

The boundaries of the impact area are selected by the analyst to represent adequately the hazard, performance, exposure, vulnerability, and consequence in the impact area. Or, stated another way, the impact area is a study unit in which flooding characteristics, land use, population density, or effect of a proposed measure are similar throughout.

An index point is visible on the impact area boundary in Figure A-3. An index point is a single point that represents the interface between the impact area (floodplain) and the channel. Important information about the flood hazard, system performance, exposure, vulnerability, and consequence in the impact area is aggregated at the index point. Multiple index points may also be used for a single impact area, if multiple sources of flooding need to be considered (i.e., if the impact area is subject to inundation from multiple unique sources). Different methods are available to account for multiple index points that address the potential problem of double-counting damage estimates (Pingel and Watkins 2010).

Figure A-3. Risk Analysis Identifies Long-Term Damage in an Impact Area Due to Rising Water in the Adjacent Water Body

(Google Earth Map, Europa Technologies, 2010)

A.6.2 Example 1. System Without Engineered Structures

Figure A-4 conceptually illustrates a simple flood risk analysis with no engineered structures. The descriptions of hazard, performance, exposure, vulnerability, and consequences are described below.

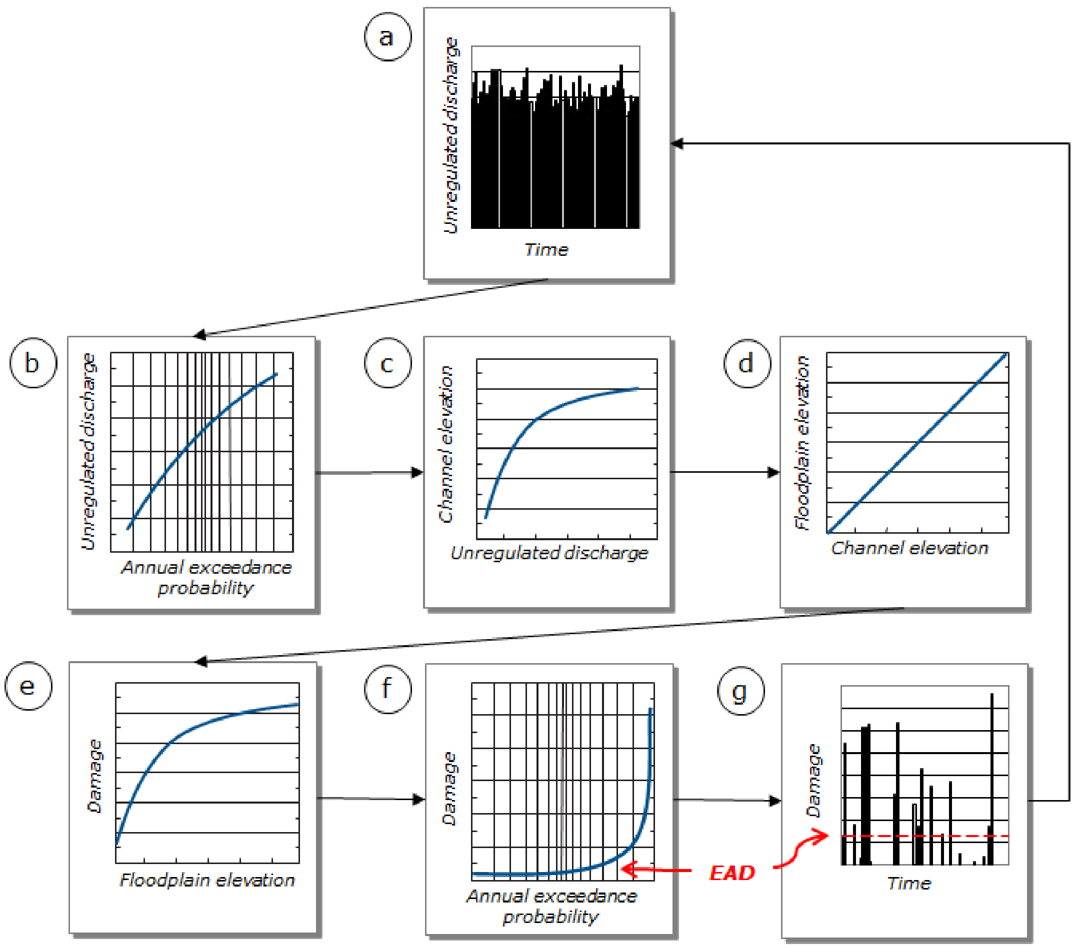


Figure A-4. Flood Risk Analysis with No Engineered Structures

In Figure A-4: the hazard is described by identifying a long term series of discharge in the channel (a), which yields an unregulated discharge-probability function (b). Channel discharge can be transformed to water surface elevation (stage) in the channel (c), which is then transformed to water surface elevation in the floodplain (d). Combining exposure and vulnerability information with floodplain water surface elevation results in a floodplain water surface elevation-damage relationship (e). Damage information can be combined with probabilities to obtain the damage-probability function (f), which can be integrated to obtain expected annual damage (EAD). An alternative way to show annual damage over a long time series is shown in (g), with EAD represented by the dashed line, which can be referenced back to the channel discharge over time shown in (a). To obtain project benefits, this process must be done for without- and with-project conditions.

Hazard. The flood hazard is described by a long series of hydrologic conditions in the channel, such as the discharge time series shown in Figure A-4a. Such a discharge time series is derived by sampling the unregulated discharge-probability function that is developed with standard hydrologic engineering methods. These include, but are not limited to:

- Statistical analysis of unregulated annual maximum discharge observations with which a probability function is fitted.
- Design storm analysis in which precipitation of specified probability is used as the boundary condition for a rainfall-runoff-routing model such as HEC-Hydrologic Modeling System (HMS), computing a peak discharge to which a consistent probability is assigned.
- Continuous simulation in which a long discharge record is synthesized from a long record of rainfall after which a probability model is fitted to the resulting synthesized sample.
- Regional regression methods in which statistical analyses at similar sites are used to develop equations to predict discharge magnitudes of specified exceedance probability.

These hydrologic analysis methods yield an unregulated discharge-probability function, as shown in Figure A-4b.

In many cases, describing flood hazard within an impact area is best done as a function of channel water surface elevation, rather than as a function of discharge rate. Accordingly, the series of discharge for the channel at the index point is transformed to an equivalent series of water surface elevation using a discharge-to-elevation transform, shown in Figure A-4c. This function may be developed empirically if measurements are available at a stream gage for the condition of interest. Otherwise, the function is developed with a conceptual model of the physics of flow in the channel, such as HEC-River Analysis System (RAS) and the FLO-2D hydrologic and hydraulic flood routing model.

Next, the relationship between water surface elevation in the channel and water surface elevation in the floodplain must be determined, as shown in Figure A-4d, which defines the extent and depth of flooding (e.g., the floodplain). This relationship, called the interior-exterior function, may be derived from measurements of coincident elevations in the impact area (interior) and channel (exterior). Alternatively, it can be derived with a model that simulates hydraulics of flow from the channel onto the impact area, considering the terrain in the impact area and the physics of flowing and ponded water.

Applying the interior-exterior function to the channel water surface elevation yields a water surface elevation in the impact area. Subtracting the ground elevation at any point then yields inundation depths throughout the impact area. These depths can be assigned to property and other assets exposed to the flood hazard to assess consequences. This process essentially defines the floodplain.

In Figure A-4d, the impact area is not protected by a levee, so as the elevation in the channel increases, the floodplain elevation also increases. For simplicity, this illustration shows a straight line relationship, but the terrain and hydraulics may yield a nonlinear relationship.

Determining Exposure

Structure category (1)	Number of structures (2)
Single family, 1 story	12,251
Single family, 2 story	9,803
Multi-family, 1 story	183
Multi-family, 2 story	27
Commercial	383
Industrial	176
Total	**22,823**

Exposure can be determined by overlaying a floodplain on a parcel map using GIS

Performance. Because there are no engineered structures (e.g., reservoirs or levees) in this example, no performance descriptions pertaining to these structures are included.

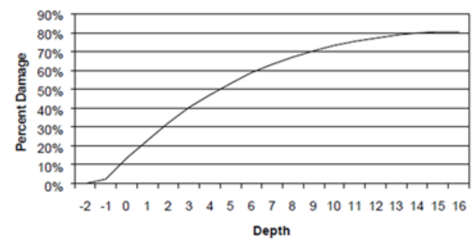
Exposure. Exposure is a description (inventory) of the property in the inundated area, including damageable structures and content, critical infrastructure, crops, etc. Identifying which properties and other assets are affected by the flood is often accomplished by overlaying floodplains over census tracts or county assessor parcel maps, as illustrated in the box below.

Vulnerability. Once the depths have been identified at parcels, the vulnerability of structures and other assets at those parcels is assessed. One measure of vulnerability is the damage that occurs to structures and contents with increasing depth, as indicated by a depth-percent damage function illustrated in the box (lower right). The depth-percent damage function may be developed for existing property in the floodplain from inspection, appraisal, and review of the history of damage to like property when inundated. The function may represent physical damage to a single item, such as a residential structure, a vehicle, or a section of roadway. It may also represent the economic cost due to loss of function. Thus, if a business is unable to operate following a flood, the lost revenue may be included. Similarly, if economic costs associated with displacement of floodplain occupants can be related to the depth of flooding of structures, that damage can be included. Costs included or not included vary with the economic analysis procedures used by various agencies. Although depth is the primary measure of vulnerability, other measures could include velocity, water temperature, water quality (debris and other contaminants), or other factors. The USACE has developed economic guidance memoranda describing depth-percent damage functions.

Consequences. Inundation depths at property locations within the impact area are transformed to estimates of damage at those locations, which are aggregated for the impact area to yield a water surface elevation (stage)-damage function, such as the one in Figure A-4e. This function can be combined with probabilities to obtain the probability-damage function shown in Figure A-4f, which displays consequences. Computationally, EAD can be computed by integrating the area under the damage-probability function, as described above.

An alternative way to display economic damage is to show the maximum inundation-related damage in an impact area for each year in a long time series, as shown in Figure A-4g. Note that in this illustration, property is not damaged in many years. Water surface elevation in the channel does not exceed the channel capacity or the depth is so small that no significant damage is incurred. The time series of damage information shown in Figure A-4g can be referenced back to the time series of channel discharge shown in Figure A-4a.

Determining Consequence



A depth-percent damage function shows the percent structural or other damage for respective flood depths. Depth-percent damage functions have been developed by the USACE and FEMA for different type of structures and their contents.

To obtain project benefits, this process must be done for without- and with project conditions.

A.6.3 Example 2: System With Upstream Reservoirs

Figure A-5 illustrates a flood risk analysis with upstream reservoirs. The conceptual descriptions of hazard, performance, exposure, vulnerability, and consequences are the same as described with no engineered structures, except for the differences described below:

- **Hazard.** There are no differences from Example 1 in the method used to describe the hazard.
- **Performance.** If discharge in the channel is regulated by reservoir storage, the performance of that storage is described with an unregulated-to-regulated discharge transform (Figure A-5c), which modifies unregulated discharge upstream of the reservoir to the corresponding regulated value downstream of the reservoir.
- **Exposure.** There are no differences from Example 1 in the method used to describe exposure.
- **Vulnerability.** There are no differences from Example 1 in the method used to describe vulnerability.
- **Consequences.** There are no differences from Example 1 in the method used to describe consequences.

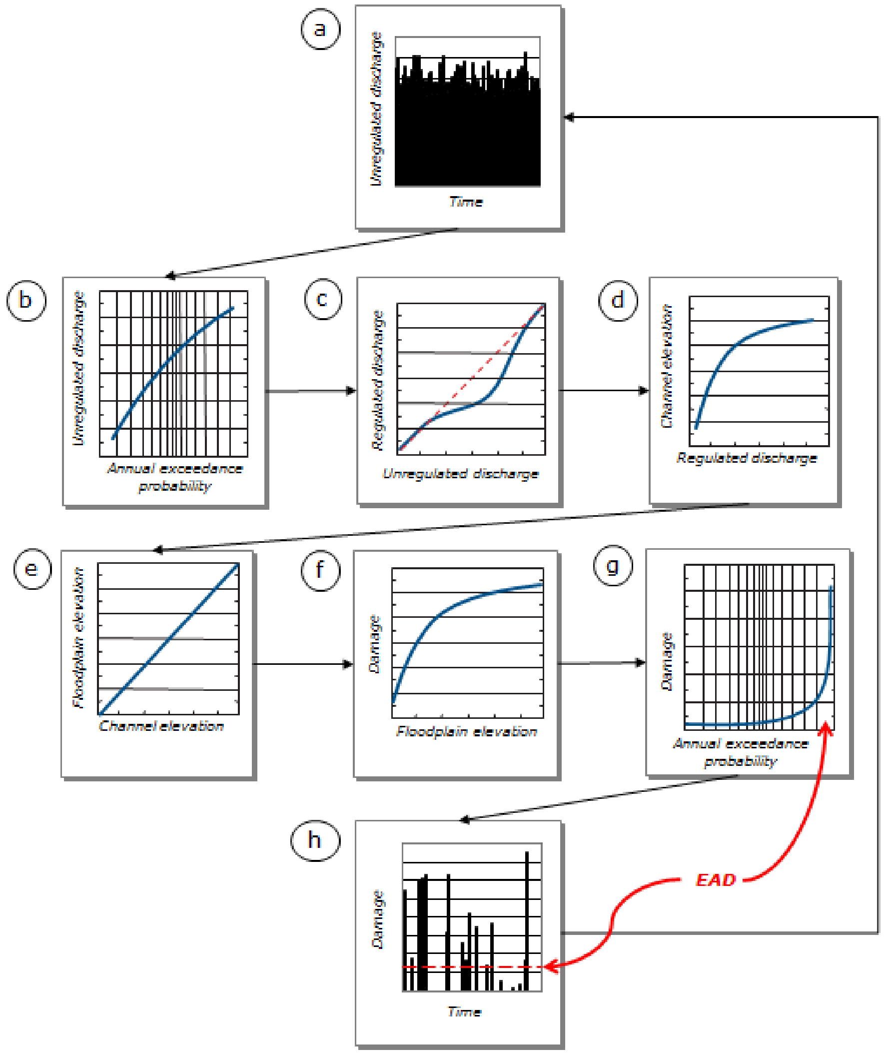


Figure A-5. Flood Risk Analysis with Upstream Reservoirs

In Figure A-5: The hazard is described by identifying a long term series of discharge in the channel (a), which yields an unregulated discharge-probability function (b). Because of the performance of the engineered structure (for example, reservoir), the timing and amount of regulated channel discharge is different than the unregulated discharge (c). Regulated channel discharge can be transformed to water surface elevation (stage) in the channel (d), which is then transformed to water surface elevation in the floodplain (e). Combining exposure and vulnerability information with floodplain water surface elevation results in an aggregated floodplain water surface elevation-damage relationship (f). Damage information can be combined with probabilities to obtain the damage-probability function (g), which can be integrated to obtain expected annual damage (EAD). An alternative way to show annual damage over a long time series is shown in (h), with EAD represented by the dashed line, which can be referenced back to the channel discharge over time shown in (a). To obtain project benefits, this process must be done for without- and with-project conditions.

A.6.4 Example 3: System With Upstream Reservoirs and Levees

Figure A-6 illustrates a flood risk analysis with upstream reservoirs and levees. The conceptual descriptions of hazard, performance, exposure, vulnerability, and consequences are the same as described with reservoirs, except for the differences described below:

Hazard. There are no differences from Example 1 in the method used to describe the hazard.

Performance. If a levee is present, it will limit the movement of water into the impact area until it is overtopped or fails. The performance of a levee is described with a levee failure probability function, shown in Figure A-6e. Thus, the impact area water surface elevation (and the corresponding depth and damage) is zero until the channel water surface elevation exceeds the top of the levee or causes it to fail. When overtopping or failure occurs, water in the impact area rises to the water surface elevation near that which would have been reached without the levee, shown in Figure A-6f.

Exposure. There are no differences from Example 1 in the method used to describe exposure.

Vulnerability. There are no differences from Example 1 in the method used to describe vulnerability.

Consequences. There are no differences from Example 1 in the method used to describe consequences.

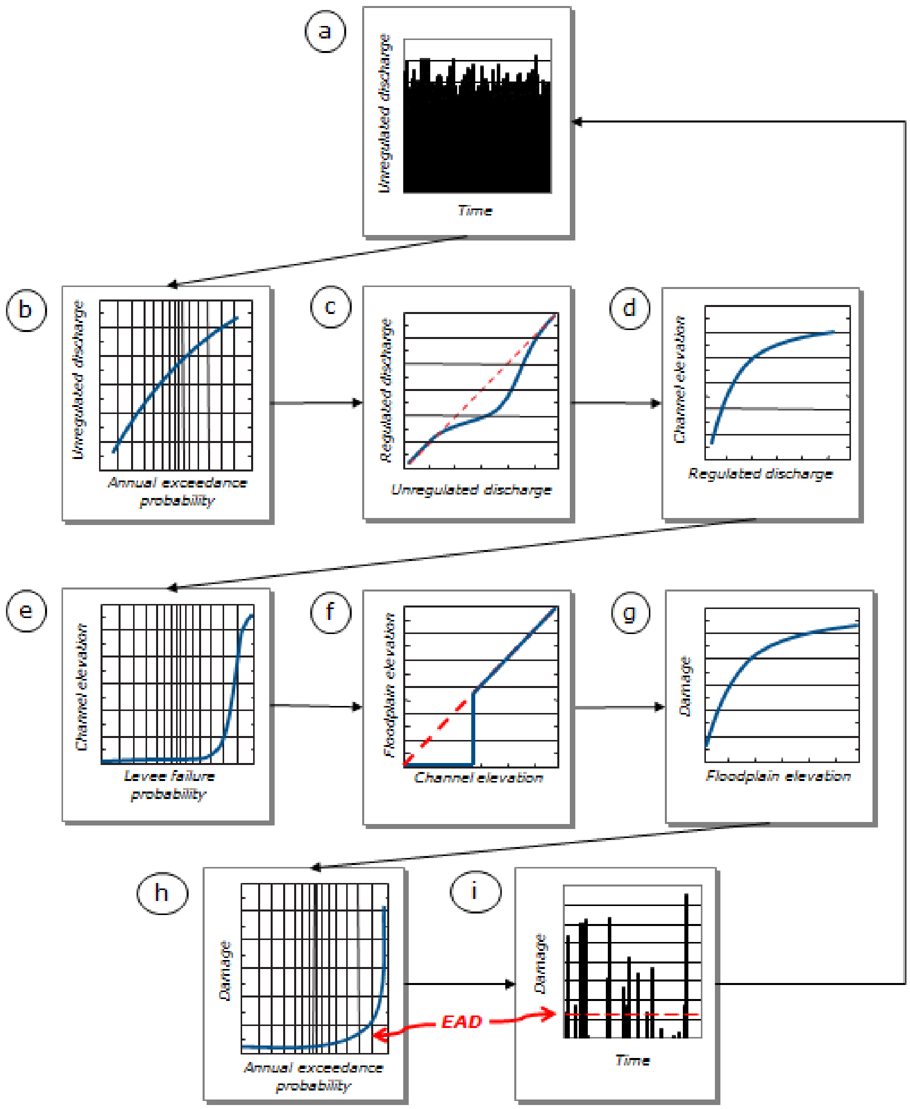


Figure A-6. Flood Risk Analysis with Upstream Reservoirs and Levees

The hazard is described by identifying a long term series of discharge in the channel (a), which yields an unregulated discharge-probability function (b). Because of the performance of the reservoir, the timing and amount of regulated channel discharge is different than the unregulated discharge (c). Channel discharge can be transformed to water surface elevation (stage) in the channel (d). Levee performance is defined by levee failure probability, which is a function of water surface elevation (e). Floodplain water surface elevation is eliminated until the levee overtops or fails (f). Combining exposure and vulnerability information with floodplain water surface elevation results in an aggregated floodplain water surface elevation-damage relationship (g). Damage information can be combined with probabilities to obtain the damage-probability function (h), which can be integrated to obtain expected annual damage (EAD). An alternative way to show annual damage over a long time series is shown in (i), with EAD represented by the dashed line, which can be referenced back to the channel discharge over time shown in (a). To obtain project benefits, this process must be done for without- and with-project conditions.

A.7 Importance of Uncertainty

Uncertainty is present in estimating all of the flood risk components (flood hazard, system performance, exposure, vulnerability, and consequence). Some examples of uncertainty (and how HEC-FDA accounts for them) are described below.

A.7.1 Uncertainty about Flood Hazard

Information required for computing the flood hazard (for example, the discharge-probability) is not known with certainty. This uncertainty is due to errors in estimating discharge from imperfect measurements, lack of certain knowledge about the mathematical form of the probability function, and limitations inherent with using small samples of observations from which the properties of the probability distribution must be estimated. Likewise, the discharge-to-water surface elevation transform is not known with certainty. Again this is due to uncertainty about the physical system properties and about models of the physical system that are used to derive the transform.

HEC-FDA accounts for this uncertainty with each of the inputs and transforming functions by sampling a probability distribution that describes the potential errors in each of those inputs and transforms. For example, uncertainty about the discharge-to-water surface elevation (stage) transform is described with a probability distribution, illustrated conceptually in Figure A-7. This shows a distribution of potential error about the elevation predicted for a specified discharge. Rather than using the best estimate elevation in every case for the transformation, HEC-FDA samples the error distribution during the transformation. Occasionally a value much higher or lower than the best estimate is used, and often a value slightly higher or lower is used. The average of all transformed values tends toward the best estimate. [Note: The HEC-FDA user has the option to run HEC-FDA without uncertainty; however, most applications include uncertainty.]

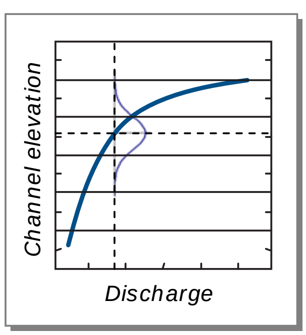


Figure A-7. Probability Distribution of Error about Elevation Predicted for Specified Discharge

A.7.2 Uncertainty about Performance

If engineered features such as levees are present, a significant source of uncertainty is the manner in which those features will perform with the flood hazard. For example, for an impact area protected by a levee, the hazard is excluded from the impact area by the levee until that levee is overtopped. In addition, a levee may breach prior to overtopping, leading to an uncontrolled flow of water into the impact area. This may be due to voids in the levee created by burrowing animals, through-seepage, underseepage, erosion, or other unplanned and uncontrollable factors.

To account for the uncertainty regarding levee performance, the risk analysis within HEC-FDA includes sampling of the levee failure (or fragility) function, such as that illustrated by Figure A-8.

This function defines the probability of the levee failing to provide the planned-for protection as the channel water surface elevation reaches the value shown. At the top of the levee, the probability is 1.00, as it is certain that water will enter the impact area when the levee is overtopped. At some lower elevation, the probability of water reaching the interior area approaches 0.00.

Figure A-8. Levee Failure Function

A.7.3 Uncertainty about Consequence

HEC-FDA accounts for uncertainty about the damage incurred at each impact area elevation by sampling a probability distribution that describes the potential error in damage for a specified impact area elevation, such as that illustrated by Figure A-9. This is consistent with the sampling of uncertainty about the hazard, in which a distribution is described, and rather than using the best estimate damage, HEC-FDA samples the error distribution during the transformation. Thus the transformed value tends towards the best estimate, but occasionally a much higher or lower value is used.

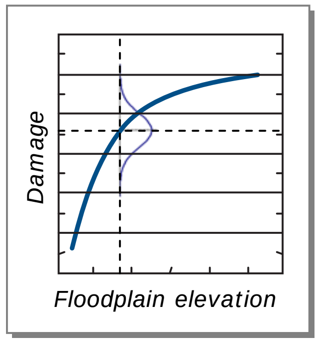


Figure A-9. Elevation-Damage Function

To illustrate the effect of uncertainty in all of the flood risk components, uncertainty bands can be added to Figure A-2 as shown in Figure A-10.

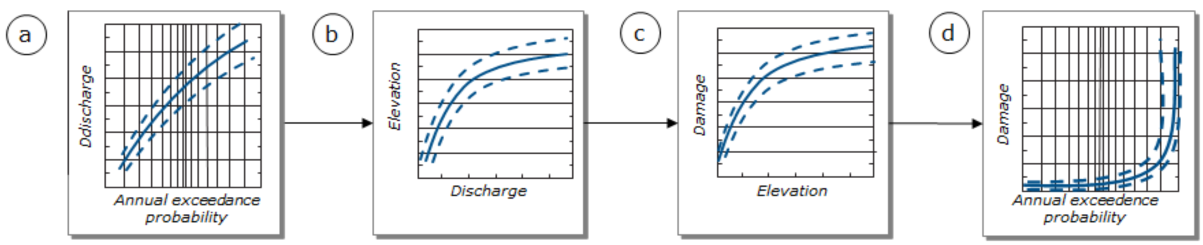


Figure A-10. Illustration of Uncertainty in All of the Flood Risk Components that Affect the Expected Annual Damage (EAD) Computation

A.8 Changes in Flood Risk Due to Measures

A goal of FRM is to protect lives, property, and other resources (i.e., reduce risk) in a cost-effective manner. FRM measures can reduce risk by changing one or more of the factors of flood risk. For example, constructing a new levee will reduce the frequency of flood flows reaching the floodplain (i.e., the *hazard*). Strengthening an existing levee will improve the *performance* of the existing levee. Likewise, changes in the location of property in the impact area can reduce risk by changing the *exposure* of assets to the flood hazard. Table A-1 provides examples of changes in the risk factors attributable to proposed flood risk management measures, all of which should also affect the consequence.

Table A-1. Example Changes in Flood Risk Factors Caused by Proposed Flood Risk Management Measures

Measure	Changed by Measure?				
	Hazard	Performance	Exposure	Vulnerability	Consequence
(1)	(2)	(3)	(4)	(5)	(6)
Constructing new water management measure (levee, floodwall, diversion, interior drainage system, similar facilities)	•				•
Modifying existing water management measure (levee strengthening, erosion repair, reservoir operation enhancement)		•			•
Managing floodplain use and occupancy (land use restriction, property relocation, evacuation)			•		•
Flood proofing (raising structures, waterproof construction, similar actions)				•	•
Installing flood warning system			•	•	•

A.9 USACE Flood Risk Analysis Resources

Essential USACE flood risk analysis resources include:

- EM 1110-2-1619, Risk Analysis for Flood Risk Studies
- ER 1105-2-100, Planning Guidance Notebook
- ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies
- CPD-72, ver. 1.2.4, HEC-FDA Flood Damage Reduction Analysis User's Manual

Other relevant USACE resources include:

- EM 1110-2-1100, Coastal Engineering Manual
- EM 1110-2-1415, Hydrologic Frequency Analysis
- EM 1110-2-1416, River Hydraulics
- EM 1110-2-1417, Flood Run-off Analysis
- EM 1110-2-1419, Hydrologic Engineering Requirements for Flood Damage Reduction Studies
- EM 1110-2-1601, Hydraulic Design of Flood Control Channels

- EM 1110-2-1913, Design and Construction of Levees
- ER 1110-2-1150, Engineering and Design for Civil Works Projects
- ER 1110-2-1405, Hydraulic Design for Local Flood Protection Projects
- ER 1110-2-1450, Hydrologic Frequency Estimates
- EC 1110-2-6067, USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation
- EGM 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements
- EGM 01-03, Generic Depth-Damage Relationships

Online resources:

- USACE Planning Community Toolbox
- USACE online National Economic Development manuals

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Appendix B: Central Valley Flood Protection Plan Conservation Strategy Ecosystem Services and Benefit Assessment Methods

June 2014

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Appendix B: Central Valley Flood Protection Plan Conservation Strategy Ecosystem Services and Benefit Assessment Methods

This appendix summarizes a framework for assessing the economic benefits of potential ecosystem services associated with the Central Valley Flood Protection Plan (CVFPP) conservation strategy. Table B-1 describes these ecosystem services, including the possible CVFPP effect and types of benefits.

Table B-2 summarizes the types of benefits, magnitude of benefit, and valuation methods.

Table B-1. Ecosystem Services Framework (Source: DWR 2011c)

Ecosystem Service (1)	Description (2)	CVFPP Effect and Description (3)		Benefits (4)
Provisioning services: physical materials obtained from ecosystems				
Food	Production of food (e.g., the portion of gross primary production extractable as food)	(+) (-) (-)	Salmonid production from riverine, shaded riverine aquatic, and inundated floodplain habitat restoration Crop production from converting agricultural land to non-agricultural uses Warm water fish from eliminating habitat (e.g., abandoned gravel pits for bass)	Fisheries
Water supply	Storage and retention of water (see also water regulation)	(+)	Groundwater recharge from restored wetlands and increased floodplain storage of floodwater	Water supply Flood control
Fiber and fuel	Production of lumber, fuel, fiber (e.g., the portion of gross primary production extractable as raw materials)	(-)	Reduction in biofuel, firewood, and cotton production from conversion of agricultural land to riparian or wetland vegetation	Negligible
Biochemical resources	Provision of natural biota with a variety of medicinal uses	(=)	Existing collection of medicinal plants	Negligible
Genetic materials	Generation and sustenance of sources of unique biological materials and products	(NA)		Negligible
Regulating services: regulation of processes that affect the production of other ecosystem services				
Climate regulation	Regulation of favorable climatic conditions (e.g., temperature, precipitation) at local and global levels, including greenhouse gas (GHG) fluxes	(+)	Carbon sequestration from converting agricultural land to natural vegetation and expanding mature riparian forest	Carbon storage
		(+)	GHG fluxes because from converting agricultural land to marsh, whose GHG flux is closer to neutral	
		(-)	Methane emissions from marsh restoration	
Water regulation	Regulation of hydrological flows, including flood flows, and buffering of fluctuations in river flows under drought conditions and groundwater fluctuations	(+) (+) (+)	Floodplain storage of water Flood management actions Reduced flood system maintenance costs from shortening flood management facilities or buffering channel banks to reduce wave action and damage	Flood control Water supply

Table B-1. Ecosystem Services Framework (Source: DWR 2011c)

Ecosystem Service (1)	Description (2)	CVFPP Effect and Description (3)		Benefits (4)
Waste treatment	Storage and recycling of nutrients through dilution, assimilation, and chemical recomposition	(+)	Denitrification in riparian vegetation, primarily from groundwater in the vegetation root zone	Water quality
		(+)	Degradation of synthetic organic compounds from increased retention time (e.g., surface water infiltration in riparian areas, transient retention in wetlands)	
		(+)	Reduced pollutant inputs from buffering aquatic ecosystems from agricultural lands (e.g., pesticides)	
		(-)	Increased methylmercury production from sediments of restored marshes	
Erosion regulation	Retention of soils and sediments	(+)	Reduced soil erosion rates from replacing streambank agricultural land with riparian vegetation, installation of biotechnical bank protection	Water quality Carbon storage Habitat
		(-)	Increased soil erosion rates from revetment removal	
Disturbance regulation	Dampening the impacts from environmental fluctuations (providing resistance and resilience)	(+)	Storm protection, flood control, drought recovery, and resistance and resilience to other aspects of environmental variability from increasing floodplain storage of floodwater, groundwater recharge, and extent and diversity of natural vegetation	Flood control Water supply Habitat
Pollination	Animal-assisted pollen transfer between plants, without which many plants cannot reproduce	(+)	Habitat for bees that pollinate crop plants from converting agricultural land to natural vegetation	Habitat Crop production
		(-)	Habitat for bees that pollinate crop plants from converting herbaceous plant-dominated upland vegetation to wetland and riparian vegetation	
Biological control	Trophic-dynamic regulation of populations, including effects of predator control on prey species, effects on pests and diseases, and the spread of invasive species	(=) (-) (=) (+)	Control of crop diseases by converting agricultural land to natural vegetation adjacent to croplands Disease source (mosquito abundance) increase from conversion of upland to wetland vegetation Reduced/increased levee damage from restoration of riparian vegetation Reduced levee damage from reduced ground squirrel abundance in restored riparian areas	Crop production Flood control Public health (negligible)
Cultural services: nonmaterial benefits provided by ecosystems				
Recreational	Provision of opportunities for recreational activities, including eco-tourism, sport fishing, bird watching, and hiking	(+)	Recreational opportunities from converting agricultural land to natural vegetation	Recreation
Aesthetic	Provision of conditions suitable for sensory enjoyment of the environment, including open space and scenic views	(+)	Open space and scenic views, particularly along rivers	Scenic value

Table B-1. Ecosystem Services Framework (Source: DWR 2011c)

Ecosystem Service (1)	Description (2)	CVFPP Effect and Description (3)		Benefits (4)
Educational	Provision of natural areas for scientific and educational enhancement, including field laboratories and opportunities for experiments	(+)	Educational and research opportunities from restoration	Education
		(+)	Knowledge of ecology encourages conservation and stewardship	
Cultural, spiritual, and religious	Provision of natural areas for cultural use, including supporting belief systems	(+)	Preservation of sacred places, cultural resource sites, and historic resources concentrated on the floodplain	Cultural value
		(-)	Increased floodplain inundation and channel migration that can damage and degrade cultural resource sites	
Existence	Value placed on knowing a resource exists, even if no benefits are accumulated, including the species preservation and biodiversity maintenance	(+)	Public awareness of conservation and restoration of Central Valley waterways, natural lands, and habitats	Existence value
Supporting services: ecosystem processes and conditions necessary for the production of other ecosystem services				
Soil formation	Processes that form and structure soil and sustain its fertility	(+)	Floodplain soil structure and organic matter content from restoring geomorphic processes including floodplain sediment deposition	Flood control Carbon storage Habitat
		(+)	Subsidence reduction and reversal from marsh restoration on subsided islands	
Nutrient cycling	Storage, internal cycling, processing, and acquisition of nutrients	(+)	Reduced nutrient inputs from agricultural land resulting from conversion to non-agricultural uses	Water quality Habitat
		(+)	Sediment retention on floodplains and/or in wetlands	
		(-)	Release of sediment from channel bank erosion	
Habitat provision	Provision of habitat for resident and transient populations, including migration corridors	(+)	Fish and wildlife habitat from restoring riverine, wetland, shaded riverine aquatic, inundated floodplain, and riparian habitats	Habitat Existence value
		(-)	Agricultural wildlife habitats (e.g., Swainson's hawk and giant garter snake) from converting agricultural land to other uses	

Key: (+) positive effect; (-) adverse effect; (=) negligible effect; (NA) not applicable

Table B-2. Benefits Valuation Framework (Source: DWR 2011c)

Benefit (1)	Magnitude of Benefit (2)	Rationale (Magnitude) (3)	Value Type (4)	Valuation Approach (5)	Ease of Valuation (6)	Rationale (Valuation) (7)
Flood control	Very high	Restoration actions can increase floodplain storage of floodwaters and otherwise reduce peak flows, reducing assets at risk and O&M requirements	Utilitarian	Avoided damages Avoided cost	Moderate	Existing FEMA methodology for avoided damages; O&M costs available from DWR; requires data on flood damage reduction estimates
Habitat/ ecosystem function	High	Preservation and restoration actions would conserve habitat that provides the supporting services of riverine, wetland, and riparian ecosystems (and that can be applied to mitigation requirements)	Utilitarian/ Intrinsic	Market value Avoided cost Willingness to pay	High	Wetland mitigation prices available from mitigation banks for some species; consultation and permitting fees available; literature contains examples of habitat value
Water supply	Moderate	Additional floodplain inundation and increased wetland acreage would result in additional groundwater recharge	Utilitarian	Avoided cost Willingness to pay[1]	Moderate	Data available on rate payer and DWR delivery costs; requires estimates of likely groundwater and surface water supply improvements
Carbon storage	Moderate	Restoration and enhancement would increase riparian forest acreage that has a greater carbon stock than existing vegetation; some reduction in floodplain agricultural acreage and associated emissions would occur	Utilitarian	Market value	High	Carbon prices available from carbon markets; data available on carbon sequestration/acre by vegetation type
Existence (includes cultural, educational, and intrinsic values)	High	Restoration and enhancement of highly altered and impacted riverine and floodplain ecosystems and sensitive species' habitats would contribute substantially to continued existence	Intrinsic	Willingness to pay	Moderate	Literature contains examples of cultural and spiritual value; benefits are site-specific and may not transfer

Table B-2. Benefits Valuation Framework (Source: DWR 2011c)

Benefit (1)	Magnitude of Benefit (2)	Rationale (Magnitude) (3)	Value Type (4)	Valuation Approach (5)	Ease of Valuation (6)	Rationale (Valuation) (7)
Water quality	Low	Some restoration actions would increase floodplain deposition of sediment and associated water quality constituents, and locally reduce inputs of some water quality constituents associated with agriculture; other actions would increase channel bank erosion	Utilitarian	Avoided cost	Moderate	Requires data on current costs of treatment and pollution control; requires estimates on likely water quality improvements
Recreation	Low	Additional recreational opportunities would be limited; recreational benefits may also require additional infrastructure (e.g., for access)	Utilitarian	Economic impact Willingness to pay	Moderate	Requires data on visitor spending and visitation trends; literature contains examples of recreational value; benefits are site-specific and may not transfer
Crop production	Low	Additional riparian and wetland vegetation would provide only limited habitat for crop pollinators and may not represent a considerable increase above existing vegetation	Utilitarian	Market value	Moderate	Crop production values available from county crop reports; literature contains estimates of pollination benefits in Central Valley
Scenic	Moderate	Riparian and wetland restoration along rivers would result in localized increases in visual quality (based on vividness, intactness, and unity)	Utilitarian/ Intrinsic	Historic pricing Willingness to pay	Low	Requires parcel-level property value data; literature likely contains few comparisons of scenic values of natural and agricultural lands (focus on open space vs. development)

Note:
[1] Willingness to pay should have been included as a valuation approach for water supply benefits in the original DWR source document.

Appendix C: Cost Effectiveness/Incremental Cost Analysis Example

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Appendix C: Cost Effectiveness/ Incremental Cost Analysis Example

Current US Army Corps of Engineers (USACE) environmental plan evaluation consists of comparing the environmental outputs and the economic costs of plans. The costs of these plans are similar to the costs for other water resource projects, as described elsewhere in this handbook. However, unlike planning for other water resource projects, there is (a) no universal metric for quantifying environmental outputs and (b) no consensus on methods to monetize environmental outputs. Without a quantified and monetized measure of project benefits, it is not possible to conduct a traditional benefit-cost (B-C) analysis to evaluate ecosystem restoration alternatives. However, short of a B-C analysis, economic tools are available to evaluate ecosystem restoration plans.

Figure C-1 shows some tools of economic analysis that can provide varying levels of information to support environmental decision making. This decision-support continuum ranges from cost-oblivious decision making (e.g., ignoring cost information) to B-C analysis, a quantified (and monetized) comparison of benefits and costs. Between these two extremes are the economic tools of cost effectiveness/incremental cost (CE/IC) analysis:

- Cost effectiveness analysis ensures that either (a) a set level of environmental output is produced at the least cost possible, or (b) that for a set level of expenditures, environmental output production is maximized.

- Incremental cost analysis provides for the explicit comparison of the relevant changes in costs and outputs between alternative plans.

Although these tools may not identify an optimal solution, together they provide a structured and flexible framework to assist in environmental plan evaluation in a CE/IC analysis. The results of these CE/IC analyses, displayed as graphs of outputs against costs, as shown in Figure C-2, allow decision makers to compare progressively alternative levels of environmental outputs and ask if the next level is “worth it;” that is, is the additional environmental output in the next attainable level worth its additional cost (USACE 1995b)?

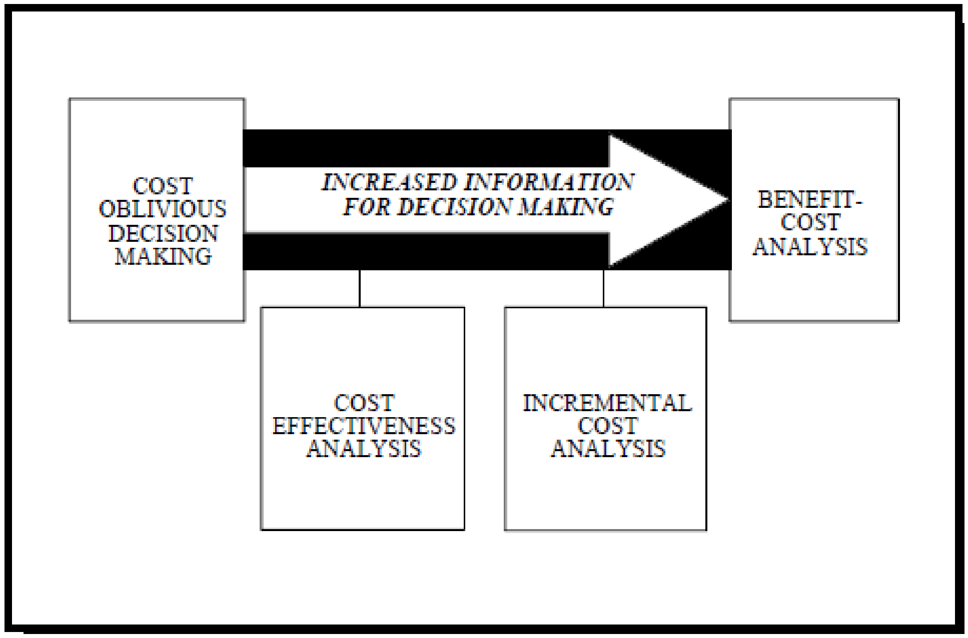

Figure C-1. Decision-Support Continuum

(USACE, 1995b)

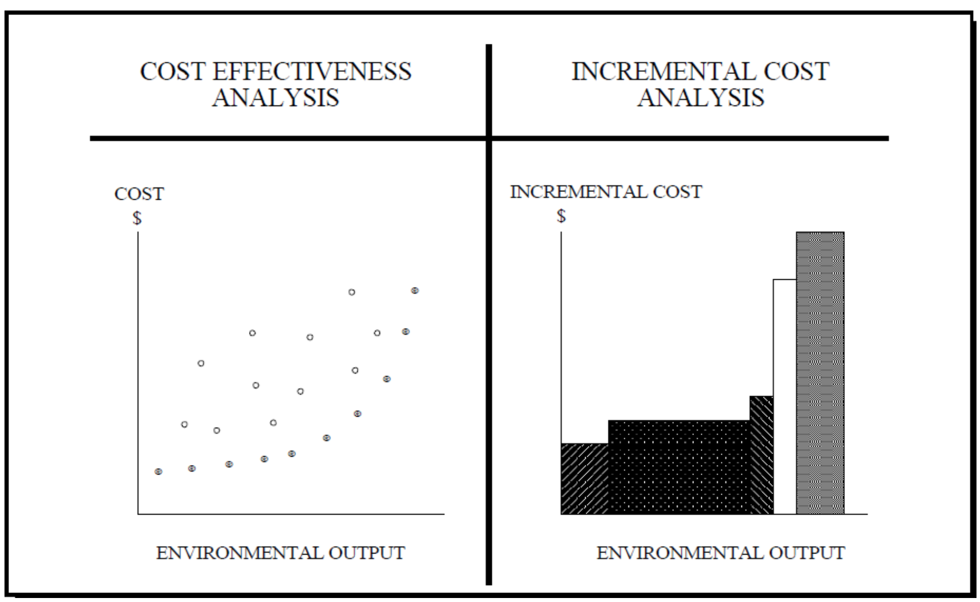

Figure C-2. Cost Effectiveness/Incremental Cost Analyses

(USACE, 1995b)

C.1 Single Purpose Ecosystem Restoration Plans

The following example illustrates the application of CE/IC analysis to single purpose ecosystem restoration plans, following the CE/IC evaluation steps described in Chapter 4.

CE/IC steps 1, 2, and 3 identify potential implementable solutions, combine them into plans, and sort the plans in terms of increasing output. To illustrate these steps, Table C-1 lists six hypothetical environmental plans (in addition to the No Action plan) in order of increasing output (acres) and associated costs.

Table C-1. Hypothetical Environmental Plans Sorted by Increasing Output

Plan (1)	Total Cost (2)	Total Output (3)
No Action	$0	0 acres
Plan A	$20,000	40 acres
Plan B	$10,000	40 acres
Plan C	$15,000	45 acres
Plan D	$15,000	55 acres
Plan E	$42,000	105 acres
Plan F	$40,000	110 acres

Table source: USACE, 1995b

CE/IC Step 4 is the cost effectiveness analysis to determine that (a) for a particular level of output, no other plan costs less, and (b) no plan yields more output for the same or less cost. Thus, comparing the plans in Table C-1:

- Plan A and Plan B both produce 40 acres, but Plan B does so at a lower cost. Thus, Plan A is economically inefficient (i.e., not cost effective).
- Plan C and Plan D each cost $15,000, but Plan D produces more output than Plan C. Thus, Plan C is economically ineffective (i.e., not cost-effective).
- Plan F provides more output, at a lower cost, compared to Plan E. Thus, plan E is also economically ineffective.

This example illustrates the three criteria used to screen the cost-effectiveness of alternative plans. These criteria suggest that a plan can be identified as non-cost effective (or inferior) if:

- The same output level could be produced by another plan at less cost;
- A larger output level could be produced at the same cost; or
- A larger output level could be produced at less cost.

Thus, in Table C-1, Plans B, D, and F are considered to be cost effective. Plans A, C, and E should be dropped from further analysis, all other considerations aside, because they are not cost effective. The cost-effective plans are shown in Table C-2.

Table C-2. Cost-Effective Plans

Plan (1)	Total Cost (2)	Total Output (3)
No Action	$0	0 acres
Plan B	$10,000	40 acres
Plan D	$15,000	55 acres
Plan F	$40,000	110 acres

Table source: USACE, 1995b

The cost effectiveness analysis can also be displayed graphically, as shown in Figure C-3. In this figure, all six plans are plotted based on the relationship of their total cost and total output. A line is then drawn through the cost effective plans (B, D, and F) which delineates the "cost-effective frontier." Any plans above or to the left of plans on the "frontier" are not cost effective. For example, at the total output of 40 acres, Plan A clearly is more expensive than Plan B.

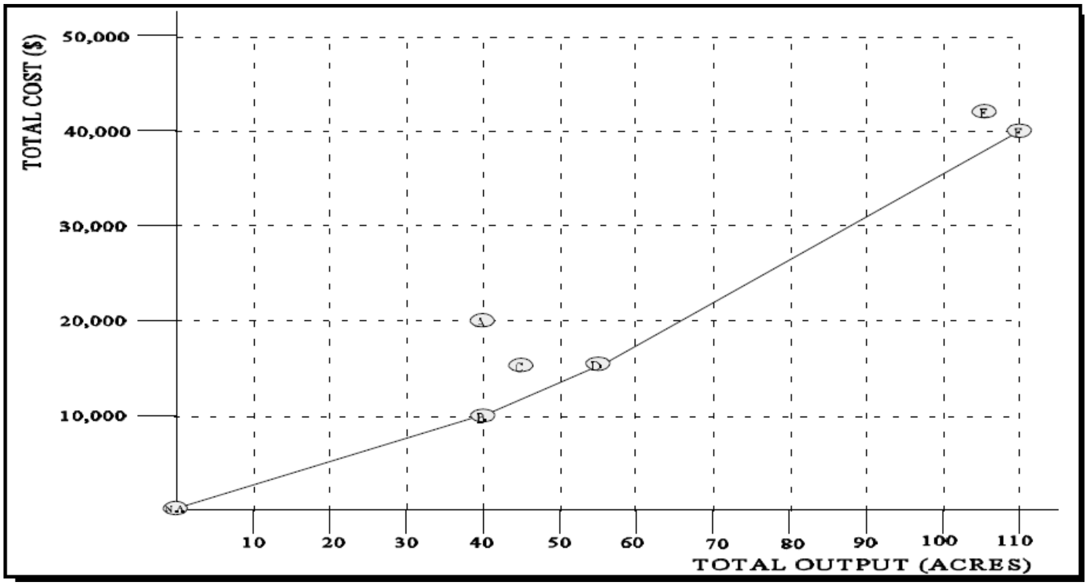

Figure C-3. Cost-Effective Frontier Graph

(USACE, 1995b)

CE/IC Step 5 is the incremental cost (IC) analysis that is applied to the cost-effective plans. To do the IC analysis, additional columns are added to show incremental changes in costs and outputs for the cost-effective plans, which are still arranged in order of increasing output, as shown in Table C-3. Based on the incremental changes in costs and outputs, incremental cost per unit is also calculated.

Table C-3. Incremental Cost, Incremental Output, and Incremental Cost per Unit of Increasing Output to Next Successive Level

Plan (1)	Total Cost (2)	Total Output (3)	Incremental Cost (4)	Incremental Output (5)	Incremental Cost per Unit (6)
No Action	$0	0 acres	NA	NA	NA
Plan B	$10,000	40 acres	$10,000	40 acres	$250/acre
Plan D	$15,000	55 acres	$5,000	15 acres	$333/acre
Plan F	$40,000	110 acres	$25,000	55 acres	$455/acre

Table source: USACE, 1995b

The results of the incremental analysis shown in Table C-3 are the types of cost and output data that are pertinent to output level selection decisions. For example, this table shows that the first 40 acres of habitat can be produced at a cost of $250/acre. If it is decided that these 40 acres are worth $250 each (for a total cost of $10,000), then it must next be decided if 15 additional acres are worth $333 each (an additional $5,000). If it is decided that those additional 15 acres are worth $333 each, then it must be decided if 55 more acres are worth $455/acre (an additional $25,000). This decision process can be facilitated by providing a graphic representation of the incremental cost and incremental output associated with each cost-effective plan under consideration. Such an incremental cost graph is shown in Figure C-4.

Each “box” within Figure C-4 corresponds to an individual “best buy” plan. The width of each box represents the incremental output provided by implementing the corresponding plan instead of the plan preceding it (what additional output will be provided). The height of each box represents the incremental cost per unit of implementing the corresponding plan instead of the preceding plan (the cost of each additional unit of output). By examining this graph, it can be seen that the first 40 acres can be produced for $250 each. If more output is desired, then 15 additional acres can be obtained for $333 each. If the project scale is to be increased further, an additional 55 acres can be produced at a cost of $455 each. This type of incremental cost and incremental output information, along with descriptions of resource significance and other guidelines described in Chapter 4 (for example, output targets and thresholds, cost limits, breakpoints), make up the types of information that can lead to better informed and supportable plan selection decisions.

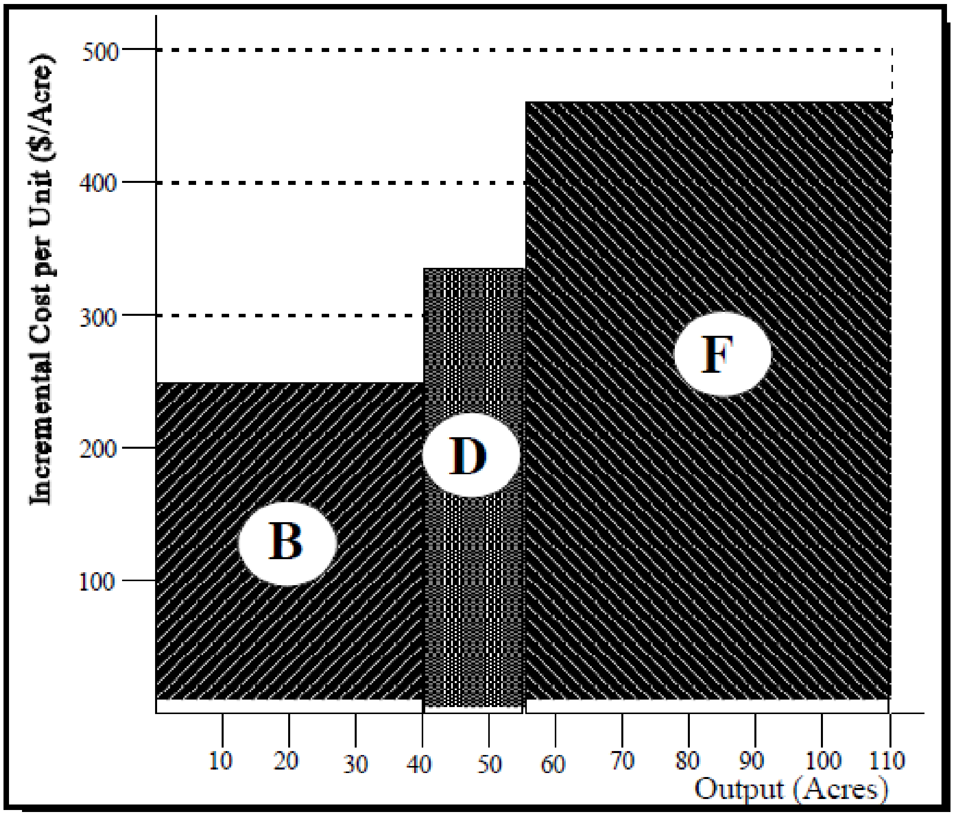

Figure C-4. Incremental Cost Graph

(USACE, 1995b)

This example involved the evaluation of a discrete set of independent plans assuming that cost and output estimates of the individual plans are additive. Within the CE/IC evaluation process, the USACE refers to this approach as the "relative production efficiency" approach which provides a list of plans such that the first plan is the most efficient in production (provides output at the lowest cost per unit), and then each successive plan is the next-most-efficient in production (provides additional output at the lowest additional cost per unit). Generally this approach can be accomplished with spreadsheet models. Although this approach is acceptable (especially for "programmatic level" decision making), it may not always identify all possible cost-effective plans that could be formulated given the management measures being considered, as required in CE/IC Step 3. Thus, the unidentified information could result in the selection of a less desirable plan than what would have been chosen had the information been available.

To remedy this, the "derive all possible combinations of management measures approach" can be used, but this is best facilitated using the software application IWR Planning Suite described in Chapter 4 because literally thousands of plans could be generated. This approach, which is described in CE/IC Step 6, recalculates incremental per-unit costs based on a comparison of each plan with the No Action condition, rather than the comparison of successive plans described above. Because it is more complex, this recalculation approach is not described here, but can be found in USACE guidance (USACE 1995b).

C.2 Multipurpose Ecosystem Restoration Plans

If a proposed project incorporates ecosystem restoration along with other objectives whose benefits are typically monetized (for example, flood risk management or water supply), the USACE conducts a “combined plan” analysis. This is a more complex procedure than described above, because it may have to account for tradeoffs between the ecosystem restoration outputs and the other outputs of multipurpose plans. This USACE’s combined plan analysis is described further in Chapter 11; an example combined plan analysis is provided in Appendix D.

Appendix D: USACE Combined Plan Analysis Example

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Appendix D: USACE Combined Plan Analysis Example

[Note: the following description is from the DWR *Economic Analysis Guidebook*, Appendix B (Example analyses). At the time of this writing, the Hamilton City project is the only one that utilized the USACE combined plan analysis which has been authorized by Congress and has been appropriated funds for construction in the federal 2013-2014 fiscal year.].

In 2004, the US Army Corps of Engineers (USACE) and State Reclamation Board completed the Hamilton City Flood Damage Reduction and Ecosystem Restoration feasibility study. Hamilton City (which in the year 2000 had a population of about 2,000) is located along the west bank of the Sacramento River about 85 miles north of Sacramento. The community is protected by a privately owned "J" levee, which was built in 1914 very close to the river. The "J" levee does not meet any construction standards. Portions of Hamilton City flooded in 1974, and extensive flood fight efforts were necessary in 1983, 1986, 1995, 1997, and 1998. In addition to the flood problem, the native habitat and natural functioning of the Sacramento River have been altered by the construction of the "J" levee and the subsequent conversion of the floodplain to agricultural and rural development. The USACE conducted several single-purpose national economic development (NED) evaluations for Hamilton City focusing on improving or rebuilding the "J" levee, but none were economically justified. In 2004 expected annual flood structural and crop damage was estimated to be about $726,000 in the study area.

During the 2004 feasibility study, various flood damage reduction and ecosystem management measures were identified and screened using the USACE four basic planning criteria (completeness, effectiveness, efficiency, and acceptability) described in Chapter 2. Some measures were dropped, but others were retained for further analysis. Next, a primary project purpose was identified (ecosystem restoration) based on the new USACE guidance for developing alternative combined NED/NER [national ecosystem restoration] plans (USACE 2003). Although past studies focused only on flood damage reduction, this area has significant opportunities for ecosystem restoration, especially if done in conjunction with a setback levee. Several stakeholders including The Nature Conservancy (which owns significant acreage in the study area) and CALFED were very interested in pursuing ecosystem restoration.

Further, based on previous flood damage reduction studies, it was considered unlikely that a single-purpose flood damage reduction project would be cost-effective, partially because of the low income and property values of the community.

Six alternative single-purpose ecosystem restoration alternative plans were formulated. They consisted of various setback levee alignments with habitat restoration on the waterside of the new levee. Some of these levee setbacks were close to the river (sometimes following the current alignment of the "J" levee), some were far from the river, and others were an intermediate distance from the river. Sometimes the levee setbacks differed depending on whether they were north of Dunning Slough (about mid-point along the Sacramento River in the study area) or south of Dunning Slough. The NER alternatives included:

- No Action.
- **Alternative 1 –** Locally developed setback levee (closest to the river; farthest from the community).
- **Alternative 2 –** Intermediate setback levee.
- **Alternative 3 –** Ring levee (farthest from the river; closest to the community).
- **Alternative 4 –** Locally developed setback levee upstream of Dunning Slough, intermediate setback levee downstream of Dunning Slough.
- **Alternative 5 –** Intermediate setback levee upstream of Dunning Slough, locally developed setback levee downstream of Dunning Slough.
- **Alternative 6 –** Intermediate setback levee upstream of Highway 32, locally developed levee downstream of Highway 32.

Using the four planning criteria (including the cost-effectiveness/ incremental cost analysis to determine a plan's efficiency), the most cost-effective single purpose NER plans were identified and grouped into the "final array" of NER plans: alternatives 1, 5, and 6. An incremental cost analysis was performed for these three alternatives to determine "best buy" plans that provided the greatest increase in output (in this case, average annual habitat units or AAHUs) for the least cost increase and which had the lowest incremental costs per unit of output relative to other cost-effective plans. Alternatives 5 and 6 were identified as "best buy" plans. However, of these two plans, Alternative 6 produced AAHUs at an incremental cost of $4,900 per AAHU, compared to $7,300 per AAHU from Alternative 5. Thus, Alternative 6 was selected as the single-purpose NER plan. This plan consisted of an intermediate setback levee about 6.8 miles in length with a levee height approximately equal to the existing “J” levee (about six feet). This cost-effectiveness/incremental cost analysis was conducted using the USACE IWR Plan software which is described in Chapter 4.

After the NER plan was identified, six alternative combined NER/NED plans were formulated that included both ecosystem restoration and flood damage reduction objectives. These six alternatives were essentially the same levee setback as the NER alternatives, except an additional 1.5 feet of levee height was included (bringing the total levee height to about 7.5 feet) to provide additional flood protection (NED) for the community. After an initial screening using the four USACE planning criteria (completeness, effectiveness, efficiency, and acceptability), only four of these plans were retained for further evaluation. The four combined alternatives produced flood damage reduction benefits (which could be monetized and also included avoided flood fight costs) and ecosystem restoration benefits (which could be quantified as AAHUs but were not monetized). The annual outputs of these four alternatives, plus their annual costs, are summarized in Table D-1.

Table D-1. Hamilton City Trade-Off Analysis Combined National Economic Development and National Ecosystem Restoration (NED/NER) Alternatives

Combined Alternative (1)	Annual Flood Damage Reduction Benefits (2)	Average Annual Habitat Units Gained (3)	Total Annual Costs (4)
1	$576,000	783	$2,606,000
4	$536,000	642	$2,541,000
5	$568,000	937	$3,048,000
6	$577,000	888	$2,687,000

These remaining four combined plans were evaluated and compared using a trade-off analysis, which allows for a comparison of plans that produce both monetary and nonmonetary outputs. Although trade-off analyses can be done using several different methods (USACE 2002b), the “percentage of maximum” method was used by the Hamilton City study team. The criteria measurements used for the trade-off analysis included flood damage reduction benefits (monetized), average annual costs (monetized), and AAHUs gained by the plan (nonmonetary). Because ecosystem restoration and flood damage reduction are equally important to stakeholders in the study area, the study team used an intermediate set of weighting factors to give equal weight to environmental and economic factors: 0.50 monetary (includes flood damage reduction and costs) and 0.50 nonmonetary (environmental). Within the monetary category, a 0.42 factor was given to average annual total costs and 0.08 to flood damage reduction benefits. The rationale for the 0.42/0.08 split in the monetary category was to make a dollar of flood damage reduction benefits equal in weight to a dollar of costs. Thus, the "normalized" units of cost was given a weight that is 5.3 times as much as the weight given to the normalized units of flood damage reduction benefits, because the maximum annual costs ($3,048,000) represented by one normalized unit of cost was 5.3 times as much as the maximum annual flood damage reduction benefit ($577,000) represented by one normalized unit of flood damage reduction benefit. Because of this normalization process, this subjective weighting implied that the maximum ecosystem restoration benefit (937 AAHUs) was equally as valuable as the sum of the maximum monetary annual flood damage reduction benefit ($577,000) and the maximum total annual costs ($3,048,000).

Table D-2 shows the resulting decision matrix combining "proportion of maximum values" along with the weighting factors. The column values show the percent of maximum value of each alternative compared to the maximum value for that column. For example, the 0.9844 value of flood damage reduction for Combined Alternative 5 means that the benefit value for this alternative ($568,000) is 98.44% of the maximum flood damage reduction value for all of the combined alternatives being compared ($577,000). A 1.00 value means that the benefit value for this combined alternative is the maximum value for all of the alternatives. The last row shows the weighting factor assigned to each benefit type. The weighted product column shows the results of multiplying each proportion of maximum value by the weighting factor, and then summing for all benefits. For example, the weighted product for Combined Alternative 6 was determined by multiplying 1.00 times 0.08, 0.9477 by 0.50, and -0.8816 by 0.42, and then adding these products together for the weighted product (0.1836). These weighted products can then be directly compared with each other, with the higher scores representing the most effective combined alternatives. In this case, Combined Alternative 6 has the highest score of 0.1836.

Table D-2. Decision Matrix Normalized by Proportion of Maximum Method with Assigned Weight Factors

Combined Alternative (1)	Ecosystem Restoration (2)	Flood Damage Reduction Benefits (3)	Total Annual Costs (4)	Sum of Weighted Product (5)	Rank (6)
1	[783] 0.8356	[$576,000] 0.9983	[$2,606,000] -0.8550	0.1386	3
4	[642] 0.6852	[$536,000] 0.9289	[$2,541,000] -0.8337	0.0668	4
5	[937] 1.000	[$568,000] 0.9844	[$3,048,000] -1.000	0.1588	2
6	[888] 0.9477	$577,000 1.000	[$2,687,000] -0.8816	0.1836	1
Weighting factor	0.50	0.08	0.42	-----	-----

Note: study estimates shown in brackets [ ].

It was recognized that different weighting factors might affect the results. Thus, a sensitivity analysis was conducted to test the effect if different weighting factors were used. The results of this sensitivity analysis are shown in Table D-3. In most cases, Combined Alternative 6 still ranked first, although in a couple of cases, combined alternatives 1 and 5 also ranked first. Thus, combined alternatives 1, 5, and 6 were selected as a potential "final array" of combined alternative plans that would be subjected to a final incremental cost analysis. However, unlike combined alternatives 5 and 6, Combined Alternative 1 was not identified as a "best buy" plan in previous screenings, thus it was dropped from further consideration. An incremental analysis of combined alternatives 5 and 6 was performed considering ecosystem restoration benefits and "remaining costs" (total costs minus flood damage reduction benefits). Based on this incremental cost analysis, Combined Alternative 6 produces more output at less cost than Combined Alternative 5 ($7,550 vs. $2,380/AAHU). The results of this incremental costs analysis are shown in Table D-4.

Table D-3. Weighting Factor Sensitivity Analysis

Weighting Factors			
FDR Benefits (1)	AAHUs Gained (2)	Total Costs (3)	Ranking of Plans (4)
0.14	0.10	0.76	1,4,6,5
0.13	0.20	0.67	6,1,4,5
0.11	0.30	0.59	6,1,5,4
0.10	0.40	0.50	6,1,5,4
0.08	0.50	0.42	6,5,1,4
0.06	0.60	0.34	6,5,1,4
0.05	0.70	0.25	5,6,1,4
0.03	0.80	0.17	6,5,1,4
0.02	0.90	0.08	6,5,1,4

Table D-4. Incremental Cost Analysis of "Best Buy" Plans

Combined Alternative (1)	Average Annual Habitat Units (AAHU) (2)	Incremental Output (AAHUs) (3)	Remaining Cost (4)	Incremental Cost (5)	Incremental Cost/Unit Output (AAHUs) (6)
5	937	49	$2,480,000	$370,000	$7,550
6	888	888	$2,110,000	$2,110,000	$2,380

The final step in selecting the recommended plan is to compare Combined Alternative 6 with the single-purpose NER plan discussed above. Using the data presented in Table D-5, Combined Alternative 6 produces $153,000 more annual flood damage reduction benefits and the same AAHUs as the NER plan. However, Combined Alternative 6 costs only $67,000 more than the NER plan, thus the additional benefits of Combined Alternative 6 exceed the additional costs of this plan. Combined Alternative 6 thus is the recommended plan. This combined plan consists of a setback levee about 6.8 miles in length and a restored riparian habitat area of about 1,500 acres in an area currently devoted to agricultural uses (Figure D-1). The height of the levee was increased up to 1.5 feet higher than the existing “J” levees to achieve additional flood damage reduction benefits. The estimated total project first cost of this combined plan is about $45 million.

Table D-5. Comparison of Combined Alternative 6 with Single-Purpose National Ecosystem Restoration (NER) Plan

Alternative (1)	AAHUs (2)	Annual Flood Damage Reduction Benefits (3)	Annual Total Cost (4)
Single purpose NER plan	888	$424,000	$2,620,000
Combined Alternative 6	888	$577,000	$2,687,000
Difference	0.90	$153,000	$67,000

The identification of a recommended plan was significant because the USACE had been unable to justify a single-purpose NED (flood damage reduction) plan in several previous analyses. This plan was justified because two purposes (NED and NER) were included. However, a critical question concerns cost allocation—how much of the total costs of the plan should be allocated to the ecosystem restoration vs. flood damage reduction objectives? After the cost allocation process, approximately 90% of the total costs were assigned to ecosystem restoration, with the remainder to flood damage reduction. Based on the costs allocated to flood damage reduction resulting from the increased levee height, the NED benefit/cost ratio for this project purpose is about 1.8. Because this combined plan is cost-effective, it was recommended for implementation rather than the single-purpose NER plan. [Note: technically the recommended plan is not the federal NED/NER plan because it is not the fully optimized plan (that is, other plans could provide additional NED and/or NER benefits.) However, because of cost and “level of protection” issues, this plan is acceptable to the local sponsors, so it technically is called the “locally preferred plan.”

Figure D-2 summarizes the Hamilton City plan formulation process.

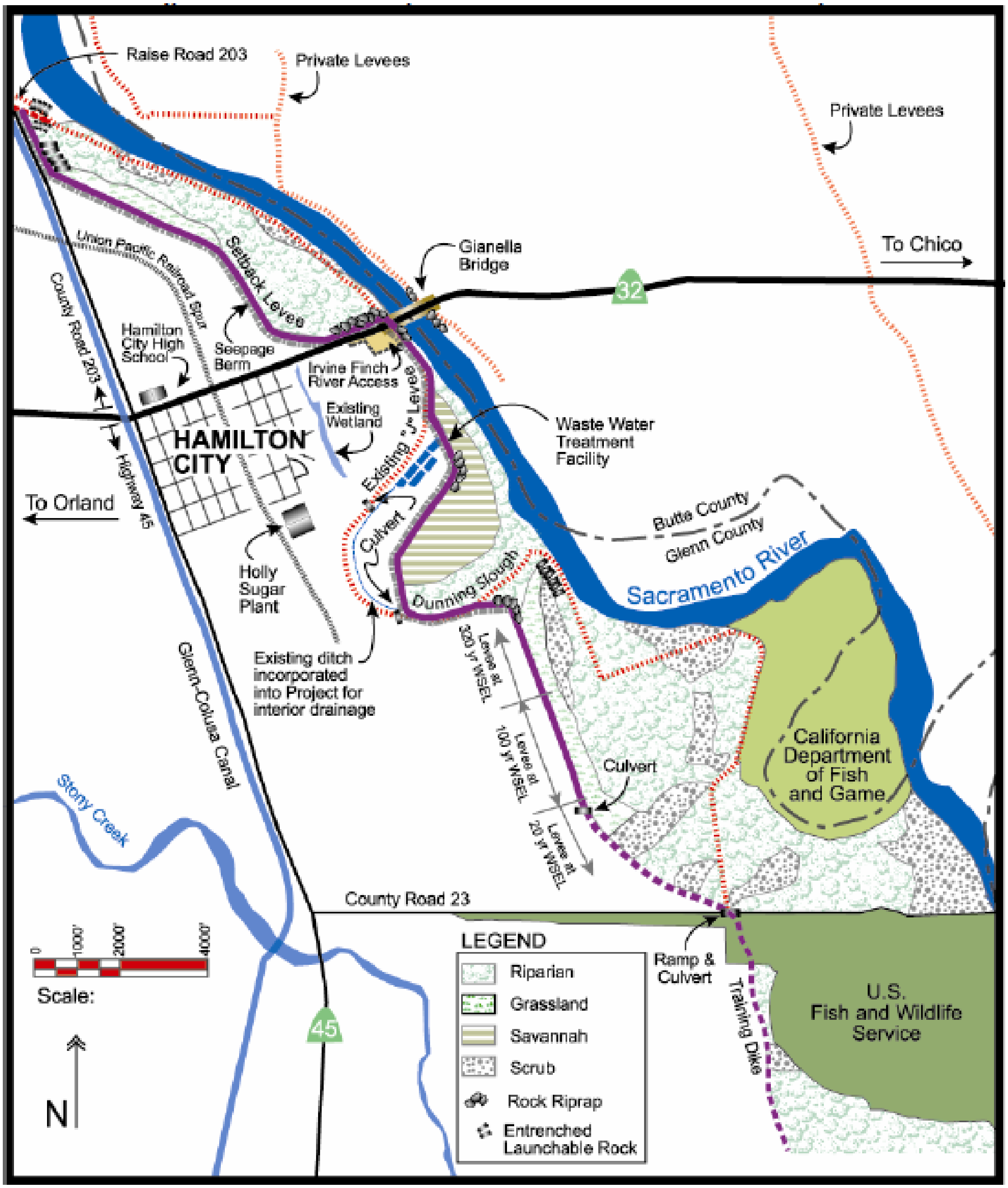

Figure D-1. Hamilton City Recommended Combined National Economic Development/ National Ecosystem Restoration (NED/NER) Plan

(DWR 2008a)

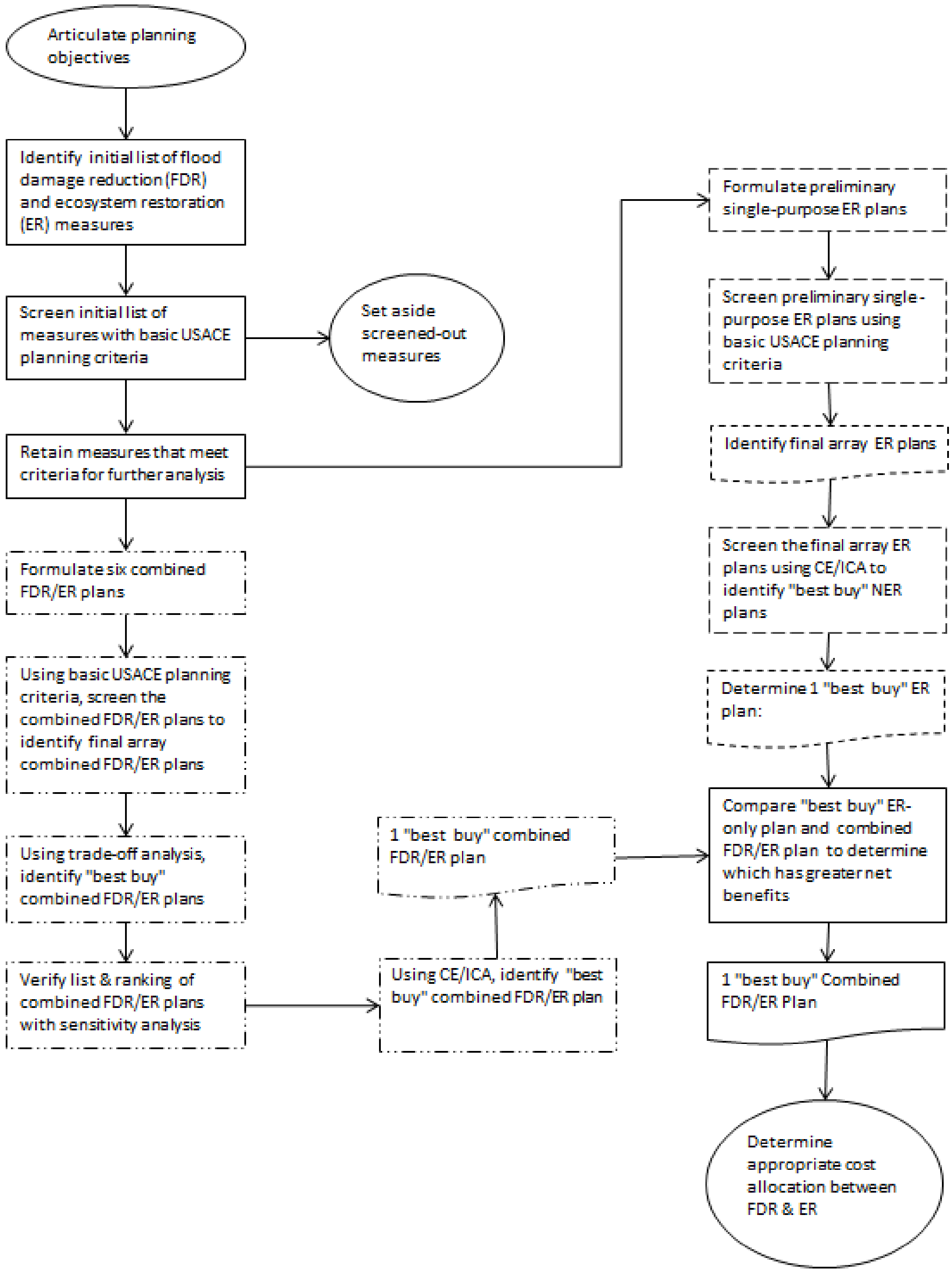

Figure D-2. Hamilton City ER and NED Plan Formulation Process

(Adapted from DWR 2008a)

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Appendix E: Common Assumptions Methods and Models

June 2014

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Appendix E: Common Assumptions Methods and Models

Common Assumptions was an effort initiated in 2002 to develop consistency and improve efficiency among proposed surface storage investigations. One of the objectives of this process was to "develop and refine a common analytical framework including tools and methods for integrated hydrologic and economic analyses." Common Assumptions, which can be used to evaluate M&I and agricultural water supply reliability benefits, was a joint effort by the California Department of Water Resources (DWR), US Bureau of Reclamation, and the California Bay-Delta Authority. The following summary was adapted from DWR (2013b).

E.1 Municipal and Industrial Water Supplies

Two municipal and industrial (M&I) analysis methods were developed for different areas of the State:

- Least cost planning simulation model (LCPSIM): includes State Water Project (SWP) and Central Valley Project (CVP) contractors that serve M&I water users in the South Coast Region and the South Bay Area of the San Francisco Bay Region.

- Other municipal water economics model (OMWEM): M&I water agencies that receive SWP or CVP water that are not included in LCPSIM. These agencies are in the Sacramento River, San Joaquin River, Tulare Lake, North San Francisco Bay, Central Coast, and South Lahontan regions and receive about one-quarter of the SWP and CVP deliveries.

E.1.1 Least Cost Planning Simulation (LCPSIM)

LCPSIM is an annual time-step urban water service system simulation/ optimization model. Its objective is to find the least cost (i.e., most economically efficient when the cost of shortages is included) water management strategy for a region, given the mix of demands and available supplies. It uses shortage management measures, including the use of regional carryover storage, water market transfers, contingency conservation, and shortage allocation rules, to reduce regional costs and losses associated with shortage events. It also considers the adoption of long-term regional demand reduction and supply augmentation measures that reduce the frequency, magnitude, and duration of shortage events.

A shortage event, or forgone use, is the most direct consequence of water service system unreliability. Forgone use occurs when, for example, residential users or businesses have an established lifestyle or level of economic production based on expected availability of water that is not met in a particular year or sequence of years. The model uses a shortage loss function derived from contingent valuation studies and water agency shortage allocation strategies to value forgone use.

Assuming that long-term demand reduction and supply augmentation measures are adopted in order of their cost, with lowest cost measures adopted first, LCPSIM finds the water management strategy that minimizes the sum of the total annual cost of the long-term reliability enhancement measures and the annual shortage costs and losses remaining after their adoption. Beyond the least-cost point, the cost of additional reliability enhancement exceeds the avoided costs and losses resulting from forgone use. At any lower level of reliability enhancement, the expected costs and losses from forgone use exceed the costs to enhance reliability. The change in economic value resulting from a change in the availability of supply, for example, can be determined from the change the reduction produces in the total cost of the least-cost mix of regional short-and long-term demand management and supply augmentation measures and shortages.

Figure E-1 illustrates the LCPSIM optimization process.

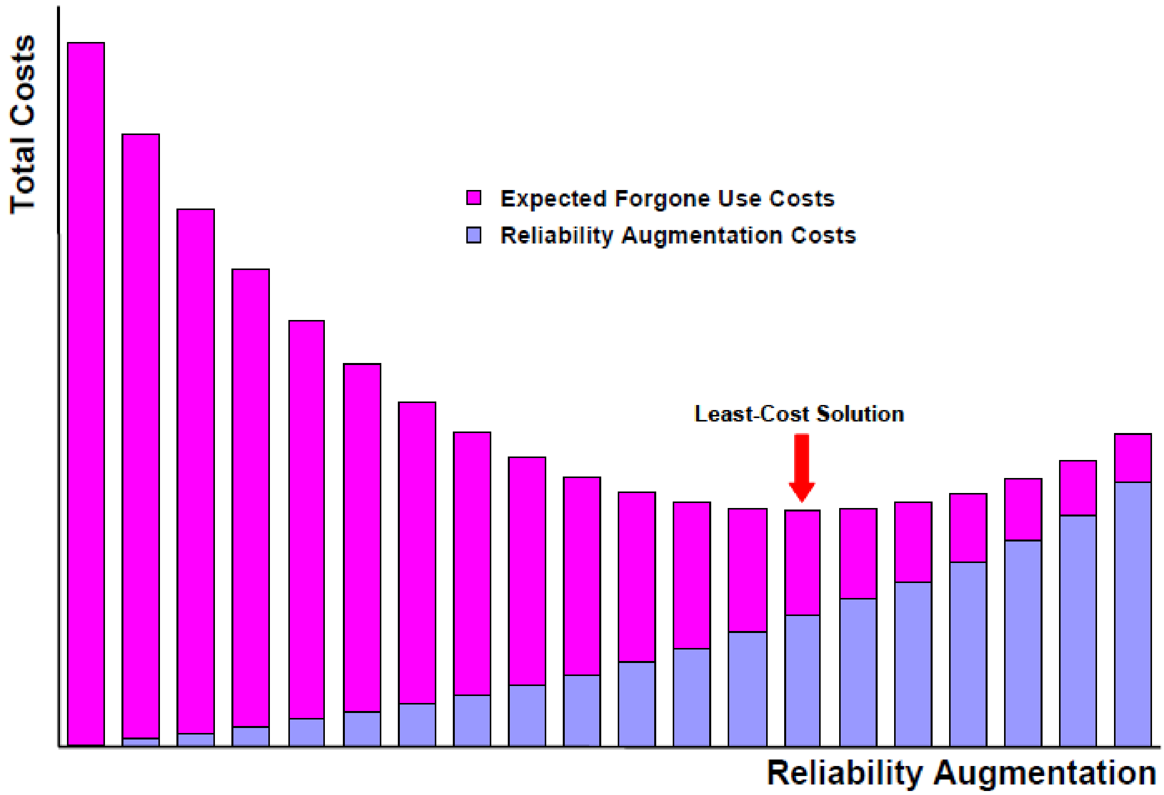

Figure E-1. Conceptual Illustration of the Least Cost Planning Simulation (LCPSIM) Optimization Process

The least cost solution is economically efficient; that is, the level of reliability enhancement beyond which it is economically less costly (compared to the cost of additional reliability enhancement) to accept the expected costs and losses from forgone use. Conversely, at any level of augmentation less than this (compared to the expected costs and losses from forgone use), it is less costly to enhance reliability (DWR 2012l).

E.1.2 Other Municipal Water Economics Model (OMWEM)

A number of relatively small M&I water providers receive SWP or CVP water but are not included in LCPSIM. A set of individual spreadsheet calculations, collectively called Other Municipal Water Economics Model (OMWEM), can be used to estimate economic benefits of changes in SWP or CVP supplies for those potentially affected M&I water agencies. The OMWEM model includes CVP M&I supplies north of the Delta, and SWP and CVP supplies to the Central Valley and the Central Coast. In addition, the model includes SWP supplies or supply exchanges to the desert regions east of LCPSIM's South Coast region. The model estimates the economic value of M&I supply changes in these areas as the change in cost of shortages and alternative supplies (such as groundwater pumping or transfers).

Further details of LCPSIM and OMWEM are available from DWR (DWR 2012l; DWR 2013b).

E.2 Agricultural Water Supplies

The Statewide Agricultural Production Model (SWAP) was developed specifically for large-scale analysis of agricultural water supply and cost changes. SWAP is a regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers (farmers) in California. Its data coverage is most detailed in the Central Valley, but it also includes production regions for the Central Coast, South Coast, and desert areas.

Agricultural water sources in SWAP include CVP contract supply, CVP rights and exchange supply, SWP contract supply, local surface water, and local groundwater. As conditions change within a SWAP region (e.g., the quantity of available project supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. It also fallows land when that appears to be the most cost-effective response to resource conditions.

The SWAP model covers 27 agricultural sub-regions in the Central Valley. The sub-regions are based on water budget areas, called Detailed Analysis Units, which DWR uses for water planning. Figure E-2 shows regions included in SWAP. SWAP is used to compare the long-run agricultural economic responses to potential changes in SWP and CVP irrigation water delivery, other surface or groundwater conditions, or other economic values or restrictions.

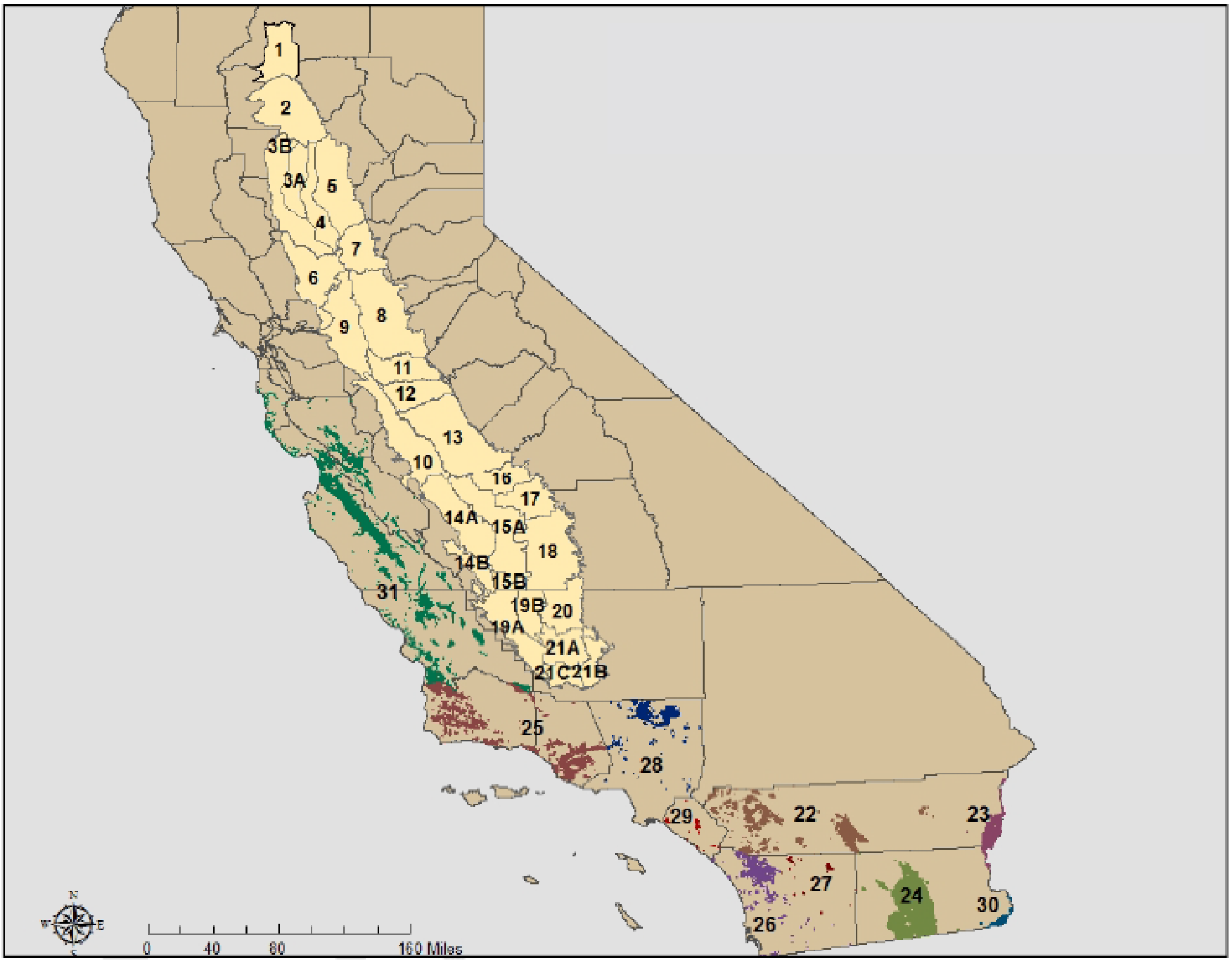

Figure E-2. Map of Statewide Agricultural Production Model (SWAP) Regions

(DWR 2012m)

Typical output of the SWAP model includes revenues by regions and crop, land use, water use, crop stress percent, and marginal value of water. The SWAP model results are further processed to convert its results to estimate the economic value of the various project water supply changes to agricultural producers. In addition to aggregating the results for the numerous sub-regions, the post-processing analysis also converts the results into a national perspective consistent with the 1983 P&G requirements for economic analysis.

Further details of SWAP are available from DWR (DWR 2012m).

E.3 Water Quality Improvement

E.3.1 Lower Colorado River Basin Water Quality Model (LCRBWQM)

This model estimates benefits of source water salinity reductions for urban water supplies. The LCRBWQM was developed by the US Bureau of Reclamation and Metropolitan Water District of Southern California (MWD) in 1998. This model was updated as part of MWD's and US Bureau of Reclamation's 1999 Salinity Management Study. The current version of the model maintained by DWR was updated with population data from DWR, and costs have been updated to 2007 levels. Most salinity costs are the reduced life of appliances and infrastructure, treatment costs, and degradation of groundwater resources.

The model inputs from CALSIM II (CVP-SWP System Simulation Model) and Delta Simulation Model II (DSM2) are State Water Project East and West Branch deliveries and total dissolved solids (TDS) of these deliveries in mg/L, respectively. Some water diverted at Banks Pumping Plant (PP) is conveyed directly to Southern California; other supplies are mixed in San Luis with water diverted at Jones PP. A routine to estimate salinity of urban water supplies delivered to the south coast based on timing of urban deliveries, mixing in San Luis Reservoir, and salinity estimates at Edmonston PP can be used to obtain improved salinity inputs for LCRBWQM.

LCRBWQM divides MWD's service area into 15 subareas. The division of the south coast region into subareas provides detail regarding sources of water and salts in each area. This detail is necessary because each region obtains very different shares of supply from different sources; and some sources, the Colorado River and groundwater in particular, have higher salinity than others. (DWR 2011a)

E.3.2 Bay Area Water Quality Model (BAWQM)

The BAWQM estimates benefits of source water salinity reductions for urban water supplies in the portion of the Bay Area region from Contra Costa County south to Santa Clara County. The model was developed and used for the economic evaluation of a proposed expansion of Los Vaqueros Reservoir.

Separate calculations are provided for Contra Costa Water District (CCWD) and another region consisting of Alameda County Water District, Zone 7, and Santa Clara Valley Water District. The model inputs include water supply to the South Bay Aqueduct and Contra Costa Canal (provided by CALSIM II) and chloride concentrations in mg/L from DSM2. For

CCWD, water quality estimates are based on diversion volume and water quality at Old River and Rock Slough. For the other areas, water quality is based on diversion volume and salinity at Banks PP. In the districts receiving SWP water, water quality is a function of other supplies as well as SWP imported supplies.

This model counts residential benefits only. Input data on the percent of households having appliances and the initial cost of appliances are required. Data on the salinity of supplies obtained through CCWD's intakes, through the South Bay aqueduct, and through the San Felipe system must be developed for alternatives. The model also required the average salinity of any other non-project supplies (DWR 2011a).

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Appendix F: Cost Allocation

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Appendix F: Cost Allocation

Table 11-10 is used to demonstrate that total monetized benefits exceed total costs for a multi-purpose project, a critical test of economic efficiency. However, it must also be demonstrated that each project purpose (such as water supply, flood damage reduction, or hydropower) provides benefits at least equal to its costs. This can be done with a cost allocation.

Cost allocation is the process by which financial costs of a project are distributed among project purposes. Separable costs that can be identified with particular purposes are allocated directly to those purposes. Use of one structure for more than one project purpose allows the purposes to be included at less cost than the total cost of separate structures for each purpose. The incremental cost of including each purpose as an addition to other purposes of the combined structure should be less than the cost of the most economical single-purpose alternative means of producing similar benefits for that purpose. Thus, cost allocation results in an equitable division of costs among the various purposes served, with each purpose receiving its fair share of savings from multiple-purpose projects (DWR 2008a).

A cost allocation procedure includes these types of costs and benefits (DWR 2008a):

- Specific costs. Costs of facilities that exclusively serve only one project purpose.
- Separable costs: Costs which could be omitted from the project if one purpose of the project were excluded. They may also be costs incurred for structures serving several but not all purposes. In some cases, specific and separable costs are the same.
- Alternative costs. The cost of the least-costly single-purpose alternative means of providing the same benefits. The alternative may be a single-purpose project at the same site.
- Justifiable costs. The lesser of benefits or alternative costs which is the maximum that can be allocated to any purpose.
- Remaining benefits. Justifiable costs minus separable costs for each purpose.

There are various cost allocation methods; the one used by DWR and the USACE is Separable Costs-Remaining Benefits (SCRB). The SCRB method distributes costs among the project purposes by identifying separable costs and allocating joint costs or joint savings in proportion to each purpose's remaining benefits. The SCRB method includes the following steps (DWR 2008a):

1. Estimate the benefits for each purpose. [Note: if ecosystem restoration benefits are not monetized, then these benefits are assumed to be equal to the least-cost alternative.]
2. Estimate the alternative costs of single-purpose projects to obtain the same benefits.
3. Select the lesser amount from Step 1 or Step 2 for each purpose as the maximum amount which can be allocated to the purpose; this is designated as the justifiable cost.
4. Estimate the separable cost of each purpose. The project with the purpose omitted should be the least-costly project capable of providing the same benefits for the remaining project purposes. That project can be at the same site, but can also be at another site as long as the service areas for the remaining purposes are the same.
5. Deduct the separable cost of each purpose from the justifiable costs to determine its remaining justifiable costs (sometimes called justifiable remaining benefits).
6. Determine the percentage distribution of the remaining justifiable costs (or benefits).
7. Determine remaining joint costs based upon the percentages found in Step 6.
8. Add the distributed remaining joint cost and the separable cost to determine the cost allocation to each purpose.

An example SCRB analysis from the Hamilton City ecosystem restoration and flood damage reduction feasibility study described in Chapter 11 and Appendix D is shown in Table F-1 (DWR 2008a).

Conclusions of this SCRB analysis are:

- Flood damage reduction (FDR) average annual benefits ($577,000) exceed total FDR allocated average annual capital costs ($256,000).
- Ecosystem restoration (ER) average annual benefits ($3,521,000), which are the same as the least-cost alternative, exceed total ER allocated average annual capital costs ($2,431,000).

Thus, the benefits of each purpose exceed the costs allocated to the purpose, further demonstrating project economic efficiency.

Although not described in this handbook, the results of a cost allocation analysis will inform the apportionment of allocated costs into federal and non-federal costs, in accordance with the federal cost sharing policies applicable to each project purpose under consideration.

Table F-1. Example Separable Costs-Remaining Benefits (SCRB) Analysis from Hamilton City Ecosystem Restoration (ER) and Flood Damage Reduction (FDR) Feasibility Study ($1,000s 2003)

	Annual Costs and Benefits		
(1)	FDR[1] (2)	ER[2] (3)	Total (4)
(a) Total project annual first costs			2,687
(b) Separable costs	67	1,797	1,864
(c) Joint costs			823
(d) Average annual benefits	577	888 AAHUs[3]	
(e) Least cost single purpose alternative plan	922	3,521	
(f) Limited benefits (lesser of d and e)	577	3,521	
(g) Separable costs (b)	67	1,797	
(h) Remaining benefits [(f-g)]	510	1,724	2,234
(i) Percentage of remaining benefits	23%	77%	
(j) Allocated joint costs [(c*i)]	189	634	823
(k) Total allocated costs [(g+j)]	256	2,431	2,687

Table source: DWR 2008a

Notes:

1 Flood damage reduction.

2 Ecosystem restoration.

3 Average annual habitat units.

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Appendix G: Multiple Criteria Analysis

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Appendix G: Multiple Criteria Analysis

Multiple criteria analysis (MCA) is a decision support framework that facilitates the evaluation and selection of alternatives based on multiple differently scaled criteria. For each alternative, MCA transforms criteria values expressed in different units into a dimensionless, numerical score, which is then used to evaluate the merit of each alternative on a common scale. Thus, MCA allows for a systematic, transparent, and repeatable evaluation of diverse criteria. MCA can also be used to conduct sensitivity analyses to analyze uncertainty and test the robustness of solutions.

MCA (which is a form of trade-off analysis) is particularly well suited to supplement multi-purpose benefit and cost (B-C) analysis. To the extent that the significant benefits and costs can be quantified and expressed in monetary terms, then traditional B-C analyses will suffice. However, often benefits and/or costs are not expressed in monetary terms, or even quantified. For example, Table G-1 compares the annual benefits (compared to without-project conditions) and costs of four hypothetical multi-objective water resource plans. The annual benefits include:

- Flood damage reduction and water supply, measured in dollars.
- Riparian habitat restored, measured in average annual habitat units (AAHUs).
- Reduction in loss of life, measured in numbers of persons.
- Water quality, expressed in qualitative terms (none, low, medium, and high).

Annual costs are monetized.

Table G-1. Example Display of Hypothetical Alternative Plans' Benefits and Costs, Including Monetary and Nonmonetary Effects and Qualitative Effects

Alternative Plans (1)	Annual Flood Damage Reduction Benefits ($1000) (2)	Annual Water Supply Benefits ($1000) (3)	Riparian Habitat (AAHUs) (4)	Annual Loss of Life Benefits (Persons) (5)	Annual Water Quality Benefits (Qualitative) (6)	Annual Costs ($1000) (7)
Plan A	450	73	1,220	12	Medium	475
Plan B	220	12	980	5	Low	225
Plan C	258	60	1,000	9	None	300
Plan D	348	100	1,100	10	High	425

Because some of the benefits in Table G-1 are not monetized, it is not possible to sum them to obtain total benefits which can then be compared with total costs to determine which plan has the greatest net benefits. In these situations, the B-C analysis must be supplemented with other economic analysis tools. One of these tools is MCA.

G.1 Multiple Criteria Analysis Example

As with most evaluation methods, an MCA can be done using several different methods. However, the method described herein is believed to be "practical and easy to use" (USACE 2002b).

G.1.1 Develop Decision Matrix

A critical step in conducting an MCA is to develop the decision matrix. The decision matrix summarizes the value of each alternative, for each criterion, on which a decision will be based. By MCA convention, the alternatives are listed in the rows and the criteria in the columns. Thus, the information displayed in Table G-1 is in the format of a decision matrix:

- The alternative plans are shown in the rows. In this example, these are the hypothetical multi-objective water resource plans A, B, C, and D.

- The criteria to evaluate alternative plans are shown in the columns. For this example, there are five benefit and one cost criteria. Although not used in this example, the other benefits described herein (such as recreation and hydropower) could also be used, as well as any other benefit (or cost) pertinent to making a decision among alternative plans.

Care must be taken in defining the decision criteria. To be effective, these criteria must be (USACE 2002b):

- Directional: characterized by a clear preference for the direction in which they are to be driven, i.e., minimized, maximized, or otherwise optimized.
- Concise: providing the smallest number of measures that allows all significant impacts to be assessed.
- Clear: defining how measurements are to be made whether in quantitative or qualitative terms.
- Complete: covering all aspects of success so that no significant impact goes unmeasured.

In addition, the criteria must not be redundant. Redundancy occurs when a criterion appears in two or more closely related forms. For example, if in addition to annual flood damage reduction benefits, another criterion was the numbers (or values) of structures exposed to the flood risk, then this would be redundant with the flood damage estimates, which are based (in part) on the numbers and values of structures.

However, criteria can be correlated and need not be independent (USACE 2002b). For example, the loss of life benefit is likely to be correlated with the flood damage reduction benefit, because both are related to the level of socioeconomic activity exposed to the flood hazard. Although loss of life benefits are likely to be correlated with flood damage reduction benefits, they are not redundant.

What is the optimal number of criteria? Research suggests that six or seven criteria are good numbers. Large numbers of criteria should be rearranged into smaller sets which may be done by (a) aggregating or grouping related criteria or (b) by dividing the criteria into a hierarchical structure with no more than seven or so criteria at each level (USACE 2002b).

Table G-2 displays a preliminary decision matrix based on the information from Table G-1. For this example, most of the benefits and costs are quantified using cardinal data, which are ratio scale data measured in fixed units of measure such as real numbers (e.g., persons or AAHUs) or dollars. However, one criterion—water quality—is expressed in qualitative terms: none, low, medium, or high effects.

Table G-2. Preliminary Decision Matrix for Multipurpose Plans

Alternative plan	Criteria					
	Annual flood damage reduction benefits ($1000)	Annual water supply benefits ($1000)	Riparian habitat benefits (AAHUs)	Annual loss of life benefits (Persons)	Annual water quality benefits (Qualitative)	Annual costs ($1000)
Plan A	450	73	1,220	12	Medium	475
Plan B	220	12	980	5	Low	225
Plan C	258	60	1,000	9	None	300
Plan D	348	100	1,100	10	High	425

Before conducting the MCA, the water quality benefits must be converted to a set of discrete, ordered measurements. One way to do this is to assign quantitative values to the qualitative values, such as:

- None = 0
- Low = 1
- Medium = 2
- High = 3

These are ordinal data which express a magnitude order, but not ratio scale, among the measurements. After this conversion has been made, a final decision matrix can be obtained, as shown in Table G-3.

Table G-3. Final Decision Matrix with Qualitative Water Quality Benefit Data Converted to Ordinal Data

Alternative plan	Criteria					
	Annual flood damage reduction benefits ($1000)	Annual water supply benefits ($1000)	Riparian habitat benefits (AAHUs)	Annual loss of life benefits (Persons)	Annual water quality benefits (Ordinal)	Annual costs ($1000)
Plan A	450	73	1,220	12	2	475
Plan B	220	12	980	5	1	225
Plan C	258	60	1,000	9	0	300
Plan D	348	100	1,100	10	3	425

G.1.2 Normalization

The objective of the MCA is to combine information developed for all criteria, for each alternative, into one score, to determine the "best" plan. However, this cannot yet be accomplished for the final decision matrix shown in Table G-3 because the data are in different units: dollars, AAHUs, people, and ordinal measurements. To combine all of these diverse data, they must be normalized, or expressed on the same scale. A scale that is most often used is a 0 to 1 scale. Using this scale, the goal is to take a series of measurements for a given criterion and convert it into a series of normalized values between 0 and 1, which can then be summed across all criteria.

The most widely used technique to normalize data for an MCA is proportion of maximum (USACE 2002b). This technique assumes that the MCA maximizes values, which is the focus of a B-C analysis to maximize benefits over costs (i.e., net benefits). Thus, larger numbers of benefits would logically rank higher in a net benefit analysis, other factors being equal. With this technique, the maximum value for each benefit criterion is assigned the value of 1.00. All other values for that criterion are assigned a proportion of the maximum value, or normalized value. For example, in Table G-4, the maximum annual flood damage reduction benefit occurs in Plan A ($450,000), so it is assigned a value of 1. The next highest annual flood damage reduction benefit occurs in Plan D ($348,000), which is 0.7733 of Plan A's maximum benefit value. All of the other plans are assigned proportions relative to the maximum Plan A benefit value. This method transforms all of the different measurements into a common scale and preserves the proportionality among the different alternatives. The procedure for normalizing costs is the same as described for benefits, except that costs are multiplied by a -1. (An alternative normalization technique to develop proportions which sum to 1.00 is described in the references [USACE 2002b].)

Once the proportions of maximum estimates are computed for all criteria, they can be summed to obtain a total proportion score, which can then be ranked from lowest to highest. In Table G-4, Plan D has the highest proportion score (2.6194) and thus has a rank of 1. Although the proportion scores can be used for the MCA, proportions are sometimes not intuitive to use. Thus, for convenience, each proportion score can be multiplied by the same factor (100) and the resulting product called "points." After applying points, the Plan D proportion score becomes a point score of 262. Since all proportion scores are multiplied by the same factor, no change in overall ranking occurs. Table G-5 shows the proportion scores with points and the resulting overall ranking. Total points range from 262 (Plan D) to 116 (Plan B).

Table G-4. Proportion of Maximum Scores Based on the Proportion of Each Criterion's Measurements with the Maximum Value for that Criterion, Which Is Assigned 1

Alternative plan	Criteria: Annual flood damage reduction benefits ($1000)	Proportion Score	Annual water supply benefits ($1000)	Proportion Score	Annual riparian benefits (AAHUs)	Proportion Score	Annual loss of life benefits (Persons)	Proportion Score	Annual water quality benefits (Qualitative)	Proportion Score	Annual costs ($1000)	Proportion Score	Total Proportion Score	Rank
Plan A	450	1.0000	73	0.7300	1,220	1.0000	12	1.0000	2	0.6667	-475	-2.1111	2.2856	2
Plan B	220	0.4889	12	0.1200	980	0.8033	5	0.4167	1	0.3333	-225	-1.0000	1.1622	4
Plan C	258	0.5733	60	0.6000	1,000	0.8197	9	0.7500	0	0.0000	-300	-1.3333	1.4097	3
Plan D	348	0.7733	100	1.0000	1,100	0.9016	10	0.8333	3	1.0000	-425	-1.8889	2.6194	1
MAX	*450*		*100*		*1,220*		*12*		*3*		*-225*		*2.6194*	

Table G-5. Proportion of Maximum Scores with Points Estimated by Multiplying Each Criterion's Proportion Score by 100

Alternative plan	Criteria: Annual flood damage reduction benefits ($1000)	Proportion Score	Annual water supply benefits ($1000)	Proportion Score	Annual riparian benefits (AAHUs)	Proportion Score	Annual loss of life benefits (Persons)	Proportion Score	Annual water quality benefits (Qualitative)	Proportion Score	Annual costs ($1000)	Proportion Score	Total Point Score	Rank
Plan A	450	100	73	73	1,220	100	12	100	2	67	-475	-211	229	2
Plan B	220	49	12	12	980	80	5	42	1	33	-225	-100	116	4
Plan C	258	57	60	60	1,000	82	9	75	0	0	-300	-133	141	3
Plan D	348	77	100	100	1,100	90	10	83	3	100	-425	-189	262	1

*Point score = proportion score * factor (for this example, factor = 100)*

G.1.3 Apply Weights

For a multipurpose water resource B-C analysis, it is likely that not all criteria are going to be equal: the analysis team may find that one criterion is more or less important than another. To reflect differences in importance, weights can be assigned to the criteria as a measure of their relative importance. One method to do this is to assign a fixed range of weights (for example, 0 to 10), with individual criterion weights assigned within this range. Once the weights are assigned, they are totaled for all criteria and each criterion's weight is then divided into the total weight, resulting in a proportionate, or normalized, weight for each criterion. This normalized weight is then multiplied by the respective criterion's point scores.

Table G-6 shows weights for the B-C analysis example MCA where a 0-to-10 range of weights is used. Although the assignment of a range of weights is subjective, it is recommended that a smaller range be used because it may be easier to discriminate between a small number of weights (for example, 10 or less) compared to a large number of weights (for example, 100). For this example MCA analysis, an initial weight of 1 was applied to all criteria.

Table G-7 shows the weighted scores for each criterion, as well as the total weighted scores and ranking.

An optional approach to assigning weights is to limit the total number of weights that can be assigned for all criteria combined. For example, in Table G-6, if each criterion were assigned a weight of 10, the total number of weights that would be assigned would be 60 which are used to compute each criterion's normalized weight. However, the analysis team could decide that only a limited number to total weights would be assigned for all criteria (for example, 10, 20, 30, etc.), which forces the team to consider trade-offs among the criteria explicitly when assigning weights.

G.1.4 Synthesize Results

In this step, the alternatives, criteria, weights, and the exposure matrix are all brought together to inform the decision makers. To facilitate this, the measured magnitudes shown in the final exposure matrix for each criterion can be replaced with the weighted scores (Table G-7), resulting in the summary of weighted scores shown in Table G-8. These scores can then be shown graphically as in Figure G-1, which shows the contribution of each criterion to each alternative. These scores can be converted to ranks, as shown in Table G-9.

Table G-6. Developing Normalized Weights with All Criteria Assigned an Initial Weight of 1

Criteria	Weights (0-10)	Normalized Weights	Because....
Flood damage reduction	1	0.17	
Water supply	1	0.17	
Riparian habitat	1	0.17	
Loss of life	1	0.17	
Water quality	1	0.17	
Costs	1	0.17	
Total	6	1.00	

Table G-7. Weighted Point Scores Computed by Multiplying the Point Scores by the Normalized Weight for Each Criterion

Alternative plan	Criteria												Total Weighted Score	Rank
	Annual flood damage reduction benefits		Annual water supply benefits		Annual riparian benefits		Annual loss of life benefits		Annual water quality benefits		Annual costs			
	($1000)	Weighted Score	($1000)	Weighted Score	(AAHUs)	Proportion Score	(Persons)	Weighted Score	(Qualitative)	Weighted Score	($1000)	Weighted Score		
Plan A	450	17	73	12	1,220	17	12	17	2	11	-475	-35	38	2
Plan B	220	8	12	2	980	13	5	7	1	6	-225	-17	19	4
Plan C	258	10	60	10	1,000	14	9	13	0	0	-300	-22	23	3
Plan D	348	13	100	17	1,100	15	10	14	3	17	-425	-31	44	1

*Weighted score = point score * normalized weight*

Table G-8. Summary of Weighted Scores

Alternative plan	Criteria						Total Weighted Score
	Annual flood damage reduction benefits	Annual water supply benefits	Riparian habitat benefits	Annual loss of life benefits	Annual water quality benefits	Annual costs	
Plan A	17	12	17	17	11	-35	38
Plan B	8	2	13	7	6	-17	19
Plan C	10	10	14	13	0	-22	23
Plan D	13	17	15	14	17	-31	44

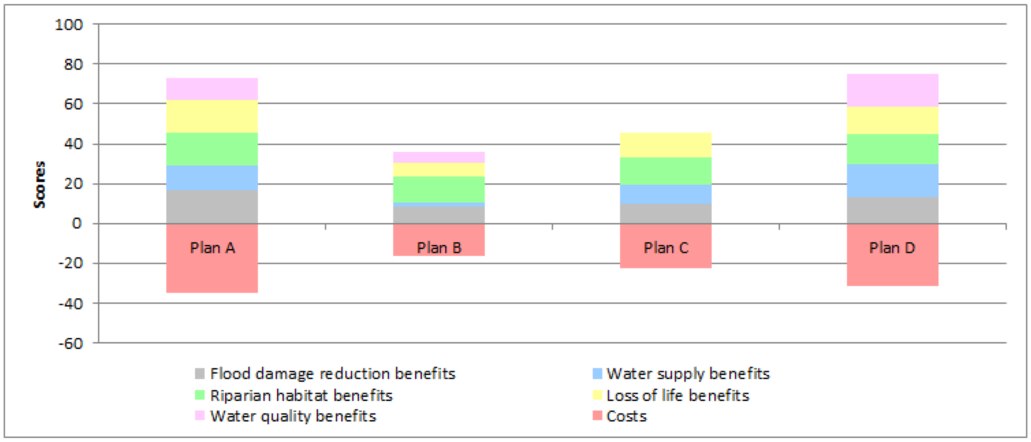

Figure G-1. Plot of Weighted Scores with Initial Weights of 1 for All Criteria

Table G-9. Summary of Ranks

Alternative plan	Criteria						Overall Rank
	Annual flood damage reduction benefits	Annual water supply benefits	Riparian habitat benefits	Annual loss of life benefits	Annual water quality benefits	Annual costs	
Plan A	1	2	1	1	2	4	2
Plan B	4	4	4	4	3	1	4
Plan C	3	3	3	3	4	2	3
Plan D	2	1	2	2	1	3	1

A critical part of analyzing results is a sensitivity analysis, especially focusing on the weights, which will be important to the various stakeholders. What happens to the scores and ranking if weights are changed? To illustrate this, the weight of the riparian habitat criterion was increased to 5 and the resulting change in scores and rankings are shown in Table G-10 and Figure G-2. Plan A now has the highest rank.

Table G-10. Summary of Ranks after Increasing Riparian Habitat Criterion Weight from 1 to 5 (Plan A Now Has the Highest Rank)

Alternative plan	Criteria						Overall Rank
	Annual flood damage reduction benefits	Annual water supply benefits	Riparian habitat benefits	Annual loss of life benefits	Annual water quality benefits	Annual costs	
Plan A	1	2	1	1	2	4	1
Plan B	4	4	4	4	3	1	4
Plan C	3	3	3	3	4	2	3
Plan D	2	1	2	2	1	3	2

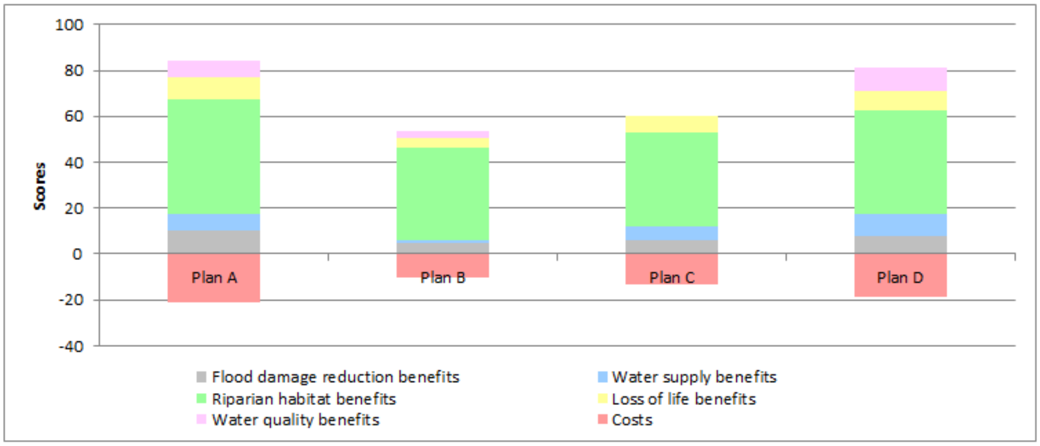

Figure G-2. Sensitivity Analysis with the Riparian Habitat Criterion Weight Increased From 1 to 5 and All Other Weights Remaining at 1

G.2 Multiple Criteria Analysis Tools

To facilitate the MCA, a customized MS Excel 2010 workbook was prepared for DWR to assist in the evaluation and prioritization of Delta levee improvements based on several criteria related to the exposure of population and critical assets exposed to the potential flood hazard. This tool (DeltaLevees_MCA_Tool.xlsx) could be adapted for the evaluation of FloodSAFE and other DWR multi-purpose water resource projects.

In addition, the USACE Institute of Water Resources has developed a multiple criteria decision analysis module as part of IWR Planning Suite (USACE IWR 2010), and commercial software is available to do MCA.

Appendix H: Multiyear Analysis

June 2014

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Appendix H: Multiyear Analysis

Table 11-10 in Chapter 11 is a template to compute the present worth of average annual benefits and costs over a 50-year analysis period, taking into account multiple benefits. Implicitly, this table assumes that benefits and costs do not vary significantly over the analysis period, which is appropriate if the benefit and cost comparison is based only on existing conditions (or some other arbitrary point in time). However, benefits and costs could vary over time if future conditions without and with the project are considered. For example, a flood inundation reduction analysis could include increased housing stock (and other building types) as a result of population growth. The same population growth may also affect a proposed project's delivery of water supplies or recreation opportunities. When conditions change over the analysis period, another method is required to do the present worth analysis of benefits and costs.

H.1 Procedures

Table H-1 can be used to evaluate changes in benefits and costs over the entire 50-year analysis period. In addition, this table includes five years prior to the base year, for the case in which project capital costs (or benefits) are incurred prior to the base year, requiring the computation of forgone investment values. The table also allows escalation to be assigned to costs and/or benefits (escalation is the change in price levels above the general price level inflation rate). To use this table, the user inputs:

- The appropriate analysis parameters, including:
    - Discount rate.
    - Escalation rates for capital and OMRR&R costs and benefits.
- The annual capital and OMRR&R costs as they are expected to occur before, during, and after the base year.
- The annual flood risk management intensification and location benefits, as they are expected to occur, using procedures described in Chapter 3. Although inundation reduction benefits could conceptually be included, they are calculated separately using HEC-FDA and then added to Table H-1 as described below.
- Any other annual benefits (e.g., water supply, water quality, and recreation) as they are expected to occur, based on procedures described in chapters 5-9. Ecosystem restoration benefits could also be included in the "Other" category, <u>if</u> they are monetized (Chapter 4).

Table H-1. DWR-Recommended Template for Computing Multiyear Benefits and Costs

Analysis year	Analysis calendar year (e.g., 20XX)	Discount factor[1] (e.g., X.XXXX)	Capital costs	Capital escalation factor[2] (e.g., 1.XXXX)	Project Costs: OMRR&R costs	Project Costs: OMRR&R escalation factor	Project Costs: Total costs (escalated) [(4*5)+(6*7)]	Project Costs: Discounted total costs (escalated) [3*8]	Project Benefits: Flood risk management[4]	Project Benefits: Water supply/quality	Project Benefits: OMRR&R costs	Project Benefits: Recreation/open space	Project Benefits: Hydropower	Project Benefits: Navigation	Project Benefits: Commercial fisheries	Project Benefits: Other	Project Benefits: Total benefits [10+ …+17]	Project Benefits: Benefit escalation factor[2]	Project Benefits: Total benefits (escalated) [18*19]	Project Benefits: Discounted total benefits (escalated) [3*20]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
-5																				
-4																				
-3																				
-2																				
-1																				
0[3]																				
1																				
2																				
3																				
4																				
5																				
…																				
50																				
Total																				

Note:

1 Based on x% discount rate identified by user; (2) Based on escalation rates identified by user; (3) Base year; (4) Intensification and location benefits only. Inundation reduction benefits over the 50-year analysis period are computed separately by HEC-FDA as equivalent annual damage and inserted in Step 5 of the procedure shown in Section H.3 below.

Based on user input analysis parameters and cost and benefit information, Table H-1 is used to compute the annual benefits and costs as well as the net benefits and benefit/cost ratio.

Annual inundation reduction (IR) benefits are computed separately using HEC-FDA and entered into Table H-1, as described below.

H.2 HEC-FDA Inundation-Reduction Benefit Equivalent Annual Computation Procedures

The expected annual damage (EAD) computation described in Chapter 3 is for an average annual year. If hydrologic, hydraulic, and economic (structural inventory) conditions remain the same over the 50-year analysis period, then the EAD computation can be used as in Table 11-10.

However, if there are changes in any of these variables, then HEC-FDA accommodates these changes by computing equivalent annual damage. This is the damage associated for the without-project or-with project condition over the analysis period considering changes in hydrology, hydraulics, and/or structural inventories. EAD is computed for each analysis year and discounted to present worth, which is then annualized to obtain the equivalent annual damage value. However, rather than compute EAD for each year, it is computed for the base year and the most likely future year (identified by the user in HEC-FDA) and interpolated for intervening years. Expected annual damage for years beyond the most likely future condition year is assumed equal to that year, as shown in Figure H-1. As with EAD, the equivalent annual damage computation displays damage without and with a plan, damage reduced, and the probability that reduced damage is exceeded with specified probability. An example HEC-FDA equivalent damage analysis is shown in Figure H-2, which is similar to the EAD analysis shown in Table 3-1 (USACE 2008a). For the selected plan, the IR damage reduced benefit estimate from Figure H-2 is inserted in Column 10 of Table H-1.

One of the more critical variables that can change is the level of development, reflecting changes in the number and/or composition of structures exposed to the flood hazard. In HEC-FDA, structural inventory changes can be accommodated by developing one or more structural modules that allow users to vary structure characteristics by plan and year. For example, a base year structure inventory module would only include structures that exist at the time of the base year. Development expected to occur by the most likely year would be included in a separate "development" structure module.

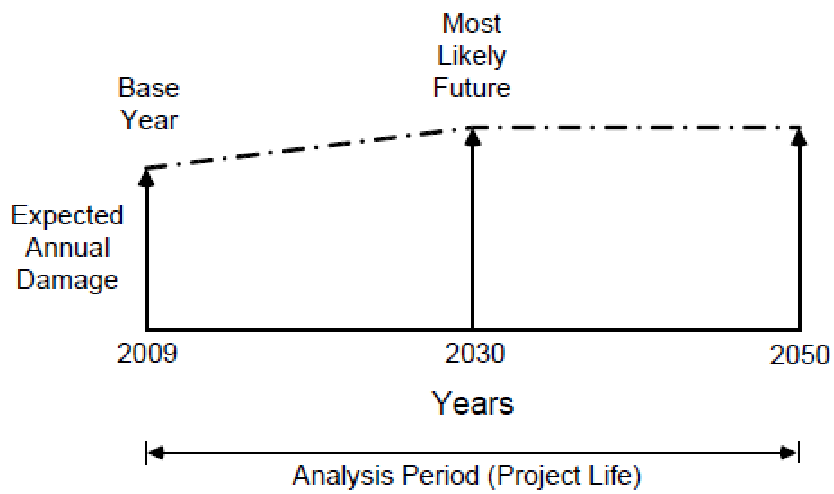
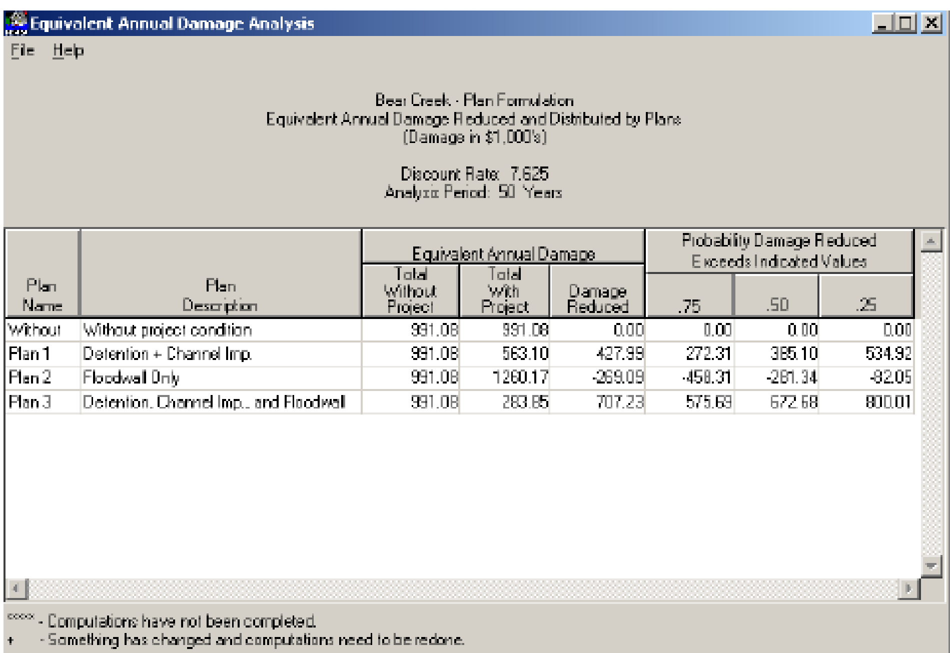


Figure H-1. HEC-FDA Analysis Year Computation

An analysis year represents a static time period or year that the hydrologic engineering and economic data must be developed for analyses. Base year is the first year of plan operation. The most likely future year is normally a development projection for a specified future year.



Plan Name	Plan Description	Equivalent Annual Damage			Probability Damage Reduced Exceeds Indicated Values		
		Total Without Project	Total With Project	Damage Reduced	.75	.50	.25
Without	Without project condition	991.08	991.08	0.00	0.00	0.00	0.00
Plan 1	Detention + Channel Imp.	991.08	563.10	427.99	272.31	385.10	534.92
Plan 2	Floodwall Only	991.08	1260.17	-269.09	-458.31	-281.34	-82.05
Plan 3	Detention, Channel Imp., and Floodwall	991.08	283.85	707.23	575.69	672.68	800.01

Figure H-2. HEC-FDA Equivalent Annual Damage Computation Showing Equivalent Annual Damage Reduced and the Probability of Damage Reduced, by Plan

H.3 Annual Net Benefit Computation Steps

Using the information in Table H-1, compute the benefit/cost ratio as follows:

1. Total present value benefits, excluding IR benefits (Column 21 of Table H-1)…………………………………… __________
2. Total present value costs (Column 9 of Table H-1)…………… __________
3. Capital recovery factor (50-year analysis period; x% discount rate)……………………………………….….. __________
4. Annual benefits, excluding IR benefits [(line 1) x (line 3)].… __________
5. Annual equivalent IR benefits, from HEC-FDA………..…… __________
6. Total annual benefits [(line 4) + (line 5)]……………………. __________
7. Total annual costs [(line 2) x (line 3)]……………………….. __________
8. Annual net benefits [(line 6) – (line 7)]……………………… __________
9. Benefit/cost ratio [(line 6)/(line 7)]………………………….. __________

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Appendix I: Software Applications

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Appendix I: Software Applications

I.1 Flood Risk Management Benefit Assessment Software

I.1.1 HEC-FDA

Developed by the USACE Hydrologic Engineering Center (HEC), Flood Damage Analysis (FDA) is the USACE's primary flood damage reduction software application. HEC-FDA integrates hydrologic, hydraulic, and geotechnical engineering and economic data for the formulation and evaluation of flood damage reduction plans. The program incorporates risk-based analysis by quantifying uncertainties in the hydraulics, geotechnical, and economics data using Monte Carlo simulation. The two primary outputs from HEC-FDA are expected annual damage estimates and project performance statistics.

Expected annual flood damage is the average of all possible damage values, taking into account all expected flood events and associated hydrologic, hydraulic, geotechnical, and economic uncertainties.

Project performance statistics describe the hydraulic performance of a plan incorporating geotechnical levee failure assumptions. These include:

- Expected annual exceedance probability (the annual probability of having a damaging flood event in a given year, such as a levee failure).
- Long-term risk (the chance of having one or more damaging events over a period of time, similar to the question: what's the chance my house could be flooded during my 30-year mortgage?
- Conditional nonexceedance probability (the probability of containing specific flood events and avoiding damage). [Note: the USACE now calls conditional nonexceedance "assurance."]

Strengths of HEC-FDA include the following:

- This is the software that is used by the USACE. Thus, if DWR or other agencies are seeking federal cost sharing, analyses will be compatible.

- Uncertainty is directly incorporated into the analysis using Monte Carlo simulation, which explicitly accounts for uncertainty in key functions (discharge-exceedance, stage-discharge, and stage-damage).

- Levee failure assumptions (for water surface elevations below top-of-levee) can be entered into the analysis.

- It can estimate most direct flood damage losses (for example, single-family residential, multi-family residential, commercial, industrial, and public structural and contents damage).

- Although designed for urban flood damage analyses, can be adapted for agricultural analyses.

- Structural inventories can be directly input into the software and it will develop the stage-damage functions, or stage-damage functions can be developed outside the software and then directly input into it.

- Project performance statistics (annual exceedance probability, long-term risk, and conditional nonexceedance) are output. These can be used for levee certification purposes.

- The application is useful for plan formulation.

- Although multiple flood events may occur in any given year, HEC-FDA restricts the estimation of flood damage to the largest event that occurs in any year. The effects of multiple floods, and the time required to recover from those flood events, is ignored.

- It is not typically used for life loss analysis, although a method to do this was developed for the 2012 CVFPP and is being refined for the 2017 CVFPP.

Weaknesses of HEC-FDA include the following:

- It typically cannot be run “off the shelf” without user training.

- It is data intensive; it requires hydrologic, hydraulic, geotechnical (if levees are present), and economics data.

- It is not GIS-based (but, GIS can be used to develop data inputs such as structural inventories).

- It is not applicable for coastal analyses.

- It does not estimate indirect or regional impacts (income, employment, etc.).

Information about HEC-FDA and the software package are available on the USACE HEC website.

I.1.2 HEC-FIA

HEC-FIA (for "Flood Impact Analysis"), developed by the USACE HEC, analyzes the consequences from a single flood event. It evaluates impacts either with (1) geo-referenced data grids with inundation, terrain, agricultural, and structural data, or (2) single, continuous, or forecasted HEC-DSS hydrographs. For the specified analysis period, the program calculates damages to structures and contents, losses to agriculture, and estimates the potential for loss of life. HEC-FIA models are typically used to analyze dam and levee failure scenarios to support consequence estimates to determine the risk posed or prevented by USACE projects. HEC-FIA can inform real-time emergency response activities. HEC-FIA can also be used to compute annual benefits across the full range of potential flood events when it is used in conjunction with programs such as HEC-WAT with the Flood Risk Assessment compute option.

Strengths of HEC-FIA include the following:

- It allows for the display of GIS data, and manipulation of data, inputs, and outputs through table and form editors.

- It can receive many types of hydraulic inputs such as data in gridded format or flow and stage hydrographs can be incorporated through HEC-DSS-Vue.

- It incorporates point-based structure inventories that can be imported from the Hazus database, U.S. Parcel Data, or existing point structure inventory shapefiles. It also supports aggregated stage-damage functions at index locations.

- It includes a simplified approach to estimate life loss when the correct hydraulic data and structure inventory data is provided.

- It can calculate agriculture losses for multiple events, taking into account dry-out periods between floods.

Weaknesses of HEC-FIA include the following:

- It computes urban flood damage based on the maximum peak stage, if multiple flood events are being analyzed.

- Because it analyzes only a single event, it does not provide project performance statistics for the full range of events (unless used in conjunction with HEC-WAT).

Information about HEC-FIA and the software package are available from the USACE HEC website.

I.1.3 Hazus-MH

U.S.-Multi-Hazards (Hazus-MH) is a GIS-based modeling application developed by the Federal Emergency Management Agency (FEMA) for assessing potential losses from earthquakes, hurricanes, and floods. The Flood Model in Hazus-MH includes flood hazard analysis and flood loss estimation modules for riverine and coastal analyses. The flood hazard analysis module uses characteristics such as frequency, discharge, and ground elevation to estimate flood depth, flood elevation, and flow velocity. The loss estimation module estimates direct and indirect economic losses using the results of the flood hazard analysis and structural inventories. These losses include structural and contents damage and loss of functions to general building stock (residential, commercial, industrial, etc.), essential facilities (emergency centers, medical care centers, schools, etc.), transportation systems (highways, rails, airports, bus systems, etc.), utilities (potable water, waste water, electrical, communications, etc.), and agricultural products. Impacts to population, especially groups of special concern (low income, ethnicity, age groups over 65, etc.), and shelter requirements are also estimated.

Hazus-MH analyses can be conducted at different levels of rigor. A Level 1 analysis uses default hydrologic, hydraulics, and economic inventory information; Leve2 and Level 3 analyses incorporate user-input local data to improve the accuracy of analyses.

Strengths of Hazus-MH include the following:

- It is GIS-based, which greatly facilitates analyses and display of results.
- It can be adapted to different analysis levels depending on user-input data.
- The availability of default values allows for reconnaissance-level analyses and analyses which otherwise could not be conducted because of a lack of local data.
- It can be used for riverine and coastal flood analyses.

- It can estimate direct flood damage losses as well as indirect regional impacts (income, employment, casualties, etc.).
- It is often used by communities in preparing their FEMA-required local hazard mitigation plans.

Weaknesses of Hazus-MH include the following:

- Because it is GIS-based, Hazus-MH requires ArcGIS software and expertise.
- It does not incorporate uncertainty directly, although this can be alleviated by sensitivity analyses.
- It does not provide a rigorous analysis of levees, although a levee can be “drawn” into the study area and a “level of protection” assigned to it.
- Project performance statistics are not estimated.

Information about Hazus-MH and the software package are available on the FEMA website.

I.1.4 DWR F-RAM

Flood Rapid Assessment Methodology (F-RAM) is a spreadsheet model to estimate flood damage. This model develops loss-probability curves for without- and with-project conditions based on hydrologic and hydraulics data, probability of levee failure data, structural and crop inventories, depth-damage curves, etc. Damage categories include residential, commercial, and industrial properties; crops; and roads. Other categories can be added. An adjustment (for example, 25%) is added to damage estimates to account for indirect damage not specifically included in the model. The model is flexible in that many of the analysis assumptions and parameters can be changed (for example, structural foundation heights, unit replacement values, and depreciation factors; depth-damage curves; discount rates; analysis period; and other indirect damage adjustment factors). Like all other models, the quality of the F-RAM analyses is directly dependent on the quality of the input data such as floodplain extents and depths, and structural inventories.

Strengths of F-RAM include the following:

- It can provide relatively quick estimates of EAD depending on the availability of input data.

- It can be adapted to different analysis levels, depending on the quality of the input data.
- It incorporates probability of levee failure.
- It can be used for riverine analyses, but could be applicable to coastal analyses.
- Users can easily see data inputs and calculations (i.e., it is “transparent).

Weaknesses of F-RAM include the following:

- It does not incorporate uncertainty directly, although this can be offset by sensitivity analyses.
- It does not estimate regional impacts (income, employment, casualties, etc.).
- Project performance statistics are not estimated (although F-RAM inputs and model outputs can be input into HEC-FDA to obtain project performance statistics).
- Its use would likely not be acceptable to the USACE if DWR were partnering with that agency on a project.

F-RAM is available from DWR economics staff.

I.1.5 Comparison of Flood Risk Management Benefit Assessment Software Applications

Table I-1 compares key characteristics of the flood risk management benefit assessment applications described above.

Table I-1. Comparison of Flood Risk Management Benefit Assessment Applications

Characteristic (1)	Application			
	HEC-FDA (2)	HEC-FIA (3)	Hazus-MH (4)	F-RAM (5)
Sponsoring Agency	USACE	USACE	FEMA	DWR
Model Outputs				
Event Damage	Yes	Yes	Yes	Yes
Expected Annual Damage	Yes	No	Yes	Yes
Project Performance Stats	Yes	No	No	No
Life Loss	Yes[3]	Yes	No[4]	No
Type of Damage				
Direct[1]	Yes	Yes	Yes	Yes
Indirect[2]	No	No	Yes	No
Levee Failure Analysis	Fragility curves	Fragility curves	Assumed LOP[5]	Assumed failure probability
Uncertainty	Yes	No	No	No

Notes:

[1] Includes physical damage, loss of functions, other costs of floodplain, and emergency management costs.

[2] Regional income and employment effects.

[3] The 2012 CVFPP incorporated life risk evaluations into the HEC-FDA economic models, with modifications.

[4] Hazus-MH does not estimate casualties in the earthquake and hurricane wind modules.

[5] Level of protection, e.g., “100-year (annual p = 0.01).”

I.2 Ecosystem Restoration Benefit Assessment Software: IWR Planning Suite

The IWR Planning Suite was developed by the USACE Institute for Water Resources; the Natural Resource Conservation Service is a co-sponsor of its development. This software suite assists with the formulation and comparison of alternative environmental restoration and watershed planning studies. It can assist with plan formulation by combining solutions to planning problems and calculating the additive effects of each combination or “plan.” IWR Planning Suite can assist with plan comparison by conducting cost effectiveness/incremental cost analyses (CE/ICA), identifying the plans that are the best financial investments, or displaying the effects of each on a range of decision variables (USACE IWR, 2006).

IWR Planning Suite uses procedures based on the planning framework established in Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (U.S. Water Resources Council, 1983).

Information about IWR Planning Suite and the software package are available from the IWR Planning Suite website.

I.3 Water Supply Benefit Assessment Software: IWR-MAIN

IWR-MAIN, developed by Planning and Management Consultants, Ltd., originally under sponsorship of the USACE Institute for Water Resources, is designed for:

- Projecting municipal and industrial water demands.
- Analyzing the potential water savings from water demand management (water conservation) programs and incorporating these savings into projections of water demands.
- Analyzing the potential monetary benefits and costs of water conservation alternatives.

IWR-MAIN provides a disaggregated estimate of the current and future municipal and industrial demand for water for a given study area. Water demands are estimated by sectors such as single-family residential, multifamily residential, commercial, manufacturing, and government. The water demands of each sector are expressed as a product of the number of users (housing units, employees) and the average rate of water use per household or per employee as determined by a set of explanatory variables for each sector.

The conservation component of IWR-MAIN provides estimates of water savings from passive, active, and emergency conservation programs. Conservation savings estimates are generated by sector and by twenty different end uses of water. The water savings are incorporated into long-term forecasts of water demand for the study area. The benefit-cost component of IWR-MAIN uses a number of economic justification tests to evaluate the economic merits of conservation programs. The results of the benefit-cost analysis can be used in comparing supply augmentation and demand management alternatives. Once the water planner has conducted the initial analysis of water use, conservation, or benefits and cost, IWR-MAIN provides the ability to conduct numerous sensitivity analyses to examine the impact of changes in socioeconomic conditions, weather, water pricing, or conservation programs on long-term water demands.

Strengths of IWR-MAIN include the following:

- IWR-MAIN provides water demand forecasts disaggregated by sector, geographic/political boundaries, and time periods.
- Forecasting models may be simple or complex depending on data availability.
- Many factors affecting water demand, such as household income, persons per household, weather, water and wastewater rates, housing and employment projections, and conservation programs, can be changed to assess the impacts of alternative scenarios on future water demands.

Weaknesses of IWR-MAIN include the following:

- The level of forecast model verification is dependent on the detail of water use data available in the given study area.
- It does not compute benefits and costs for structural water supply alternatives.

I.4 Navigation Benefit Assessment Software: HarborSym

HarborSym, developed by the USACE, is a planning-level simulation model designed to assist in economic analyses of coastal harbors. With user-provided input data such as the port layout, vessel calls, and transit rules, the model calculates vessel interactions within the harbor. Unproductive wait times result when vessels are forced to delay sailing due to transit restrictions within the channel; HarborSym captures these delays. Using the model, analysts can calculate the cost of these delays and any changes in overall transportation costs resulting from proposed modifications to the channel's physical dimensions or sailing restrictions.

Features of HarborSym include the following:

- It has a graphical user interface for data entry and customization of the harbor network.
- It models coastal harbor vessel movement behavior.
- It uses Monte Carlo simulation to incorporate uncertainty.

Information and the software package are available from the USACE's HarborSym website.

I.5 Other Effects Assessment Software: IMPLAN and REMI

Two software applications that can be used to estimate regional secondary economic effects include IMPLAN and REMI.

I.5.1 IMPLAN

IMPLAN uses a national input-output (I-O) dollar flow table called the Social Accounting Matrix. For a specified region, the I-O table accounts for all dollar flows between different sectors of the economy. Using this information, IMPLAN models the way a dollar injected into one sector of the economy is spent and re-spent in other sectors (the economic multiplier effect). The model uses national industry data and county-level economic data to generate a series of multipliers, which, in turn, estimate the total economic implications of economic activity (City of Richmond, Undated). Outputs include:

- **Direct impacts –** the dollar value of economic activity available to circulate through the economy. For example, a new housing development would result in discretionary spending at local businesses by those new households.

- **Indirect impacts –** the "inter-industry impacts of the input-output analysis." For example, in the case of a new housing development, indirect impacts result from the spending by the local companies that the new households buy goods and services from.

- **Induced impacts –** impacts of household spending by employees generated by the direct and indirect impacts. For example, a new housing development leads to discretionary spending at local businesses (direct impact). The employees of those local businesses, in turn, buy goods and services at other businesses (induced impacts).

Information about IMPLAN and the software package are available at the IMPLAN website.

I.5.2 REMI

[Note: the following text summarizes information found on the REMI website (www.remi.com).]

The REMI model incorporates aspects of four major modeling approaches: Input-Output, General Equilibrium, Econometric, and Economic Geography. Each of these methodologies has distinct advantages as well as limitations when used alone. The REMI integrated modeling approach builds on the strengths of each of these approaches.

At its core, the REMI model has the inter-industry relationships found in Input-Output models. As a result, the industry structure of a particular region is captured within the model, as well as transactions between industries. Changes that affect industry sectors that are highly interconnected to the rest of the economy will often have a greater economic impact than those for industries that are not closely linked to the regional economy.

General Equilibrium is reached when supply and demand are balanced. This tends to occur in the long run, as prices, production, consumption, imports, exports, and other changes occur to stabilize the economic system. For example, if real wages in a region rise relative to the U.S., this will tend to attract economic migrants to the region until relative real wage rates equalize. The general equilibrium properties are necessary to evaluate changes such as tax policies that may have an effect on regional prices and competitiveness.

REMI is sometimes called an "Econometric model," as the underlying equations and responses are estimated using advanced statistical techniques. The estimates are used to quantify the structural relationships in the model. The speed of economic responses is also estimated, since different adjustment periods will result in different policy recommendations and even different economic outcomes.

The New Economic Geography features represent the spatial dimension of the economy. Transportation costs and accessibility are important economic determinants of interregional trade and the productivity benefits that occur due to industry clustering and labor market access. Firms benefit from having access to a large, specialized labor pool and from having access to specialized intermediate inputs from supplying firms. The productivity and competitiveness benefits of labor and industry concentrations are called agglomeration economies, and are modeled in the economic geography equations.

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Appendix J: Example Integrated Flood Risk Management Benefit-Cost Analysis

June 2014

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Appendix J: Example Flood Risk Management Benefit-Cost Analysis

J.1 Purpose of Example Analysis

The HAV describes a broad array of benefit categories applicable to integrated flood management investment evaluations. It also describes the recommended DWR approach for computing each benefit, including the major analysis steps, analysis results templates, and recommended software applications (where appropriate). The purpose of this example analysis is to demonstrate the recommended DWR approaches (for a specified set of benefits) based on an actual study, modified to illustrate the procedures described in the HAV.

The study selected for this example analysis is the Three Rivers Levee Improvement Agency's (TRLIA) Feather River Levee Repair Project (FRLRP), which evaluated alternative combinations of levee strengthening and setbacks along the left (east) bank of the Feather River between the confluences of that river with the Yuba and Bear rivers in Yuba County. The FRLRP is part of the fourth phase of a larger TRLIA Levee Improvement Program (LIP) to reduce flood risk to the Reclamation District 784 (RD 784) service area. The TRLIA LIP has received funding from DWR's Yuba Feather Flood Protection Program for projects recommended by the FRLRP. The TRLIA LIP, in turn, is part of a county-wide Yuba-Feather Supplemental Flood Control Project (Y-FSFCP) (TRLIA 2006).

Note

Data for this example analysis have been adapted from an actual study. However, the data have been modified as necessary to illustrate issues or procedures. Consequently, no conclusions regarding decisions made in the actual study should be drawn from the results presented here.

This example analysis builds upon (and sometimes modifies) the analyses conducted for the TRLIA FRLRP. In addition, to demonstrate the evaluation of additional benefits likely to be evaluated for many integrated flood management studies, this example analysis also includes hypothetical water supply benefits (resulting from groundwater recharge) and recreation benefits not evaluated by the TRLIA FRLRP.

J.2 Project Description

Yuba County has a long history of catastrophic flooding from high flow events on the Feather, Yuba, and Bear rivers (Figure J-1). The county has experienced five major floods since 1950, the most recent of which occurred in 1997. These floods resulted in the loss of 41 lives, caused significant property damage, and constrained economic development in the county. Levees extend along the length of these three rivers in Yuba County, which were originally built by local landowners, reconstructed by the federal government as part of the Sacramento River Flood Control Project, and subsequently turned over to the State as “project levees.” Levee operation and maintenance in southwest Yuba County are the responsibility of Reclamation District 784 (RD 784) and are monitored by the California Department of Water Resources (DWR). Countywide flood issues are overseen by the Yuba County Water Agency (YCWA). The project described herein involves levee improvements along the left (east) bank of the Feather River between the confluences of that river with the Yuba River to the north and Bear River to the south. This project is one of several projects to improve countywide flood protection. (TRLIA 2006)

Following the 1997 flood, the YCWA initiated the Yuba-Feather Supplemental Flood Control Project (Y-FSFCP) to develop enhancements to flood protection facilities in the county. One of the elements identified by the Y-FSFCP was to construct setback levees along the Feather River in Yuba County, referred to as the Feather River levee repair project (FRLRP).

The primary objective of the FRLRP is to reduce **flood risk**. The FRLRP will protect about 17,000 acres within RD 784 which are predominately agricultural. However, there is concentrated urban development in Linda and Olivehurst (located in the northwest portion of RD 784), with large-scale residential development occurring within the Plumas Lakes area south of the above two communities. The goal is to increase flood protection for at least a flood event with a 0.005 annual exceedance probability (AEP), compared to the current flood protection estimated to be no greater than for a 0.05 AEP flood event.

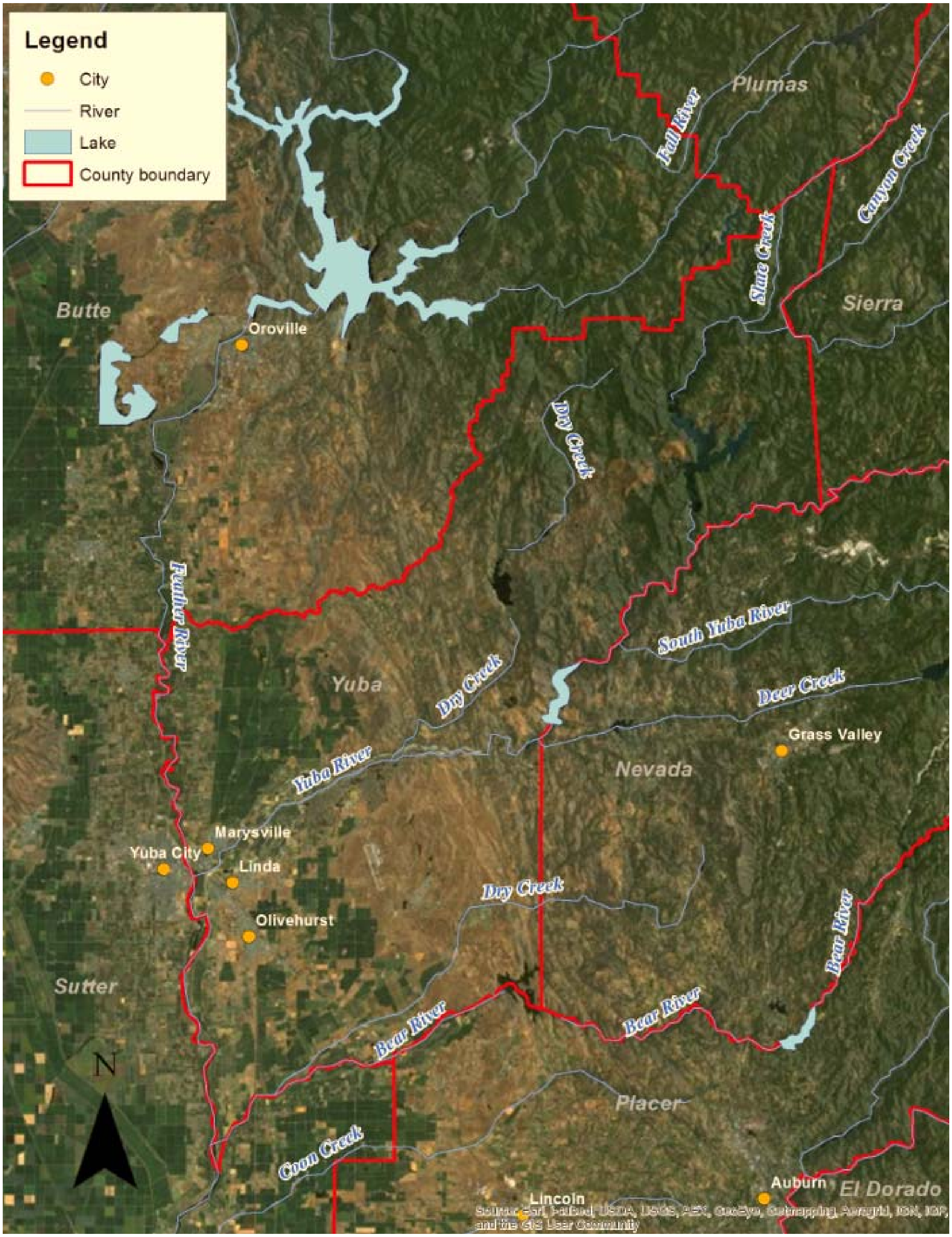

Figure J-1. Yuba County

Project purpose or objective?

A project purpose is one included in the plan formulation process for which benefits are estimated and to which costs are allocated. A project may also provide benefits from other objectives that are incidental to the project purposes for which benefits can also be estimated, but no cost allocation occurs. The USACE refers to these types of benefits as “other direct benefits” (USACE 2000).

A supporting project purpose is to implement **ecosystem restoration** if the levee setback can provide opportunities for ecosystem restoration on the portion of the floodplain reconnected with the river channel. In addition, other benefits are expected to be realized from the FRLRP, including:

- **Water supply –** The improved levee project may permit a greater rate of release from an upstream reservoir (due to increased safe capacity of the river reach), thus water in the reservoir flood pool can be evacuated more quickly. In that case, the storage commonly kept empty for future flood “control” could be reallocated for conservation storage, either officially or with an understood capability to infringe on the flood pool with water for supply.
- **Recreation –** If a levee setback is incorporated into the project, opportunities will exist for recreation.

Figure J-2 shows the location of RD 784, the alignment of the existing Feather River left levee, and protected communities.

Alternatives that were evaluated for this example analysis include:

- Plan A: strengthen existing Feather River left levee in place (e.g., no setback).
- Plan B: full levee setback.
- Plan C: intermediate levee setback.

Plan A is essentially a single-purpose plan to reduce flood risk in the study area, whereas plans B and C may also have (in addition to flood risk management) ecosystem restoration, water supply, and recreation benefits. These alternatives are shown in Figure J-3.

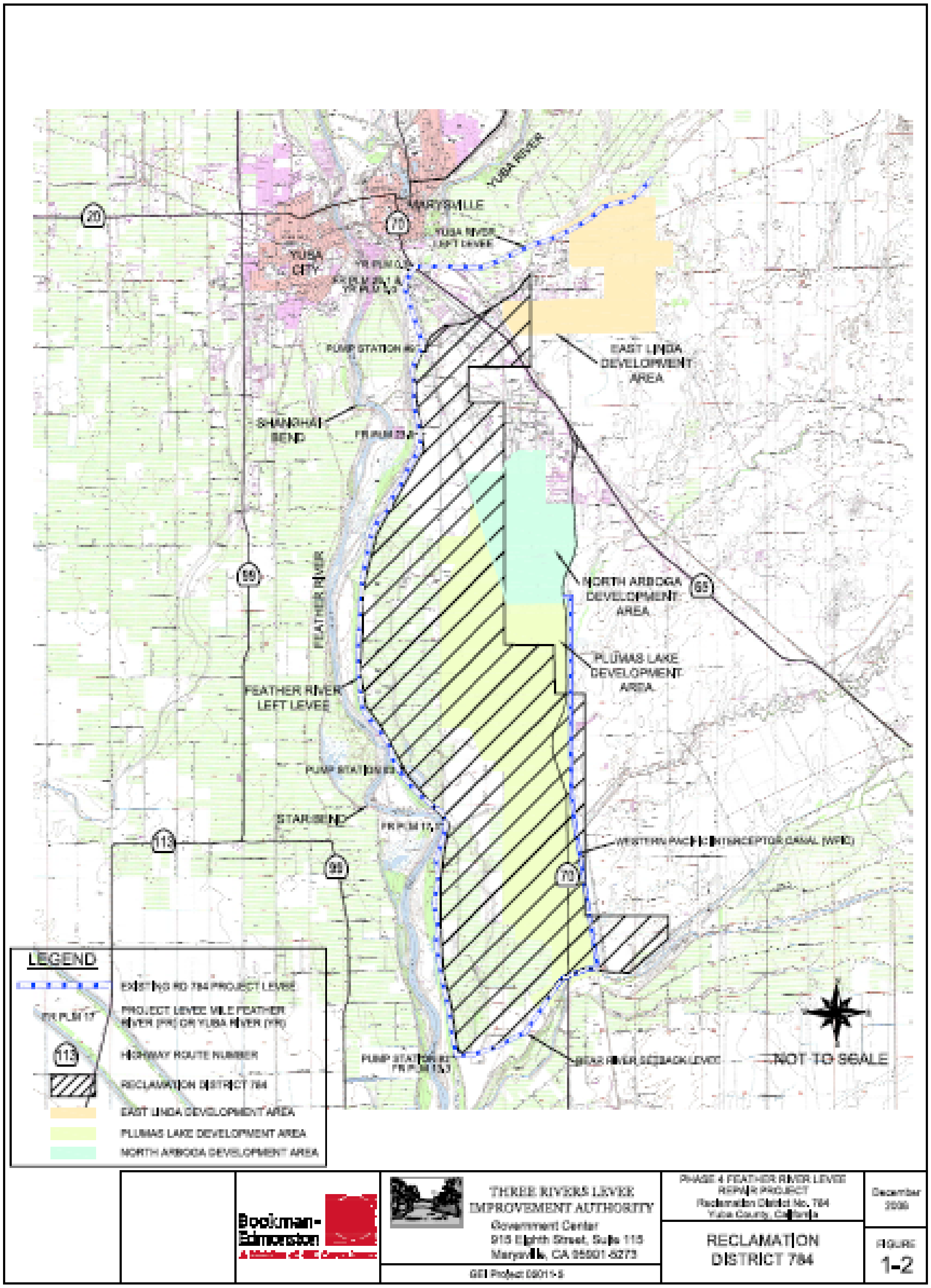

Figure J-2. Reclamation District 784 Showing the Existing Feather River Left Levee Alignment and Protected Communities

(TRLIA 2006)

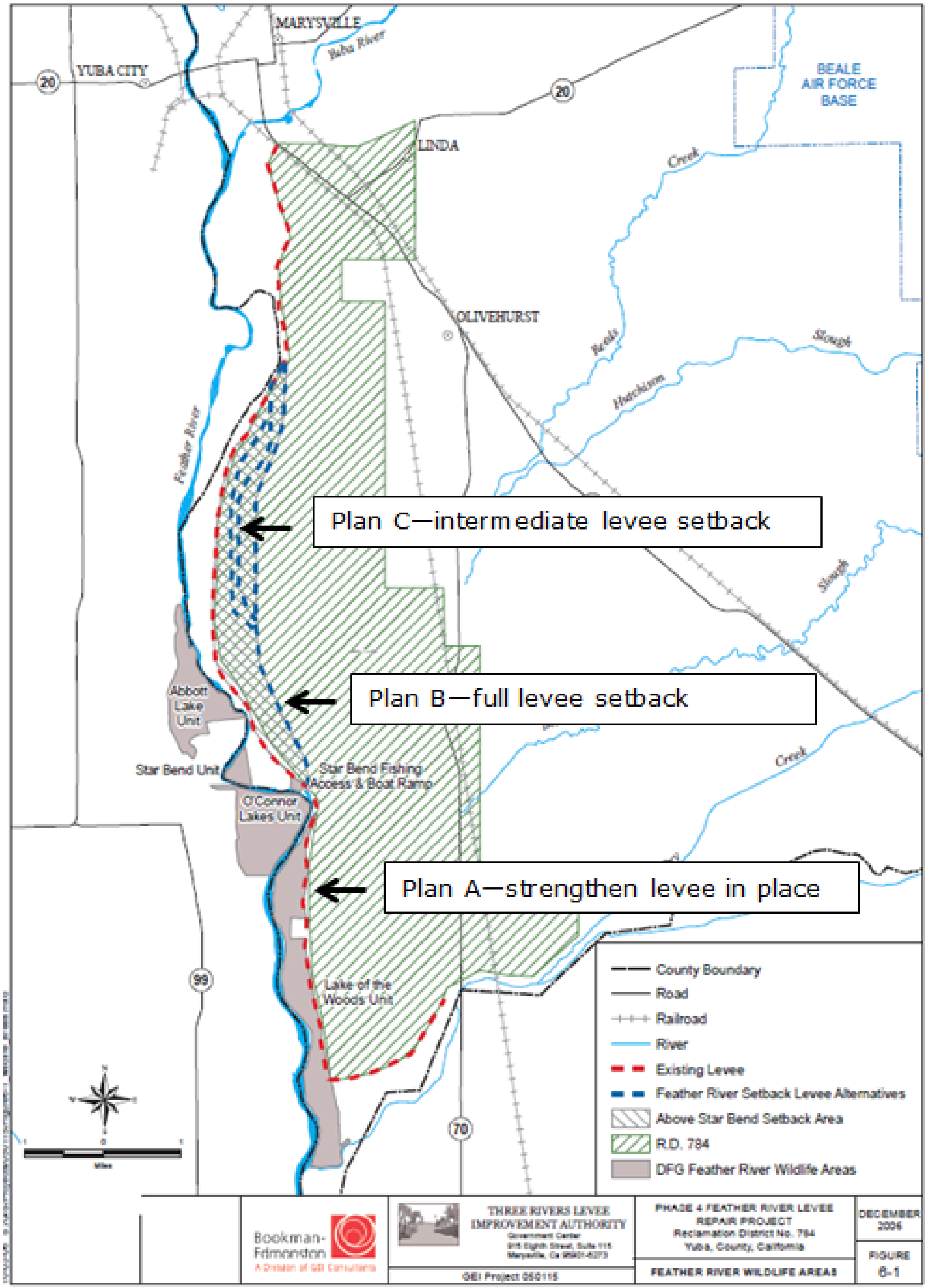

Figure J-3. FRLRP Alternatives, including Plan A (Strengthen Levee in Place), Plan B (Full Levee Setback), and Plan C (Intermediate Levee Setback)

(TRLIA 2006)

J.3 Study Area

Although the focus of this study is the RD 784 service area, the evaluation of flood risk management benefits (and costs) requires a broader region be studied because of the complex hydraulic connectivity of the three-river system. Thus, a larger economic analysis study area will be defined (as described below) to evaluate any potential benefits (and costs) to the regions north and west of RD 784, including the cities of Marysville and Yuba City.

Note about FRLRP Alternatives

Another modified intermediate levee setback (closer to the existing levee) was evaluated by TRLIA but not included in this example analysis.

J.4 Study Base Year, Analysis Period, and Discount Rate

This study uses a 50-year analysis period with a base year of 2009. This base year was selected because of specific issues related to the existing (as of 2009) level of flood protection and implications for further urban development, as described below. The current DWR discount rate of 6% is used to adjust dollars received or spent at different times to present-day dollars ("present worth" or "present value"). All benefits and costs are expressed in October 2013 dollars.

J.5 Flood Risk Management Benefits

Flood risk management (FRM) benefits result from protecting existing and future development from flood damage and making flood-prone land more suitable for appropriate uses. In general, FRM primary benefits can be grouped into three subcategories:

- Inundation-reduction (IR) benefits
- Intensification benefits
- Location benefits

IR benefits are reduced or modified flood damage, costs, and/or losses to existing or future economic activity. Their computation is the main focus of this example analysis. However, potential economic development facilitated by improved flood protection is a critical issue for this region and is discussed qualitatively in the context of regional impacts.

J.5.1 Inundation Reduction Benefits

IR benefits are the reduction in damages associated with existing or future land use. Damages and damages reduced are reported in annualized terms (expected annual damage, or EAD). EAD is calculated as the integral of the damage-probability function which weights the damage for each event by the probability of that event happening in any given year and then sums across all possible events.

The damage-probability function is derived commonly by transformation of available hydrologic, hydraulic, and economic information, as illustrated in Figure J-4. A discharge-probability function (Figure J-4a) and a discharge-water surface elevation (rating) function (Figure J-4b) are developed using principles of hydrology and hydraulics. An elevation-damage function (Figure J-4c) is developed from information about location and value of damageable property in the floodplain, which can be transformed to yield the required damage-probability function (Figure J-4d). Finally, to compute the expected annual damage, the damage-probability function can be integrated.

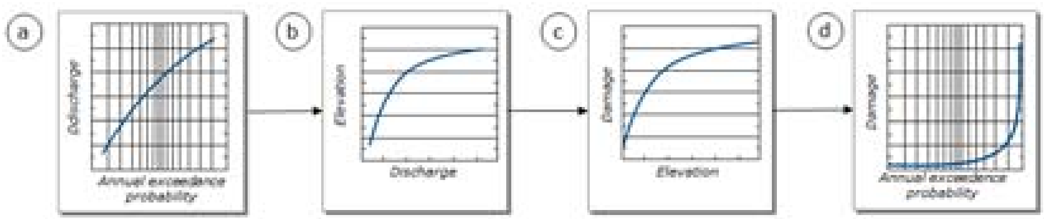

Figure J-4. Computation of Expected Annual Damage

The IR benefit is the value of damage prevented: damage incurred without the project less damage incurred with the project. For example, if EAD is $1 million in damage to property without the project, but reduced to $0.4 million with the project, then the IR benefit (the EAD losses avoided due to the project) is $0.6 million. For comparison, all benefits (and costs) can be expressed either as average annual values over the analysis period, or as total present value over the analysis period.

J.5.2 Inundation-Reduction Benefit Study Area

For this example analysis, the computation of IR benefits must account for potential hydraulic effects in other areas besides RD 784 as well as flooding from multiple sources within RD 784.

Effects in Multiple Areas

IR benefits (or costs) may occur in areas outside the area of primary concern to the study (RD 784) because of the complex hydraulic connectivity of the three-river system. Thus, three regional economic study impact areas were delineated (IA1, IA2, and IA3) that include not only RD 784, but also Marysville and Yuba City, as shown in Figure J-5.

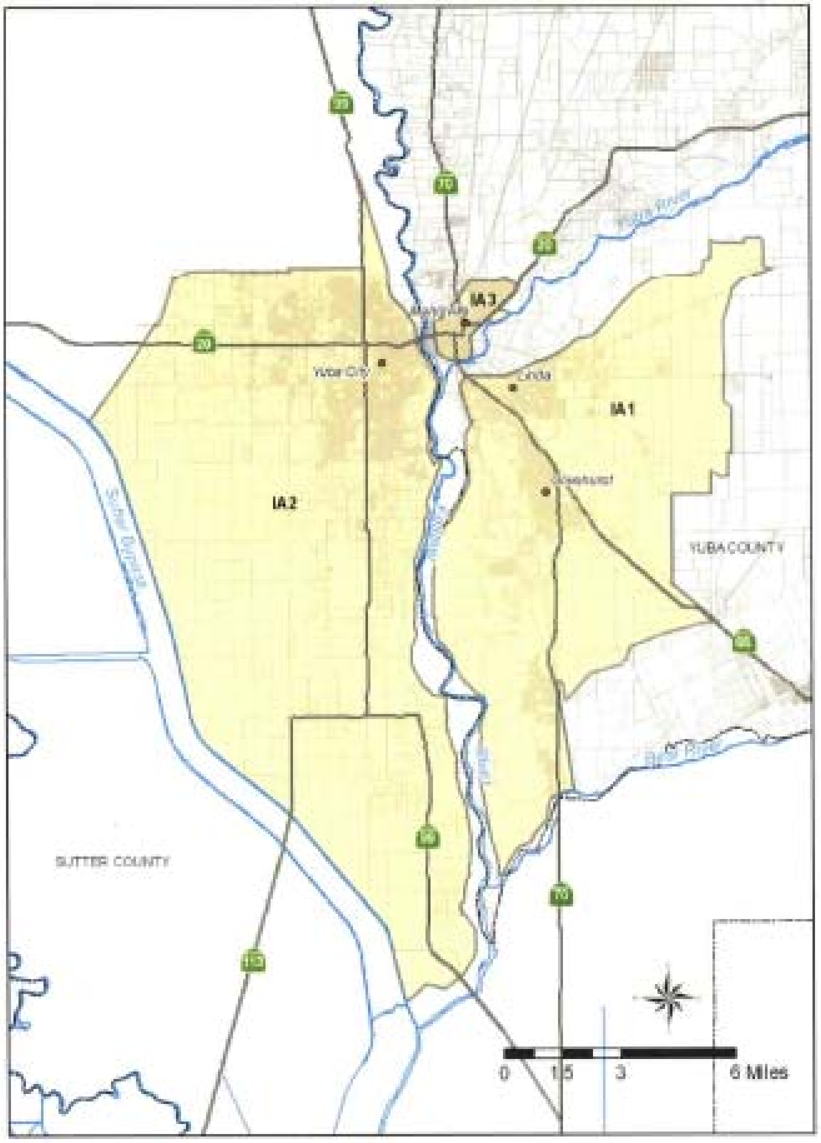

Figure J-5. Regional Economic Study Impact Areas Include IA1 (RD 784), IA2 (Yuba City), and IA3 (Marysville)

(TRLIA December 2006)

Multiple Flooding Sources

Within RD 784 (IA1), flooding may occur from the Yuba River to the north, the Feather River to the east, and the Bear River to the south. In addition, flooding may also occur from the Western Pacific Interceptor Canal (WPIC) located east of (and roughly parallel to) Highway 70. The WPIC captures runoff from the foothills and diverts it to the Bear River to the south. To address multiple flooding sources, several index points were assigned to the impact areas. An index point is a single location that represents the interface between the impact area (floodplain) and the channel. Some of these index points were used to report economic damage, whereas others were used to evaluate hydraulic performance. Finally, the impact areas were divided into analysis subareas to better represent flood depths at structures.

A single index point was used to compute damage for IA2 (Yuba City) and IA3 (Marysville). However, for IA1 (RD 784), five index points were used to represent the variability in hydraulic performance and the impact of alternative project measures (plans A, B, and C). For the EAD calculation, a source-specific damage associated with a levee failure at each index point was computed and then combined into a weighted, or expected, EAD value, as described below.

Figure J-6 shows the location of the various index points and analysis subareas. Table J-1 lists the economic impact areas and Table J-2 lists the index points, their locations, and economic impact areas for which they are used in the computation of flood damage.

Table J-1. Economic Impact Areas

Impact Area (1)	Description (2)
IA1	RD 784 area
IA2	Yuba City area
IA3	City of Marysville

Table J-2. Index Point Locations and Economic Impact Areas for Which They Are Used

Index Point ID (1)	River (2)	River Mile (3)	Bank (4)	Associated Economic Impact Area (5)
FR-1	Feather	29.00	Right	IA2
JS-1	Feather	29.25	Left	IA3
YR-1	Yuba	1.55	Left	IA1
YR-2	Yuba	1.14	Left	IA1
FR-2	Feather	26.00	Left	Used for hydraulic performance only
FR-3	Feather	23.50	Right	Used for hydraulic performance only
FR-4	Feather	19.00	Left	IA1
IC-1	WPIC	2.44	Right	IA1
BR-1	Bear	3.44	Right	IA1

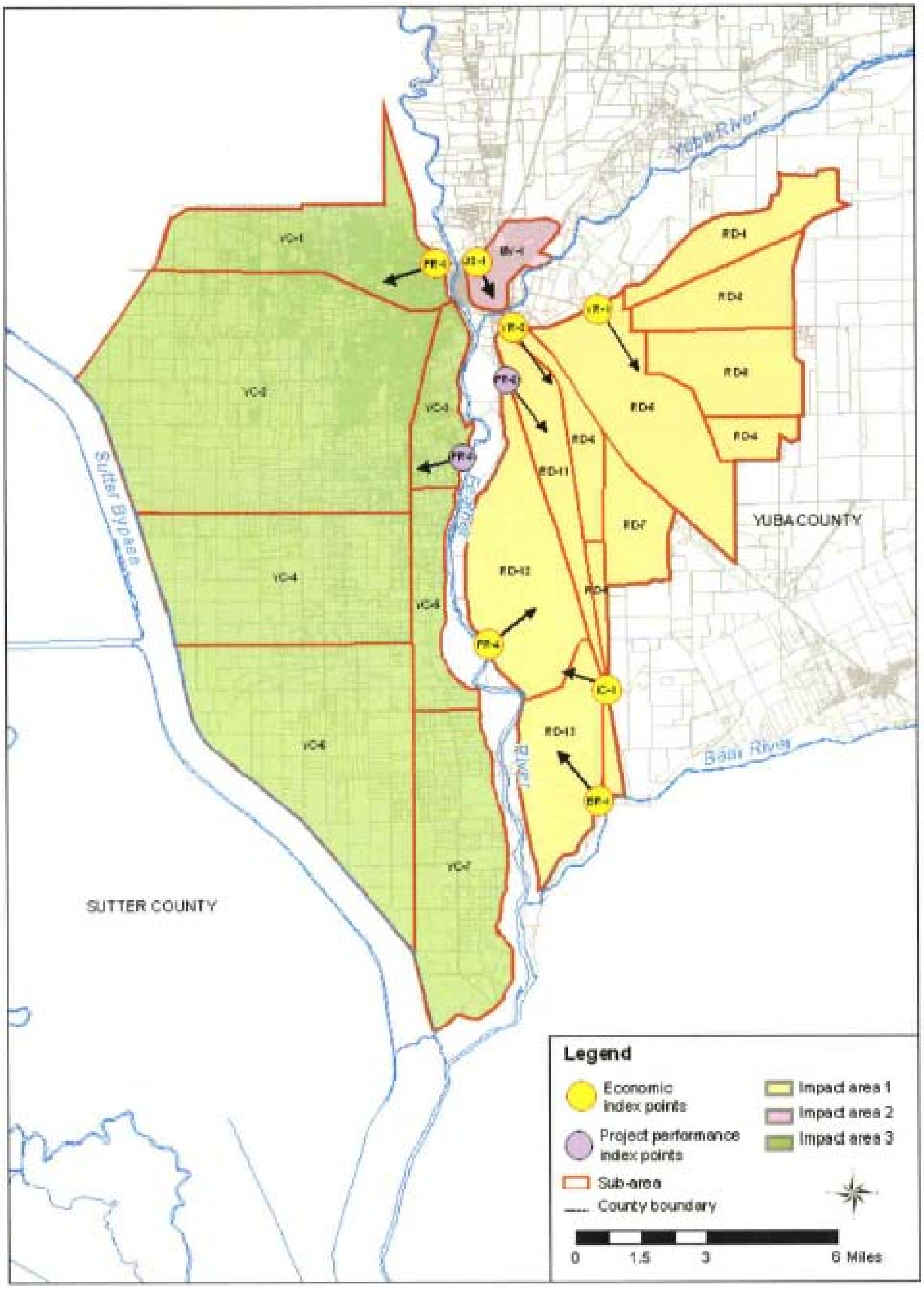

Figure J-6. Index Points and Analysis Subareas

(TRLIA December 2006)

J.6 Benefit Computation Procedures

This example analysis focuses on the IR benefit, which is the value of damage prevented or cost avoided, i.e., damage incurred without the project less damage incurred with the project in place. The IR benefit is computed from change in:

- Structure damage to residential, commercial, industrial, and public facilities.
- Content damage to those facilities.
- Automobiles and landscaping damage.
- Displacement and temporary housing costs.

For the evaluation of alternative plans, EAD is computed for without-project and with-project conditions. The difference is the expected annual IR benefit. However, the damage potential, and hence, this benefit, are likely to change throughout the project life as the value of damageable property changes due to growth in the protected floodplain. Thus, a base year and period of analysis must be defined. For this example analysis, a base year of 2009 was selected with an analysis period of 50 years.

The base year of 2009 was selected because an earlier reevaluation by the US Army Corps of Engineers (USACE) of flood protection in RD 784 showed a level of protection less than required by the National Flood Insurance Program (NFIP) (i.e., less than 100-year [annual p = 0.01] level of protection). Thus, it was likely that Federal Emergency Management Agency (FEMA) would map the lower portion of RD 784 into the regulated floodplain in 2009, causing a halt to extensive planned development in the North Arboga and Plumas Lake development areas. The FRLRP was also to be constructed in 2009.

Two development scenarios were considered in the IR analysis without-project condition:

- Base year development (2009) with no additional growth through the analysis period.
- Future year development (2009-2058) reflecting adopted local development plans and NFIP requirements that all new development be above the 100-year (annual p = 0.01) water surface elevation. Therefore, the IR benefit computation for future conditions takes no IR credit for this future development for events more frequent than that of

the 100-year (annual p = 0.01) event if the area is mapped in the regulatory floodplain.

J.6.1 Software Application

HEC-FDA version 1.2.5a (USACE, 2008) was used for the flood damage analysis. HEC-FDA is the standard-of-practice software application for computing flood risk. It combines hydrologic, hydraulic, geotechnical, and economics data and information to compute EAD (and can also be configured to compute life risk). The program incorporates risk-based analysis by quantifying uncertainties in the hydrology, hydraulics, geotechnical, and economics data and information using Monte Carlo simulation. EAD is computed as the average of flood inundation damages that are incurred over a very long time period. In addition to EAD, the program also computes project performance statistics, including AEP and conditional nonexceedance probability (defined in Section J.6.6 below).

J.6.2 HEC-FDA Data Requirements

HEC-FDA data requirements include:

- Channel water surface elevation (stage)-frequency function for each index point. This describes the annual probability of water surface in the river (exterior channel) reaching a specified elevation.

- Exterior-interior elevation function for each impact area. This function relates the water surface elevation in the channel (exterior) at the index point to the elevation of flooding in the floodplain adjacent to the channel (interior).

- Interior elevation-damage functions for each impact area. This function relates economic damage in the floodplain to water surface elevation in the interior floodplain.

As described below, these data may change between without-project and with-project conditions.

J.6.3 Models of Uncertainty about the Information

The three required functions are not known with certainty. For example:

- Uncertainty about future precipitation events and watershed conditions leads to uncertainty about discharge frequency. For example, it is not known with certainty the magnitude of the discharge with an AEP of 0.01 at any point in the system. This leads, in turn, to uncertainty about the stage-frequency function.

- Uncertainty arises from the use of models to describe complex hydraulic phenomena such as upstream levee failures, from the lack of detailed geometric data, from material variability, and from errors in estimating slope and roughness factors. All this leads to uncertainty about the stage-frequency function. For example, it is not known with certainty what water surface elevation will be reached along the Feather River if the discharge rate is 150,000 cubic feet/second (cfs).

- Economic and social uncertainties, including lack of information about the relationship between depth and inundation damage, lack of accuracy in estimating structure values and locations, and lack of ability to predict how the public will respond to a flood, leads to uncertainty about the elevation-damage function. Thus, it is not known with certainty what damage will be incurred at a given water depth in an impact area.

- If an impact area is protected by a levee, the exterior-interior relationship is not known with certainty, because it is not certain how a levee subjected to rare stresses and loads caused by floods will perform. For example, if the levee is able to provide protection to its top, the interior flooding elevation will be zero for all stages less than the top of levee elevation. However, if the levee breaches at a lower elevation, water will flow into the impact area, and the interior elevation will be greater than zero.

Consistent with traditional engineering standards of practice, the study team developed the required best-estimate functions. HEC-FDA, consistent with USACE guidance (USACE 199b), allows models of uncertainty about these functions to be described. Those models were used for this analysis by providing model parameters for uncertainty about the best-estimate water surface elevation-frequency functions, uncertainty about the best-estimate elevation-damage functions, and uncertainty about the best-estimate exterior-interior functions (in the form of levee fragility functions).

J.6.4 HEC-FDA Data Inputs

Specific HEC-FDA data inputs for the example analysis are summarized below.

Water Surface Elevation-Probability Functions

The flood hazard is partly defined by water surface elevation-probability functions, which describe the probability that a water surface elevation at a given index point will equal or exceed a specified magnitude. The without-project and with-project water surface elevation-probability functions for index point FR-4 (IA1) are shown in Table J-3. The uncertainty about the water surface elevation-probability function is represented in HEC-FDA with a parameter that reflects the length of record from which the function is developed. With this, a long record length yields a function with more certainty compared to a shorter record length.

Table J-3. Water Surface Elevation-Probability Functions for the Index Point FR-4 Feather River (IA1)

Annual Exceedance Probability (1)	Without Project (ft) (2)	Plan A Strengthen Levee (ft) (3)	Plan B Levee Setback (ft) (4)	Plan B Intermediate Levee Setback (ft) (5)
0.5000	47.73	47.70	47.01	47.02
0.1000	56.80	56.74	55.94	55.93
0.0400	60.07	60.02	59.22	59.21
0.0200	61.39	61.34	60.54	60.53
0.0100	61.72	61.70	60.89	60.88
0.0050	64.89	64.85	64.10	64.08
0.0020	69.14	69.12	69.41	69.22

Note: Equivalent record length for these stage-frequency functions is 94 years.

Exterior-Interior Relationships

The flood hazard is also partly defined by the exterior-interior relationships, which relate channel water surface elevations to floodplain water surface elevations. Figure J-7 shows an aerial photograph of a leveed floodplain and the adjacent stream. Figure J-8 further illustrates the meaning of the terms interior and exterior. Because a levee is present in these examples (as in the study area), as the water level rises in the stream, flow out of the channel and into the floodplain is prevented. However, if the levee is overtopped or is breached, then water can flow into the (interior) floodplain, although depths may vary throughout the floodplain.

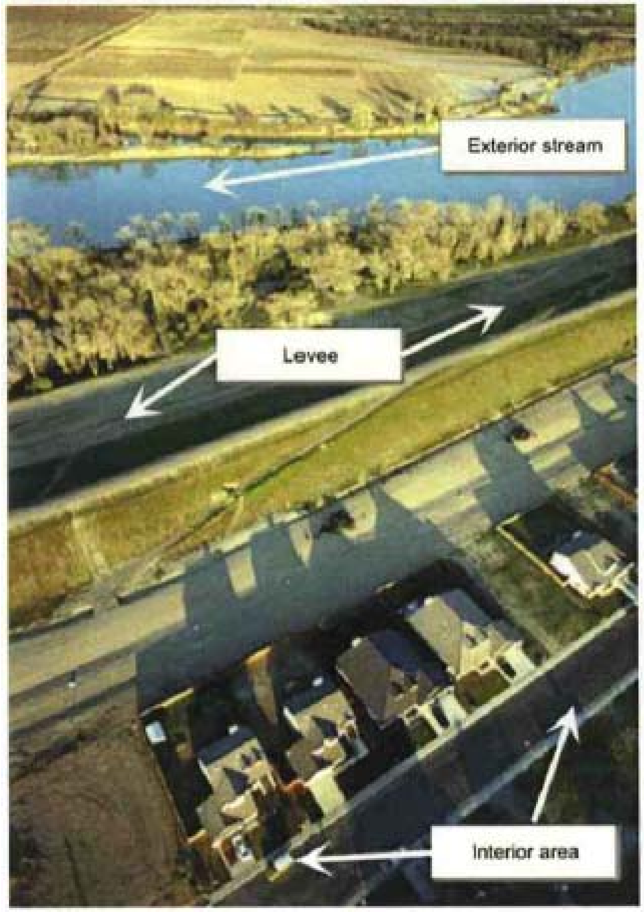

Figure J-7. Photo of Leveed Floodplain

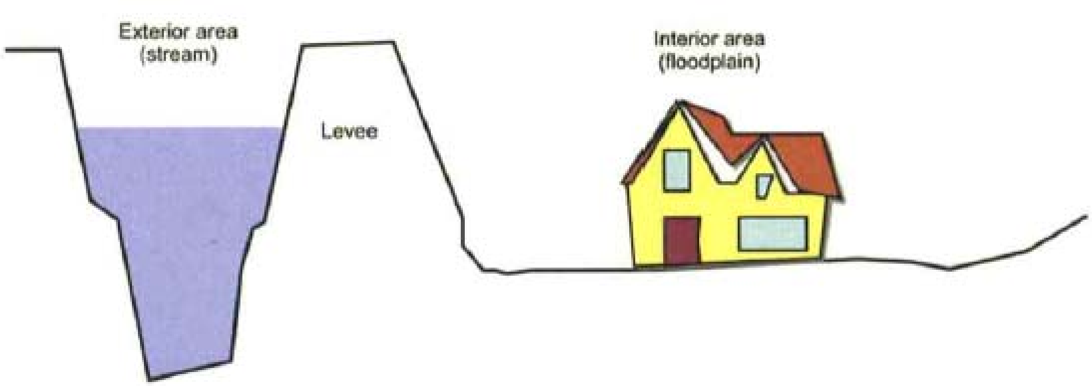

Figure J-8. Conceptual Illustration of Leveed Floodplain Showing Exterior and Interior Areas

To better represent depths at structures (which can vary significantly because of topography), IA1 (RD 784) and IA2 (Yuba City) were divided into subareas, which are shown in Figure J-6. The exterior-interior relationships for index point FR-4 (IA1) are shown in Table J-4.

Table J-4. Exterior-Interior Relationships for Index Point FR-4 Feather River (IA1)

Exterior (Channel) Elevation (1)	Interior Elevation			
	Without Project (ft) (2)	Plan A Strengthen Levee (ft) (3)	Plan B Levee Setback (ft) (4)	Plan B Intermediate Levee Setback (ft) (5)
47.73	47.00	47.00	47.00	47.00
56.80	47.54	47.55	47.55	47.55
60.07	52.91	52.91	52.92	52.91
61.39	55.68	55.69	55.69	55.69
61.72	57.56	57.57	57.57	57.56
64.89	58.29	58.29	58.29	58.29
69.14	60.38	60.39	60.41	60.36

Levee Fragility Functions

The levee fragility function defines the levee performance, expressed as the probability of failure of the levee, given an exterior water surface elevation. For this example analysis, this function was defined with two points: the probable non-failure point (PNP) and the probable failure point (PFP). According to USACE guidance, the PNP is the water surface elevation below which it is highly likely that the levee would not fail; the PFP is the water surface elevation above which it is highly likely that the levee would fail (USACE 1996a). These translate into probabilities of failure equal to 0.15 for the PNP and 0.85 for the PFP. The top of levee elevation is also defined. [NOTE: More recent flood risk analyses use additional points to define the levee fragility function more completely.] Table J-5 presents the levee fragility functions for without-project and with-project conditions at index point FR-4.

Table J-5. Levee Fragility Functions for Index Point FR-4 Feather River (IA1)

Levee Fragility Function Parameters (1)	Without Project (ft) (2)	Plan A Strengthen Levee (ft) (3)	Plan B Levee Setback (ft) (4)	Plan B Intermediate Levee Setback (ft) (5)
Top of levee	68.0	68.0	68.0	68.0
PFP[1]	62.9	67.0	67.0	67.0
PNP[2]	56.3	65.5	65.5	65.5

Notes:
1 Probable failure point (PFP): The elevation with an 85 percent probability of failure.
2 Probable non-failure point (PNP): The elevation with a 15 percent probability of failure.

Elevation-Damage Functions

The elevation-damage function relates inundation damage to water surface elevation. HEC-FDA generates this function based on the hazard inputs [elevation (or discharge)-frequency functions and exterior-interior relationships] and information about locations and values of property in the floodplain. Although not used in this example analysis, the user may also develop these functions outside of HEC-FDA and enter them into the model.

The key input required to develop this function is an inventory of property in the floodplain. For this example analysis, a structure inventory was developed following these steps:

1. Identify structures within each impact area.
2. Classify each structure into a structure category (residential, commercial, industrial, public use, etc.).
3. Assign depth-percent damage relationships to each structure.
4. Estimate structure and content values.

Although not used for the example analysis, crop inventories can be developed based on DWR county GIS-based land use surveys.

A structure inventory was developed starting with a 2004 inventory developed by the USACE for this region that was based on county parcel data. [NOTE: DWR now has access to current statewide county parcel data available from the CA Department of Technology.] This inventory was updated to reflect base year (2009) conditions. Structure counts (by structure category) are summarized in Table J-6. Structure depreciated replacement values are summarized in Table J-7. Content values are calculated within HEC-FDA using user-defined content to structure value ratios. The ratios used for the example analysis are shown in Table J-8. Finally, foundation heights were assigned to all structures using values shown in Table J-9.

The computation of IR benefits is over a 50-year analysis period (2009-2058). The example analysis computes IR benefits based on the base year (2009) level of development. However, because growth is likely to continue beyond the base year, the example analysis also includes a scenario analysis based on a projection of new structures likely to be constructed, based on adopted local specific development plans. This scenario assumes that all new structures meet NFIP requirements (e.g., no flood damage can be incurred for events more frequent than the 100-year [annual p=0.01] event).

Table J-6. Base Year Structure Counts

Structure Category (1)	Impact Area 1 (RD 784) (2)	Impact Area 2 (Yuba City) (3)	Impact Area 3 (Marysville) (4)	Total Study Area (5)
Single-family residential	17,166	16,270	3,261	36,697
Multi-family residential	0	835	0	835
Mobile homes	1,303	79	0	1,382
Farmhouses	179	0	0	179
Commercial	314	749	300	1,226
Industrial	172	309	53	429
Public	74	230	118	417
Total	19,208	18,472	3,732	41,412

Table J-7. Base Year Structure Depreciated Replacement Values (Millions $2013)

Structure Category (1)	Impact Area 1 (RD 784) (2)	Impact Area 2 (Yuba City) (3)	Impact Area 3 (Marysville) (4)	Total Study Area (5)
Single-family residential	$6,497	$1,917	$317	$8,731
Multi-family residential	$0	$203	$0	$203
Mobile homes	$31	$11	$0	$43
Farmhouses	$11	$0	$0	$11
Commercial	$65	$347	$123	$535
Industrial	$47	$179	$24	$250
Public	$112	$128	$269	$508
Total	$6,763	$2,785	$732	$10,281

Table J-8. Content-to-Structure Value Ratios

Structure Category (1)	Ratio of Content Value to Structure Value (2)
Single-and multi-family residential	0.50[1]
Mobile homes	0.50[1]
Farmhouses	Living quarters 0.50[1] Outbuildings 1.00
Commercial	1.00
Industrial	1.00
Public	0.50

Note:
[1] Residential depth-percent damage functions require residential content damage to be calculated using full structure value rather than a percentage of the structure's value; a content value is not computed directly.

Table J-9. Foundation Heights

Structure Category (1)	Foundation Height (ft) (2)
Single-and multi-family residential	1.0
Mobile homes	3.0
Farmhouses	1.5
Commercial	0.5
Industrial	0.5
Public	1.00

J.6.5 Depth-Percent Damage Functions

The final HEC-FDA input is the definition of depth-percent damage functions. The example analysis used depth-percent damage functions from either the USACE or FEMA, depending upon the structure category. An example USACE residential depth-damage structure function is shown in Table J-10.

Table J-10. USACE Residential Depth-Percent Damage Functions

First-Floor Depth (ft) (1)	One Story, No Basement		Two or More Stories, No Basement	
	Structure Damage[1] (2)	Standard Deviation (3)	Structure Damage[1] (4)	Standard Deviation (5)
-2.0	0.0	0.0	0.0	0.0
-1.0	2.5	2.7	3.0	4.1
0.0	13.4	2.0	9.3	3.4
1.0	23.3	1.6	15.2	3.0
2.0	32.1	1.6	20.9	2.8
3.0	40.1	1.8	26.3	2.9
4.0	47.1	1.9	31.4	3.2
5.0	53.2	2.0	36.2	3.4
6.0	58.6	2.1	40.7	3.7
7.0	63.2	2.2	44.9	3.9
8.0	67.2	2.3	48.8	4.0
9.0	70.5	2.4	52.4	4.1
10.0	73.2	2.7	55.7	4.2
11.0	75.4	3.0	58.7	4.2
12.0	77.2	3.3	61.4	4.2
13.0	78.5	3.7	63.8	4.2
14.0	79.5	4.1	65.9	4.3
15.0	80.2	4.5	67.7	4.6
16.0	80.7	4.9	69.2	5.0

Source: USACE Economics Guidance Memorandum 01-03: Generic Depth-Damage Relationships (December 2000)

Note:

[1] Percentage of structure value.

J.6.6 Multiple Sources of Flooding

Using the inputs described above, HEC-FDA was used to compute EAD and project performance statistics for each impact area and index point. If a single index point was assigned to a single impact area, then the EAD outputs from HEC-FDA can be used directly. This was the case for IA2 (Yuba City) and IA3 (Marysville). The use of a single index point for a single impact area is illustrated in Figure J-9(A).

However, for IA1 (RD 784) flooding can occur from multiple sources, including the Yuba River to the north, Feather River to the west, Bear River to the south, and WPIC to the east, all of which have levees. In an impact area such as this, the hydrologic and hydraulic conditions may vary in the surrounding watercourses, especially when the impact area is adjacent to a major confluence. Additionally, levee failures will result in major flood damage. Thus, a single primary source of flooding does not exist, and a single index point does not represent the flood risk well. For these cases, multiple index points are assigned to an impact area, as shown in Figure J-9(B).

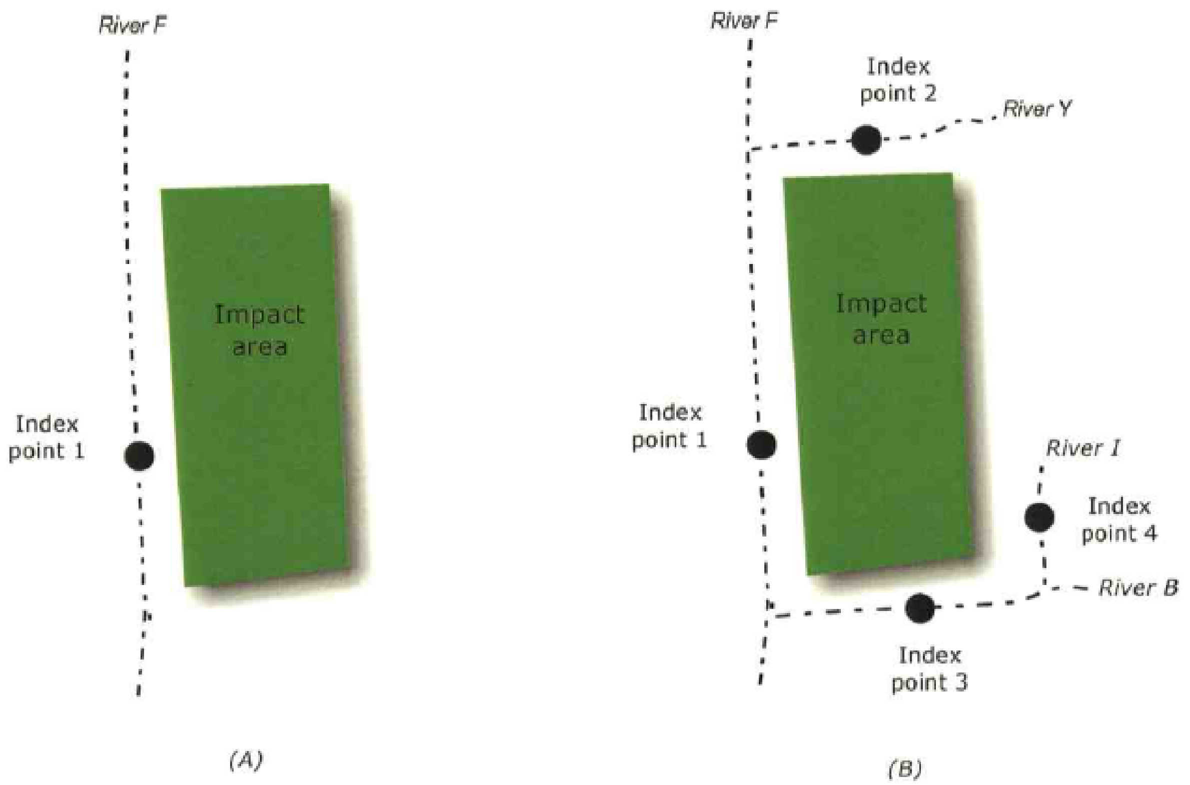

Figure J-9. Impact Area Index Points

If multiple index points are assigned, then they must be accounted for in the EAD computation for the impact area. Various methods can be used for this computation (Pingel and Watkins 2010). For the example analysis, a weighted EAD was computed by estimating the EAD for each index point, then weighting it by the annual exceedance probability (AEP) value output by HEC-FDA. The AEP is the annual probability that the interior floodplain in an impact area will be inundated due to channel or levee overtopping or failure. This is Option 7 described in Pingel and Watkins (2010), which requires post-processing of the HEC-FDA outputs. [Note: the 2017 CVFPP has selected Option 3 which uses the greatest index-point specific EAD of all flooding sources. This assumes a high correlation of flooding from all of the flooding sources (DWR 2013c).]

J.7 Flood Risk Management Benefits

Flood risk management benefits include reductions in EAD and improvements in project performance statistics, both outputs of HEC-FDA.

J.7.1 Expected Annual Damage

EAD was computed for the without- and with project conditions for the three FRRLP alternative plans (Plans A, B, and C). Table J-11 shows EAD for base year (2009) conditions, which includes the following:

- Structure damage to residential, commercial, industrial, and public facilities.
- Content damage to those facilities.
- Automobiles and landscaping damage.
- Displacement and temporary housing costs.

The annual IR benefit is the difference (damage reduced) between the without- project and with-project conditions. For base year conditions, the greatest reduction in annual damage (about $63.2 million) is estimated for Plan B: Levee Setback. Most of the benefits occur in RD 784, as expected, but benefits are also estimated for upstream (Marysville) and across-stream (Yuba City) locations. For this plan, there is a 75% confidence that the annual benefit exceeds $74.5 million, a 50% confidence that the annual benefit exceeds $63.2 million, and a 25% confidence that it exceeds almost $70.0 million.

Table J-12 shows similar information for the scenario analysis that includes future growth. For this scenario, Plan B: Levee Setback still has the greatest estimated annual IR benefit (about $65.5 million).

If no other benefits were expected from any of these plans, then these annual benefits could be compared with annual costs to determine net benefits and the benefit/cost (B/C) ratio. However, other benefits are expected (for at least plans B and C, as described below), so the benefit and cost comparison will be done after those benefits (and allocated costs) have been estimated.

Table J-11. FRLRP Estimated Project Inundation Reduction Benefits (Base Year 2009 Conditions) (Thousands $2013)

Plan (1)	EAD		Damage Reduced		EAD Reduced That Is Exceeded with Specified Probability		
	Without Plan (2)	With Plan (3)	Mean (4)	Standard Deviation (5)	0.75 (6)	0.50 (7)	0.25 (8)
Plan A: Levee Strengthening	$80,711	$20,807	$59,904	$10,184	$52,712	$60,503	$65,899
Yuba City	$5,593	$5,587	$7	$1	$3	$6	$11
Marysville	$4,852	$4,846	$6	$1	$4	$6	$7
RD 784	$70,266	$10,374	$59,892	$10,182	$52,705	$60,491	$65,881
Plan B: Levee Setback	$80,711	$17,536	$63,176	$10,740	$54,460	$63,172	$69,869
Yuba City	$5,593	$4,255	$1,338	$227	$467	$1,101	$1,951
Marysville	$4,852	$3,959	$892	$152	$360	$517	$878
RD 784	$70,266	$9,321	$60,945	$10,361	$53,632	$61,555	$67,040
Plan C: Intermediate Levee Setback	$80,711	$18,087	$62,624	$10,646	$54,208	$62,774	$69,159
Yuba City	$5,593	$4,514	$1,079	$183	$393	$918	$1,550
Marysville	$4,852	$4,137	$715	$122	$285	$418	$697
RD 784	$70,266	$9,436	$60,830	$10,341	$53,530	$61,438	$66,913

Table J-12. FRLRP Estimated Project Inundation Reduction Benefits (Future 2009-2058 Conditions) (Thousands $2013)

	EAD		Damage Reduced		EAD Reduced That Is Exceeded with Specified Probability		
Plan (1)	**Without Plan (2)**	**With Plan (3)**	**Mean (4)**	**Standard Deviation (5)**	**0.75 (6)**	**0.50 (7)**	**0.25 (8)**
Plan A: Levee Strengthening	$89,976	$29,103	$60,874	$11,598	$53,565	$61,481	$66,967
Yuba City	$8,525	$8,514	$11	$2	$6	$9	$17
Marysville	$6,519	$6,510	$9	$2	$8	$10	$11
RD 784	$74,932	$14,078	$60,854	$11,594	$53,551	$61,462	$66,939
Plan B: Levee Setback	$89,976	$24,439	$65,537	$12,486	$56,083	$65,387	$72,843
Yuba City	$8,525	$6,483	$2,042	$389	$713	$1,679	$2,978
Marysville	$6,519	$5,320	$1,199	$228	$550	$788	$1,339
RD 784	$74,932	$12,636	$62,296	$11,869	$54,820	$62,919	$68,525
Plan C: Intermediate Levee Setback	$89,976	$25,235	$64,741	$12,335	$55,711	$64,792	$71,773
Yuba City	$8,525	$6,879	$1,646	$314	$600	$1,400	$2,364
Marysville	$6,519	$5,558	$962	$183	$434	$637	$1,063
RD 784	$74,932	$12,799	$62,133	$11,838	$54,677	$62,755	$68,347

J.7.2 Project Performance

While the EAD and IR benefits described above convey significant information about the economic impact of flooding and effectiveness of the evaluated plans, additional information about flood risk can help with decision making. HEC-FDA outputs project performance statistics for without-project and with-project conditions, including:

- **Expected annual exceedance probability (AEP) –** This is the annual probability that the interior floodplain in an impact area will be inundated due to channel overflow, or in the case of a leveed area, due to overtopping or failure. AEP is computed by HEC-FDA considering the uncertainty in the hydrologic and hydraulic inputs. AEP ranges in value from 0 to 1, with smaller values indicating a lower risk of flood damage in any given year. For example, if the AEP without the project is 0.10, inundation is expected in 1 year out of 10, on the average. If the project reduces this to 0.005, then the risk is reduced, with flooding expected in only 1 year out of 200, on the average.

- **Long-term risk –** This is the probability of flooding over longer periods of time. HEC-FDA computes long-term risk over the 10-, 30-, and 50-year time periods.

- **Conditional nonexceedance probability –** This is the probability that the levee will not fail if a specified event occurs. HEC-FDA computes conditional nonexceedance probability for the p=0.10, 0.04, 0.02, 0.01, 0.004, and 0.002 events. The USACE now calls conditional nonexceedance "assurance."

Table J-13 displays the AEP and long-term risk factors for the without-project condition and the three plans that were evaluated at the FR-2 index point (IA1 RD 784) on the left bank of the Feather River. The without-project AEP is 0.0396, which indicates there is about a 1 in 25 chance of flooding in any given year without the project. The greatest reduction in AEP occurs with Plan B: Levee Setback, with an AEP of 0.042 (or about a 1 in 238 chance of flooding in any given year). Both plans B and C have similar reductions in long-term risk compared to the without-project condition. Also, both of these plans have greater reductions in AEP and long-term risk compared to Plan A.

Table J-14 displays the conditional nonexceedance (assurance) statistics, again at the FR-2 index point. Unlike the AEP or long-term project performance statistics, a larger conditional nonexceedance probability indicates a greater chance of surviving a flood event. Both plans B and C have similar increases in conditional-nonexceedance probabilities compared to the without-project condition. Also, both of these plans have greater increases in conditional nonexceedance probabilities compared to Plan A.

Table J-15 compares the annual exceedance probabilities for all impact areas and all plans. Whereas all of the plans reduce the AEPs (e.g., reduce the annual risk of flooding), the Plan B levee setback either equals or has the greatest AEP reduction for all plans, for most index points. This corresponds to the reduction in EAD for all impact areas attributable to Plan B described above (Table J-13 and Table J-14).

Table J-13. Annual Exceedance Probability and Long-Term Risk at FR-2 Index Point (IA1)

Plan (1)	Annual Exceedance Probability (AEP)[2] (2)	Long-Term Risk: Chance of Exceedance[1] (Long-Term Risk)[2]		
		10 years (3)	30 years (4)	50 years (5)
Without plan	0.0396 (1 in 25)	0.3326 (1 in 3)	0.6362 (1 in 2)	0.8676 (1 in 1)
Plan A: Levee Strengthening	0.0042 (1 in 238)	0.0414 (1 in 24)	0.1004 (1 in 10)	0.1907 (1 in 5)
Plan B: Levee Setback	0.0031 (1 in 323)	0.0304 (1 in 33)	0.0744 (1 in 13)	0.1432 (1 in 7)
Plan C: Intermediate Levee Setback	0.0033 (1 in 303)	0.0324 (1 in 31)	0.0791 (1 in 13)	0.1520 (1 in 7)

Notes:
[1] Chance of exceedance over indicated time period.
[2] Alternative description of risk.

Table J-14. Conditional Nonexceedance Probability (Assurance) at FR-2 Index Point (IA1)

Plan (1)	Conditional Nonexceedance Probability by Events					
	10% (2)	4% (3)	2% (4)	1% (5)	0.4% (6)	0.2% (7)
Without plan	0.9465	0.5500	0.3725	0.3346	0.0085	0.0000
Plan A: Levee Strengthening	1.0000	1.0000	0.9970	0.9958	0.5093	0.0309
Plan B: Levee Setback	1.0000	1.0000	1.0000	1.0000	0.8554	0.0932
Plan C: Intermediate Levee Setback	1.0000	1.0000	1.0000	1.0000	0.7907	0.0693

Table J-15. Comparison of Annual Exceedance Probabilities for All Index Points for All Plans

Index Point ID (1)	River (2)	Economic Impact Area (3)	Annual Exceedance Probabilities: Without Plan (4)	Plan A: Levee Strengthening (5)	Plan B: Levee Setback (6)	Plan C: Intermediate Levee Setback (7)
FR-1	Feather	IA2 (Yuba City)	0.0172	0.0172	0.0119	0.0130
JS-1	Feather	IA3 (Marysville)	0.0047	0.0047	0.0038	0.0040
YR-1	Yuba	IA1 (RD 784)	0.0058	0.0043	0.0037	0.0037
YR-2	Yuba	IA1 (RD 784)	0.0191	0.0037	0.0031	0.0032
FR-2[1]	Feather	IA1 (RD 784)	0.0396	0.0042	0.0031	0.0033
FR-3[1]	Feather	IA2 (Yuba City)	0.0059	0.0059	0.0032	0.0035
FR-4	Feather	IA1 (RD 784)	0.0548	0.0040	0.0036	0.0036
IC-1	WPIC	IA1 (RD 784)	0.0523	0.0026	0.0027	0.0027
BR-1	Bear	IA1 (RD 784)	0.0538	0.0030	0.0032	0.0031

Note:
[1] Used to measure hydraulic performance only; EAD not computed at this index point.

J.8 Ecosystem Restoration Benefits

Of the three alternative FRLRP plans being considered, two include proposed levee setbacks that would provide opportunities for ecosystem restoration by reconnecting the floodplain to the river channel. Plan B is the full levee setback which would result in about 1,600 acres that could be restored and Plan C is an intermediate levee setback that would result in about 1,200 acres that could be restored. For both of these plans, restoration is expected to result in primarily riparian habitat that would be connected to existing nearby habitat on both sides of the Feather River (Figure J-3). Plan A, a single-purpose flood risk management plan, is the levee strengthening in place which would provide no significant opportunities for restoration activities.

Because DWR is partnering with the USACE on the FRLRP project, it shall evaluate the outputs of ecosystem restoration alternative plans using cost-effectiveness/incremental cost (CE/IC) analysis, consistent with existing USACE guidance (USACE 2000). However, DWR has also been investigating innovative methods to monetize ecosystem restoration benefits based on ecosystem services, and has applied one of those methods to supplement the federal CE/IC analysis for the FRLRP project. Both methods are described below.

J.8.1 USACE Cost-Effectiveness/Incremental Cost Analysis

Current USACE policy does not monetize ecosystem benefits, based on the 1983 P&G: “Increments that do not provide net NED [national economic development] benefits may be included…*if they are cost effective*” (USACE 1999, WRC 1983, emphasis added). Thus, USACE procedures focus on cost-effectiveness/incremental cost analyses (CE/IC) that evaluate the change in costs to achieve various levels of ecosystem outputs. Using CE/IC analysis avoids placing a monetary value on those outputs.

The USACE recommended ecosystem restoration plan “should be the justified alternative and scale having the maximum excess of monetary and nonmonetary beneficial effects over monetary and nonmonetary costs. This plan occurs where the incremental beneficial effects just equal the incremental costs, or alternatively stated where the extra environmental value is just worth the extra costs. This plan should be called the NER (National Ecosystem Restoration) plan. In making these value and cost comparisons it is assumed that each plan and scale is the minimum cost way of achieving that level of output; i.e., that an appropriate least cost or cost effectiveness algorithm was used in their development” (USACE 2000). This process describes the evaluation of a single-purpose NER plan.

However, for plans that have both economic benefits (for example, flood damage reduction or water supply benefits) and ecosystem restoration benefits, the plan “with the greatest net sum of economic and restoration benefits is to be selected, consistent with protecting the Nation’s environment” (USACE 2000). This is a combined plan which includes monetized National Economic Development (NED) and NER nonmonetized NER benefits. Under current USACE guidance, the three FRLRP alternative plans would be evaluated as combined NED and NER plans.

To evaluate the FRLRP alternative plans as USACE combined plans requires this information:

- **Identification of primary purpose of plan –** The primary project purpose of the FRLRP is to reduce flood risk in RD 784 as well as surrounding areas. Each of the three plans (Plan A, Plan B, and Plan C) meets this purpose by reducing without-project EAD and AEPs as described above. Plans B and C include levee setbacks that provide opportunities for ecosystem restoration, but this restoration is not the primary purpose of the FRLRP, nor does it interfere with achieving the flood risk management benefits.

- **Cost allocations of alternative plans between NED and NER project purposes –** Because the CE/IC analysis is conducted for a plan's NER outputs, a cost allocation is required to allocate total project costs to the NED and NER project purposes. Usually this is accomplished with a separable cost-remaining benefit (SCRB) method described in Appendix F. TRLIA did such a cost allocation for the FRLRP plans with results displayed in Table J-16, which shows the cost allocations between the flood risk management (e.g., IR benefits) and ecosystem restoration purposes of each plan. These allocated costs include the separable costs specific to each plan purpose as well as its share of joint costs.

- Monetized benefits attributable to the NED purposes as well as the physical NER outputs (such as acres or habitat units) of each plan – The NED benefits (e.g., IR benefits) were described above for each plan (Table J-11 and Table J-12). NER outputs (e.g., acres of riparian habitat) potentially achievable with the three plans are:

    - Plan A: Levee strengthening – 0 acres.
    - Plan B: Levee setback – 1,600 acres.
    - Plan C: Intermediate setback – 1,200 acres.

Table J-16. FRLRP Alternative Plans' Cost Allocations (Thousands $2013)

Alternative Plan (1)	Total Capital Cost[1] (2)	Capital Recovery Factor[2] (3)	Annual Capital Cost (4)
Plan A: Levee Strengthening	$114,201	0.0634	$7,245
Flood Risk Management	$114,201	0.0634	$7,245
Ecosystem restoration	$0	0.0634	$0
Plan B: Levee Setback	$209,573	0.0634	$13,296
Flood Risk Management	$156,774	0.0634	$9,946
Ecosystem restoration	$52,799	0.0634	$3,350
Plan C: Intermediate Levee Setback	$196,382	0.0634	$12,459
Flood Risk Management	$151,470	0.0634	$9,610
Ecosystem restoration	$44,913	0.0634	$2,849

Table source: TRLIA 2006
Notes:
[1] 50-year analysis period using DWR’s current 6% discount rate.
[2] Source: Capital cost allocations obtained from TRLIA (2006).

All of the above information is brought together in Table J-17 as follows [Note: the plans have been re-ordered in this table based on increasing NER outputs (e.g., restored acres)]:

- The annual NED (e.g., IR) benefits and costs are displayed in columns (2) and (3) and a typical benefit/cost ratio is computed in column (4) and the net benefits in column (5).
- The annual NER outputs (e.g., acres of habitat) are displayed in column (6) and allocated NER costs are shown in column (7).
- Column (8) displays any NED benefits that may be foregone if the NER benefits are achieved. For example, if the vegetation that is planted in the setback area to achieve ecosystem restoration hinders flood flows (e.g., increases “roughness”), then that could reduce inundation reduction benefits achieved by the setback. For this example analysis, no NED benefits were assumed to be foregone by either of the levee setback plans.
- Column (9) is the sum of the NER annual costs plus any foregone NED benefits.
- Column (10) computes the total NER cost/acre (cost-effectiveness).
- Column (11) computes the incremental cost/acre based upon the change in acres and total annual costs among the plans.

- Column (12) displays the total annual project costs.

Some observations of the information displayed in Table J-17:

- The NED B/C ratios are much greater than 1.00 with significant annual net monetized benefits.
- The average cost per acre to restore habitat under Plan B (about $2,100 per acre annual cost) is a little less than for Plan C, the intermediate setback (at about $2,400 per acre annual cost). Plan C also has greater incremental costs than Plan B.
- By themselves, the average (or incremental) costs per acre do not reveal which plan is the "optimal" of the levee setback plans. The decision-makers must decide if "it is worth it" to incur the costs of either of these plans in the absence of any other measure of benefit.
- The information described above is meant to illustrate, in a simplified manner, the application of a USACE CE/IC analysis. However, this example CE/IC analysis does not adequately portray the rigor of such an analysis as conducted by the USACE. For example, often a USACE NER plan may evaluate several proposed plans with multiple management measures, resulting in hundreds of different combinations of plans that must be analyzed, requiring the use of IWR PLAN and other more detailed procedures. This simplified manner may be sufficient for screening and making non-complex or low risk decisions.

Table J-17. USACE Combined NED and NER Analysis for FRLRP Alternative Plans (Thousands $2013)

Alternative Plan[1] (1)	NED Annual Benefits (2)	NED Annual Costs (3)	NED B/C Ratio (4)	NED Annual Net Benefits (5)	NER Annual Outputs (Acres) (6)	NER Annual Costs (7)	NED Benefits Foregone (8)	Total NER Costs (9)	Annual NER Cost/Acre (10)	Incremental NER Cost/Acre (11)	Total Annual Project Costs (12)
			(2)/(3)	(2)-(3)				(7)+(8)	(8)/(6)		
Plan A: Levee Strengthening	$59,904	$7,245	8.3	$52,659	0	$0	$0	$0	$0	$0	$7,245
Plan C: Intermediate Levee Setback	$62,624	$9,610	6.5	$53,014	1,200	$2,849	$0	$2,849	$2.4	$2.4	$12,459
Plan B: Levee Setback	$63,176	$9,946	6.4	$53,229	1,600	$3,350	$0	$3,350	$2.1	$1.3	$13,296

Note:
[1] Plans have been re-ordered based on increasing NER outputs (acres restored).

J.9 DWR Monetized Ecosystem Services Approach

Ecosystems perform many complex and interrelated functions which not only provide basic biological support, but also provide valuable goods and services to society. If these societal goods and services can be identified and measured, then that may provide an opportunity to monetize them. The DWR Economic Analysis Guidebook encourages the investigation of "emerging methods of performing economic analysis, particularly those involving benefit assessment for project outputs not usually assigned monetary values" (DWR 2008a).

For FloodSAFE programs, most of the ecosystem services and values identified in are directly related to the natural and beneficial functions of floodplains. Building on the ecosystem services concept, DWR has developed a framework for assessing the potential economic benefits of the CVFPP conservation strategy (DWR 2011c) based on these types of services:

- **Provisioning services** – physical material benefits obtained from ecosystems.
- **Regulating services** – regulation of ecosystem processes that affect the production of other ecosystem services. Examples include:
    - **Cultural services** – nonmaterial benefits provided by ecosystems.
    - **Supporting services** – ecosystem processes and conditions necessary for the production of other ecosystem services.

The DWR Economic Analysis Guidebook (2008a) also describes various ecosystem services valuation methods, organized according to willingness to pay (revealed, imputed, and expressed), as well as benefit transfers. The benefit transfer method was used to monetize ecosystem restoration benefits of the FRLRP levee setback plans.

The benefit transfer method is used to estimate economic values for ecosystem services (or other types of benefits, as well) by transferring available information from studies already completed in another location or context. For example, values for recreational fishing in a particular area may be estimated by applying measures of recreational fishing from a study conducted for another area. Thus, the basic goal of benefit transfer is to estimate benefits for one context by adapting an estimate of benefits from some other context. Benefit transfer is often used when it is too expensive or there is too little time available to conduct an original valuation study, yet some measure of benefits is needed. The benefit transfer method is most reliable when the original site and the current study site are similar in terms of factors such as quality, location, and population characteristics; when the environmental change is very similar for the two sites; and when the original valuation study was carefully conducted and used sound valuation techniques. Although original studies are preferable to benefit transfer, in the absence of funding and other resources needed for the conduct of such studies, benefit transfer can provide a reasonable valuation of benefits provided the above factors are met.

For the FRLRP analysis, the original study selected to transfer a benefit from was the Colusa Basin Integrated Watershed Management Plan described in the DWR Economic Analysis Guidebook, Appendix B (2008a). This study evaluated seven structural and nonstructural plans to achieve flood risk management benefits in the Colusa Basin watershed, including the city of Willows and surrounding rural area. In addition to flood risk management benefits, this study also considered ecosystem restoration benefits. Where possible, the proposed flood management measures included environmental enhancements such as designing detention basins to include seasonal wetlands and augmenting rice field spreading basins with riparian habitat. In addition, stand-alone environmental enhancements were also proposed.

Thus, an objective of the Colusa Basin study was to monetize environmental benefits based on habitat services, including water quality, biodiversity, threatened and endangered species habitat, and carbon sequestration. An original study was not conducted to monetize these types of benefits. Rather, an “imputed willingness to pay” method was used which assumed the value of the proposed habitat ($/acre) is at least equal to the costs incurred by others to produce similar types of habitat in the project area. A lower bound value was derived based upon actual expenditures by other agencies in the nearby Natomas basin for habitat project costs. An upper bound was estimated based upon Wildlands Inc. Sheridan conservation bank credit process. For stream restoration activities on the Sacramento River valley floor, a habitat lower bound estimate of $74,109/acre was estimated along with an upper bound estimate of $85,519/acre. In addition, an average value of $70,814/acre (in July 2004 dollars) was estimated. This average value was transferred for use with the FRLRP levee setback plans and updated to about $84,000/acre in October 2013 dollars. A further adjustment was to convert this to an average annual benefit of about $5,400/acre, based on a 50-year analysis period and DWR 6% discount rate. This value was then used to compute monetized ecosystem restoration benefits as shown in Table J-18. These values (along with the allocated ecosystem restoration costs shown in Table J-16) can then be used to compute an overall net benefit for each plan, as described below. [Note: The use of a benefit transfer value should be collaborated by field surveys and/or other information to determine if the characteristics of the original study are similar to those of the study the value is being transferred to. For ecosystem restoration, this should include a comparison of ecosystem structure and/or functions. This was not done for this example analysis.]

Table J-18. FRLRP Monetized Ecosystem Restoration Benefits Using Benefit Transfer Method ($2013)

Alternative Plan (1)	Benefit Units (2)	Without Plan (3)	With Plan (4)	Change (5)	Benefit $/Acre[1] (6)	Annual Benefit (Thous $) (7)
				(4)-(3)		(5)*(6)
Plan A: Levee Strengthening	Acres	0	0	0	$5,400	0
Plan B: Levee Setback	Acres	0	1,600	1,600	$5,400	$8,640
Plan C: Intermediate Levee Setback	Acres	0	1,200	1,200	$5,400	$6,480

Note:
[1] Annualized benefit transfer value .

J.10 Annualized Value of Water Supply and Recreation Benefits

The primary objective of the FRLRP is to reduce **flood risk** in an urbanizing area. Another major objective is **ecosystem restoration**, taking advantage of opportunities provided by a levee setback to reconnect the floodplain with the river channel. Benefits attributable to these project objectives were described above.

In addition, the FRLRP may provide incidental benefits, including:

- **Water supply –** The improved levee project may permit a greater rate of release from an upstream reservoir (due to increased safe capacity of the river reach), thus water in the reservoir flood pool can be evacuated more quickly. In that case, the storage commonly kept empty for future flood "control" could be reallocated for conservation storage, either officially or with an understood capability to infringe on the flood pool with water for supply.

- **Recreation –** If a levee setback is incorporated into the project, opportunities will exist for recreation.

These benefits are described below.

J.10.1 Water Supply

The FRLRP may provide opportunities to achieve water supply benefits. Upstream of the FRLRP project are several reservoirs that have significant storage space dedicated for flood reservation (for example, Oroville Reservoir). A levee setback implemented by FRLRP would allow for more opportunity to store additional water for conservation purposes, since reservoir operators would be able to release the additional water if necessary due to potential flooding conditions. This assumes the reservoir operators have some flexibility in operations so that they can encroach into the flood reservations when watershed conditions are dry and/or the forecast is for dry weather in the near term. This would also necessitate that the upstream reservoirs have large flood reservations compared to the estimated water supply benefit realized from the flood space encroachment.

Thus, it is estimated that the FRLRP could provide, on average, about 3,000 acre-feet (AF) per year. It is assumed that about 2,000 AF would go to local agricultural users and another 1,000 AF could be sold by the Yuba County Water Agency to other urban water supply contractors in the state, via State Water Project transfers. The estimated values of these water supplies are $150/AF for agricultural users (based on avoided ground water pumping costs) and $300/AF for the urban water transfers, based upon current water market transfer prices. The average value of this additional water supply (considering agricultural uses and urban water transfers) is about $200/AF.

For this analysis, the 3,000 AF of water supply is a fairly small encroachment into the flood reservation during the spring fill period, compared to the large flood reservations at Oroville Reservoir (750,000 AF) and New Bullards Bar (170,000 AF).

Estimated FRLRP incidental water supply benefits are shown in Table J-19.

Table J-19. FRLRP Water Supply Benefits ($2013)

Alternative Plans (1)	Annual Water Deliveries (AF)			$/AF Value (5)	Annual Benefit (Thous $) (6)
	Without Project (2)	With Project (3)	Change (4)		
			[(3)-(2)]		[(4)*(5)]
Plan A: Levee Strengthening	0	0	0[1]	0	0
Plan B: Levee Setback	0	3,000	3,000	$200[2]	$600
Plan C: Intermediate Levee Setback	0	3,000	3,000	$200[2]	$600

Notes:

[1] A water supply benefit would likely be achieved whether the FRLRP levee is strengthened in place or is setback from the river. However, for this example analysis, this benefit is only being claimed for the levee setback plans so that a benefit-cost comparison for a single purpose flood risk management project can be demonstrated, as described below.

[2] Average value of 2,000 AF for agricultural uses ($150/AF) and 1,000 AF for urban uses ($300/AF).

J.10.2 Recreation

A levee setback, combined with ecosystem restoration, should provide opportunities for recreation, assuming that recreational activities do not interfere with the ecosystem restoration objectives. Recreational activities are commonly characterized as either general or specialized recreation. General recreation refers to activities that are attractive to the majority of outdoor users and that generally require the development and maintenance of convenient access and adequate facilities. Examples of general recreation activities include picnicking, camping, hiking, riding, cycling, fishing, and hunting. Specialized recreation involves those activities for which opportunities are limited, intensity of use is low, and a high degree of skill, knowledge, and appreciation of the activity by the user may be involved. Examples of specialized recreation include big game hunting, wilderness pack trips, and white water canoeing.

A common method of assigning dollar benefit values to recreational activities is the unit day method. Unit day values have been developed by the USACE for a wide range of general and specialized recreational activities, and these also incorporate “points” which reflect the quality of the recreational experience. Thus, general recreational unit day values can range from $3.80/user/day (with 0 points) to $11.39/user/day (100 points). USACE unit day values can be found at the USACE Planning Community Toolbox website.

For the FRLRP, incidental recreation benefits are only anticipated to occur with the levee setback plans (plans B and C) as shown in Table J-20.

Table J-20. FRLRP Recreation Benefits ($2013)

Alternative Plans and Type of Recreation (1)	Annual Visitor Days							USACE Unit Day $ Value[3] (9)	Annual Benefit (Thous $) (10)
	Without Project (2)	With Project (3)	Change (4)	Displaced Use[1] (5)	Transferred Use[2] (6)	Total Displaced or Transferred Use (7)	Net Change (8)		
			[(3)-(2)]			[(5)+(6)]	[(4)-(7)]		[(8)x(9)]
Plan A									
General	0	0	0	0	0	0	0	$0	$0
Specialized	0	0	0	0	0	0	0	$0	$0
Total	0	0	0	0	0	0	0		$0
Plan B									
General	0	4,100	4,100	0	0	0	4,100	$4.51	$19
Specialized	0	3,200	3,200	0	0	0	3,200	$6.17	$20
Total	0	7,300	7,300	0	0	0	7,300	$5.30	$39
Plan C									
General	0	3,100	3,100	0	0	0	3,100	$4.51	$14
Specialized	0	2,200	2,200	0	0	0	2,200	$6.17	$14
Total	0	5,300	5,300	0	0	0	5,300	$5.26	$28

Notes:

[1] Existing on-site recreation uses displaced by proposed project.

[2] New recreation uses at site transferred from another existing recreation area.

[3] USACE EGM 13-03: Unit day values.

J.10.3 Regional Economic Impacts

Some of the immediate, direct impacts of flood damage are included in the HEC-FDA models, such as structure and content damage, automobiles, landscaping damage, and displacement and temporary housing costs. Other types of direct impacts include impacts on critical facilities, impacts on lifeline utilities, and fatalities. These were not included in the example analysis, but some (if not all) could be included in the HEC-FDA models. The 2012 CVFPP developed a method to estimate changes in life risk making some changes to exposure and vulnerability inputs of the HEC-FDA economic models.

In addition to these primary impacts included in a B-C analysis, a major flood will have a wide range of short-term, intermediate-term, and long-term economic impacts, including changes in population, employment, business and personal income, taxes and other revenues and changes in regional economic activity. However, to some extent, negative economic impacts could be counterbalanced by the large inflow of federal disaster relief funds to local governments and to individuals, disaster relief by non-profit organizations, and insurance payments to individuals and businesses. In effect, such inflows of relief and insurance transfer some of the economic impacts to the nation as a whole and substantially reduce (but certainly do not eliminate) the economic impacts on Yuba and Sutter counties. Similarly, while there may be temporary and/or permanent job loss because of damage to commercial and industrial facilities, other jobs will be created by the reconstruction and redevelopment activities. If partnering with a federal agency, DWR would describe these types of secondary impacts in the federal Regional Economic Development (RED) planning account.

J.11 Comparison of Benefits and Costs

The comparison of benefits and costs depends on whether all (or, at least the most significant) benefits can be monetized. For the FRLRP, this distinction is most important for ecosystem restoration benefits, which were evaluated with monetized as well as nonmonetized methods (to be consistent with current USACE procedures). Whether ecosystem restoration benefits are monetized affects how benefits and costs are displayed and compared, as described below.

J.11.1 All Monetized Benefits and Costs

Table J-21 summarizes the FRLRP annual monetary benefits (including ecosystem restoration) and costs. The inundation-reduction benefits shown in this table are based on the base year (2009) level of development, which provides a check if the project is justified based on existing development conditions, without relying upon growth projections (which may or may not occur).

Some observations from the information displayed in Table J-21:

- Plan A: Levee strengthening has the greatest benefit/cost ratio (8.2).
- Plan B: Levee setback has the greatest net benefits (about $59 million).

Plan B is recommended for further evaluation, because the primary decision criterion is the selection of the plan that maximizes annual net benefits.

Another decision criterion is to determine if the benefits allocated to each project purpose exceed the costs allocated to that purpose for the recommended plan. This comparison of benefits and costs by project purpose is shown in Table J-22 for Plan B (except for water supply and recreation, for which no costs were allocated because these are incidental benefits). Net benefits for the major objectives (flood risk management and ecosystem restoration) are positive.

Table J-21. Summary of FRLRP Annual Monetary Benefits and Costs (Thousands $2013)

Benefits and Costs[1] (1)	Alternative Plans A (2)	B (3)	C (4)	X (5)
Annual benefits				
(a) Flood risk management				
(b) Inundation reduction[2]	$59,904	$63,176	$62,624	$0
(c) Intensification	$0	$0	$0	$0
(d) Location	$0	$0	$0	$0
(e) Total FRM benefits [(a)+(b)+(c)+(d)]	$59,904	$63,176	$62,624	$0
(f) Water supply and quality	$0	$600	$600	$0
(g) Recreation and open space	$0	$39	$28	$0
(h) Hydropower	$0	$0	$0	$0
(i) Navigation	$0	$0	$0	$0
(i) Commercial fisheries	$0	$0	$0	$0
(k) Ecosystem restoration	$0	$8,562	$6,422	$0
(l) Other	$0	$0	$0	$0
(m) Total annual benefits [(e)+(f)+(g)+(h)+(i)+(j)+(k)+(l)]	$59,904	$72,377	$69,674	$0
Annual costs				
(n) Capital	$7,245	$13,296	$12,457	$0
(o) OMRR&R	$85	$148	$141	$0
(p) Total annual costs [(n)+(o)]	$7,331	$13,444	$12,598	$0
Annual net benefits [(m)-(p)]	**$52,574**	**$58,932**	**$57,075**	**$0**
B/C ratio [(m)/(p)]	**8.2**	**5.4**	**5.5**	**0.0**

Notes:
1 Annual benefits and costs computed with a 50-year analysis period and current DWR 6% discount rate.
2 Base year (2009) level of development.

Table J-22. Comparison of Monetized Benefits and Allocated Costs by Project Purpose: Plan B (Thousands $2013)

Item	Flood risk Management		Ecosystem Restoration		Other[4]		Total Costs and Benefits	
	Allocated Costs[5]	Benefits	Allocated Costs[5]	Benefits	Allocated Costs[5]	Benefits	Allocated Costs[4]	Benefits
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Capital cost								
First cost	$156,774		$52,799		$0		$209,573	
Foregone investment value[1]	$0		$0		$0		$0	
Total	$156,774		$52,799		$0		$209,573	
Annual cost[2]								
Interest and amortization	$9,946		$3,350		$0		$13,296	
OMRR&R	$63		$85		$0		$148	
Subtotal	$10,009		$3,435		$0		$13,444	
Annual benefits[2]								
Flood risk management[3]		$63,176						$63,176
Ecosystem restoration				$8,562				$8,562
Other						$639		$639
Total								$72,377
Annual net benefits		**$53,166**		**$5,127**		**$639**		**$58,932**
B/C ratio		**6.3**		**2.5**		**NA**		**5.4**

Notes:
1 Construction assumed to occur within one year.
2 Annual benefits and costs computed with a 50-year analysis period and DWR 6% discount rate.
3 Base year (2009) level of development.
4 Water supply and recreation benefits. No cost allocation was done for these project purposes.
5 Using SCRB cost allocation method.

J.11.2 Monetized and Nonmonetized Benefits and Costs

If ecosystem benefits are identified and DWR is partnering with the USACE on the project, then according to USACE guidance, these are not to be monetized. Thus, a table similar to Table J-21 cannot be used. However, the USACE has developed a table template to compare monetary (NED) and nonmonetary (NER) benefits and costs; this was described above to compare the FRLRP alternative plans in this manner (Table J-17). This table demonstrated that Plan B also had the greatest net monetized benefits and the most cost-effective levee setback configuration. A comparison of the monetized and nonmonetized benefits and costs, by project purpose, for Plan B is shown in Table J-23.

Table J-23. Comparison of Monetized and Nonmonetized Benefits and Allocated Costs by Project Purpose: Plan B (Thousands $2013)

Item	Monetary				Nonmonetary		Total Costs and Benefits	
	Flood Risk Management		Other[4]		Ecosystem Restoration			
	Allocated Costs[5]	Benefits	Allocated Costs[5]	Benefits	Allocated Costs[5]	Benefits	Allocated Costs[5]	Benefits
(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)	(10)
Capital cost								
First cost	$156,774		$0		$52,799		$209,573	
Foregone investment value[1]	$0		$0		$0		$0	
Total	$156,774		$0		$52,799		$209,573	
Annual cost[2]								
Interest and amortization	$9,946		$0		$3,350		$13,296	
OMRR&R	$63		$0		$85		$148	
Subtotal	$10,009		$0		$3,435		$13,444	
Annual benefits[2]								
Monetary[3]		$63,176		$639				$63,814
Nonmonetary								1,600 acres
Annual net benefits		**$53,166**		**$639**		**NA**		**$58,805**
B/C ratio		**6.3**		**2.5**		**NA**		**6.4**

Notes:
1 Construction assumed to occur within one year.
2 Annual benefits and costs computed with a 50-year analysis period and DWR 6% discount rate.
3 Inundated reduction benefits computed for base year (2009) level of development.
4 Water supply and recreation benefits. No cost allocation was done for these project purposes.
5 Using SCRB cost allocation method.

J.11.3 Uncertainty Considerations

Risk and uncertainty are intrinsic in water resources planning and design. Risk is the probability that a defined set of events will result in adverse (or beneficial) consequences. A risk analysis accounts explicitly for uncertainty in the contributing factors by first determining the best estimate of each of the functions used for the risk computation, and then describing the confidence in each with a statistical distribution about that best estimate. If descriptions of the statistical distributions of these functions cannot be developed, then uncertainty can be evaluated with sensitivity analysis.

Ideally, DWR should conduct risk analyses for all benefits and costs, with results displayed as shown in Table J-11 or J-12 for flood risk management benefits. However:

- The tools to do risk analyses for benefits other than flood risk management, and in particular, inundation-reduction benefits, are not yet available.

- The tools to do risk analyses of costs are not yet available. [Note: the USACE Walla Walla District has developed the Cost and Schedule Risk Analysis Guidance and a tool to incorporate uncertainties in USACE project cost estimates (USACE 2009). However, these cost uncertainties are computed differently than flood damage reduced uncertainties; thus, they are not recommended for DWR B-C analyses at the present time.]

Given these limitations, benefits and costs that are displayed in Tables J-17, J-18, J-19, J-20, J-21, J-22, and J-23, shall be characterized as "best estimates." The critical variables and associated uncertainties underlying these benefits and costs shall, at a minimum, be identified and qualitatively described.

For this case analysis, some of the significant variables affecting uncertainties about the benefit evaluations described above (other than inundation reduction benefits, in which uncertainty is explicitly evaluated by HEC-FDA), include:

- Ecosystem Restoration
  - Structure and functions of proposed restored habitat.
  - Structure and functions of habitat used as the source of the monetary benefit transfer values.
  - Benefit transfer dollar value.

- Water Supply
  - Amount of water available.
  - Value of available water.

- Recreation
  - Types of recreation created.
  - Amount of recreation use.
  - Value of recreation use.
  - Potential double-counting of recreation values if monetized habitat values are being used which may already include a recreation value (if so, at a minimum, conduct benefit/cost comparison with and without recreation benefits).

For each of these variables, ranges of values could be identified and the benefit subjected to a sensitivity analysis to determine how changes in these values affect the selection of the recommended plan. [Note: A sensitivity analysis was not conducted by this example analysis.]

Finally, ranges of capital and OMRR&R costs could be evaluated, along with different construction period assumptions. (This example analysis assumed construction occurred in one year.)

J.12 Multiple Criteria Analysis

Multiple criteria analysis (MCA) is a decision support framework that facilitates the evaluation and selection of alternatives based on multiple differently scaled criteria. For each alternative, MCA transforms criteria values expressed in different units into a dimensionless, numerical score, which is then used to evaluate the merit of each alternative on a common scale. Thus, MCA allows for a systematic, transparent, and repeatable evaluation of diverse criteria. MCA can also be used to conduct sensitivity analyses to analyze uncertainty and test the robustness of solutions.

MCA (which is a form of trade-off analysis) is particularly well suited to supplement multi-purpose benefit and cost (B-C) analysis. To the extent that the significant benefits and costs can be quantified and expressed in monetary terms, then traditional B-C analyses will suffice. However, often benefits and/or costs are not expressed in monetary terms, or even quantified. In these situations, the B-C analysis can be supplemented with other analysis tools, including MCA. MCA is described in Appendix G, along with an example analysis.

Back cover photo: The Sacramento Weir and Bypass is located along the right bank of the Sacramento River approximately 4 miles upstream of the Tower Bridge and about 2 miles upstream from the confluence with the American River. Its primary purpose is to protect the City of Sacramento from excessive flood stages in the Sacramento River channel downstream of the American River. The weir limits flood stages (water surface elevations) in the Sacramento River to project design levels through the Sacramento/West Sacramento area. Photo by DWR.

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