Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species

Comparison of Alternatives Analysis

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Prepared for the State of Washington

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LIST OF ACRONYMS AND ABBREVIATIONS

ASEP	Aquatic Species Enhancement Plan
BCA	Benefit-Cost Analysis
BCR	benefit-cost ratio
BEA	Bureau of Economic Analysis
BNSF	Burlington Northern Santa Fe Railroad
BLS	Bureau of Labor Statistics
BT	benefits transfer
CHTR	controlled handling, transport, and release
COA	Comparison of Alternatives
CVM	Contingent Valuation Method
EDT	Ecosystem Diagnosis & Treatment
EIA	Economic Impact Analysis
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FRO	Flood Retention Facility
GDP	Gross Domestic Product
GHG	greenhouse gas
HAZUS	Natural Disaster Model by FEMA
H&H	hydraulic/hydrology
I-5	Interstate 5
IO	input-output
IDC	interest during construction
IMPLAN	Economic Impact model developed by MIG, Inc.
LWM	Large woody material
MPD	Multi-purpose Dam
MPF	Multi-purpose Facility
MW	Megawatt
MWh	Megawatt hours
NASS	National Agricultural Statistics Service
NED	National Economic Development
NEEA	Northwest Energy Efficiency Alliance
NFIP	National Flood Insurance Program
NPV	Net Present Value
NMF	non-managed forest
OMB	Office of Management and Budget
OFM	Washington Office of Financial Management
O&M	operation and maintenance
OM&R	operation, maintenance, and replacement
PFMC	Pacific Forest Management Council

PHABSIM	Physical Habitat Simulation System
PSAP	Puget Sound and Pacific Railroad
PV	Passive-use value
RCC	roller-compacted concrete
TCM	Travel Cost Method
TEV	Total Economic Value
TRA	Temporary Relocation Assistance
Treasury	U.S. Department of the Treasury
USDA	U.S. Department of Agriculture
UV	Use Value
WDFW	Washington Department of Fish and Wildlife
Work Group	Governor's Chehalis Basin Work Group
WSDF	Washington State Dairy Federation
WSDOT	Washington State Department of Transportation
WTP	willingness to pay

Executive Summary

Introduction

This Comparison of Alternatives (COA) study is part of the Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species. The purpose of this study is to analyze the potential impacts (positive and negative) to the Chehalis Basin of Alternative Flood Reduction Potential and Aquatic Species Enhancement projects. The COA does not attempt to forecast chronological outcomes; rather, it assess the expected value[1] of flooding impacts and aquatic species effects under different Project Alternatives.

This COA is also the result of input from the Comparison of Alternatives Technical Committee (composed of employees from Washington State agencies Department of Ecology, Department of Fish and Wildlife, and Department of Transportation, and consulting firms EES, HDR, and Anchor QEA) the Work Group, and other stakeholders (Project Team). The COA was collaboratively developed, where the Project Team vetted and agreed to its methodology and assumptions during development.

Study Purpose

The purpose of this study is to evaluate Project Alternatives that reduce risk to life, property, and economy from flooding while attempting to enhance habitat conditions in the Chehalis River Basin (Chehalis Basin), recognizing that these goals may not always be aligned. The results of this analysis can be used by the Governor's Chehalis Basin Work Group and others to aid in the determination of a combination of future projects that can be implemented to reduce flood damage and enhance aquatic species in the basin.

Project Alternatives

Several Project Alternatives are evaluated, including various combinations of projects. Project Alternative components are described below:

- **Flood Retention Facility (FRO) –** This option consists of a flood water retention facility on the Upper Chehalis (Upper Chehalis Storage). The purpose of this alternative is exclusively flood protection. The retention facility will only retain water in the case a flood event is predicted.
- **Multi-purpose Facility (MPD) –** The MPD facility provides the same level of flood protection as the Flood Retention Facility; however, this alternative also enables river flow augmentation, at least on a seasonal basis. The retention facility will not only retain water when flood events occur, it can also release water accumulated during the wet season to augment summer flows, assuming accumulation is sufficient for such seasonal release. Three different fish passage options are evaluated for the MPF. In addition, the economic viability of adding hydropower to this facility is examined assuming the operation of the retention facility is optimized for downstream benefits rather than optimized for power generation.
- **Airport Levee –** An airport levee would protect the Chehalis Airport, businesses in the area and a portion of I-5 during a flood event of 100-year magnitude.

[1] For the purpose of this report "Expected Value" refers to a predicted quantification of a variable. It is calculated as the sum of possible values multiplied by the probability of its occurrence.

- **Interstate 5 Project –** The Washington State Department of Transportation (WSDOT) is currently exploring options for preventing the flooding of Interstate 5 (I-5). The current option under consideration is a series of levees, walls, and berms that would protect I-5 during a 100-year flood event.
- **Flood-Proofing –** The Flood-proofing component of the Project Alternatives includes raising all residential homes within the 100-year floodplain. If the cost to raise a home is greater than the value of the structure plus land, the value of the structure plus land is included in the cost for Floodproofing. Essentially, these homes and properties would be acquired. For other buildings (commercial, industrial, government, schools) the expected case assumes that only 25% of the buildings within the 100-year floodplain are flood proofed. This lower achievability rate was selected based on conversations with commercial property owners. While some buildings, regardless of flood level, would be flood proofed, some building owners would not flood proof based on one or more of the following factors:
    1. Floodproofing is not cost-effective. The cost of Floodproofing is too high compared with the perceived risk.
    2. Floodproofing is not feasible. The property or business is not conducive to Floodproofing measures such as walls, berms, or levees due to lack of space or business function.
    3. Other location specific factors.
- **Aquatic Species Enhancement Programs –** Enhancement programs provide species-specific improvements through habitat restorative actions in the basin.

These project components are combined into basin-wide solutions, identified as Project Alternatives for this study. The main report includes the following Project Alternatives:

1. Flood Proofing Only
2. Low Enhancement Only
3. High Enhancement Only
4. I-5 Project plus Airport Levee, Flood Proofing, and Low Enhancement
5. I-5 Project plus Airport Levee, Flood Proofing, and High Enhancement
6. Flood Retention Only Storage plus Airport Levee, Flood Proofing, and Low Enhancement
7. Flood Retention Only Storage plus Airport Levee, Flood Proofing, and High Enhancement
8. Multipurpose Storage plus Airport Levee, Flood Proofing, and Low Enhancement
9. Multipurpose Storage plus Airport Levee, Flood Proofing, and High Enhancement
10. Flood Retention Only Storage, I-5 Project, Airport Levee, Flood Proofing, and Low Enhancement
11. Flood Retention Only Storage, I-5 Project, Airport Levee, Flood Proofing, and High Enhancement
12. Multipurpose Storage, I-5 Project, Airport Levee, Flood Proofing, and Low Enhancement
13. Multipurpose Storage, I-5 Project Airport Levee, Flood Proofing, and High Enhancement

The Flood Retention Only option includes the construction of a trap-and-haul facility for upstream fish passage during the storage and release of flood waters. The results for the Multi-purpose facility are shown for three fish passage design options. The three fish passage options include: controlled handling, transport and release (CHTR) for upstream passage with combination collectors for downstream passage; conventional fishway for upstream passage and forebay collector for downstream passage; and an experimental fishway (pools and automated gates) for upstream passage combined with forebay collector for downstream passage.

In addition, Appendix O shows results for additional Project Alternative combinations, e.g., flood storage facility plus airport levee only.

Methodology

Project Alternatives are evaluated based on their costs and impacts relative to a Baseline condition (without Project Alternatives). The Baseline condition is defined as current conditions plus any projects that are currently funded. In terms of flood reduction, the Baseline condition does not include any other flood hazard mitigation projects and does not consider population growth and development within the floodplain.

Costs for each Project Alternative are defined as the financial costs needed to implement and operate each Project Alternative. Project Alternative impacts are defined as the measurable change in flood damages and environmental changes. Impacts may be either positive or negative.

Project implementation costs are compared with project impacts resulting in net benefits over the study period. Benefit-cost ratios are also reported for informational purposes. An uncertainty analysis is provided to demonstrate a range project costs and impacts. The uncertainty analysis is based on available information and is not meant to show the full range of possible values. Finally, a discussion is provided for the Project Alternative qualitative impacts that were identified by the Technical Work Group during the process of developing this study.

Study Assumptions

PERSPECTIVE

The COA analysis evaluates Project Alternatives from three different perspectives, which are defined as geographic boundaries:

- **State –** State of Washington
- **Basin-wide –** includes Lewis, Thurston, and Grays Harbor Counties
- **Federal –** National Economic Development account

The costs and impacts of Project Alternatives vary according to perspective. For example, the closure of Interstate 5 has different economic consequences to the State vs. the basin since not all traffic on Interstate 5 is confined to the basin (through trips have consequences to the State but not necessarily to the basin).

GENERAL ASSUMPTIONS

A 100-year study period was selected for the purposes of comparing project implementation costs and estimated project impacts. All dollars are in real 2014 terms, thus inflation is excluded in the cost and impact estimates. Real interest rates are used for net present value calculations and these discount rates may vary across perspectives. An average risk-free market interest rate of 1.63 percent was used to discount costs and impacts for the State and Basin perspective based on the average of a 30-year U.S. Treasury Inflation-Protected Security and the 2014 30-year real Treasury interest rate as reported by the OMB. The Federal perspective applied a 3.5 percent discount rate to the analysis based on federal requirements.

PROJECT ALTERNATIVE COSTS

Project Alternative costs include the capital costs needed to implement the project, annual operation and maintenance costs needed to operate and maintain the project over the entire 100-year study period, and interest costs during the project construction phase. Interest during construction is calculated based on project construction schedules and a borrowing rate of 3.5%. Capital costs are provided in current 2014 dollars. Table ES-1 provides the initial capital costs and estimated annual operating costs.

Table ES-1
Project Alternative Initial Capital Costs and Annual O&M ($2014)

	CAPITAL COSTS	ANNUAL O&M[1]
Flood Proofing Only[2]	$91,500,000	$0
Low Enhancement Only	$90,760,000	$470,000
High Enhancement Only	$122,630,000	$625,000
I-5 Project[3]	$100,000,000	$5,000
Airport Levee	$4,500,000	$8,000
Flood Retention RCC with CHTR Fish Passage	$280,250,000	$1,374,000
Multipurpose RCC with CHTR Fish Passage	$370,350,000	$1,539,000
Multipurpose RCC with Conventional Fishway	$405,350,000	$1,391,000
Multipurpose Rockfill with Experimental Fishway	$574,100,000	$1,624,000
I-5 PROJECT ALTERNATIVE VARIATIONS		
I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement	$282,510,000	$483,000
I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement	$314,380,000	$638,000
UPPER CHEHALIS STORAGE ALTERNATIVE VARIATIONS		
Storage + Airport Levee + Flood Proofing + Low Enhancement		
Flood Retention RCC with CHTR Fish Passage	$424,510,000	$1,271,000
Multipurpose RCC with CHTR Fish Passage	$514,610,000	$2,017,000
Multipurpose RCC with Conventional Fishway	$549,610,000	$1,869,000
Multipurpose Rockfill with Experimental Fishway	$718,360,000	$2,102,000
Storage + Airport Levee + Flood Proofing + High Enhancement		
Flood Retention RCC with CHTR Fish Passage	$456,380,000	$1,426,000
Multipurpose RCC with CHTR Fish Passage	$546,480,000	$2,172,000
Multipurpose RCC with Conventional Fishway	$581,480,000	$2,024,000
Multipurpose Rockfill with Experimental Fishway	$750,230,000	$2,257,000
UPPER CHEHALIS STORAGE + I-5 PROJECT ALTERNATIVE VARIATIONS		
Storage + I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement		
Flood Retention RCC with CHTR Fish Passage	$504,131,345	$1,276,000
Multipurpose RCC with CHTR Fish Passage	$594,231,345	$2,022,000
Multipurpose RCC with Conventional Fishway	$629,231,345	$1,874,000
Multipurpose Rockfill with Experimental Fishway	$797,981,345	$2,107,000
Storage + I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement		
Flood Retention RCC with CHTR Fish Passage	$536,001,345	$1,431,000
Multipurpose RCC with CHTR Fish Passage	$626,101,345	$2,177,000
Multipurpose RCC with Conventional Fishway	$661,101,345	$2,029,000
Multipurpose Rockfill with Experimental Fishway	$829,851,345	$2,262,000

Notes:

1. Annual O&M costs for Enhancement Projects are for the first 10 years only.
2. Flood Proofing costs are reduced when combined with other projects.
3. The annual O&M for I-5 is incremental to current O&M performed

Figures ES-1 and ES-2 summarize the Project Alternative Costs for the state perspective.

Figure ES-1
Project Alternatives Expected Cost Summary with Low Enhancement, 100-Year NPV

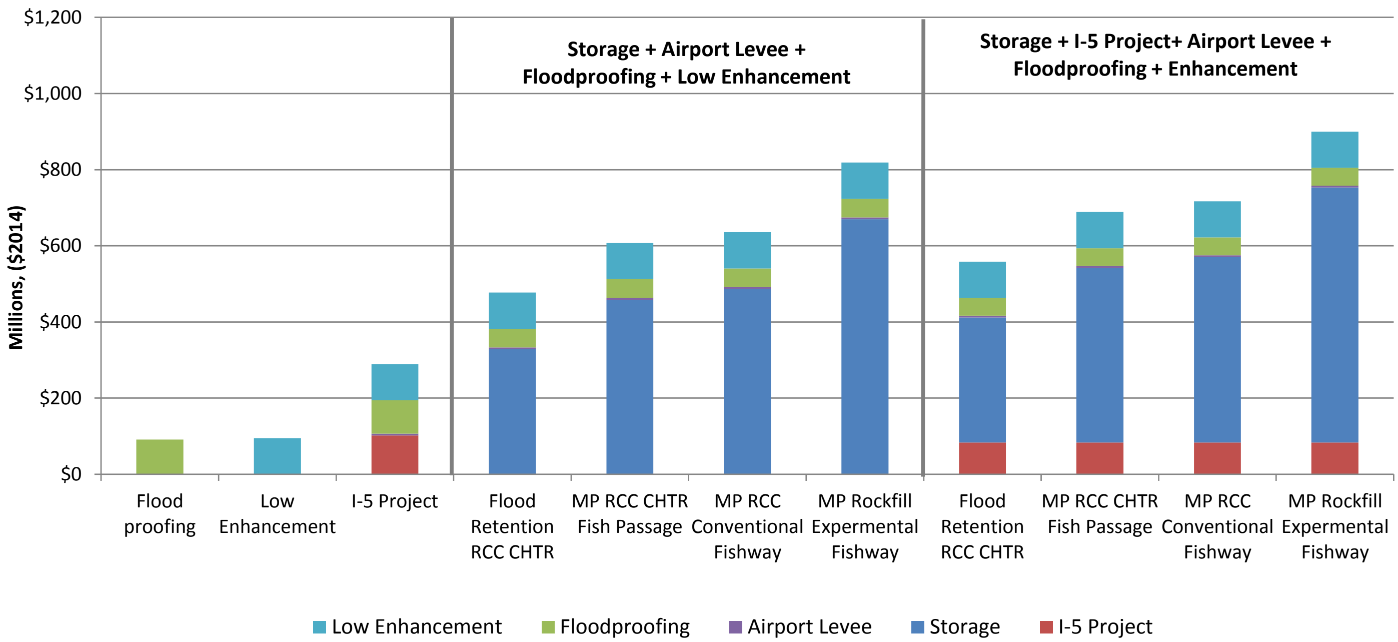
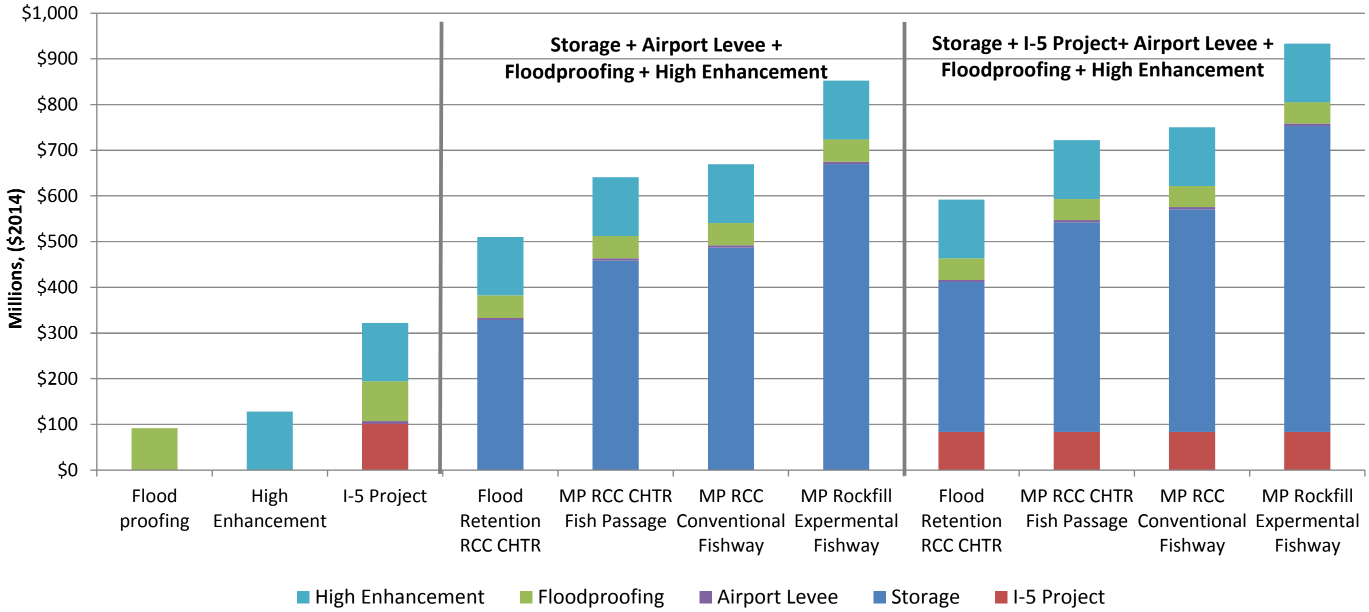


Figure ES-2
Project Alternatives Expected Cost Summary with High Enhancement, 100-Year NPV



PROJECT ALTERNATIVE IMPACTS (POSITIVE AND NEGATIVE)

The following project impacts are quantified in this study:

- Flood damage to structures, content, and inventory
- Cleanup costs for buildings and agricultural acreage
- Vehicle damages
- Loss of agriculture crops or crop damage
- Transportation delays on I-5
- Temporary relocation costs for evacuated residents
- Public assistance for emergency protective measures for bridges, utilities, water control facilities, or debris removal
- Business interruption
- Tribal Fishing
- Commercial fishing
- Sport fishing
- Economic Development

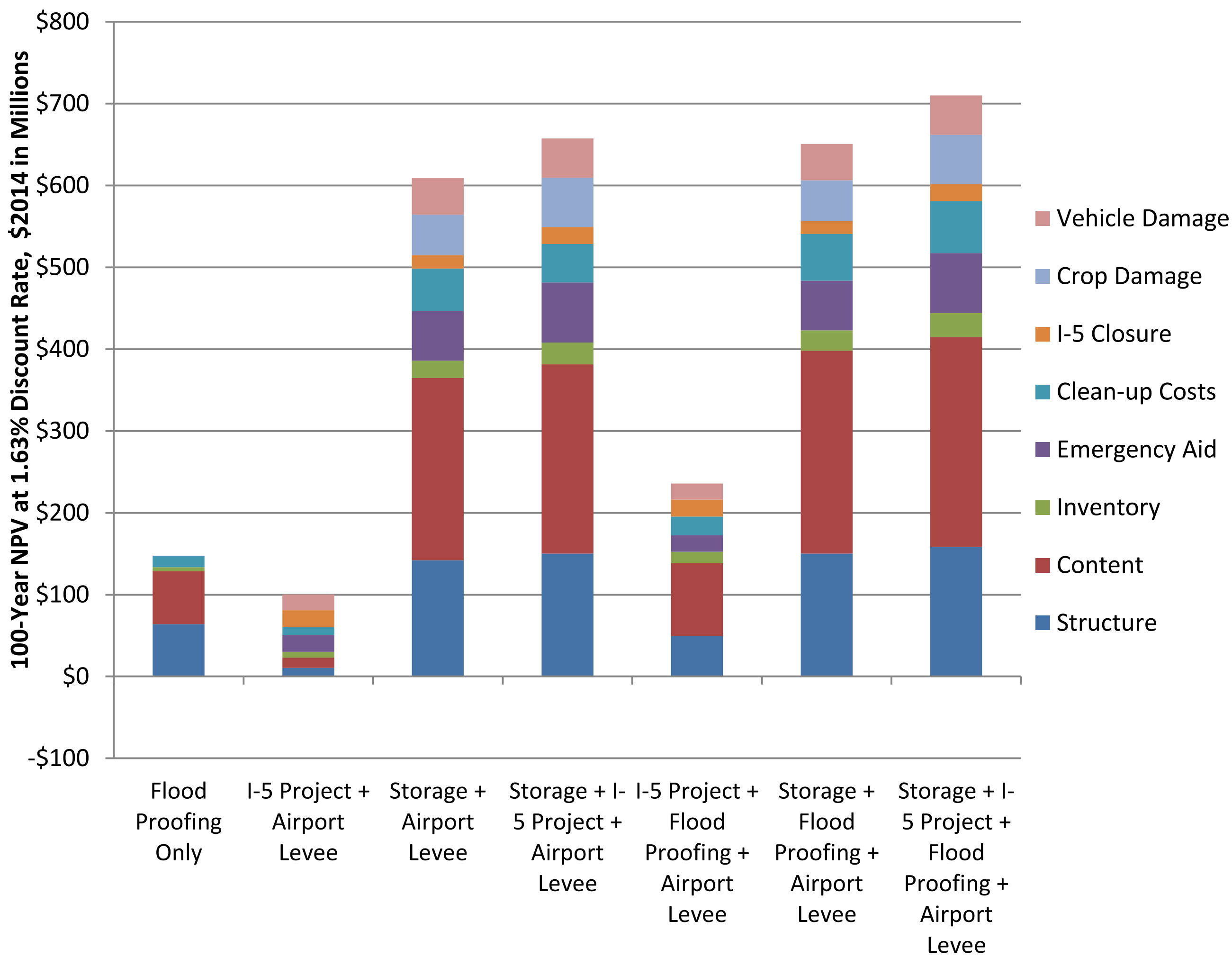
In addition, environmental non-use values are quantified for informational purposes and are not included in the study's analysis of net benefits. The environmental non-use values measure the value of fish/aquatic species/habitat from the perspective of all of Washington State residents. The environmental non-use values are so large that their inclusion would result in all Project Alternatives being highly cost-effective. See appendix K for the non-use values.

FLOOD DAMAGE REDUCTION IMPACTS

Flood damage reduction impacts were estimated for five flood events (2, 10, 20, 100, and 500-year). Based on the avoided damages and probability of each flood event, expected annual impacts were calculated for each Project Alternative. Figure ES-3 demonstrates the breakdown of Project Alternative-expected annual flood reduction impacts in 100-year net present value from the State Perspective. Note that the flood reduction impacts are the same regardless of storage facility configuration (flood control vs. MPD facility). Enhancement projects are excluded from the figure as they do not result in flood reduction impacts.

The most significant flood reduction impacts for Project Alternatives with storage options are due to avoided structure, content, and inventory damages for both residential and commercial structures. While Flood-proofing avoids residential structure, content, and inventory damages as well as building cleanup costs, it only impacts a portion of the non-residential structures, content and inventory damages. Finally, an I-5 Project reduces some damages to property; however, the primary impact is due to avoided I-5 closure costs.

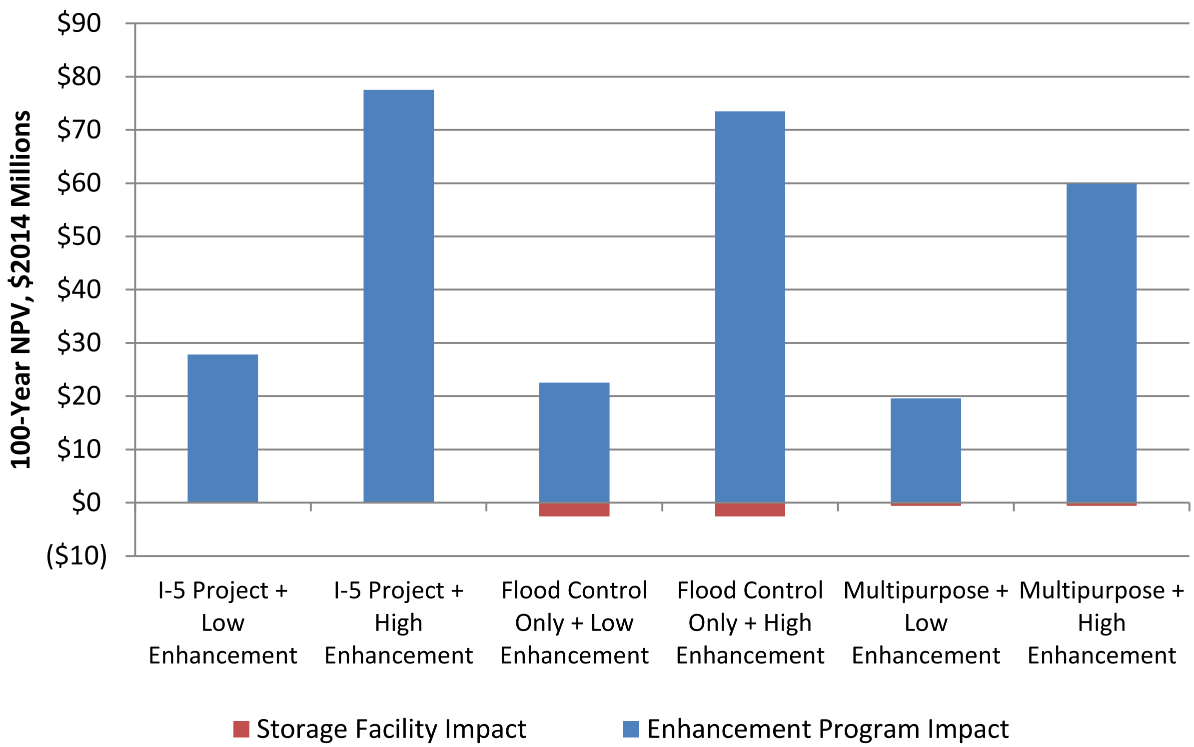
Figure ES-3
State Perspective: 100-Year NPV Expected Annual Flood Reduction Impacts



ENVIRONMENTAL IMPACTS

Impacts to commercial, tribal and sport fisheries (salmonid species) were estimated for each of the Enhancement Plans (Low Enhancement and High Enhancement) as well as for each flood water storage facility (flood control or MPD). Even with fish passage facilities, the flood storage facilities have negative impacts on salmonid populations. Figure ES-4 illustrates the environmental impacts monetized in this study (use values only).

Figure ES-4
State Perspective Environmental Impacts, Use Values



Results

Table ES-2 compares the Project Alternative implementation costs with the Project Alternative impacts for the state perspective. Table ES-3 provides the comparison for the Federal perspective. Flood damage reduction impacts are reported separately from the environmental impacts. All dollars are shown in 100-year net present value. The Net Benefit column shows the expected total net benefit for the full 100-year period. The costs and impacts shown in Table ES-1 are a result of the best available information and subsequent model output available at the time of this study's publication. The estimates in Table ES-1 represent the expected impacts and costs but should not be interpreted as representing the 50th percentile for the costs and impacts. With the exception of flood return intervals, the Project Alternative impacts are not based on probability distributions.

Table ES-2
State Perspective Results

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRON-MENTAL (USE VALUES ONLY)	PROJECT IMPLE-MENTATION COSTS	NET BENEFIT	BENEFIT/ COST
Floodproofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$236	$28	$289	-$26	0.9
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$236	$78	$322	-$9	1.0
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$20	$477	$194	1.4
Multipurpose RCC with CHTR Fish Passage	$651	$19	$608	$62	1.1
Multipurpose RCC with Conventional Fishway	$651	$19	$636	$34	1.1
Multipurpose Rockfill with Experimental Fishway	$651	$19	$819	-$149	0.8
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$71	$511	$211	1.4
Multipurpose RCC with CHTR Fish Passage	$651	$59	$641	$69	1.1
Multipurpose RCC with Conventional Fishway	$651	$59	$669	$41	1.1
Multipurpose Rockfill with Experimental Fishway	$651	$59	$852	-$142	0.8
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$20	$559	$171	1.3
Multipurpose RCC with CHTR Fish Passage	$710	$19	$689	$40	1.1
Multipurpose RCC with Conventional Fishway	$710	$19	$717	$12	1.0
Multipurpose Rockfill with Experimental Fishway	$710	$19	$900	-$171	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$71	$592	$189	1.3
Multipurpose RCC with CHTR Fish Passage	$710	$59	$722	$47	1.1
Multipurpose RCC with Conventional Fishway	$710	$59	$750	$19	1.0
Multipurpose Rockfill with Experimental Fishway	$710	$59	$933	-$164	0.8

Table ES-3
Federal Perspective Results

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS		PROJECT IMPLE-MENTATION COSTS	NET BENEFIT	BENEFIT/ COST
	FLOOD DAMAGE REDUCTION	ENVIRON-MENTAL (USE VALUES ONLY)			
Floodproofing Only	$83	$0	$92	-$8	0.9
Low Enhancement Only	$0	$15	$95	-$80	0.2
High Enhancement Only	$0	$42	$128	-$86	0.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$109	$15	$290	-$167	0.4
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$109	$42	$324	-$173	0.5
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$11	$465	-$53	0.9
Multipurpose RCC with CHTR Fish Passage	$401	$10	$581	-$169	0.7
Multipurpose RCC with Conventional Fishway	$401	$10	$613	-$202	0.7
Multipurpose Rockfill with Experimental Fishway	$401	$10	$794	-$383	0.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$39	$498	-$59	0.9
Multipurpose RCC with CHTR Fish Passage	$401	$32	$614	-$181	0.7
Multipurpose RCC with Conventional Fishway	$401	$32	$646	-$213	0.7
Multipurpose Rockfill with Experimental Fishway	$401	$32	$827	-$394	0.5
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$11	$548	-$106	0.8
Multipurpose RCC with CHTR Fish Passage	$430	$10	$663	-$223	0.7
Multipurpose RCC with Conventional Fishway	$430	$10	$696	-$255	0.6
Multipurpose Rockfill with Experimental Fishway	$430	$10	$877	-$436	0.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$39	$581	-$112	0.8
Multipurpose RCC with CHTR Fish Passage	$430	$32	$697	-$234	0.7
Multipurpose RCC with Conventional Fishway	$430	$32	$729	-$266	0.6
Multipurpose Rockfill with Experimental Fishway	$430	$32	$910	-$447	0.5

Uncertainty Analysis

The results in Table ES-1 are based on the best information available; however, there are many uncertainties related to this information. These uncertainties may include the following: uncertainty inherent in modeling, such as the hydraulic modeling and assumptions or flood damage modeling (HAZUS); uncertainty related to values or prices, i.e., the value of fish or the cost for cleanup of a residential building; or uncertainty related to number estimates such as the number of people relocated during a flood event or the change in fish populations. The uncertainty analysis evaluated low and high values for many of the study inputs and assumptions. These low and high values are not inclusive of the full possible range of outcomes; rather, they are based on available information via surveys, literature research, and conversations with local residents and business owners. Figures ES-5 and ES-6 demonstrate the results of the uncertainty analysis from the State Perspective.

Figure ES-5
State Perspective Uncertainty Summary Low Enhancement Actions

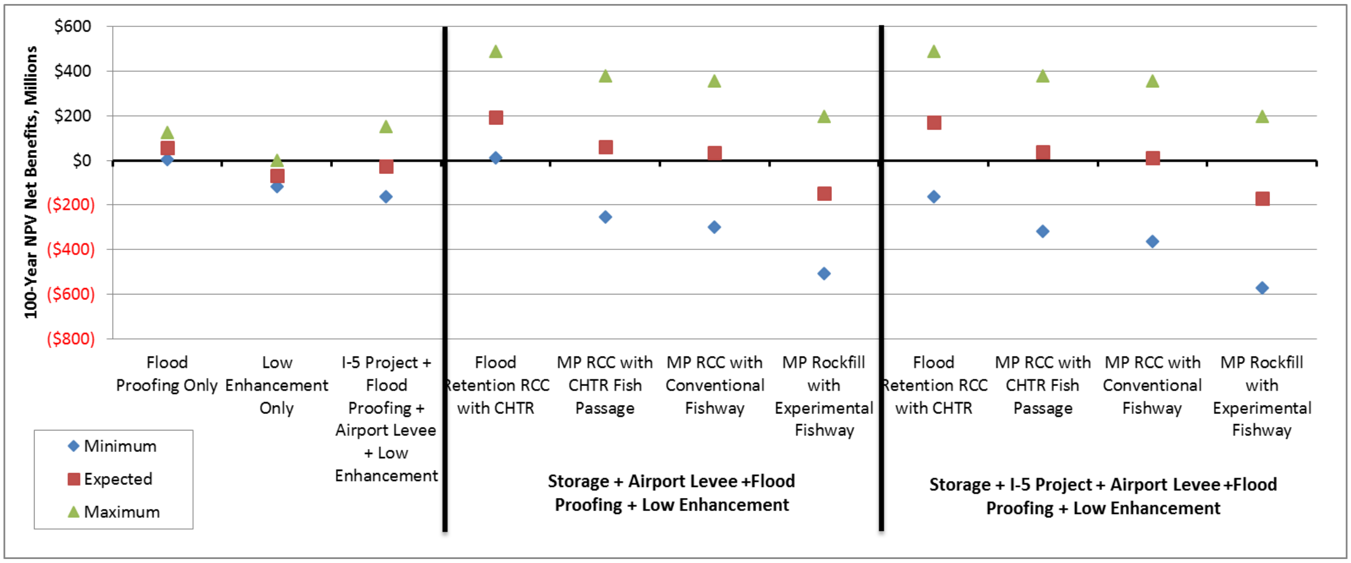
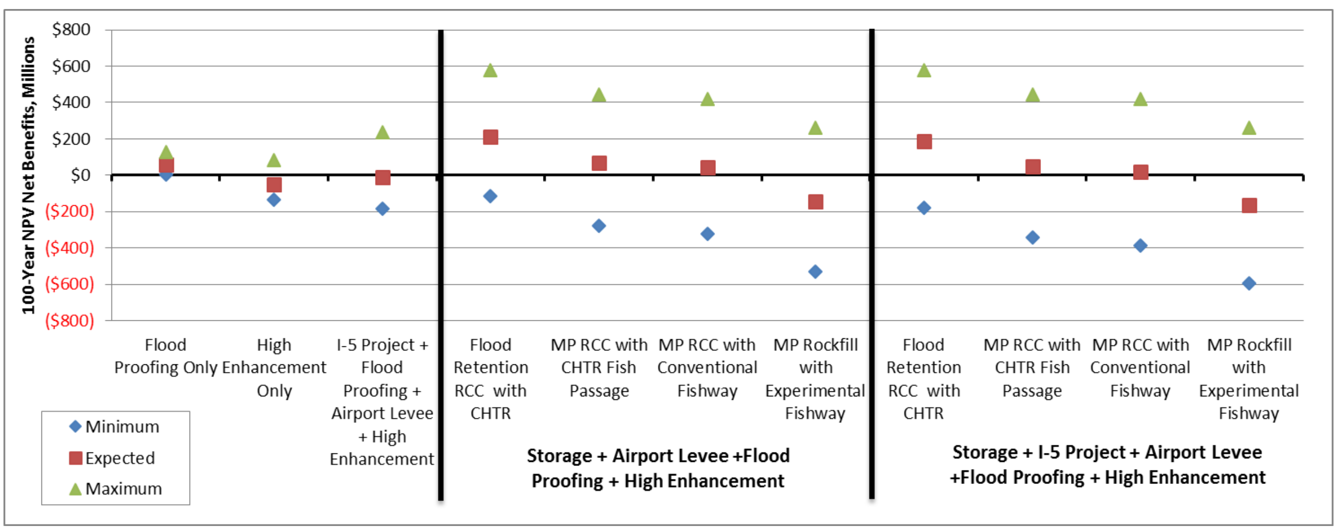


Figure ES-6
State Perspective Uncertainty Summary High Enhancement Actions



Qualitative Discussion

In addition to the quantitative analysis, a qualitative assessment was made for several issues that were identified by the technical committees. Each of these areas should be considered in combination with the quantitative analysis as project alternatives are reviewed. The impacts that are considered qualitatively in this study are as follows:

- **Rail Service –** Major flood events in the Chehalis River Basin result in floodwaters covering rail lines through the I-5 corridor. Similar to closures of I-5, rail line closures have significant impact on state and regional economies. These rail lines provide transportation ways for both freight and passenger trains.
- **Livestock –** The 2007 flood event resulted in the loss of 1,600 livestock, however, the 2009 flood event did not result in a substantial loss according the USDA. Since 2007, five critter pads and two evacuation routes were constructed and more are planned. The impact of project alternatives on the loss of livestock is therefore uncertain and was not included.
- **Environmental Justice –** Natural disasters have regressive effects on affected populations. Studies have found that families with higher incomes were more prepared for disaster, more receptive to information regarding disaster preparedness, and experienced less damage than lower-income families. In addition, homeownership was found to be a predictor for the degree of structure damage. These findings support the theory that low income populations are at higher risk for flood damages. The risk is further compounded since lower income families generally have less flexibility in employment schedules and less working capital for post-flood cleanup.
- **Cultural Impacts –** Cultural resources include any archeological, built, or ethnographic property. Some cultural resources may be deemed significant to the history of the community, state, or nation and require preservation. Project Alternatives may impact cultural resources directly or indirectly, such as disturbance from construction, inundation, filling, changes in traffic patterns, or erosion from changes in land exposure.

  Property Values – Studies have shown that properties located within a floodplain have lower values by nearly 8%. Project alternatives that reduce the amount of flooding will mean that homes no longer at risk of flooding might experience an increase in value.
- **Economic Growth –** Areas affected by repeat flood events are found to have long-term negative impacts on economic growth. Investment in capital as well as out-migration of residents contribute to slower economic growth in disaster prone areas.
- **Health and Safety –** Project Alternatives may have multiple impacts on health and safety. The primary impacts evaluated in this study include the following theories:
  - Access to I-5 during flood events may improve health and safety since emergency medical facilities might be easier to access.
  - Reduced flooding levels improve health and safety by reducing the number of properties affected as well as reduced flood water levels.
  - Reduced structure damage may improve health and safety as people may be able to return to their homes sooner after an event with minimal cleanup. In particular, Floodproofing a home may eliminate cleanup costs and the risk of contamination from flood waters or molds.
- **Other Fish (non-salmonid) and Non-Fish Species –** Other Fish (non-salmonid) and Non-Fish Species are impacted by the Project Alternatives and enhancement actions. In particular, impacts on Other Fish and Non-Fish Species correlate with changes in habitat. In general, results of model studies indicated that all dam alternatives reduced off-channel habitat, which would result in negative effects on aquatic and semi-aquatic species dependent on those habitats. Stream flow was found to be more limiting in the Upper Chehalis River reaches than the lower reaches for Other Fish Species based on Physical Habitat Simulation System (PHABSIM) model studies. Also, low flows during the drier summer months appeared to be a limiting factor for several species.

  Most non-salmonid species modeled, including the western toad, small and largemouth bass, large-scale sucker, and speckled dace generally sustained declines in habitat in response to all dam alternatives.

However, there were both increases and decreases in modeled habitat depending on species and life stage. It is important to note that very little is known about Other Fish and Non-Fish (e.g., amphibian) species in the basin and more information is needed to support more detailed effects analyses in the future.

Key Findings

The Comparison of Alternatives revealed the following:

- The analysis shows that the biggest driver for benefit comes from reducing the damage to structure, content, and inventory.
- When impacts are quantified, the cost of the two suites of habitat enhancement programs analyzed is higher than their predicted economic value using just user values. However, if non-use values and qualitative benefits are included, the economic benefits predicted far exceed the costs.
- Flood proofing is a viable solution to eliminating residential damage to structure, content, and inventory. However, it is unlikely to eliminate all damages to non-residential structures, content, and inventory. In addition, flood proofing will not solve the issue of flooded roads and agricultural lands. Finally, the climate change scenarios demonstrate that flood damage and the benefit from flood proofing will increase under both the 18% and 90% scenarios.
- The cost to construct walls and levees to protect I-5 exceeds the estimated economic benefits.
- Either alone or combined with other projects, a flood water storage facility in the Upper Chehalis Basin shows a positive net benefit under the State and Basin perspectives. Under the Federal perspective with a higher discount rate, a water-retention-only structure has a positive Benefit-Cost Analysis (BCA) when combined with floodproofing. The BCA under the federal perspective is not positive for the combination of water retention, I-5, floodproofing, and aquatic species enhancement.
- The baseline expected estimated damages over a 100-year period for the Basin is in the order of more than $3.5 billion. None of the Basin-wide alternatives will mitigate all flooding damages in the Basin. In addition, the study alternatives are designed based on flooding during a “design 100-year flood.” If project alternatives are implemented, flooding damages may still occur during floods that are different from the “design 100-year flood.”
- Including climate change assumptions increases non-environmental benefits for most project alternatives. The specific results can be found in Appendix M for the non-environmental climate change impacts and Appendix K for the environmental climate change impacts.

1 Overview/Objective

1 Introduction

This Comparison of Alternatives (COA) study is part of the Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species. The purpose of this study is to analyze the potential effect to the Chehalis Basin of Alternative Flood Reduction Potential and Aquatic Species Enhancement projects. The COA is a risk assessment of the expected value of flooding impacts and aquatic species effects under different Project Alternatives; it is not a forecast of chronological outcomes. The study was developed for the Governor's Chehalis Basin Work Group (Work Group), and others, so that they may make a recommendation to the Governor regarding next steps for reducing flood damage and enhancing aquatic species in the Chehalis Basin.

2 Scope of Comparison of Alternatives Task

The methodology used to evaluate the economics of potential alternatives, including the Aquatic Species Enhancement Plan (ASEP), is the result of decisions made by stakeholders and the interdisciplinary agencies participating in the technical meetings.

In order for the Work Group to provide a recommendation to the Governor, the Work Group will need to be able to compare flood reduction and aquatic species enhancements alternatives in a clear, concise manner. The potential impact of each alternative is a complex issue that is difficult to summarize. The objective of this task is, therefore, to provide sufficient information so that the Work Group can compare different alternatives and understand the potential impact of each alternative. The analysis is a summary of impact analysis tools that provides consistent information about each alternative. The study summarizes the results of the impact analyses; however, the framework does not conclude which alternative is preferred. Rather, the decision makers/Work Group will be deciding which alternative or alternatives are preferred based on the COA results and other factors.

3 Restricted Scope of Study

This study relies both on targeted, independent studies as well as "best available information" from the relevant literature. Not all conceivable topics were addressed nor all possible analyses performed.

4 Report Organization

The model framework is described in the next section, followed by Project Alternative descriptions and cost estimates. The methodology used to determine the quantifiable impacts for each alternative is described next followed by a chapter describing the qualitative impacts for each alternative. The results of the COA analysis are provided in three sections, or one for each perspective. Appendices provide detailed information for each study component as well as more detailed results of the analysis.

2 Model Framework

1 Project Purpose

The purpose of the Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species project is to evaluate Project Alternatives that reduce risk to life, property, and economy from flooding and enhance habitat conditions in the Chehalis River Basin.

2 Objective

The objective of this Study is to evaluate the risk associated with flooding in the basin and compare flood mitigation and aquatic species enhancement alternatives in the Chehalis Basin. This COA is the culmination of the work performed by numerous technical committees and input from the technical committees and the Work Group, as well as stakeholder input received during the study.

The methodology used to evaluate the economics of potential alternatives, including the ASEP, is the result of decisions made by stakeholders and the interdisciplinary agencies participating in the technical meetings.

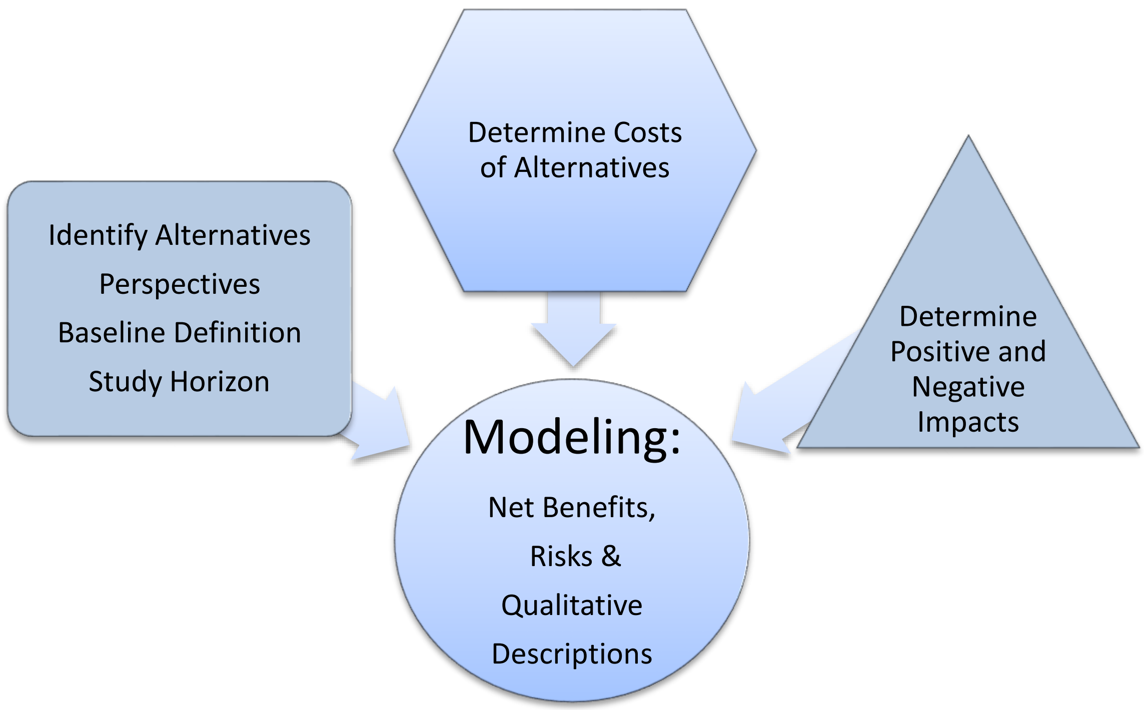
Because the COA analysis depends on input received from multiple technical committees, it was essential to define a consistent framework under which data and analysis were to be developed. In addition, the designed framework takes into account lessons learned from previous Chehalis Basin studies. In particular, the intent of this COA is to incorporate the following principles:

- The COA will measure the change in Flood Damage and Aquatic Species Enhancements due to investments in each Project Alternative.
- The COA evaluates multiple Project Alternatives including Washington State Department of Transportation (WSDOT) alternatives, retention facilities, Small Flood Projects (where data is available), and the ASEP. This impact analyses evaluates all projects on a consistent and objective basis and provides a comprehensive analysis and discussion of impacts for each Project Alternative.
- The COA quantifies environmental impacts and non-environmental impacts where possible and provides qualitative discussion of Project Alternative impacts where quantitative analysis is challenging or impractical.
- The COA incorporates uncertainty and risks associated with cost and impact estimates for each Project Alternative.
- The COA modeling is transparent and source data is clearly identified and documented, and calculations available to stakeholders. The COA is modeled in a disaggregate manner such that information can be presented both in a consolidated summary fashion, but also on a disaggregated basis depending on the needs of the decision makers.

3 Overview of Comparison of Alternatives Methodology

Figure 1 provides an overview of the COA framework that was used in this study. The rectangle represents the foundation of the analysis; all of the remaining data gathering and analysis are based on this foundation. The hexagon describes the task of gathering cost data for each of the alternatives. These are the *financial* costs of implementing each alternative. The triangle represents the determination of impacts, both positive and negative, for each alternative and the determination of how to value each of these impacts. Finally, the circle represents the final calculation steps, which brings the analysis together and provides analysis and results that can be reviewed by decision makers and stakeholders.

Figure 1
COA Process



Throughout the process, the COA research, analysis, and findings were shared and discussed with the Work Group, agency experts and technical committees. The continual involvement of interested participants is an important part of the COA in order for the economic results to be validated and approved once finalized.

There are generally nine steps in the development of a COA methodology. These steps are listed below:

1. Determine Baseline
2. Identify Alternatives
3. Determine the perspective from which the analysis will be conducted
4. Develop cost of Alternative

5. Analyze incremental impacts of the Alternative
   - Impact with Alternative
   - Impact without Alternative
6. Gather data about the value of impacts of Alternative
7. Develop a deterministic model to calculate the Net Present Value (NPV) of expected net benefits
8. Develop a risk profile around the expected net benefit
9. Consider qualitative impacts with the quantitative impacts to inform decision makers

Each of these steps is described further below.

3.1 BASELINE DEFINITION

In order to determine incremental impacts of each alternative, each Project Alternative must be compared with the Baseline, or the without project scenario. Functionally, the without project scenario is the status quo, or existing reality prior to any financial investment into project alternatives. While the COA is an analysis with a study period 100 years into the future, and using the existing reality ignores the fact that changes take place over time, this methodology is preferable to comparing Alternatives based on a forecasted future. It is very difficult to forecast what will happen in the future if none of the alternatives are implemented. For this reason and because of the potential for bias, forecasts were not used in the COA.

In deciding on a Baseline, it is important to remember how the Baseline is used in the analysis. The impact of each Project Alternative is based on changes from the Baseline. Therefore, as long as the Project Alternatives are compared to the same Baseline, the resulting impact across alternatives will be consistently calculated and should allow for comparisons of Project Alternatives.

The Baseline for this study was vetted and agreed upon by the Project team and is defined as the status quo, i.e., current reality, including currently funded and approved projects. This methodology avoids uncertainty about the future (eliminating bias), while incorporating known and measurable changes.

3.1.1 INTERSTATE 5

The WSDOT is exploring actions that can be taken to reduce the risk of flooding to Interstate 5 (I-5) during the 100-year study period. The I-5 Project is not part of the Baseline definition since decisions regarding an I-5 Project are being made simultaneously with decisions for other basin projects explored in this study. Additionally, the I-5 Project does not currently have funding or a planned construction schedule to support an I-5 project; the preferred I-5 Project final cost and configuration may in part depend on whether or not a flood storage option or other small projects are pursued; and funding has not been secured, so the timing of an I-5 Project is unknown. Because the costs and impacts of an I-5 Project are evaluated both separately and combined with other Projects, the COA results do not reflect a bias in the Project Alternative impact and cost estimation.

If the I-5 Project were to be included in the Baseline, the Project Alternative flood reduction benefits would be reduced mainly by the avoided I-5 closure in the 100-year flood event. Project Alternatives where net benefits are less than $20 million (in 100-year net present value) would therefore be sensitive to the decision to include or exclude the I-5 Project in the Baseline.

3.1.2 AIRPORT LEVEE

Similar to the I-5 Project, the Airport Levee is evaluated as part of each Project Alternative (except where noted otherwise) and as part of the I-5 Project. Funding has not been secured for this project and it is therefore evaluated as part of the basin-wide approach and not included in the definition of the Baseline. Because the Airport Levee was not evaluated separately from the I-5 Project or Storage options, it is unclear how much these Project Alternatives would be impacted if the Airport Levee were included in the Baseline definition.

3.2 DEFINE PROJECT ALTERNATIVES

Project Alternatives are potential solutions to the flood damage that occurs in the Chehalis Basin to people and analysis of enhancement measures on the environment. The five components included in various combinations in the Project Alternatives are summarized briefly below:

a) Flood Retention Facility (FRO)– This option consists of a flood water retention facility on the Upper Chehalis sub-basin (Upper Chehalis Storage). The purpose of this alternative is flood protection only. The retention facility would retain water only in the case where a flood event is predicted. The Flood Retention Only facility includes controlled handling, transport and, release (CHTR) for upstream fish passage.

b) Multipurpose Facility (MPF) – This option also consists of a retention facility on the Upper Chehalis. The purpose of this project is flood protection and summer flow augmentation. The retention facility would retain water in the case a flood event is predicted, and this facility will also hold water from the winter months. The stored water would be released in the summer months to improve downstream water quality. The Multipurpose facility is evaluated with three fish passage design options including: CHTR for upstream passage with combination collectors for downstream passage; conventional fishway for upstream passage and forebay collector for downstream passage; and an experimental fishway (pools and automated gates) for upstream passage combined with forebay collector for downstream passage.

   In addition, adding hydropower generation to this MPD retention facility is examined. The potential revenue and additional cost of adding hydro power generation is determined assuming the operation of the dam is optimized for downstream benefits rather than optimized for power generation.

c) WSDOT Transportation Options – WSDOT is currently exploring options for solving the flooding of I-5. Several flood protection concepts are considered by WSDOT: levees and floodwalls, raising I-5, Interstate express lanes, and Interstate emergency bypass. The COA evaluates the impact of the current option being analyzed by WSDOT (levees and walls).

d) Suite of Basin-wide Options (Floodproofing) – A suite of smaller local projects was developed for this study; however, only structure Floodproofing is evaluated in this study. The Floodproofing component of the Project Alternatives includes raising all residential homes within the 100-year floodplain. If the cost to raise a home is greater than the value of the structure plus land, the value of the structure plus land is included in the cost for Floodproofing instead. Essentially, these homes and properties would be acquired. For other buildings (commercial, industrial, government, schools) the expected case assumes that only 25% of the buildings within the 100-year floodplain are flood proofed. This lower achievability rate was selected based on conversations with commercial property owners. While some buildings, regardless of flood level, would be flood proofed, some building owners would not flood proof based on one or more of the following factors:

   1. Floodproofing is not cost-effective. The cost of Floodproofing is too high compared with the perceived risk.

2. Floodproofing is not feasible. The property or business is not conducive to Floodproofing measures such as walls, berms, or levees due to lack of space or business function.
3. Other location specific factors.

Flood reduction impacts for other small, basin-wide projects were unavailable at the time of this study and therefore could not be evaluated alongside the other alternatives presented in this study. Therefore, projects that protect key infrastructure, control bank erosion, and improve flow conveyance and drainage at key locations in the basin are not evaluated in this report.

e) **Aquatic Species Enhancement Plan and effects to the environment –** The last set of projects that is evaluated in the COA is the ASEP projects. The ASEP will provide effects from species-specific and ecosystem-based enhancement actions and analyses of potential effects on aquatic species from flood control actions in the basin.

Two types of projects are evaluated: those that may impact other alternatives; and those that are independent. For example, a small flood project raising homes in Chehalis will impact the flood damage reduction modeled for a retention facility. On the other hand, it is unlikely that a project controlling bank erosion in Grays Harbor County will significantly impact the flood damage reduction modeled for an I-5 Project in Lewis County. Therefore, these independent projects can be treated differently in the analysis. If a project does not affect the impact analysis of the retention facilities or WSDOT Alternative, then the costs and impacts are added to the analysis after the fact. On the other hand, if a project does affect the impact analysis of the retention facilities or WSDOT Alternative, then the COA explicitly ensures that no double counting of impacts occurs.

3.3 DEVELOP PERSPECTIVES (GEOGRAPHIC BOUNDARY) FOR ANALYSIS

When evaluating Project Alternatives, understanding the perspective of the stakeholders and decision makers is crucial to developing a useful study. For this study, stakeholders include not only the local community in the Chehalis Basin and the State of Washington, but also entities that may provide funding for future projects.

The three perspectives are described in more detail below:

- State: For the purposes of this study, a regional perspective is defined as the geographic area of the State of Washington (State Perspective). This perspective explores the impact of each Project Alternative on the State of Washington and tribal lands located within Washington.
- Basin-wide: The Basin-wide perspective examines each alternative based on the impacts within the basin. Because the focus is narrower, this perspective may not include all impacts included in the State perspective, however, the basin-wide perspective may include additional social and economic impacts that would otherwise be excluded under the State or Federal perspective. The basin is defined as Lewis, Thurston, and Grays Harbor Counties.
- Federal: Federal agencies, such as the Corps of Engineers and the Bureau of Reclamation evaluate projects from a national perspective. These agencies examine impacts on a national level. For example, local business losses may not be included in the analysis as other businesses outside the basin may experience increases in economic activity during or following a flood event. The Federal Perspective evaluates all impacts to the nation including impacts on the local Tribes.

Table 1 illustrates the types of impacts included for each of the perspectives. Blue or black circles indicate the impact is included. Blue circles indicate that the impact is included and may differ between perspectives. Black circles indicate that the impact is included and the estimated value is the same across perspectives.

Table 1
Perspective with Included Quantified Impacts

QUANTIFIED IMPACTS	STATE	BASIN-WIDE	FEDERAL
Structures, Content and Inventory	●	●	●
Flood Cleanup Costs	●	●	●
Loss of Agriculture Crops	●	●	●
Transportation delays on Interstate 5	●	●	●
Temporary Relocation Costs for Evacuated Residents	●	●	●
Emergency Protective Measures	●	●	●
Business Interruption		●	
Commercial Fishing	●	●	●
Sport Fishing	●	●	●
Environmental Non-Use	●	●	●
Economic Growth	●	●	

The Project Alternative costs and impacts are compared within each perspective. While Table 1 shows which impacts differ across the three perspectives, the COA task is meant to show a comparison of Project Alternatives from different perspectives and it is not meant to compare projects or specific impacts across the perspectives.

3.4 DEVELOP COSTS FOR EACH ALTERNATIVE

Cost analysis is an important element in the COA. For each of the identified Project Alternatives the cost of implementing the included projects is determined over the 100-year analysis period. The cost of each Project Alternative includes labor, equipment, and materials for the following cost categories:

- Initial and re-investment Capital Costs including applicable taxes and financing costs
- Operations expenses
- Maintenance expenses
- Permitting expenses

3.5 DETERMINE INCREMENTAL IMPACTS FOR EACH PROJECT ALTERNATIVE

The fifth step of the analysis is to determine the impact of each of the alternatives. These impacts can be positive or negative (costs or benefits), and the impacts can be quantitative or qualitative results expected or resulting from the implementation of a Project Alternative. The impacts to be evaluated for the Project Alternatives were determined through several technical workgroup meetings involving various state agencies. The impacts evaluated in this study include the following:

- Commercial fisheries for salmon and steelhead
- Tribal fisheries for salmon and steelhead
- Recreational (sport) fisheries for salmon and steelhead
- Terrestrial and non-fish aquatic habitat species
- Other fish species (non-salmonids)
- Other environmental benefits such as carbon sequestration and resiliency to climate change

- Structures, contents, and inventory damages
- Agricultural flood damages
- Cleanup costs
- Transportation
- Value of hydropower and its renewable qualities
- Local employment and business income
- Social, historic, or cultural effects
- Environmental non-use value
- Community health and safety

The methodology and assumptions for how these impacts were evaluated in this study are described in detail later in this report. These impacts are compared with the Baseline conditions described above.

3.6 GATHER DATA ABOUT THE VALUE OF EACH PROJECT ALTERNATIVE

Once the impacts have been identified, a value is determined. There are many methods for establishing value, including cost avoidance, cost savings, revenue generation, willingness to pay, and others. This step of the process involved a significant amount of research, analysis, and consultation with agencies and technical teams.

3.7 DEVELOP DETERMINISTIC MODEL TO CALCULATE NET PRESENT VALUE OF EXPECTED NET-BENEFITS

An essential impact analysis that needs to be completed for the COA task is a benefit-cost analysis (BCA). Traditionally, BCA is used to evaluate alternatives. BCA is a conceptual framework that quantifies in monetary terms as many of the costs and benefits of a project as possible. Benefits are broadly defined. They represent the extent to which people impacted by the project are made better-off, as measured by their own willingness-to-pay or willingness-to-accept. In other words, central to BCA is the idea that people are best able to judge what is "good" for them, what improves their well-being or welfare.

BCA also adopts the view that a net increase in welfare (as measured by the summation of individual welfare changes) is a good thing, even if some groups within society are made worse-off. A project or proposal would be rated positively if the benefits to some are large enough to compensate the losses of others.

Finally, BCA is typically a forward-looking exercise, seeking to anticipate the welfare impacts of a project or proposal over its entire life-cycle. Future welfare changes are weighted against today's changes through discounting, which is meant to reflect society's general preference for the present, as well as broader inter-generational concerns.

The metric that is often used to compare alternatives is net benefit. Net benefits are, equal to estimated benefits less estimated costs. For the impacts that can be quantified, i.e., represented by a dollar value, it is recommended that reported metrics for each alternative is the expected Net Present Value of Net Benefits (benefits less costs) in constant dollars.

The BCA model is designed as a disaggregated model, so decision makers can understand the contribution to overall net benefits from each impact.

The specific methodology developed for this BCA is consistent with standard principles and includes the following general assumptions:

- All costs are in 2014 dollars.
- The analysis period is 100 years.[2]
- The real discount rate used in the National Economic Development (NED) analysis (Federal perspective) has been determined at 3.5% for studies conducted in 2014.[3]
- A real discount rate of 1.63% is used for the State and Basin Perspectives.
- Results are also provided using a low (0%) real discount rate and a high (7%) real discount rate.[4]

3.8 ECONOMIC BENEFITS AND ECONOMIC IMPACTS

An often misunderstood aspect in the evaluation of project impacts is the differences between BCA and Economic Impact Analysis (EIA). A BCA is the valuation of changes in societal welfare while an EIA is a measure of changes in expenditures resulting from a project. The combination of the two analyses results in a complete measure of economic benefits. Appendix N provides an example of the two analyses and how they are used together to determine the full impact of Project Alternatives in this study.

This COA will seek to evaluate both the improvements in societal welfare (net economic value) through BCA and the changes in expenditures as measured in the EIA framework.

3.9 UNCERTAINTY AND RISK

The risks and uncertainty associated with each Project Alternative is generally not reflected in the standard comparison of benefits and costs (BCA). In order to provide the Work Group with sufficient detail needed to make an informed decision, the COA includes information about uncertainty and risks associated with the analyses.

In order to understand risks and uncertainties related to each alternative, the technical team used probability distributions where historic data is available and used deterministic analysis (high/medium/low) and ranges where data is not available.

3.10 CONSIDER QUALITATIVE IMPACTS WITH THE QUANTITATIVE IMPACTS TO INFORM DECISION MAKERS

The BCA, discussed above, includes only those impacts that can be quantified in dollar terms. In order for the COA to be comprehensive, impacts that are not quantifiable in dollar terms are addressed as well. These qualitative impacts may have significant importance in decision-making and they were included in the COA so they can be considered by the Work Group and others.

The technical team provided a description of qualitative measures and impacts based on input from the technical committees. The information on both qualitative and quantitative impacts is presented separately so Decision Makers can apply their own judgment.

[2] See Memo on Analysis Horizon
[3] See Appendix A
[4] See Id.

3 Project Alternative Costs

1 Project Alternatives

Several Project Alternatives are evaluated in a benefit-cost framework. These alternatives include:

1. Floodproofing Only
2. Low Enhancement Only
3. High Enhancement Only
4. I-5 Project plus Airport Levee, Floodproofing, and Low Enhancement
5. I-5 Project plus Airport Levee, Floodproofing, and High Enhancement
6. Flood Control Only Storage plus Airport Levee, Floodproofing, and Low Enhancement
7. Flood Control Only Storage plus Airport Levee, Floodproofing, and High Enhancement
8. Multipurpose Storage plus Airport Levee, Floodproofing, and Low Enhancement
9. Multipurpose Storage plus Airport Levee, Floodproofing, and High Enhancement
10. Flood Control Only Storage, I-5 Project, Airport Levee, Floodproofing, and Low Enhancement
11. Flood Control Only Storage, I-5 Project, Airport Levee, Floodproofing, and High Enhancement
12. Multipurpose Storage, I-5 Project, Airport Levee, Floodproofing, and Low Enhancement
13. Multipurpose Storage, I-5 Project Airport Levee, Floodproofing, and High Enhancement

Floodproofing, Enhancement Actions, and the Airport Levee are included in all Project Alternatives; however, Floodproofing and Enhancement Actions are also evaluated separately in Appendix O. The Multipurpose Storage option includes three configurations, which are described in this section.

2 Project Cost Assumptions

Project capital costs are provided in current, 2014 dollars. These capital costs are not discounted, levelized, or otherwise transformed. Interest during construction is calculated based on a borrowing rate of 3.5% for all Perspectives. The costs provided in this section account for the incremental cost for implementing and operating a Project Alternative. The amount of funding needed to finance a Project Alternative is a different value and is not discussed in this report. In addition, alternative funding sources and the cost of funding is not addressed as part of the study scope. Once a preferred Project Alternative is selected, funding sources will need to be evaluated and borrowing costs estimated. Finally, the cost for potential litigation in each of the Project Alternatives is not estimated and not included. Generally, BCA analyses do not include potential litigation costs because these are highly speculative.

3 I-5 Project: Levees and Berms

WSDOT is evaluating several alternatives that would keep I-5 open during a 100-year flood event. Without any improvements it is estimated that I-5 would be closed for 5 days during a 100-year event. Without an I-5 project, but with a storage option (either FRO or MPF), it is estimated that I-5 would be closed for 1 day during a 100-year event. Based on their analysis, WSDOT selected one of the proposed projects for additional analysis in the COA framework. The selected project, I-5 Alternative 1, consists of a series of levees, walls, and berms to keep I-5 open during a 100-year flood event. The I-5 Project evaluated in the COA differs slightly from the I-5 Project impacts evaluated at the time of this report's publication. Because the I-5 Project has changed somewhat from what is evaluated in the hydraulic model and subsequently in the flood damage reduction model (HAZUS), impacts of the current design may differ from what is presented in the COA. The schedule and scope of the COA did not allow for updates to the Project Alternatives once the COA was undertaken.

The cost of the I-5 Project is shown in Table 2 as provided by WSDOT. WSDOT provided lower and upper bound cost estimates to encompass the project variations that could be implemented. For the purposes of this study, the expected cost is the average of upper and lower bounds provided by WSDOT. The operation and maintenance (O&M) costs are annualized costs required to maintain the project throughout the entire 100-year study period.

Table 2
Interstate 5 Project Cost Estimates

$2014			
I-5 PROJECT	**CAPITAL COSTS**	**ANNUAL O&M**	**INTEREST DURING CONSTRUCTION**
Expected	$100,000,000	$5,000	$1,630,000
Lower Bound	$90,000,000	$5,000	$1,467,000
Upper Bound	$110,000,000	$5,000	$1,793,000
I-5 PROJECT COMBINED WITH STORAGE			
Expected	$82,000,000	$5,000	$1,330,000
Lower Bound	$71,000,000	$5,000	$1,160,000
Upper Bound	$93,000,000	$5,000	$1,510,000

When the I-5 project is modeled along with storage in the Upper Chehalis Basin (either FRO or MPF), the I-5 option has lower costs. The height for the levees, walls, or berms required to keep I-5 dry during a 100-year event is lower when paired with a storage option. Therefore, the I-5 project costs are also lower when combined with a water storage project.

Interest during construction (IDC) is calculated based on a 4-year construction schedule where 25%, 30%, 30%, and 15% of the costs are needed. The same construction schedule is assumed for each cost estimate (lower bound, upper bound, and expected) regardless of whether or not a storage option is also implemented.

4 Airport Levee

The airport levee is included in each Project Alternative. This levee is needed to help keep the Chehalis airport from flooding during a 100-year event. When paired with Upper Basin storage alone, I-5 would close for 1 day during a 100-year event (compared to nearly 5 days of closure with neither option). WSDOT prepared a range of cost estimates for the airport levee as shown in Table 3. The expected cost is the average of the lower and upper bound. IDC is calculated based on a 4-year construction schedule where 25%, 30%, 30%, and 15% of the costs are needed. The same construction schedule is assumed for each cost estimate (lower bound, upper bound, and expected).

Table 3
Airport Levee Cost Estimates

$2014			
	CAPITAL COSTS	ANNUAL O&M	INTEREST DURING CONSTRUCTION
Expected	$4,500,000	$8,000	$70,000
Lower Bound	$4,000,000	$8,000	$70,000
Upper Bound	$5,000,000	$8,000	$80,000

5 Upper Chehalis Storage

Storage in the Upper Chehalis Basin can be accomplished by either a single-purpose structure or MPD structure. Both structures store up to 65,000 acre-feet of flood water. In addition, the MPD structure stores water year-round to augment low flows during the summer months. The single purpose project does not store water except during a flood event. The Project Team's engineers (HDR) evaluated several options for both structure purposes as described in the Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species. Dam Design Technical Memorandum. All projects store the same quantity of water during flood events. A summary of the options is provided in this section as well as the estimated costs.[5]

5.1 SINGLE PURPOSE: FLOODING RETENTION ONLY

The single-purpose FRO structure is assumed to be a roller-compacted concrete (RCC) structure. RCC is a blend of concrete with different ratios of ingredients and generally less water making it much less susceptible to slump. The dam footprint is approximately 6 acres with a total height of 227 feet from base to crest. The reservoir resulting from utilizing maximum flood storage is 860 acres along 6.8 miles of river. Fish passage for the single purpose project would include a CHTR facility for upstream passage.

5.2 MULTI-PURPOSE RCC

One option for the MPD structure is an RCC structure. Its footprint is approximately 10 acres with a total height of 287 feet from base to crest. The reservoir resulting from utilizing maximum flood storage is 1,307 acres along 7.5 miles of river.

HDR developed two options for fish passage under the MPD RCC dam scenario. The first is a CHTR facility for upstream passage with combination collector facilities for downstream passage. The upstream fish passage for this first option is known more commonly as “trap and haul.” The second fish passage option is a conventional fishway for upstream passage paired with a forebay collector for downstream passage. The conventional fishway is a fish ladder consisting of 220 pools including 25 resting pools.

5.3 MULTI-PURPOSE ROCKFILL

The second option for the MPD structure is rockfill dam. A rockfill dam is an embankment of compacted soil combined with an impervious zone. The rockfill dam's footprint is approximately 40 acres. The height and reservoir acreage is approximately the same as the RCC dam.

[5] For the full description of structure options, please refer to: HDR, Inc. Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species. Dam Design Technical Memorandum. Draft March 2014.

The rockfill dam fish passage option includes an experimental fishway for upstream passage paired with a forebay collector for downstream passage. The experimental fishway consists of a 2,300-foot-long fishway or transition to the reservoir from the downstream side of the dam. This fishway results in an 80-foot rise in elevation from the downstream side of the dam to the reservoir and consists of 165 pools including 19 resting pools. Twenty automated gates control flows within the fishway.

5.4 LAND VALUE

The proposed dam site and reservoir area are located on timberlands in Lewis County. With the Upper Chehalis Basin storage alternatives, this land will no longer be productive timber land and would need to be purchased or leased. The cost of this land (purchase) is included in the project cost estimates for the storage options. The acreage needed is shown in Table 4.

Table 4
Acreage Needed for Storage Alternatives

	ACRES		
	INUNDATED AREA	DAM FOOTPRINT	TOTAL
Flood Retention RCC	1,052	4	1,056
Multipurpose RCC with CHTR Fish Passage	1,510	8	1,517
Multipurpose RCC with Conventional Fishway	1,510	8	1,517
Multipurpose Rockfill with Experimental Fishway	1,501	31	1,532

The value of acreage is based on current market rates for timber land sales. Both current land sales as well as historic sales were evaluated to determine a normalized price for timberland. Timberland is valued at a range of $1,221 to $8,108 per acre. In the expected case, the value is assumed at $4,248 per acre. Table 5 shows the resulting timber and land value for the expected case. More information can be found in Appendix H.

Table 5
Timber and Land Values

NET PRESENT VALUE $2014	
Flood Retention RCC	$4,480,000
Multipurpose RCC with CHTR Fish Passage	$6,440,000
Multipurpose RCC with Conventional Fishway	$6,440,000
Multipurpose Rockfill with Experimental Fishway	$6,510,000

The above cost estimates assume the land is purchased. In practice the land may be leased or have some other agreement with the current landowner.

In addition, the State of Washington's mitigation policies will require compensatory mitigation for the temporary and permanent impacts of maintaining a reservoir to the various habitat types in the inundated area via protection or acquisition of habitat elsewhere at a ratio of 1:1 or greater. The costs of implementing compensatory mitigation have not been incorporated into this analysis, but should be anticipated in a future phase.

5.5 ESTIMATED COSTS

The Project Team engineers provided a range of costs for each project configuration. The operation, maintenance, and replacement (OM&R) are annualized costs needed to keep the project operating for the 100-year study period. IDC is calculated based on the construction spending schedule provided by HDR.[6] The construction schedules are the same across storage options for each cost estimate (lower bound, upper bound, and expected). The lower bound costs represent a reasonable minimum cost that would be incurred to implement the project rather than the lowest possible cost. Similarly, upper bound cost estimates shown in Table 6 represent a reasonable cost higher than what is expected based on today's prices. The upper bound cost estimate is not the highest possible cost.

Table 6
Upper Chehalis Storage Estimated Project Costs

$2014			
EXPECTED	**CAPITAL**	**ANNUAL OM&R**	**INTEREST DURING CONSTRUCTION**
Flood Retention RCC	$280,250,000	$793,000	$4,568,075
Multipurpose RCC with CHTR Fish Passage	$370,350,000	$1,539,000	$6,040,000
Multipurpose RCC with Conventional Fishway	$405,350,000	$1,391,000	$6,610,000
Multipurpose Rockfill with Experimental Fishway	$574,100,000	$1,624,000	$9,360,000
LOWER BOUND			
Flood Retention RCC	$227,500,000	$725,000	$3,708,250
Multipurpose RCC with CHTR Fish Passage	$302,700,000	$1,385,000	$4,930,000
Multipurpose RCC with Conventional Fishway	$332,700,000	$1,252,000	$5,420,000
Multipurpose Rockfill with Experimental Fishway	$479,100,000	$1,462,000	$7,810,000
UPPER BOUND			
Flood Retention RCC	$333,000,000	$862,000	$5,427,900
Multipurpose RCC with CHTR Fish Passage	$443,000,000	$1,693,000	$7,220,000
Multipurpose RCC with Conventional Fishway	$494,000,000	$1,530,000	$8,050,000
Multipurpose Rockfill with Experimental Fishway	$687,100,000	$1,786,000	$11,200,000

[6] HDR, Inc. Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species. Dam Design Technical Memorandum. Draft March 2014.

6 Flood Proofing

Flood-proofing includes raising homes and Flood-proofing commercial buildings within the 100-year floodplain. These structures are then protected in a 100-year event reducing structure, content, and inventory damages as well as some cleanup costs. Raising buildings reduces flood damages related to the structures; however, no other damage categories are affected. For example, flood waters might still surround a home or business such that households would need to be relocated or businesses would need to close. Flood-proofing consists of the following:

- Raising residential buildings to avoid damages from a 100-year event. The cost is based on $35 per square foot plus permitting, contractor fees, and incidental costs of 20%.

Flood-proofing commercial and industrial buildings to avoid 100-year flood event damages. The cost of Flood-proofing is based on costs published by the Federal Emergency Management Agency (FEMA)[7] including building floodwalls, interior drainage, and closures. The costs amount to $4.67/square foot of flood wall surface plus $10,000 per building for permitting, backflow prevention, and contingencies.[8]

Flood-proofing and structure raising costs are limited by the value of the structure plus the land. If the structure plus land value is less than the cost to flood proof, the property would be purchased instead.

7 Flood Proofing Achievability

The Flood-proofing component of the Project Alternatives includes raising all residential homes within the 100-year floodplain. If the cost to raise a home is greater than the value of the structure plus land, the value of the structure plus land is included in the cost for Flood-proofing. Essentially, these homes and properties would be acquired.

For other buildings (commercial, industrial, government, schools) the expected case assumes that only 25% of the buildings within the 100-year floodplain are flood proofed. This lower achievability rate was selected based on conversations with commercial property owners. While some buildings, regardless of flood level, would be flood proofed, some building owners would not flood proof based on one or more of the following factors:

1. Flood-proofing is not cost-effective. The cost of Flood-proofing is too high compared with the perceived risk.
2. Flood-proofing is not feasible. The property or business is not conducive to Flood-proofing measures such as walls, berms, or levees due to lack of space or business function.
3. Other location specific factors.

The cost for commercial Flood-proofing is based on 25% of the total cost to flood proof all commercial buildings. Note that a cost-effectiveness evaluation for each building is not part of the study scope. The 25% achievability rate is the best approximation for achievability, cost, and impacts. In addition to the expected case, low and high achievability rates are analyzed. A low achievability rate of 10% is selected and a high rate of 50% is also analyzed. This range is based on conversations with local building owners regarding the applicability of Flood-proofing. The high value represents a high achievability rate given the issues raised by building owners. The selected range of achievability reflects the uncertainty related to how many commercial building owners would implement Flood-proofing if provided with the opportunity. The results with low and high achievability rates are presented as part of the uncertainty analysis.

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[7] Southern Tier Central Regional Planning and Development Board. Selecting Floodproofing Techniques – Financial Considerations. FEMA. Floodproofing Info #10.

[8] Floodproofing costs developed by Larry Karpack, Watershed Science & Engineering. Email dated March 5, 2014.

Table 7 shows the estimated number of structures that would be raised or flood proofed within the 100-year floodplain in the Baseline and in each of the Project Alternatives.

Table 7
Flood-proofing: Number of Buildings and Costs

EXPECTED CASE 100% RESIDENTIAL AND 25% ACHIEVABILITY FOR NON-RESIDENTIAL $2014					
	BUILDINGS IN 100-YEAR FLOODPLAIN	BASELINE	WITH I-5 PROJECT	WITH STORAGE	WITH I-5 PROJECT AND STORAGE
Residential Buildings	677	677	653	368	354
Non-Residential Buildings	446	112	95	71	64
Total Buildings Flood Proofed		789	748	439	418
Cost, Millions		$91.5	$87.3	$49.0	$46.8

It is important to note that even after flood proofing, properties will still be flooded and structures may be damaged depending of the severity and location of the flood.

8 Enhancement Projects

Several enhancement projects were evaluated in the ASEP in conjunction with other Project Alternative components. Table 8 provides a summary of these enhancement actions. The following projects were evaluated:

- **NMF-Riparian20/50 –** Increase the modeled riparian attributes by 20% in the non-managed forests in 50% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.
- **NMF-Riparian60/50 –** Increase the modeled riparian attributes by 60% in the non-managed forests in 50% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.
- **NMF-Riparian20/75 –** Increase the modeled riparian attributes by 20% in the non-managed forests in 75% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.
- **NMF-Riparian60/75 –** Increase the modeled riparian attributes by 60% in the non-managed forests in 75% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.
- **NMF-LWM50/50 –** Increase the modeled instream wood attributes by 50% in 50% of Spring Chinook spawning reaches. Examples include log cribs, installation of log jams, root wads, and wood structure to trap gravel and/or sediment.
- **NMF-LWM50/75 –** Increase the modeled instream wood attributes by 50% in 75% of Spring Chinook spawning reaches. Examples include log cribs, installation of log jams, root wads, and wood structure to trap gravel and/or sediment.
- **Culvert100 –** Passage at all artificial barriers = 100%. Remove the 169 barriers that are in the EDT model to allow access above the barriers.

Table 8
Enhancement Action Summary

PROJECT NAME	CAPITAL[1]	ANNUAL O&M[2]	TOTAL PV COST
NMF-LWM50/50	$17,550,000	$95,000	$18,420,000
NMF-LWM50/75	$27,800,000	$143,000	$29,110,000
NMF-Riparian20/50	$43,240,000	$216,000	$45,220,000
NMF-Riparian20/75	$64,860,000	$324,000	$67,830,000
NMF-Riparian60/50	$43,240,000	$216,000	$45,220,000
NMF-Riparian60/75	$64,860,000	$324,000	$67,830,000
Culvert100	$29,970,000	$158,000	$31,420,000

Notes:
1. Includes 30% contingency
2. O&M is required for 10 years following project implementation.

The enhancement actions from Table 8 were combined in low and high enhancement scenarios for the Project Alternatives: no Upper Chehalis storage, Flood Control Only structure, and Multi-purpose structure. Table 9 shows the combinations of enhancement actions for each Project Alternative scenario. The COA analysis assumes that each of the Project Alternatives includes either Low or High Enhancement actions. The NPV for enhancement costs (capital, O&M) is summarized below assuming a discount rate of 1.63%.

Table 9
Enhancement Actions Combinations

SCENARIO	RIPARIAN 20/50	RIPARIAN 60/50	RIPARIAN 20/75	RIPARIAN 60/75	LWM 50/50	LWM 50/75	CULVERT 100	TOTAL PV COST
Low Enhancement Only	X				X		X	$95,060,000
High Enhancement Only				X		X	X	$128,350,000

9 Project Alternative Costs

Figure 2 summarizes the total project cost for each of the Project Alternatives assuming a discount rate of 1.63 percent and Low Enhancement actions. Figure 3 shows the same information for High Enhancement actions.

Figure 2
Project Alternatives Expected Cost Summary with Low Enhancement, 100-Year NPV

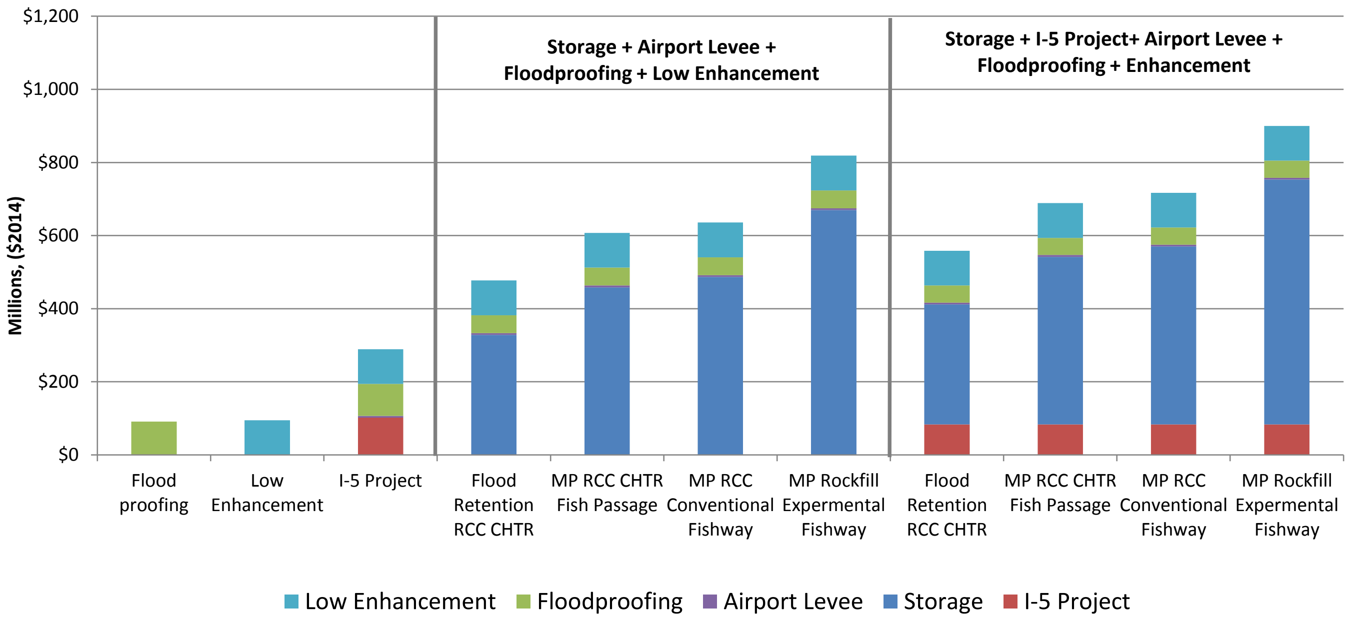
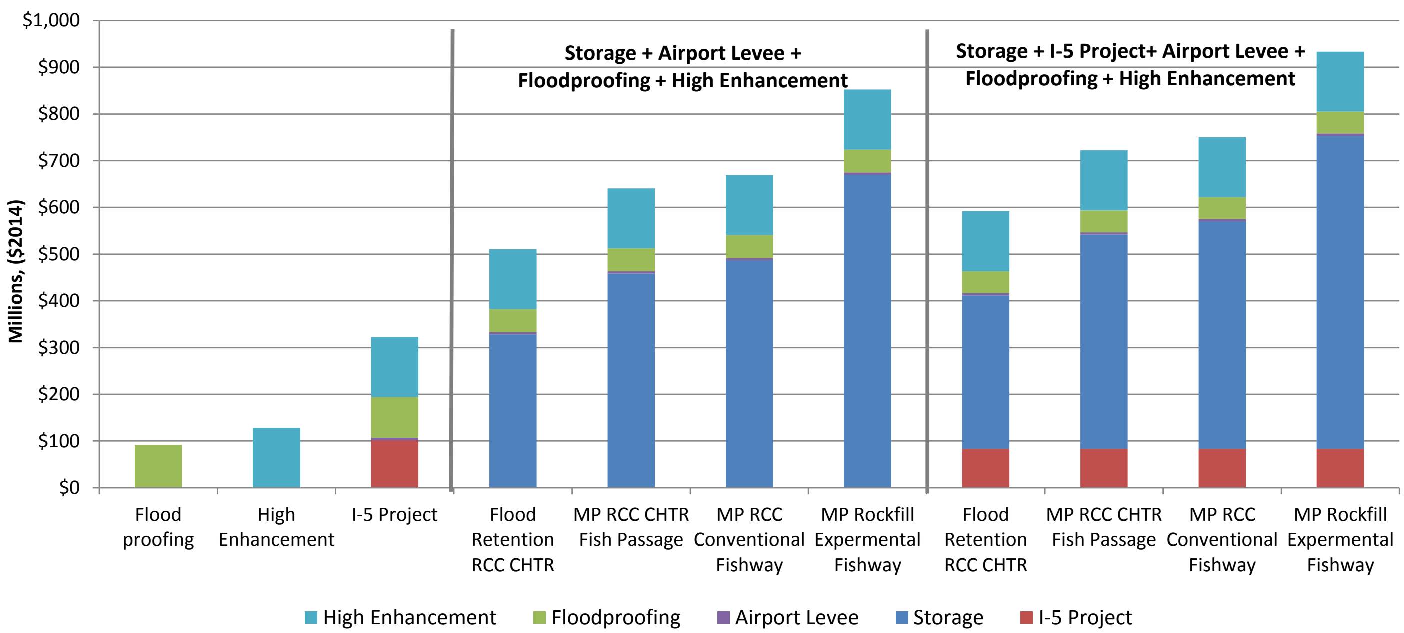


Figure 3
Project Alternatives Expected Cost Summary with High Enhancement, 100-Year NPV



The above costs are included in the COA analysis. Annual OM&R costs are calculated over the full study period and are included in the above figures in NPV terms.

10 Hydropower

In addition to the Project Alternatives above, the option of adding a small hydropower unit on a MPD dam is analyzed separately. Table 10 shows the range of estimated capital costs as well as annual OM&R costs.

Table 10
Hydropower Cost Estimates

$2014			
	CAPITAL	OM&R	INTEREST DURING CONSTRUCTION NPV
Expected	$22,500,000	$485,000	$623,000
Lower Bound	$20,000,000	$485,000	$554,000
Upper Bound	$25,000,000	$485,000	$693,000

The costs above include regulatory and permitting for the proposed 5 megawatt hydropower unit. The evaluation of this project is provided in Appendix J.

4 Project Alternative Impacts

1 Introduction

This section describes the methodology and assumptions behind the Project Alternative impact evaluations. Impact evaluation assumptions may differ across perspectives. These differences are described later within each perspective section. Qualitative impacts are discussed in the following section. Impacts are separated into those related to flood damage and other impacts not related to flood damage (e.g., sport fishing impacts are not directly related to flood damages).

All Project Alternatives are compared to the same Baseline. The Baseline is defined as current conditions plus any projects that are currently funded. Impacts related to population growth or development within the floodplain are excluded from the analysis.

2 Quantified Impacts

The following project impacts are quantified in this study:

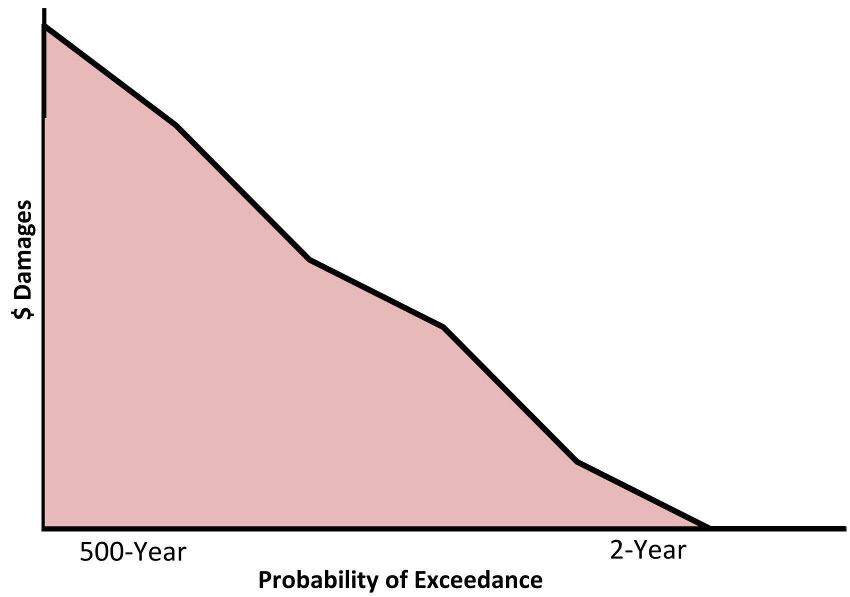
- Flood damage to structures, content, and inventory
- Cleanup costs for buildings and agricultural acreage
- Vehicle damages
- Loss of agriculture crops or crop damage
- Transportation delays on I-5
- Temporary relocation costs for evacuated residents
- Public assistance for emergency protective measures for bridges, utilities, water control facilities, or debris removal.
- Business interruption
- Economic development
- Commercial fishing
- Sport fishing
- Tribal Fishing
- Environmental Non-use

Qualitative impacts are discussed in the next section.

3 Project Impacts on Flood Damages: Methodology

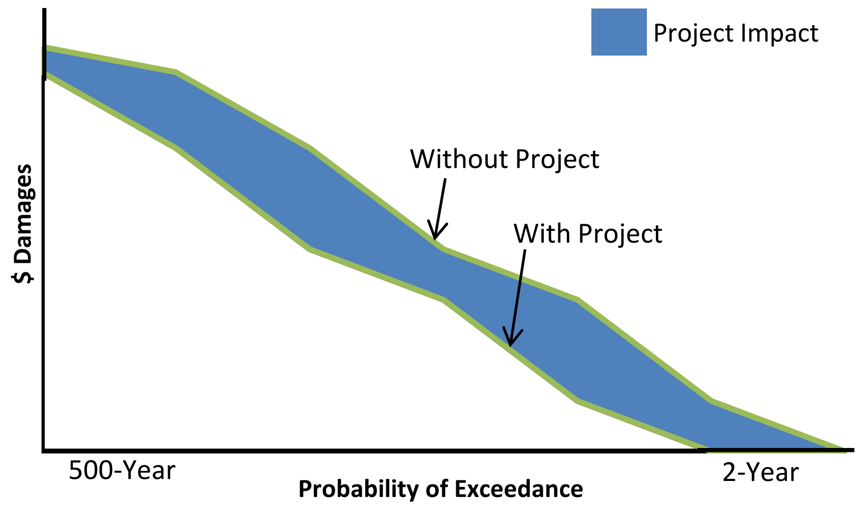
The value of flood damages for several flood return intervals (2, 10, 12, 100, and 500 years) is calculated for the Baseline and each Project Alternative. A graph relating flood damage estimates with flood return intervals is referred to as a damage curve. Figure 4 is an example of a damage curve where the area under the curve is the expected damage for a given flood hazard. Figure 4 demonstrates that as the exceedance probability of a flood decreases, damages increase. In other words, a 100-year event is much more severe and causes much more damage compared with a 10-year event.

Figure 4
Example Damage Curve



Once a flood reduction project is introduced, the damage curve will shift such that damages are reduced or increased in some or all flood events. Individual damage curves are estimated for Baseline and each Project Alternative scenario. The difference between the Project Alternative curve and the Baseline curve is the impact of the project alternative. Impacts include values such as avoided damages to building structures and contents, agriculture products and equipment, avoided cleanup costs, and avoided costs due to transportation delays and detours. Figure 5 shows a sample shift. The expected annual benefit (in dollars) of the flood reduction project is the area between the curves (blue shading) in Figure 5.

Figure 5
Example of Reduction in Damage Curve



The above methodology is used to estimate Project Alternative impacts to flood damages. The resulting impacts are in expected annual values. Therefore, the COA is a probabilistic analysis based on flood return intervals and related damages.

Note that flood damage reduction impacts are the same for all four storage facility configurations and are shown as such throughout the report.

4 Structure, Content, and Inventory

Flood damages to structures are estimated in HAZUS[9] based on depreciated building values and average flood depth by census block. HAZUS used flood depth damage curves for each structure type to estimate the percent of the depreciated building value that is damaged. Flood depth damage curves relate feet of inundation with percent of building damage depending on the structure type. These damage curves are developed from national data; however, because the curves are applied to regional building types and basin specific hydrology, the results are applicable to the basin. Content and inventory damages are based on structure value and structure type. For example, a residential structure may have 50 percent of its home value in contents while a hospital may have 150 percent of its structure value in contents.

Both depreciated replacement value and full replacement value for structure and content damages are estimated. Business inventory (goods for resale) is not depreciated. Generally, flood damage reduction analyses present only depreciated replacement value; however, due to interest in the full replacement value, the State- and Basin-wide perspective results are presented for both depreciated and non-depreciated structure and content values. Non-depreciated replacement values are provided in Appendix O.

Flood-proofing commercial and residential buildings to a 100-year flood event is included in each of the Project Alternatives unless noted otherwise. It is assumed that residential structure, content, and inventory losses in the 100-year event are avoided. Since all residential buildings are flood proofed (raised), all residential structure and content damages can be avoided in a 100-year event. In the Expected case, only 25% of non-residential

[9] Please refer to appendix B and C.

buildings (commercial, industrial, government, schools) are flood proofed (refer to section 6 in the Project Alternative Cost chapter of this report). Therefore, only 25% of the non-residential structure, content, and inventory damages are avoided. In addition, structure, content, and inventory losses for the 500-year event would likely be reduced with the Flood-proofing; however, the amount of damage reduction has not been modeled in HAZUS and is not included in the COA. Therefore, the benefits of Flood-proofing may be underestimated.

5 Cleanup Costs

Cleanup costs include the labor and materials needed to remove debris and to clean a structure or property after a flood event. The following three components are included in the cleanup cost estimates:

1. Debris removal
2. Building cleanup costs (commercial, residential)
3. Agriculture field cleanup and enhancement

HAZUS provides the tons of debris generated from a flood, mainly damaged structures and contents. The cost to remove debris is between $123 and $137 per ton.[10] Building cleanup costs are estimated at $5/square foot. The number of buildings damaged and the average square foot for each building type damaged is also provided by HAZUS. Buildings that are substantially damaged (more than 50%) are excluded in cleanup costs as these buildings would be demolished. Demolished building cleanup costs are included in the debris removal costs.

Agriculture field cleanup cost and enhancement is based on the number of acres flooded (per HAZUS) and $500/acre to restore the fields to planting condition. In addition re-seeding costs of $180 per acre are included.[11]

Similar to structure, content, and inventory, building cleanup costs, when Flood-proofing is included, are avoided in the 100-year event for the buildings that are flood proofed. The modeling assumes that cleanup costs in a 500-year event would still be required since homes and businesses are not flood proofed to the 500-year event.

6 Vehicle Damages

Historically, during severe flood events, vehicle damages have occurred. HAZUS estimates vehicle damages much the same way as structure damages are estimated. Damage estimates are calculated according to depth damage functions and vehicle depreciated replacement values. The COA analysis relies on default data within HAZUS to estimate vehicle damages for the 100- and 500-year events. It is assumed that no damages occur for flood events that are less severe.

7 Agricultural Losses

7.1 CROP DAMAGE

Damages to agricultural crops are based on either loss of currently planted crops or the lost use of acreage due to flood damage restoration. Depending on the time of year a flood occurs, farmers may need to reseed fields or they may experience total loss. Because most agricultural lands are located in or near the floodplain, flooding can cause significant loss to production. Crop damage is estimated based on the acreage flooded, cropping

[10] Please refer to Appendix F.
[11] Id.

patterns by county, and value of crops by type. Cropping patterns are estimated using averages from the U.S. Department of Agriculture National Agricultural Statistics Service (NASS) database.[12] Table 11 summarizes the cropping patterns assumed in the analysis.

Table 11
Cropping Patterns

AVERAGE ACREAGE 2002-2012[13]				
	LEWIS	THURSTON	GRAYS HARBOR	TOTAL
Field Crops	**3,996**	**10,433**	**10,533**	**24,963**
Barley (Grain)	747	0	98	845
Corn (Silage)	843	0	1,211	2,054
Wheat	1,864	0	2,281	4,145
Peas	205	3		208
Hay	338	10,430	6,908	17,677
Oats			35	35
Vegetables	1,407	192	2,240	3,839
Share of Field Crops				87%
Share of Vegetables				13%

The majority of acreage is in field crops. The share of crop type for each county is applied to the flooded acreage for each county. Crop yields (cwt/acre,[14] bushel/acre) are based on average historic yields for Washington State by crop type if available, or national data when unavailable[15]. Prices for crops are based on average 5-year normalized national or state prices for all field crops depending on perspective. Vegetable prices are based on the 4-year average of national or state prices depending on which was available and the relevant perspective.

Many farms or agricultural acreage are bordered by riparian protection areas. While this acreage is included in the estimated number of flooded agricultural acreage, it is likely that the riparian areas will be flooded regardless of whether or not a Project Alternative is implemented. Because the riparian area is included both in the Baseline and the Project Alternative cases, the presence of these riparian areas are unlikely to cause an over-estimation of Project Alternative impacts.

8 Transportation Delays

8.1 INTERSTATE 5

I-5 is closed for approximately 5 days during a 100-year flood event. WSDOT estimated the cost a 100-year event closure based on behavior surveys, traffic counters before and during the event, and the estimated cost of detour routes or delayed trips. WSDOT estimates that a 100-year event costs a total of $11.5 million, or $2.2 million per day on average in additional travel costs. Based on survey information, this estimate assumes that

[12] Please refer to Appendix D.
[13] U.S. Department of Agriculture. National Agricultural Statistics Service. Lewis, Thurston, and Grays Harbor Counties.
[14] CWT (hundredweight or centum weight) is a unit of mass defined in terms of pounds. A short hundredweight is 100 lbs. This unit of mass is used in the United States.
[15] Please refer to Appendix D.

only a share of "through" traffic takes a detour. When all "through" traffic takes a detour, the closure costs amount to $20.6 million. For the expected case scenario, the COA uses the average between the two estimates provided by WSDOT. Even if some travelers delay or cancel their trip, there are indirect costs to the traveler that are not accounted for in this estimate ($11.5 million). For example, if the detour costs $100, but the trip is worth less than $100 to a traveler, the traveler would delay or cancel the trip. Delay and cancellation costs are not accounted for, if those costs are less than the detour cost. The WSDOT methodology therefore underestimates the cost of the closure in the lower estimate case.

The expected case assumption for this study is a conservative estimate for transportation delay costs according to the U.S. Army Corps of Engineer methodology.[16] More information on the WSDOT study can be found in Appendix E.

9 Emergency Aid

Emergency aid is a combination of Temporary Relocation Assistance (TRA) and Public Assistance. TRA is the cost to house relocated families during a flood event. Public Assistance costs are emergency protective measures to secure infrastructure such as bridges, roadways, or utilities.

9.1 TEMPORARY RELOCATION ASSISTANCE (TRA)

Housing costs include reimbursements for hotel stays or public shelter costs. Those who relocate to stay with families or friends are included in the total damage estimate since the opportunity cost of staying with family is the cost of a public shelter or hotel. The total number of TRA claims is provided by HAZUS. HAZUS assumes that if a census block is at least partially flooded, the residents will need to be relocated due to loss of home, access, or utilities. The number of claims is multiplied by the estimated cost per claim. In the 2007 event, the average claim was approximately $4,000 per relocated family. This figure is used for claims in the 100- and 500- year events. For less severe flood events, the average claim is approximately half of the 2007 amount, or $2,100 per claim[17]. These claims are per household.

9.2 PUBLIC ASSISTANCE

Public Assistance costs are calculated based on a ratio of costs compared with TRA costs. This methodology is consistent with previous studies conducted by the Corps for the Chehalis River Basin.[18] Appendix G has more information. The expected case ratio of Public Assistance costs to TRA costs in this study is based on the 2007 flood event (ratio of 5.4).

9.3 BUSINESS INTERRUPTION

Business interruption costs during a flood event include the cost to businesses or landlords for building closure during flood events as well as the cost of delayed re-opening due to damages or relocation. Business interruption costs are composed of four parts:

1. Income (capital-related) losses
2. Wage losses
3. Relocation

[16] WSDOT notes in their study that the U.S. Army Corps of Engineers allows for travel costs to be calculated assuming all through traffic takes a detour.
[17] Please refer to Appendix G.
18 U.S. Army Corps of Engineers. Centralia, Washington, Flood Damage Reduction. Final General Reevaluation Report. Economics Appendix D. June 2003.

4. Rental Income losses

Each of these components is described in more detail in Appendix I.

Business interruption costs are included only in the basin-wide perspective. From the State or Federal Perspective, these costs would be recouped by other businesses located outside the affected flood area but within the geographic boundaries of the perspective. Therefore business interruption costs are local in nature and are not included when approaching the analysis from a wider geographic boundary.

10 Other Impacts

10.1 ECONOMIC DEVELOPMENT

The economic consequences of flood damage over time include both positive and negative impacts. Negative impacts are the direct damages to property immediately following an event. Positive impacts include the effects of recovery and reconstruction.[19] Some studies have asserted that the short-term impacts from a natural disaster are negligible compared with the long-term impacts of recovery.[20] While some discussion is provided for the trade-off between monetized positive and negative impacts, it is also recognized that long-term economic growth is better served by the reduction of flood hazard risk.

The Economic Development impact or input-output (IO) analyses in this study are conducted using previously prepared IO models[21]. This methodology is consistent with many other studies that have evaluated regional impacts from natural disasters using previously prepared IO models[22]. This methodology ignores the time lag effect for the positive and negative economic effects following a disaster. In order to mitigate for this shortcoming, economic impacts are reported separately depending on the type of impact. For example, structure damages are associated with immediate negative consequences followed by positive economic impacts from repair and reconstruction. Therefore, IO results are presented with and without structure damage.

Project Alternative impacts on economic development are evaluated for the State- and Basin-wide Perspectives. Increased economic activity is measured using state and county IO models. These models and results are discussed in detail in Appendix L.

10.2 ENVIRONMENTAL

Estimation of environmental benefits (and costs) are related to the positive (or negative) impacts on aquatic habitats and species populations from implementing flood control structures and enhancement actions in the basin, either singularly or in combination. Changes to aquatic habitats would affect fish and non-fish species, but the analysis of monetized benefits and costs is limited only to changes in salmonid populations, namely spring Chinook, fall Chinook, and coho salmon and steelhead trout. As discussed in Appendix K, estimated benefits are determined by estimating a value per fish for different salmonid species and applying this value to

[19] Ishikawa, Yoshimi and Toshitaka Katada. Analysis of the Economic Impacts of a Natural Disaster Using Interregional Input-Output Tables for the Affected Region: A Case Study of the Tokai Flood of 2000 in Japan. 2006 Intermediate Input-Output Modeling.
[20] Ishikawa, Yoshimi, 2006.
[21] www.implan.com
[22] See for example: Ishikawa, Yoshimi and Toshitaka Katada, 2006. Analysis of the Economic Impacts of a Natural Disaster Using Interregional Input-Output Tables for the Affected Region: A Case Study of the Tokai Flood of 2000 in Japan. 2006 Intermediate Input-Output Modeling. Also see: Sheets, Keith, 1998. Traditional Uses of Input-Output Models in Watershed Programs Planned under Principles and Guidelines. USDA Natural Resources Conservation Service. Lincoln, Nebraska. August 1998.

the predicted changes in fish populations from each project alternative. Multiple values per fish by species are estimated to reflect differences among commercial fishermen, recreational fishermen, local tribes, and others in the state who do not fish but place a value on fish habitat. Their respective values per fish are estimated from economic literature and market data and include the following factors:

- **Commercial Fisheries:** Commercial fishery value is estimated from profits resulting from harvests of salmon populations. In practice, benefits from population changes in a particular basin, such as the Chehalis, are estimated using data on harvest levels and net revenues in each US state (primarily Alaska, Oregon, and Washington) and Treaty/Non-Treaty allocation. Fish from the Chehalis Basin that are caught in Canada would not be considered a benefit to the US. Wherever fish are caught, total net revenues are a function of the total annual catch (in tons), revenue per ton (derived from wholesale prices), and costs per ton (based often on a percentage of the wholesale price).
- **Sport Fisheries:** The net economic value of anglers would be estimated separately for their activities in ocean, estuary, and river waters. In the ocean and estuary, fishing generally relies on charter and/or privately owned boats for fishing. However, river fishing generally can occur in or along the river bank. Sport fishing benefits can include not only fish caught for harvest but also catch and release activities if stocks decline enough to cause such restrictions to be imposed.
- **Passive Use:** Passive use stems not from fishing but from an individual's interest in the fact that these fish exist, can be caught by someone now or in the future, have a long-standing connection to local cultures, and are significant elements of the ecosystem. The inclusion of Passive Use value in project evaluations can be justified by the importance of salmonids to residents across the State of Washington even for people who do not fish.

Estimable impacts are differentiated geographically to account for differences in effort, costs of actions, and abundance of fish. These regions include: open ocean, estuary (Grays Harbor), and river. Commercial activities for Treaty and Non-Treaty Tribes are grouped independent of location.

Table 12 summarizes the values per fish used in the analysis. Additional information is available in Appendix K.

Table 12
Economic Values per Fish

SPECIES	OCEAN		GRAYS HARBOR		RIVER		TREATY / NON-TREATY	ANNUAL PASSIVE USE
	COMM.	SPORT	COMM.	SPORT	COMM.	SPORT	COMM.[1]	
Fall Chinook	$21.64	$82.60	$46.61	$100.11	NA	$178.47	$21.22	$2,232
Spr. Chinook	$46.61	$82.60	$46.61	$100.11	NA	$133.31	$45.71	$2,232
Coho	$9.91	$50.88	$9.91	$62.44	NA	$141.72	$9.32	$2,232
Steelhead	NA	NA	NA	NA	NA	$165.83	NA	$2,232

Notes:
1. This category combines the benefits to The Quinault Indian Nation "Treaty" and Chehalis Tribe "Non-treaty"

Significant value that cannot be monetized is the cultural value that salmonids provide to the two principal tribes in the area: the Quinault and the Chehalis Tribe. As discussed above, an economic analysis of changes in salmonid fisheries to these Tribes can be estimated for commercial activities. However, the act of fishing and subsistence harvesting is recognized as a cultural way of life that is connected to their history and identity. These types of values are beyond economic valuation, which attempts to observe value behind the choices people make rather than to provide a definition of who people are. Instead of estimating an economic value of cultural impacts to salmonid population changes, it is recognized that the estimated benefits (and costs) are incomplete insofar as cultural values are not included in these estimates.

Economic benefits and costs are determined from the change in the impact of a project over time on salmonid populations relative to baseline conditions. For each project, it is assumed that it can be implemented within a one-year construction period and impacts to species populations would be realized soon after. Impacts from either flood retention and enhancement projects would be realized within 4 years for Chinook and steelhead species and within 2 years for coho. Due to the magnitude of the enhancement efforts, it would take several years to construct all of the projects. It is difficult to predict where and when projects would be implemented because funding sources and quantities are unknown. Therefore, while the benefits are assumed to be realized in the first few years, the actual benefits from the projects would likely take longer to be realized.

Several baseline conditions are evaluated in this analysis. Data on baseline populations for no-growth and managed forest baseline conditions are provided in Table 13. Baseline fish populations under a No-Growth scenario remain stable and unchanged throughout the period of analysis. However, in a managed forest context, the outcomes from the Forest Practices Act are expected to increase fish populations for all species over time. Spring Chinook populations are the most affected with an increase in population of 34.3%.

Table 13
Baseline Fisheries Population Forecasts – No Growth and Managed Forest Scenarios

SCENARIO	SPECIES	CURRENT	FUTURE	PERCENT CHANGE
Baseline with No Growth				
	Spring Chinook	2,448	2,448	0.0%
	Fall Chinook	15,894	15,894	0.0%
	Steelhead	10,417	10,417	0.0%
	Coho	60,000	60,000	0.0%
Baseline with Managed Forests				
	Spring Chinook	2,448	2,935	19.9%
	Fall Chinook	15,894	17,217	8.3%
	Steelhead	10,417	11,825	13.5%
	Coho	60,000	69,984	16.6%

Table 14 shows the estimated population changes due to the implementation of a FRO facility or MPF.

Table 14
Fish Population Changes with Structure (% Change from Projected Populations)

SPECIES	% CHANGE IN FISH POPULATION WITH FLOOD RETENTION FACILITY (50% Impact)	% CHANGE IN FISH POPULATION WITH MULTIPURPOSE FACILITY
Spring Chinook	-8.1%	6.5%
Fall Chinook	-1.1%	0.3%
Steelhead	-4.0%	-7.4%
Coho	-1.9%	-0.6%
Total	**-2.1%**	**-1.1%**

Finally, Table 15 presents the effects on each fish species from some combination of a flood retention structure and one or more enhancement actions, as defined in Table 8. The impacts to spring Chinook differ considerably between the structure designs in that there is an 8% decline for flood retention facility and a 6.5% increase for the MPD option. Steelhead populations are worse off with a MPD option. While structures cause an overall reduction in fish populations (with the exception of a MPD structure with regard to Chinook), the combination of structures and enhancement actions all enhanced fish populations. The largest overall effect is observed for spring Chinook. The combination of enhancement projects enhances fish populations above any single action. However, the sum of single enhancement action impacts is not equal to the combination of these actions.

Table 15
Fish Population Changes with Combined Structure and Enhancement (% Change from Projected Populations)

SPECIES	LOW RIPARIAN ENHANCEMENT	HIGH RIPARIAN ENHANCEMENT	FR050 + LOW ENHANCEMENT	MULTIPURPOSE + LOW ENHANCEMENT	FRO50 + HIGH ENHANCEMENT	MULTIPURPOSE + HIGH ENHANCEMENT
Spring Chinook	49.6%	184.3%	21.9%	25.8%	164.7%	109.7%
Fall Chinook	8.4%	25.2%	6.5%	5.8%	22.8%	17.9%
Steelhead	14.3%	34.6%	9.7%	3.1%	32.1%	19.3%
Coho	23.0%	60.9%	19.7%	17.1%	58.5%	49.4%
Total	**20.1%**	**54.8%**	**16.2%**	**13.7%**	**51.9%**	**41.9%**

Note that in all cases, losses to fisheries from flood reduction structures are assumed to be within the range of current management practices. In addition, the losses in populations from a structure are only mitigated in this study when increases from corresponding enhancement projects are considered. Accordingly, it is assumed that no project would, by itself, trigger an Endangered Species Act (ESA) action. There may be a variety of contributing factors that could cause an ESA listing, but it has been assumed that the Project Alternatives alone would be unlikely to be a singular cause. It is recognized that an ESA listing, such as that which occurred on August 29, 2014 with the Oregon spotted frog (USFWS 2014), would lead to significant additional economic losses, litigation costs, and/or enhancement actions and these costs could have far greater economic costs than those considered in this analysis. However, because this action was recent, the modeling of its economic outcome was prevented, an effort that will be necessary if this project extends beyond the feasibility phase.

11 Risk and Uncertainty Analysis

The Project Alternative impacts are modeled for some uncertainties. In most cases, probability distributions for the variables in the analysis were not available; therefore, a risk analysis (Monte Carlo simulation) could not be conducted. In addition, where probability distributions were unavailable, the study team did not provide probabilities associated with the projected ranges. Therefore, uncertainty is modeled in the COA analysis based on high and low values without probability distributions. The term uncertainty is used because the range of values selected for the analysis are based on available data to create low, medium, and high values. The ranges are subjective; however, the figures were reviewed by the Technical Committees as part of the COA process.

The medium values are referred to as the "expected values" or "expected case." These values, as presented above and in the appendices, represent the best estimates for values over the study period; they do not represent the 50th percentile values as there is no probability distribution associated with them. The low values presented in this section are often the minimum or lowest value found in the literature for each value; however, the low values are not necessarily the lowest possible value. The low values are used to estimate a "Low Impact" evaluation of Project Alternative impacts. Alternatively, the high values are often the highest values found in the literature or through surveys. The high values are not intended to represent the highest possible value. The high values are modeled in a "High Impact" scenario where the impact of each Project Alternative is estimated as the highest expected impact.

The uncertainty analysis does not include additional hydraulic modeling or additional HAZUS modeling.

12 Structure, Content, and Inventory

12.1 STRUCTURE, CONTENT, AND INVENTORY

The impact to structures estimated in the expected case is based on structure value, type, first floor elevation, and estimated inundation level. Uncertainty exists with regard to each of these components. For example, the level of structure inundation includes the uncertainty inherent in several areas of study such as the hydraulic modeling, structure location, and census block elevation data. In order to evaluate uncertainties related to the hydraulic modeling, additional hydrology data would be needed for HAZUS modeling; however, an uncertainty analysis of the hydraulic model is not part of the study scope. Additionally, changing structure characteristic assumptions would require additional HAZUS runs, which is also outside of the study scope.

Similarly, content and inventory damages are based on structure value and inundation level. In order to change the content and inventory damages for an uncertainty analysis, additional HAZUS modeling is required.

In absence of additional hydrology data, HAZUS was run for the Baseline and "with project" events where residential first floor elevations are adjusted either up or down by 1 foot.[23] The resulting variance in damage estimates to building and contents is approximately 12% between the +/- 1 foot scenarios. Because this variation does not include all uncertainty in the hydrology modeling, HAZUS modeling, and data assumptions, two scenarios with greater changes to the impacts are modeled. The first is a low impact scenario where HAZUS output for structure, content, and inventory damages are adjusted such that the damages are 70% of the Expected damages for these categories. The second scenario is the high impact scenario which assumes that HAZUS underestimates damages by 20%. These uncertainty assumptions are based on the uncertainty in the precision of first floor elevations as well as uncertainty for other HAZUS modeling assumptions that are not modified. The range of uncertainty is not meant to reflect the full range of possibilities. Rather, the range of uncertainty for structure, content, and inventory impacts was selected such that a reasonable amount of uncertainty is represented without resulting in large variations that may not be useful to decision makers.

12.2 FLOODPROOFING

As mentioned in the Project Alternative Cost section of this report, Flood-proofing non-residential buildings to the 100-year event is not expected to be 100% achievable. In the Expected case, it was assumed that 25% of the

[23] Based on 2 standard deviations. Watershed Science & Engineering. Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species – Description of Structures Database/Methodology for Finished Floor Estimation. August 18, 2014. Draft Memorandum.

non-residential buildings would be flood proofed. In a low impact scenario, only 10% of non-residential buildings are flood proofed and 50% are flood proofed in a high impact scenario. It is assumed that 100 percent of residential buildings are either flood proofed (or acquired).

13 Cleanup Costs

Uncertainty related to cleanup costs is modeled by adjusting the cost for debris removal. Alternatively, or in addition to the cost variance, the amount of debris generated could be modeled. However, the relevant hydraulic modeling was not available as part of the study scope. Therefore, only the cost for cleanup and debris removal is varied. For debris removal, survey respondents estimated the cost between $90 and $204 per ton of debris for finishes (drywall, insulation, etc.) and between $123 and $204 per ton for structural components (wood, brick, etc.). These values are used in high and low impact scenarios where the low impact scenario is the low value and the high impact scenario assumes the high value.

Similarly, building cleanup cost estimates varied from $3.33/square foot to $6.67/square foot based on informal survey information. These values are utilized for low and high impact scenarios. In addition, the number of non-residential buildings is adjusted based on the low and high impact scenarios for Flood-proofing.

Agriculture field cleanup cost and restoration is based on the number of acres flooded (per HAZUS) and $500/acre to restore the fields to planting condition. In addition re-seeding costs of $180 per acre are included[24]. A range of agriculture cleanup costs are estimated based on the range of costs to cleanup fields and for re-seeding. For field cleanup costs, $300/acre is assumed for the low impact scenario based on the Corps' 2003 study in the Chehalis River Basin. The high value is based on the 2007 event and is assumed to be the same as the expected value. For re-seeding costs, the range of cost is based on ranges provided in the Lewis County 2007 Disaster Recovery Strategy report[25] ($100 to $260 per acre).

14 Vehicle Damages

No uncertainty analysis has been performed for vehicle damage estimates. An uncertainty analysis would require additional hydrology data, which is not within the scope of this study.

15 Agricultural Losses

15.1 CROP DAMAGE

Damages to agricultural crops for the expected case are based on either loss of currently planted crops or the lost use of acreage due to flood damage restoration. Depending on the time of year a flood occurs, farmers may need to reseed fields or they may experience total loss. Crop damage is estimated based on the acreage flooded, cropping patterns by county, and value of crops by type

In a low impact scenario, damaged fields could be restored and utilized the growing season immediately following a flood event. This scenario assumes that crop production is not lost for events equal to or of less severity than the 100-year event.

A high impact scenario is consistent with the Expected case where all crops are assumed lost for the year following an event regardless of severity.

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[24] Please refer to Appendix F.

[25] Lewis County 2007 Flood Disaster Recovery Strategy. April 2009.

16 Transportation Delays

16.1 INTERSTATE 5

The WSDOT estimated that a 100-year event would cost $11.5 to $20.6 million from an I-5 closure. The range of costs is based on the share of through traffic that takes a detour rather than delays a trip. The higher figure assumes that all through traffic would take a detour in the event of a closure. For the expected case scenario, the COA uses the average between the two estimates provided by WSDOT. The low impact scenario is modeled assuming the low value, while the high impact value assumes the high value. This uncertainty analysis is assumed for both the State and Federal Perspectives. Uncertainty is not modeled for the basin Perspective.

17 Emergency Aid

Emergency aid is a combination of TRA and public assistance. TRA is the cost to house relocated families during a flood event. Public assistance costs are emergency protective measures to secure infrastructure such as bridges, roadways, or utilities.

17.1 TEMPORARY RELOCATION ASSISTANCE

Housing costs include reimbursements for hotel stays or public shelter costs. In order to model uncertainty in TRA impacts, the cost per claim is varied based on different claim types for the 2007 event. The low impact scenario assumes that all claims are based on lodging reimbursement costs. These claims are generally for shorter periods of relocation. Alternatively, the high impact scenario assumes that claims are equal to the average of rental assistance (longer-term housing) and lodging reimbursement. Table 16 summarizes the assumptions for the Expected, High, and Low impact scenarios.

Table 16
TRA Claim Cost Assumptions under Uncertainty

$2014/CLAIM			
EVENT RETURN INTERVAL	EXPECTED	HIGH	LOW
2 Year	$2,098	$4,074	$2,098
10 Year	$2,098	$4,074	$2,098
20 Year	$2,098	$4,074	$2,098
100-year	$4,074	$4,074	$2,098
500 Year	$4,074	$4,074	$2,098

Uncertainty regarding the number of claims filed is not modeled as this would require hydraulic modeling that is not part of the study scope.

17.2 PUBLIC ASSISTANCE

Public Assistance costs are calculated based on a ratio of costs compared with TRA costs. The Expected case ratio of Public Assistance costs to TRA costs in this study is based on the 2007 flood event. The low impact scenario is based on the ratio assumed in the Corps' 2003 study (ratio of 3.0).[26] A high impact scenario is assumed to be the same as the Expected case (ratio of 5.4).

17.3 BUSINESS INTERRUPTION

Business interruption costs are included in only the basin-wide perspective. In order to estimate a range of business interruption costs, additional hydraulic modeling would be required; however, this modeling is not part of the study scope.

18 Environmental

Key drivers of uncertainty in the environmental analysis include monetary values of fish and forecast fish populations. For the monetary values of fish, low, median, and high values were determined for each variable. For example, commercial fish values are driven by exogenous market conditions, trends, and the fishery itself is managed by the Pacific Forestry Management Council (PFMC). It is assumed that market prices respond to the relative demand for and supply of wild caught salmon (non-farmed) as set by PFMC and available substitutes. The values used in the model were determined using an average of historical values; these historical values account for recent trends in the commercial production of salmon. Ranges for commercial salmon values were established based on the historical high and low. However, these values do not account for the uncertainty that may result from a closed fishery due to low fish escapement and ESA listing.

A benefits transfer approach was used with sport and passive use values. Using estimated values from existing literature introduces multiple sources of uncertainty related to: the age of the study, the site characteristics and scale of the transfer study, and fish species types. The ocean sport value is the most site appropriate with values as recent as 2013. Ranges were established based on characteristics cited in the study (see Appendix K). River sport values are based on a sampling of several studies with ranges based on the low and high values from the sample.

The fish populations for the salmon and steelhead populations were estimated using the EDT model. Uncertainty ranges and distributions around the fish populations could not be estimated given the limitations of the EDT model. The fish populations represent an expected value into the overall analysis. Uncertainty in the outcomes for enhancement and impacts of the dams was evaluated with low and high fish response scenarios as shown in the enhancement action descriptions.

[26] U.S. Army Corps of Engineers. Centralia, Washington, Flood Damage Reduction. Final General Reevaluation Report. Economics Appendix D. June 2003.

5 Project Alternative Qualitative Impacts

1 Introduction

The qualitative impacts analyzed in this study include the following:

- Rail closure
- Livestock losses
- Environmental justice
- Cultural impacts
- Property values
- Health and safety
- Other Fish and Non-fish species

Each of these impacts is discussed below.

2 Rail Closure

Major flood events in the Chehalis River Basin result in floodwaters covering rail lines through the I-5 corridor. Similar to closures of I-5, rail line closures have significant impact on state and regional economies. These rail lines provide transportation ways for both freight and passenger trains. The rail line through the Twin Cities is classified as a major corridor and is owned by Burlington Northern Santa Fe Railroad (BNSF). Other rails lines in the area include the Puget Sound and Pacific Railroad (PSAP) line running north out of Centralia and West through Aberdeen, and Tacoma Rail Mountain Division originating just North of Chehalis and ending in Tacoma.

The BNSF rail line through Chehalis and Centralia is part of a major line connecting Portland and Seattle. This corridor averages 58 freight trains per day as well as 8 Amtrak Cascades trains. Amtrak's Coast Starlight, which connects Los Angeles and Seattle, operates once per day in each direction along this I-5 corridor.[27] One day of closure can affect up to 68 trains.

Attempts were made to contact BNSF regarding closure costs for the railway; however, BNSF did not provide comments to this study. Discussions with Tacoma Rail revealed that the damages to the rail lines would be minor and estimating the cost of rail closure would be a difficult task where the results would be challenging to defend. Primarily, cost estimation would require a full study similar to what was completed for the I-5 travel cost study where delay costs, operation, maintenance, and repair costs as well as supply chain effects are accounted for. For reference, each rail car that is delayed is the equivalent of four trucks delayed. The rail detour around the closure requires routes as far East as Walla Walla.

Information needed to monetize Project Alternative impacts on rail closures was unavailable; therefore, a qualitative review was undertaken instead.

[27] Washington State Department of Transportation. Washington State 2010-2030 Freight Rail Plan Appendices. December 2009.

2.1 FLOODPROOFING ONLY

Flood-proofing buildings would have no effect on the frequency or duration of rail closure.

2.2 HABITAT ENHANCEMENT ONLY

Based on the aquatic species enhancement studies, neither of the Habitat enhancement programs (Low or High) result in flood reduction impacts. Therefore, enhancement programs would have no effect on the frequency or duration of rail closure during flood events.

2.3 I-5 PROJECT

The I-5 Project has the potential to either increase or decrease the frequency and duration of rail closures. The data required to analyze potential rail closures in the I-5 Project case was not available.

2.4 FLOOD STORAGE

Flood storage reduces the overall flood level and duration of flooding within the entire basin. Therefore, a flood storage option could likely decrease the frequency and duration of rail closure.

3 Livestock

The 2007 flood event resulted in the loss of 1,600 livestock. Since 2007, five critter pads and two evacuation routes were constructed. According to the U.S. Department of Agriculture (USDA), no substantial decrease in livestock was observed during the 2009 event; however the 2009 event was unlike the 2007 event in that the flooding mainly occurred on the Newaukum River. With the installation of critter pads and evacuation routes, it is difficult to estimate livestock losses for future flood events. In addition, there are plans to add more critter pads to help protect livestock. At the time of this draft, not enough information was available to estimate livestock losses for the five flood events for the Baseline and each of the Project Alternatives. In addition, the planned build-out of critter pads increases the uncertainty related to whether or not additional flood hazard mitigation measures would provide additional benefit.

3.1 FLOODPROOFING ONLY

Flood-proofing buildings would likely have no effect on livestock loss.

3.2 HABITAT ENHANCEMENT ONLY

Based on the studies, neither of the habitat enhancement programs (Low or High) result in flood reduction impacts. Therefore, enhancement programs would not affect livestock loss.

3.3 I-5 PROJECT

The I-5 Project changes the flooding patterns in the basin but does not remove water. It will be important to evaluate these changes in flooding patterns when installing new critter pads since the hydraulic model shows that there is an increase in flooded agricultural acreage in some flood events. Otherwise, it is unlikely that the I-5 Project would impact livestock losses.

3.4 FLOOD STORAGE

Flood storage reduces the overall flood level and duration of flooding within the entire basin. Therefore, a flood storage option could decrease livestock losses; however, with the installation of additional critter pads these benefits may be reduced.

4 Environmental Justice

Natural disasters have regressive effects on affected populations. Studies have found that families with higher incomes were more prepared for disaster, more receptive to information regarding disaster preparedness, and experienced less damage than lower-income families.[28] In addition, homeownership was found to be a predictor for the degree of structure damage. These findings support the theory that low income populations are at higher risk for flood damages. The risk is further compounded since lower income families generally have less flexibility in employment schedules and less working capital for post-flood cleanup.

4.1 FLOODPROOFING ONLY

Flood-proofing buildings may have positive impacts on environmental justice by reducing property losses to low income families. However, Flood-proofing only may leave many buildings inaccessible during a flood event and these residents may still not be able to go to work.

4.2 HABITAT ENHANCEMENT ONLY

Based on the studies, neither of the habitat enhancement programs (Low or High) result in flood reduction impacts. Therefore, enhancement programs would not likely affect environmental justice.

4.3 I-5 PROJECT

The I-5 Project changes the flooding patterns in the basin but does not remove water. Based on the hydrology data, the net effect of the I-5 Project is a small reduction in structure and content damages. Therefore, the I-5 Project may provide some environmental justice benefits by reducing flood damages.

4.4 FLOOD STORAGE

Flood storage reduces the overall flood level and duration of flooding within the entire basin resulting in significant flood damage reduction potential. The reduced damages may positively impact environmental justice.

5 Cultural Impacts

Cultural resources include any archeological, built, or ethnographic property. Some cultural resources may be deemed significant to the history of the community, state, or nation and require preservation. Project Alternatives may impact cultural resources directly or indirectly, such as disturbance from construction, inundation, filling, changes in traffic patterns, or erosion from changes in land exposure.

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[28] Zhai G., Fukuzona T., Ikeda S. Modeling Flood Damage: case of Tokai flood 2000. Journal of the American Water Resources Association. February 2005: 77-92.

The Cultural Resources Review[29] prepared for the Chehalis Basin Flood Hazard Mitigation study identified cultural and historical resources potentially affected by each project. The Cultural Resources Review conducted site-specific studies that identified cultural resources within the proposed project areas. Excluded from study was a survey of cultural resources in the inundation areas for the storage options. Table 17 below summarizes the result of the Cultural Resources Review. Note that Flood-proofing and Enhancement Programs were not evaluated for cultural resources.

Table 17
Potential for Encountering Cultural Resources in each Project

PROJECT	CULTURAL RESOURCES PRESENT	HISTORY OF ETHNOGRAPHIC USE	LANDFORMS FAVORABLE TO CONTAIN CULTURAL RESOURCES	POTENTIAL FOR ENCOUNTERING CULTURAL RESOURCES
Flood-proofing	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated
Enhancement Programs	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated
Multipurpose Inundation	Unknown*	Yes	Yes	High
Flood Storage Only Inundation	Unknown*	Yes	Yes	High
I-5 Project	Yes	Yes	Yes	High

Notes:
*Project site area was not surveyed for cultural resources.

While no documented resources were found in the flood storage project areas, the Cultural Resources Review recommended that additional studies be conducted to rule out significant resources that are currently undocumented. In addition, consultation with the local Tribes is needed to help identify additional cultural or historic resources.

6 Property Values

Studies have shown that properties located within a floodplain have lower values by nearly 8%.[30] Project alternatives that reduce the amount of flooding will mean that homes no longer at risk of flooding might experience an increase in value.

6.1 FLOODPROOFING ONLY

Flood-proofing buildings may have positive impacts to property values within the floodplain as the risk of damages during a flood event are reduced.

6.2 HABITAT ENHANCEMENT ONLY

Based on the studies, neither of the habitat enhancement programs (Low or High) result in flood reduction impacts. Therefore, enhancement programs would not likely affect property values.

[29] Cascella, Melissa and J. Tait Edler. Cultural Resources Review for the Chehalis Basin Flood Hazard Mitigation Alternatives Analysis. Technical Memorandum. June 30, 2014.
[30] Bin, O. and S. Polasky. Effects of flood hazards on property values: evidence before and after Hurricane Floyd." *Land Economics* 80:4 (2004): 490-500.

6.3 I-5 PROJECT

The I-5 Project changes the flooding patterns in the basin but does not remove water. Based on the hydrology data, the net effect of the I-5 Project is a reduction in structure and content damages. Therefore, the I-5 Project may provide some net-benefit to property values within the floodplain by reducing the risk of flood damages.

6.4 FLOOD STORAGE

Flood storage reduces the overall flood level and duration of flooding within the entire basin resulting in significant flood damage reduction potential. The reduced damages may positively impact property values for properties located within the floodplain. No definitive research was found regarding dam construction impacts on nearby property values.

7 Economic Growth in Flood Prone Areas

Areas affected by repeat flood events are found to have long-term negative impacts on economic growth. Investment in capital as well as out-migration of residents contributes to slower economic growth in disaster prone areas.[31] Alternatively, investment in flood mitigation efforts have resulted in significant returns.[32] The returns on the Project Alternatives in this study are evaluated in the IO analysis found in Appendix L. The discussion below provides qualitative considerations in addition to the IO analysis.

7.1 FLOODPROOFING ONLY

Flood-proofing buildings reduces flood damage; however, Flood-proofing only may leave many buildings inaccessible during a flood event.

7.2 HABITAT ENHANCEMENT ONLY

Based on the studies, neither of the habitat enhancement programs (Low or High) result in flood reduction impacts. Therefore, enhancement programs would not likely affect economic growth beyond the project investment.

7.3 I-5 PROJECT

The I-5 Project results in I-5 remaining open during a 100-year event. While the interstate is open, local businesses within the floodplain may still experience closures or property losses during flooding. Businesses located outside of the floodplain may remain open and benefit from the I-5 Project.

7.4 FLOOD STORAGE

Flood storage reduces the overall flood level and duration of flooding within the entire basin resulting in significant flood damage reduction potential. In particular, many buildings may no longer be flooded in a 100-year event. While damages are significantly reduced, flood storage does not solve the flooding issues for all

[31] Cutler H., N. Dalsted, M. Shields, and S. Zahran. Economic impacts of Colorado flooding: identifying the dimensions and estimating the impacts of reduced tourism in Estes Park. Regional Economics Institute Center for Disaster and Risk Analysis, Colorado State University (2013): http://outreach.colostate.edu/REI/rei-docs/Economic%20issues%20of%20flood%20recovery%20Final.pdf

[32] Koon, B.W., D. Halstead, and M.E. Anderson. Economic Impact Analysis, Florida Division of Emergency Management's Bureau of Mitigation (2011).

homes and businesses. Therefore, flood storage may improve economic investment in the basin; however, the potential amount of increased investment is not clear.

8 Health and Safety

Project Alternatives may have multiple impacts on health and safety. The primary impacts evaluated in this study include the following theories:

- Access to I-5 during flood events may improve health and safety since emergency medical facilities might be easier to access.
- Reduced flooding levels improve health and safety by reducing the number of properties affected as well as reduced flood water levels.
- Reduced structure damage may improve health and safety as people may be able to return to their homes sooner after an event with minimal cleanup. In particular, Flood-proofing a home may eliminate cleanup costs and the risk of contamination from flood waters or molds.

The three factors above are evaluated for each project.

8.1 FLOODPROOFING ONLY

Flood-proofing buildings reduces flood damage and cleanup costs reducing risk of exposure to contaminated flood waters or mold growth following an event.

8.2 HABITAT ENHANCEMENT ONLY

Based on the studies, neither of the habitat enhancement programs (Low or High) result in flood reduction impacts. Therefore, enhancement programs would not likely affect health and safety when viewed from a flood reduction perspective. Health and safety from improved environmental habitat was not evaluated.

8.3 I-5 PROJECT

The I-5 Project results in I-5 remaining open during a 100-year event improving access to emergency medical facilities. In addition, the net effect of the I-5 Project is a reduction in the number of buildings flooded. This reduction may result in improved health and safety.

8.4 FLOOD STORAGE

Flood storage reduces the overall flood level and duration of flooding within the entire basin resulting in significant flood damage reduction potential. In particular, many buildings may no longer be flooded in a 100-year event. The reduced flood levels improve health and safety by reducing contact with contaminated flood water and exposure to mold after an event. In addition, lower flood levels improve access to emergency medical facilities as more roads may be passable.

9 Other Fish and Non-fish Species

Other Fish and Non-Fish Species are impacted by the Project Alternatives and enhancement actions. In particular, impacts on Other Fish and Non-Fish species correlate with changes in habitat. In general, results of model studies indicated that all dam alternatives reduced off-channel habitat, which would result in negative effects on aquatic and semi-aquatic species dependent on those habitats. Stream flow was found to be more limiting in the Upper Chehalis River reaches than the lower reaches for Other Fish Species based on Physical Habitat Simulation System (PHABSIM) model studies. Also, low flows during the drier summer months appeared to be a limiting factor for several species. In addition, proposed flows from the MPF would cause increases and decreases to the habitat available for Other Fish and Non-Fish Species downstream of the proposed dam site. Most Other Fish Species modeled, including the western toad, small and largemouth bass, large-scale sucker, and speckled dace generally sustained declines in habitat in response to all dam alternatives. However, there were both increases and decreases in modeled habitat depending on species and life stage. It is important to note that very little is known about non-salmonid aquatic and semi-aquatic (e.g., amphibian) species in the basin and more information is needed to support more detailed effects analyses in the future. Given the importance of flow and the currently poor understanding of non-salmonid species (other fish) in the basin, additional data are needed to corroborate these modeled findings.

Furthermore, the biological studies found that available information on Other Fish and Non-fish Species is too sparse to precisely direct enhancement activities that will positively benefit them. It is expected that enhancement projects that benefit juvenile coho salmon in side-channel habitat are likely to benefit the entire suite of Key Non-fish Species that occur in side-channel habitats (namely, northern red-legged frog, Oregon spotted frog, western pond turtle, North American beaver, and, if present, western toad). Juvenile coho co-evolved with these species, and limited information reveals that they can be abundant there where coho are present.[33] Nonetheless, the Non-fish Species' responses to enhancement approaches of any kind carry uncertainty because their responses have been so rarely tracked. For this reason, it will be crucial to track the response of Non-fish Species in enhancement projects involving juvenile coho salmon in side-channel habitats so that the results can adaptively modify future enhancement efforts.

9.1 FLOODPROOFING ONLY

Flood-proofing buildings would likely have no effect on Other Fish and Non-fish species.

9.2 HABITAT ENHANCEMENT ONLY

Based on impacts to juvenile coho salmon, the Low and High Enhancement Programs would likely have positive impacts on Other Fish and Non-fish Species.

9.3 I-5 PROJECT

It would require additional studies to determine whether or not the I-5 Project would impact Other Fish and Non-fish species. These additional studies may be completed during the permitting process.

9.4 FLOOD STORAGE

It would require additional studies to determine whether the Storage Projects would impact other fish and non-fish species. These additional studies would be completed during future phases.

[33]Henning, J.A., 2004. An Evaluation of Fish and Amphibian Use of Restored and Natural Floodplain Wetlands. Washington Department of Fish and Wildlife, Olympia, Washington. _Final Report. EPA Grant CD-97024901-1:81; and
Henning, J.A., and G. Schirato, 2006. Amphibian use of Chehalis River floodplain wetlands. *Northwestern Naturalist* 87(3):209-214.

6 State Perspective

1 Assumptions

The State Perspective includes only costs and impacts as they occur to the state as a whole. Transfers between regions within the state are not included. Impacts to areas outside of the State are not included. All dollars are in current (2014) dollars discounted using a 1.63%[34] discount rate.

For simplicity, flood reduction impacts are presented only for the Project Alternative Components that affect flood damage reduction. In particular, the "Storage + Airport Levee + Flood-proofing" impacts apply to all Project Alternatives that include storage and Flood-proofing (regardless of dam configuration).

2 Expected Case Results

2.1 STRUCTURE CONTENT AND INVENTORY

Table 18 summarizes the avoided depreciated structure and content value for each Project Alternative. Inventory value is not depreciated; however, structure and content replacement values are deprecated based on structure age. Flood-proofing alone reduces structure, content, and inventory damages in the 100-year event. Theoretically, Flood-proofing alone would also reduce structure, content, and inventory damages in a 500-year event; however, as previously noted, the impacts of Flood-proofing were not estimated in HAZUS. Therefore, the expected impact of Flood-proofing is likely underestimated in Table 18.

With the addition of either a storage option or the I-5 Project, additional structure, content, and inventory impacts are estimated. These additional impacts are due to the flood reduction capability of these projects in the 500-year event as well as lesser events for the non-residential buildings that are not flood proofed (see discussion on Flood-proofing achievability for non-commercial structures earlier in this report).

Table 18
State Perspective Depreciated Structure, Content, and Inventory

EXPECTED IMPACT, 100-YEAR NPV $2014, MILLIONS				
	STRUCTURE	CONTENT	INVENTORY	TOTAL
Flood-proofing	$64.1	$64.8	$4.6	$133.4
I-5 Project + Flood-proofing + Airport Levee	$49.3	$89.0	$14.1	$152.4
Storage + Flood-proofing + Airport Levee	$150.3	$247.9	$24.9	$423.1
Storage + I-5 Project + Flood-proofing + Airport Levee	$158.3	$256.4	$29.3	$444.0

[34] See Appendix A.

2.2 CLEANUP COSTS

Table 19
Cleanup Costs

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS					
	DEBRIS REMOVAL	RESIDENTIAL	NON-RESIDENTIAL	AGRICULTURAL	TOTAL
Flood-proofing	$7.1	$6.7	$0.4	$0.0	$14.2
I-5 Project + Flood-proofing + Airport Levee	$12.2	$10.1	$0.8	$0.0	$23.0
Storage + Flood-proofing + Airport Levee	$18.1	$15.9	$0.8	$16.1	$51.0
Storage + I-5 Project + Flood-proofing + Airport Levee	$26.9	$13.3	$1.4	$16.2	$57.8

2.3 VEHICLE DAMAGE

Table 20
Vehicle Damage

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$19.3
Storage + Flood-proofing + Airport Levee	$44.5
Storage + I-5 Project + Flood-proofing + Airport Levee	$48.1

2.4 AGRICULTURAL LOSSES

2.4.1 CROP DAMAGE

Prices for crops are based on average 5-year normalized state prices for all field crops. Vegetable prices are based on the 4-year average of national or state prices depending on which was available.

Table 21
Agriculture: Crop Damage

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	($0.1)
Storage + Flood-proofing + Airport Levee	$49.7
Storage + I-5 Project + Flood-proofing + Airport Levee	$60.0

2.5 TRANSPORTATION DELAYS

Table 22
Transportation (I-5)

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$20.7
Storage + Flood-proofing + Airport Levee	$16.2
Storage + I-5 Project + Flood-proofing + Airport Levee	$21.0

2.6 EMERGENCY AID

2.6.1 TEMPORARY RELOCATION ASSISTANCE

Table 23
Temporary Relocation Assistance

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$2.6
Storage + Flood-proofing + Airport Levee	$7.9
Storage + I-5 Project + Flood-proofing + Airport Levee	$9.5

2.6.2 PUBLIC ASSISTANCE

Table 24
Public Assistance

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$17.6
Storage + Flood-proofing + Airport Levee	$52.9
Storage + I-5 Project + Flood-proofing + Airport Levee	$63.9

2.7 ENVIRONMENTAL

Table 25
Environmental Impacts: Low Enhancement

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS							
	LOW ENHANCEMENT IMPACT, USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT USE VALUES	LOW ENHANCEMENT IMPACT, PASSIVE USE VALUES	STORAGE IMPACT PASSIVE USE VALUES	TOTAL IMPACT PASSIVE-USE VALUES	TOTAL IMPACT (USE+PASSIVE USE)
Flood-proofing	NA	NA	**NA**	NA	NA	**NA**	**NA**
I-5 Project	$27.8	$0.0	**$27.8**	$953	$0	**$0**	**$28**
Storage, Flood Retention	$22.5	($2.6)	**$20.0**	$771	($99)	**$673**	**$693**
Storage, Multipurpose	$19.6	($0.6)	**$19.0**	$649	($47)	**$602**	**$621**
Storage, Flood Retention + I-5 Project	$22.5	($2.6)	**$20.0**	$771	($99)	**$673**	**$693**
Storage, Multipurpose + I-5 Project	$19.6	($0.6)	**$19.0**	$649	($47)	**$602**	**$621**

Table 26
Environmental Impacts: High Enhancement

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS							
	HIGH ENHANCEMENT IMPACT, USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT USE VALUES	HIGH ENHANCE-MENT IMPACT, PASSIVE USE VALUES	STORAGE IMPACT PASSIVE USE VALUES	TOTAL IMPACT PASSIVE-USE VALUES	TOTAL IMPACT (USE+PASSIVE USE)
Flood-proofing	NA	NA	**NA**	NA	NA	**NA**	**NA**
I-5 Project	$77.5	$0.0	**$77.5**	$2,630	$0	**$0**	**$78**
Storage, Flood Retention	$73.5	($2.6)	**$70.9**	$2,493	($99)	**$2,395**	**$2,466**
Storage, Multipurpose	$59.9	($0.6)	**$59.3**	$2,018	($47)	**$1,972**	**$2,031**
Storage, Flood Retention + I-5 Project	$73.5	($2.6)	**$70.9**	$2,493	($99)	**$2,395**	**$2,466**
Storage, Multipurpose + I-5 Project	$59.9	($0.6)	**$59.3**	$2,018	($47)	**$1,972**	**$2,031**

3 State Expected Case Results Summary

Table 27 summarizes Project Alternative Costs, Impacts, Net Benefit, and Benefit/Cost ratios. Appendix O shows the results for the Project Alternatives when Flood-proofing and enhancement actions are excluded.

Table 27
State Perspective Results

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT/ COST
Flood-proofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood-proofing + Low Enhancement	$236	$28	$289	-$26	0.9
I-5 Alternative + Airport Levee + Flood-proofing + High Enhancement	$236	$78	$322	-$9	1.0
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood-proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$20	$477	$194	1.4
Multipurpose RCC with CHTR Fish Passage	$651	$19	$608	$62	1.1
Multipurpose RCC with Conventional Fishway	$651	$19	$636	$34	1.1
Multipurpose Rockfill with Experimental Fishway	$651	$19	$819	-$149	0.8
Storage + Airport Levee + Flood-proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$71	$511	$211	1.4
Multipurpose RCC with CHTR Fish Passage	$651	$59	$641	$69	1.1
Multipurpose RCC with Conventional Fishway	$651	$59	$669	$41	1.1
Multipurpose Rockfill with Experimental Fishway	$651	$59	$852	-$142	0.8
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood-proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$20	$559	$171	1.3
Multipurpose RCC with CHTR Fish Passage	$710	$19	$689	$40	1.1
Multipurpose RCC with Conventional Fishway	$710	$19	$717	$12	1.0
Multipurpose Rockfill with Experimental Fishway	$710	$19	$900	-$171	0.8
Storage + I-5 Alternative + Airport Levee + Flood-proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$71	$592	$189	1.3
Multipurpose RCC with CHTR Fish Passage	$710	$59	$722	$47	1.1
Multipurpose RCC with Conventional Fishway	$710	$59	$750	$19	1.0
Multipurpose Rockfill with Experimental Fishway	$710	$59	$933	-$164	0.8

4 Risk and Uncertainty Analysis

Several cost and impact scenario combinations were analyzed to determine a range of net benefits. The following scenarios were modeled for each Project Alternative:

- Expected Costs and Expected Impacts (presented in main body of report)
- Expected Costs with low and high impacts
- Lower Bound Costs with low, expected, and high impacts
- Upper Bound Costs with low, expected, and high impacts

Figures 6 and 7 below summarize the range of net benefits for Project Alternatives including Low Enhancement and High Enhancement actions, respectively (use-values only).

Figure 6
State Perspective Uncertainty Summary Low Enhancement Actions

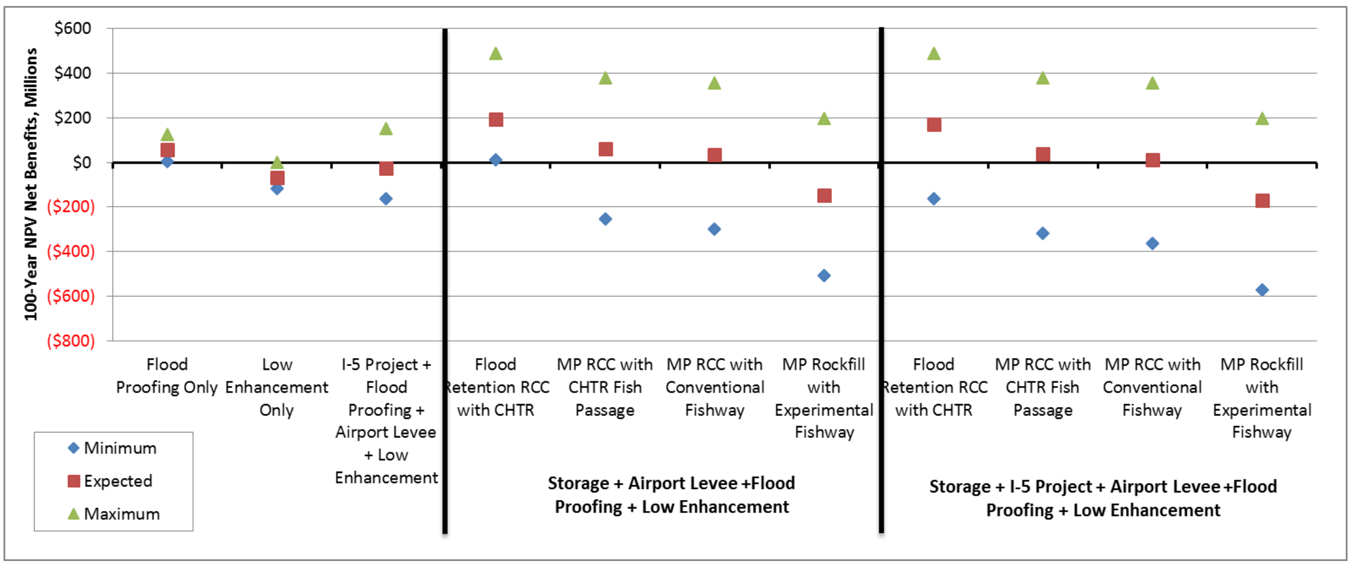
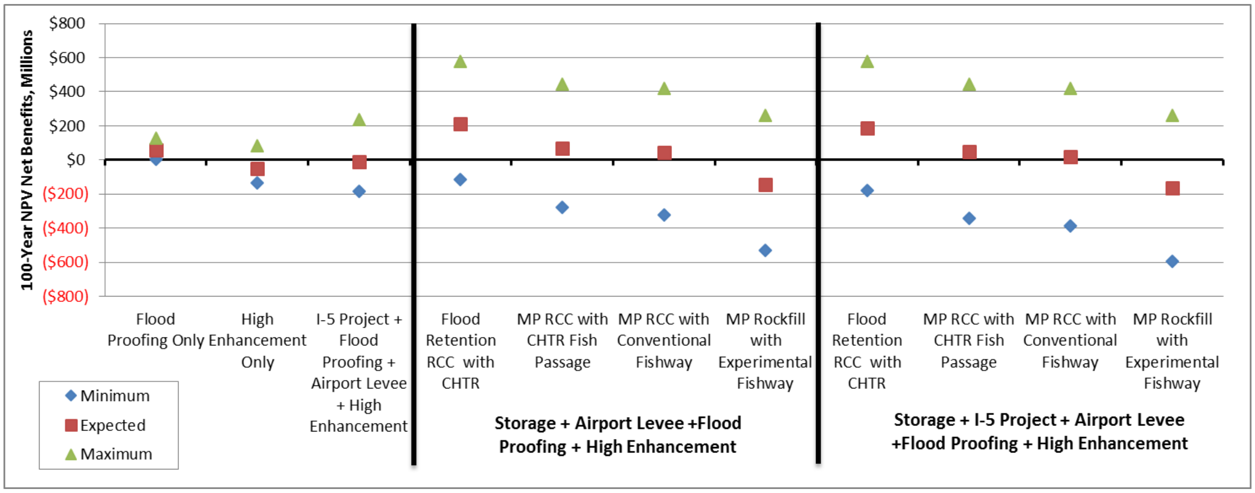


Figure 7
State Perspective Uncertainty Summary High Enhancement Actions



7 Basin-wide Perspective

1 Assumptions

The Basin-wide Perspective includes only costs and impacts as they occur to the basin (Lewis, Thurston, and Grays Harbor counties). Transfers within the basin are not included. Impacts to areas outside of the basin are not included. All dollars are in current (2014) dollars discounted using a 1.63%[35] discount rate. In addition, there is no distinction in environmental benefits and costs between the State and Basin-wide perspectives since data is not available for any of the types of fishermen to determine whether they are from the basin. Additionally, the passive use values associated with these fish extend beyond the basin; however, Basin-wide impacts could not be estimated.

2 Expected Case Results

2.1 STRUCTURE, CONTENT, AND INVENTORY

Table 28 summarizes the avoided depreciated structure and content for each building type. Inventory value is not depreciated; however, structure and content replacement values are depreciated based on structure age.

Flood-proofing alone reduces structure, content, and inventory damages in the 100-year event. Theoretically, Flood-proofing alone would also reduce structure, content, and inventory damages in a 500-year event; however, as previously noted, the impacts of Flood-proofing were not estimated in HAZUS. Therefore, the expected impact of Flood-proofing is likely underestimated in Table 28.

With the addition of either a storage option or the I-5 Project to Flood-proofing, additional structure, content, and inventory impacts are realized. These additional impacts are due to the flood reduction capability of these projects in the 500-year event as well as lesser events for the non-residential buildings that are not flood-proofed (see discussion on Flood-proofing achievability for non-commercial structures in section 3-6).

Table 28
Basin-wide Perspective Depreciated Structure, Content, and Inventory

EXPECTED ANNUAL IMPACT, 100-YEAR NPV $2014, MILLIONS				
	STRUCTURE	CONTENT	INVENTORY	TOTAL
Flood-proofing	$64.1	$64.8	$4.6	$133.4
I-5 Project + Flood-proofing + Airport Levee	$49.3	$89.0	$14.1	$152.4
Storage + Flood-proofing + Airport Levee	$150.3	$247.9	$24.9	$423.1
Storage + I-5 Project + Flood-proofing + Airport Levee	$158.3	$256.4	$29.3	$444.0

[35] See Appendix A.

2.2 CLEANUP COSTS

Table 29
Cleanup Costs

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS					
	DEBRIS REMOVAL	RESIDENTIAL	NON-RESIDENTIAL	AGRICULTURAL	TOTAL
Flood-proofing	$7.1	$6.7	$0.4	$0.0	$14.2
I-5 Project + Flood-proofing + Airport Levee	$12.2	$10.1	$0.8	$0.0	$23.0
Storage + Flood-proofing + Airport Levee	$18.1	$15.9	$0.8	$16.1	$51.0
Storage + I-5 Project + Flood-proofing + Airport Levee	$26.9	$13.3	$1.4	$16.2	$57.8

2.3 VEHICLE DAMAGE

Table 30
Vehicle Damage

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$19.3
Storage + Flood-proofing + Airport Levee	$44.5
Storage + I-5 Project + Flood-proofing + Airport Levee	$48.1

2.4 AGRICULTURAL LOSSES

2.4.1 CROP DAMAGE

Prices for field crops are based on average 5-year normalized state prices. Vegetable prices are based on the 4-year average of national or state prices depending on which was available.

Table 31
Agriculture: Crop Damage

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	($0.1)
Storage + Flood-proofing + Airport Levee	$49.7
Storage + I-5 Project + Flood-proofing + Airport Levee	$60.0

2.5 TRANSPORTATION DELAYS

I-5 closed for approximately 5 days during a 100-year flood event. WSDOT estimated the cost of this closure based on behavior surveys, traffic counters before and during the event, and the estimated cost of detour routes or delayed trips. WSDOT found that the 100-year event cost a total of $11.5 million, or $2.2 million per day on average. Of this amount it is estimated that $3 million ($0.5 million per day) in losses are due to local trips that are delayed or cancelled. Table 32 summarizes the expected impact to transportation delays on I-5.

Table 32
Transportation (I-5)

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$3.9
Storage + Flood-proofing + Airport Levee	$3.0
Storage + I-5 Project + Flood-proofing + Airport Levee	$3.9

2.6 EMERGENCY AID

2.6.1 TEMPORARY RELOCATION ASSISTANCE

Table 33
Temporary Relocation Assistance

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$2.6
Storage + Flood-proofing + Airport Levee	$7.9
Storage + I-5 Project + Flood-proofing + Airport Levee	$9.5

2.6.2 PUBLIC ASSISTANCE

Table 34
Public Assistance

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$17.6
Storage + Flood-proofing + Airport Levee	$52.9
Storage + I-5 Project + Flood-proofing + Airport Levee	$63.9

2.7 BUSINESS INTERRUPTION

Business interruption impacts are specific to businesses located in the basin and are included in the expected case analysis for the basin-wide Perspective. It should be noted that the business interruption impacts would be lower if some or all of these costs are recovered by businesses located within the basin but not affected by the floods. Ideally the analysis would include only the activity that is recovered outside of the basin; however, it is not known how much is recovered outside versus inside of the basin. Appendix I provides more information on how these impacts are estimated.

Table 35
Business Interruption

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS					
	INCOME	RELOCATION	RENTAL INCOME	WAGE	TOTAL
Flood-proofing	$0.0	$0.0	$0.0	$0.0	$0.0
I-5 Project + Flood-proofing + Airport Levee	$0.2	$0.1	$0.1	$0.4	$0.9
Storage + Flood-proofing + Airport Levee	$1.2	$0.5	$0.2	$3.2	$5.1
Storage + I-5 Project + Flood-proofing + Airport Levee	$1.2	$0.5	$0.2	$3.3	$5.2

2.8 ENVIRONMENTAL

Due to the difficulty of separating State and Basin-wide impacts, environmental impacts were not modeled for the Basin-wide perspective. Rather than exclude all environmental impacts in the basin-wide analysis, it was assumed that State and Basin-wide impacts are the same. This assumption results in a likely over-estimation of Basin-wide environmental impacts since the value of changes in fish populations are not localized to the basin only. Rather, the impacts include ocean catches of basin fish species in other states.

Table 36
Environmental Impacts Low Enhancement

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS							
	LOW ENHANCEMENT IMPACT, USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT USE VALUES	LOW ENHANCEMENT IMPACT, PASSIVE USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT PASSIVE-USE VALUES	TOTAL IMPACT (USE+PASSIVE USE)
Flood-proofing	NA	NA	**NA**	NA	NA	**NA**	**NA**
I-5 Project	$27.8	$0.0	**$27.8**	$953	$0	**$0**	**$28**
Storage, Flood Retention	$22.5	($2.6)	**$20.0**	$771	($99)	**$673**	**$693**
Storage, Multipurpose	$19.6	($0.6)	**$19.0**	$649	($47)	**$602**	**$621**
Storage, Flood Retention + I-5 Project	$22.5	($2.6)	**$20.0**	$771	($99)	**$673**	**$693**
Storage, Multipurpose + I-5 Project	$19.6	($0.6)	**$19.0**	$649	($47)	**$602**	**$621**

Table 37
Environmental Impacts High Enhancement

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014 , MILLIONS							
	HIGH ENHANCE-MENT IMPACT, USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT USE VALUES	HIGH ENHANCE-MENT IMPACT, PASSIVE USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT PASSIVE-USE VALUES	TOTAL IMPACT (USE+ PASSIVE USE)
Flood-proofing	NA	NA	**NA**	NA	NA	**NA**	**NA**
I-5 Project	$77.5	$0.0	**$77.5**	$2,630	$0	**$0**	**$78**
Storage, Flood Retention	$73.5	($2.6)	**$70.9**	$2,493	($99)	**$2,395**	**$2,466**
Storage, Multipurpose	$59.9	($0.6)	**$59.3**	$2,018	($47)	**$1,972**	**$2,031**
Storage, Flood Retention + I-5 Project	$73.5	($2.6)	**$70.9**	$2,493	($99)	**$2,395**	**$2,466**
Storage, Multipurpose + I-5 Project	$59.9	($0.6)	**$59.3**	$2,018	($47)	**$1,972**	**$2,031**

3 Basin-wide Expected Case Results Summary

Table 38 summarizes Project Alternative Costs, Impacts, Net Benefit, and Benefit/Cost ratios. Appendix O shows the results for the Project Alternatives when Flood-proofing and enhancement actions are excluded.

Table 38
Basin-wide Perspective Results

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT/ COST
Flood-proofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood-proofing + Low Enhancement	$220	$28	$289	-$42	0.9
I-5 Alternative + Airport Levee + Flood-proofing + High Enhancement	$220	$78	$322	-$25	0.9
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood-proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$643	$20	$477	$186	1.4
Multipurpose RCC with CHTR Fish Passage	$643	$19	$608	$54	1.1
Multipurpose RCC with Conventional Fishway	$643	$19	$636	$26	1.0
Multipurpose Rockfill with Experimental Fishway	$643	$19	$819	-$157	0.8

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS		PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT/ COST
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES)			
Storage + Airport Levee + Flood-proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$643	$71	$511	$203	1.4
Multipurpose RCC with CHTR Fish Passage	$643	$59	$641	$61	1.1
Multipurpose RCC with Conventional Fishway	$643	$59	$669	$33	1.0
Multipurpose Rockfill with Experimental Fishway	$643	$59	$852	-$150	0.8
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood-proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$698	$20	$559	$160	1.3
Multipurpose RCC with CHTR Fish Passage	$698	$19	$689	$28	1.0
Multipurpose RCC with Conventional Fishway	$698	$19	$717	$0	1.0
Multipurpose Rockfill with Experimental Fishway	$698	$19	$900	-$183	0.8
Storage + I-5 Alternative + Airport Levee + Flood-proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$698	$71	$592	$177	1.3
Multipurpose RCC with CHTR Fish Passage	$698	$59	$722	$35	1.0
Multipurpose RCC with Conventional Fishway	$698	$59	$750	$7	1.0
Multipurpose Rockfill with Experimental Fishway	$698	$59	$933	-$176	0.8

4 Risk and Uncertainty Analysis

Risk and uncertainty analysis is conducted using only depreciated values for structures and contents. Several cost and impact scenario combinations were analyzed to determine a range of net benefits. The following scenarios were modeled for each Project Alternative:

- Expected Costs and Expected Impacts (presented in main body of report)
- Expected Costs with low and high impacts
- Lower Bound Costs with low, expected, and high impacts
- Upper Bound Costs with low, expected, and high impacts

Figures 8 and 9 below summarize the range of net benefits for Project Alternatives including Low Enhancement and High Enhancement actions respectively (use-values only).

Figure 8
Basin-Wide Uncertainty Summary with Low Enhancement

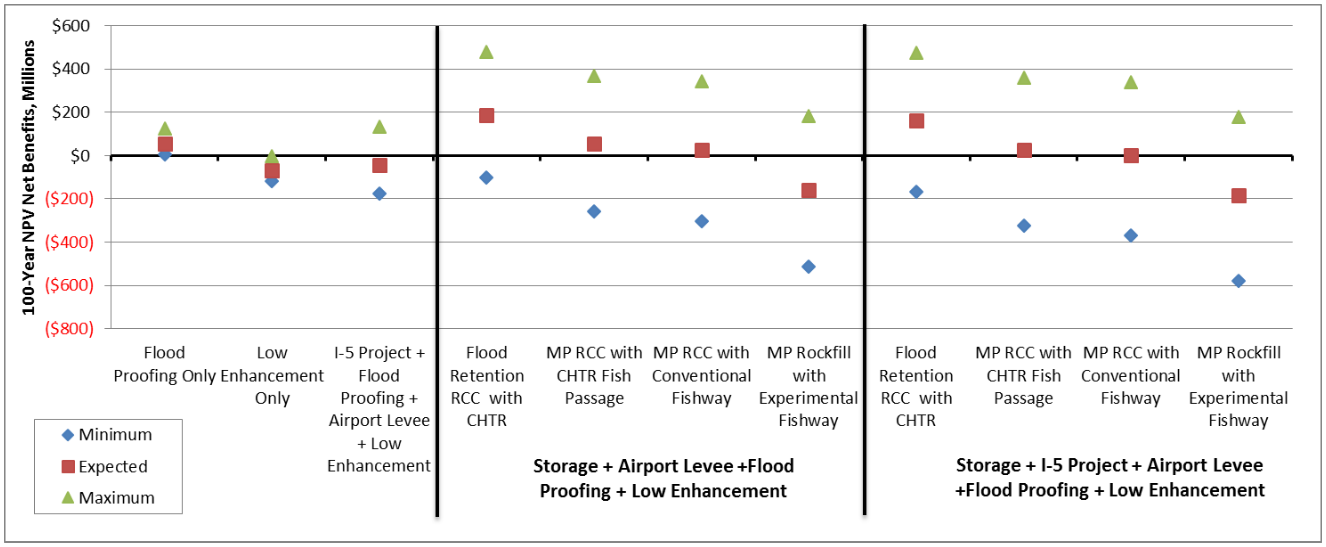
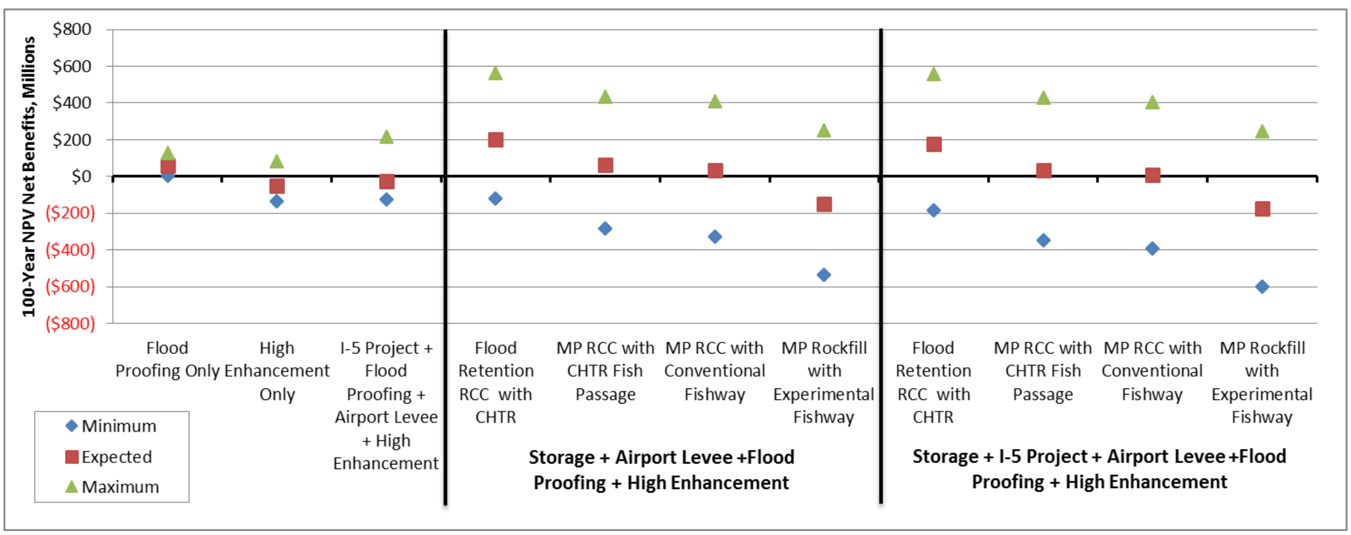


Figure 9
Basin-Wide Uncertainty Summary with High Enhancement



8 Federal Perspective

1 Assumptions

The Federal Perspective is analyzed according to the Principles and Guidelines[36] methodology under the NED account. The NED includes only costs and impacts as they occur to the Nation as a whole. Transfers between regions within the United States are not included. Impacts to areas outside of the United States (i.e., Canada) are not included. All dollars are in current (2014) dollars discounted using a 3.5% discount rate. [37]

2 Principles and Guidelines

In order to obtain Federal funding, studies using the Principles and Guidelines methodology must be used to evaluate water and related resources. The most recent Principles and Guidelines methodology was established in 1983; however, agencies are in the middle of updating these guidelines to include additional guiding principles and to integrate the National Environmental Policy Act process. While the interagency guidelines are currently under development and unavailable, the overarching principles can be incorporated into this study. The updated principles are described below.

2.1 UPDATED PRINCIPLES AND GUIDELINES

In the past, the Principles and Guidelines methodology placed larger emphasis on project costs and benefits that are more easily quantified. However, the revision of these principles has allowed for a more comprehensive assessment and evaluation of water resource alternatives. The list below summarizes the principles considered for this study and how this study addresses each:

- **Healthy and Resilient Ecosystems –** Services and effects of interest include water quality and nutrient regulation. The ASEP study includes measures and analysis of healthy ecosystems within the basin.
- **Sustainable Economic Development –** Federal investments in water resources should encourage sustainable economic development. This topic will is discussed qualitatively.
- **Floodplains –** Use of floodplains regarding of any adverse effect on public health, public safety, or floodplain function. Floodplain considerations have been evaluated as part of the study purpose.
- **Public Safety –** Project Alternative's' effect on public safety (injury, loss of life). Public safety is discussed qualitatively.
- **Environmental Justice –** Environmental justice is the fair treatment and meaningful involvement of all people regardless of ethnicity, race, national origin, economic status, etc. Environmental justice is discussed qualitatively.
- **Watershed Approach –** The watershed approach is a view that a multidisciplinary approach is needed in order to identify the effects for all interrelated land and water resources. The Chehalis Basin Flood Hazard Mitigation and Aquatic Species Enhancement study is a multidisciplinary approach to flooding issues in the Chehalis Basin.

The COA includes discussions specifically related to public safety, economic development, and environmental justice. The other principles have been addressed as part of the study process as a whole.

[36] Water Resources Council. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. March 10, 1983.
[37] See Appendix A.

In addition to the above updates, the Principles and Guidelines methodology requires specific methodologies for evaluating water resource alternatives. Mainly, an NED analysis must be based on or include the following key assumptions:

- Depreciated values for structure and content
- Depreciated vehicle values
- Costs and impacts that affect the nation as a whole (excluding transfers between regions)
- Exclusion of costs or impacts that accrue outside of the country
- Discount rate determined annually by the Office of Management and Budget (OMB)
- Exclusion of impacts on growth in floodplains (assumes floodplain development and population is constant over study period)

The Corps evaluates alternatives based on net benefits or benefit/cost ratios. The preferred alternative is generally the alternative with the highest net benefit (or benefit/cost ratio); however, a tradeoff analysis between monetized and non-monetized impacts allows an alternative without the highest benefit/cost ratio to be selected. This study uses the methodology consistent with the Corps methodology as one evaluation option; however, no alternative is selected as the preferred alternative.

3 Expected Case Results

3.1 STRUCTURE CONTENT AND INVENTORY

Table 39 summarizes the depreciated structure and content for each building type. Inventory value is not depreciated; however, structure and content replacement values are depreciated based on structure age. Flood-proofing alone reduces structure, content, and inventory damages in the 100-year event. Theoretically, Flood-proofing alone would also reduce structure, content, and inventory damages in a 500-year event; however, as previously noted, the impacts of Flood-proofing were not estimated in HAZUS. Therefore, the expected impact of Flood-proofing in Table 39 is likely underestimated.

With the addition of either a storage option or the I-5 Project to Flood-proofing, additional structure, content, and inventory impacts are realized. These additional impacts are due to the flood reduction capability of these projects in the 500-year event as well as lesser events for the non-residential buildings that are not flood proofed (see discussion on Flood-proofing achievability for non-commercial structures earlier in this report).

Table 39
Depreciated Structure, Content, and Inventory

EXPECTED ANNUAL IMPACT, 100-YEAR NPV $2014, MILLIONS				
	STRUCTURE	CONTENT	INVENTORY	TOTAL
Flood-proofing	$36.0	$36.4	$2.6	$75.0
I-5 Project + Flood-proofing + Airport Levee	$18.7	$35.9	$7.0	$61.6
Storage + Flood-proofing + Airport Levee	$84.6	$139.4	$14.0	$238.0
Storage + I-5 Project + Flood-proofing + Airport Levee	$89.0	$144.2	$16.5	$249.7

3.2 CLEANUP COSTS

Table 40
Cleanup Costs

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS					
	DEBRIS REMOVAL	RESIDENTIAL	NON-RESIDENTIAL	AGRICULTURAL	TOTAL
Flood-proofing	$4.0	$3.8	$0.2	$0.0	$8.0
I-5 Project + Flood-proofing + Airport Levee	$6.8	$5.7	$0.4	$0.0	$12.9
Storage + Flood-proofing + Airport Levee	$10.2	$9.0	$0.4	$9.1	$28.7
Storage + I-5 Project + Flood-proofing + Airport Levee	$15.2	$7.5	$0.8	$9.1	$32.5

3.3 AGRICULTURAL LOSSES

Prices for crops are based on average 5-year normalized national prices for all field crops. Vegetable prices are based on the 4-year average of national or state prices depending on which was available.

Table 41
Agriculture: Crop Damage

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$0.1
Storage + Flood-proofing + Airport Levee	$62.9
Storage + I-5 Project + Flood-proofing + Airport Levee	$64.8

3.4 TRANSPORTATION DELAYS

Table 42
Transportation (I-5)

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$11.7
Storage + Flood-proofing + Airport Levee	$9.1
Storage + I-5 Project + Flood-proofing + Airport Levee	$11.8

3.5 EMERGENCY AID

1.1.1.1. Temporary Relocation Assistance

Table 43
Temporary Relocation Assistance

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$1.5
Storage + Flood-proofing + Airport Levee	$4.4
Storage + I-5 Project + Flood-proofing + Airport Levee	$5.3

1.1.1.2. Public Assistance

Table 44
Public Assistance

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014, MILLIONS	
Flood-proofing	$0.0
I-5 Project + Flood-proofing + Airport Levee	$9.9
Storage + Flood-proofing + Airport Levee	$29.8
Storage + I-5 Project + Flood-proofing + Airport Levee	$36.0

3.6 ENVIRONMENTAL

Environmental impacts are estimated for the Federal Perspective including only use values.

Table 45
Federal: Environmental Impacts Low Enhancement

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE, MILLIONS $2014			
	LOW ENHANCEMENT IMPACT, USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT USE VALUES
Flood-proofing	NA	NA	NA
I-5 Project	$15.1		$15.1
Storage, Flood Retention	$12.2	($1.4)	$10.8
Storage, Multipurpose	$10.6	($0.3)	$10.3
Storage, Flood Retention + I-5 Project	$12.2	($1.4)	$10.8
Storage, Multipurpose + I-5 Project	$10.6	($0.3)	$10.3

Table 46
Federal: Environmental Impacts High Enhancement

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE, MILLIONS $2014			
	HIGH ENHANCEMENT IMPACT, USE VALUES	STORAGE IMPACT USE VALUES	TOTAL IMPACT USE VALUES
Flood-proofing	NA	NA	NA
I-5 Project	$42.1		$42.1
Storage, Flood Retention	$39.9	($1.4)	$38.5
Storage, Multipurpose	$32.5	($0.3)	$32.2
Storage, Flood Retention + I-5 Project	$39.9	($1.4)	$38.5
Storage, Multipurpose + I-5 Project	$32.5	($0.3)	$32.2

4 Federal Expected Case Results Summary

Table 47 summarizes Project Alternative Costs, Impacts, Net Benefit, and Benefit/Cost ratios.

Table 47
Federal Perspective Results

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT/ COST
Flood-proofing Only	$83	$0	$92	-$8	0.9
Low Enhancement Only	$0	$15	$95	-$80	0.2
High Enhancement Only	$0	$42	$128	-$86	0.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood-proofing + Low Enhancement	$109	$15	$290	-$167	0.4
I-5 Alternative + Airport Levee + Flood-proofing + High Enhancement	$109	$42	$324	-$173	0.5
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood-proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$11	$465	-$53	0.9
Multipurpose RCC with CHTR Fish Passage	$401	$10	$581	-$169	0.7
Multipurpose RCC with Conventional Fishway	$401	$10	$613	-$202	0.7
Multipurpose Rockfill with Experimental Fishway	$401	$10	$794	-$383	0.5
Storage + Airport Levee + Flood-proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$39	$498	-$59	0.9
Multipurpose RCC with CHTR Fish Passage	$401	$32	$614	-$181	0.7
Multipurpose RCC with Conventional Fishway	$401	$32	$646	-$213	0.7
Multipurpose Rockfill with Experimental Fishway	$401	$32	$827	-$394	0.5

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT/ COST
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood-proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$11	$548	-$106	0.8
Multipurpose RCC with CHTR Fish Passage	$430	$10	$663	-$223	0.7
Multipurpose RCC with Conventional Fishway	$430	$10	$696	-$255	0.6
Multipurpose Rockfill with Experimental Fishway	$430	$10	$877	-$436	0.5
Storage + I-5 Alternative + Airport Levee + Flood-proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$39	$581	-$112	0.8
Multipurpose RCC with CHTR Fish Passage	$430	$32	$697	-$234	0.7
Multipurpose RCC with Conventional Fishway	$430	$32	$729	-$266	0.6
Multipurpose Rockfill with Experimental Fishway	$430	$32	$910	-$447	0.5

5 Risk and Uncertainty Analysis

Several cost and impact scenario combinations were analyzed to determine a range of net benefits. The following scenarios were modeled for each Project Alternative:

- Expected Costs and Expected Impacts (presented in main body of report)
- Expected Costs with low and high impacts
- Lower Bound Costs with low, expected, and high impacts
- Upper Bound Costs with low, expected, and high impacts

Figures 10 and 11 below summarize the range of net benefits for Project Alternatives including Low and High Enhancement actions, respectively.

Figure 10
Federal Uncertainty Analysis Summary Low Enhancement

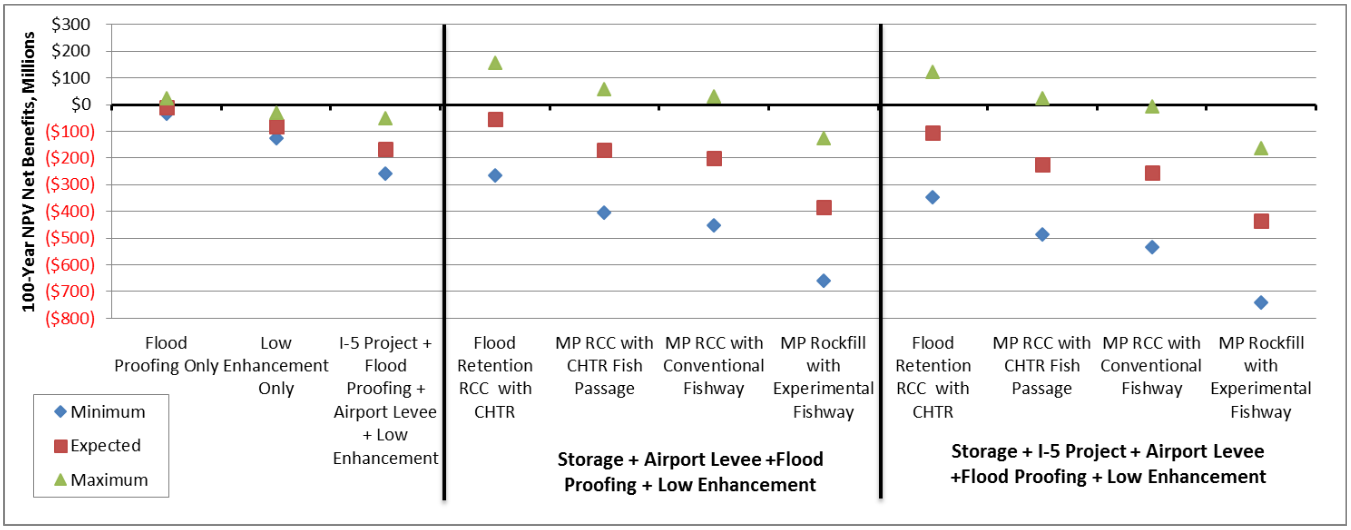
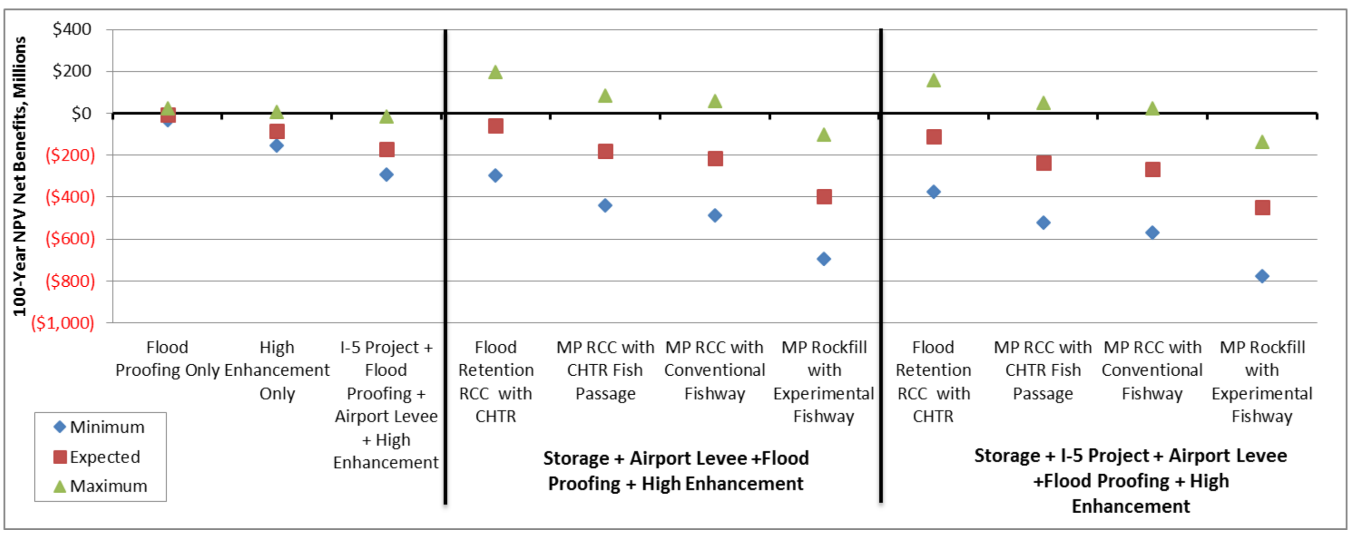


Figure 11
Federal Uncertainty Analysis Summary High Enhancement



9 Summary

1 Key Findings

The Comparison of Alternatives revealed the following:

- The analysis shows that the biggest driver for benefit comes from reducing the damage to structure, content and inventory.
- When impacts are quantified, the cost of the two suites of habitat enhancement programs analyzed is higher than their predicted economic value using just user values. However, if non-use values and qualitative benefits are included, the economic benefits predicted far exceed the costs.
- Flood proofing is a viable solution to eliminating residential damage to structure, content and inventory. However, it is unlikely to eliminate all damages to non-residential structures, content and inventory. In addition, flood proofing will not solve the issue of flooded roads and agricultural lands. Finally, the climate change scenarios demonstrate that flood damage and the benefit from flood proofing will increase under both the 18% and 90% scenarios.
- The cost to construct walls and levees to protect I-5 exceed the estimated economic benefits.
- Either alone or combined with other projects, a flood water storage facility in the Upper Chehalis Basin show a positive net benefits under the State and Basin perspectives. Under the Federal perspective with a higher discount rate, a water retention only structure has a positive Benefit-Cost Analysis (BCA) when combined with floodproofing. The BCA under the federal perspective is not positive for the combination of water retention, I-5, floodproofing, and aquatic species enhancement.
- The baseline expected estimated damages over a 100-year period for the Basin is in the order of over $3.5 billion. None of the Basin-wide alternatives will mitigate all flooding damages in the Basin. In addition, the study alternatives are designed based on flooding during a "design 100-year flood." If project alternatives are implemented, flooding damages may still occur during floods that are different from the "design 100-year flood."
- Including climate change assumptions increases non-environmental benefits for most project alternatives. The specific results can be found in Appendix M for the non-environmental climate change impacts and Appendix K for the environmental climate change impacts.

10 Glossary

100-Year Flood Event	A flood event that is expected to occur on the mainstem Chehalis River once every 100 years.
Anadromous Fish	Refers to fish such as salmon which migrate up rivers from the sea to spawn.
Alternative	Combinations of one or more Projects
Baseline	Without Project conditions
Basin-wide	Lewis, Thurston and Grays Harbor counties
Benefit Transfer Method	Method used to estimate economic values for ecosystem services by transferring information from studies already completed in another location or context.
Benefit-Cost Analysis	Conceptual framework that quantifies in monetary terms as many of the costs and benefits of a project as possible
Cap and Trade	System for trading carbon dioxide allowances in an effort to reduce overall emissions
Chehalis Basin	Includes Lewis, Thurston, and Grays Harbor Counties
Climate Change	Any change in temperature, precipitation or other weather conditions that is sustained over a period of time.
Culture Resource	Any archeological, built, or ethnographic resources; regardless of whether it has been formally evaluated for its potential to be eligible for listing in the National Register of Historic Places
Decision Makers	Washington State legislators
Depreciated Replacement Value	Replacement costs less depreciation based on structure type, age, and condition.
Economic Benefit	A positive change in economic conditions whether measured or qualitative.
Economic Impact	Includes both economic benefits and economic costs. May be defined as negative or positive.
Ecosystem	A community of living organisms in conjunction with the nonliving components of their environment, interacting as a system.
Flood Proofing	Raising of residential structures to withstand a 100-year flood event or structural measures added to non-residential structures to withstand damage during a 100-year flood event.
Flood Retention	Flood water storage in the Upper Chehalis Basin resulting in flood damage reduction.

Flood Retention Facility	A dam with flood retention capability.
Floor Area	Square footage of buildings
Full Replacement Value	The cost to replace or rebuild a damaged structure and its contents in new condition.
Habitat Restoration	Refers to habitat restoration actions as described in this document.
HAZUS	A flood hazard model developed by FEMA used to estimate flood damage reduction for Project Alternatives.
Historic Property	Any cultural resource that has been determined eligible for listing in the National Register of Historic Places
Income Recapture Factor	Percent of lost income recaptured after business reopens
Input-Output Modeling	Quantitative analysis representing relationships (dependence) between industries in an economy
Least Cost Analysis	Based on benefit/cost analysis
Levee	An embankment built to prevent overflow of a river.
Local Tribes	Chehalis, Quinault, or other Nationally recognized Tribes located in Lewis, Thurston, or Grays Harbor Counties.
Market Prices	Economic price for which a good or service is offered in the marketplace.
Mid-Columbia Prices	Market price of wholesale electricity traded at the Mid-Columbia trading hub.
Monte Carlo Simulation	A broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. Often used in risk analysis where probability distributions are known.
Net Present Value	Discounted value of a time series of cash flows.
Occupancy Class	Refers to occupancy type for non-residential buildings. For example, hospital, retail, or, restaurant.
Option Value	The value an individual places on their potential future ability to use a resource even though it is not currently used and the likelihood of future use is very low.
Passive Use Values	The value that residents in the State of Washington assign to Fish even if they never have or never will use it. It is distinguished from use value, which people derive from direct use of the good.
Profit	Also referred to as net revenue, is the realized financial benefit from revenue gained from business activity which exceeds the expenses, costs and taxes needed for the business activity.
Project	Refers to individual components included in an Alternative
Project Team	Multidisciplinary team of consultants contracted with the State of Washington to complete the Chehalis Flood Hazard Mitigation studies.

Public Assistance	Subcategory of Emergency Aid that includes emergency protective measures for roadways or other important infrastructure.
Real Discount Rate	Rate that reflects the time preference for that analysis or the perspective from which the analysis is conducted.
Restoration	Refers to habitat restoration actions as described in this document.
Revenue	Income received from the sale of goods and services.
Riparian	The area of interface between land and a river or stream
Salmonid	The family of ray-finned fish that includes salmon, trout, chars, freshwater whitefishes and graylings
Scenario	Refers to conditions analyzed that differ from the expected case in costs and or impacts.
Stakeholder	Individuals or groups affected by flood reduction or habitat restoration actions undertaken in the Chehalis River Basin.
Total Economic Value	An economic concept which refers to the value derived by people from a natural resource. It is the aggregation of values from direct interaction (use value) and the passive use value.
Use Value:	The value gained by individuals from direct interaction with and enjoyment of the environmental resource. Use values for fish species include commercial fishing, sport and recreation fishing.
Watershed	An area of land where surface water from precipitation converges to a single point at a lower elevation and joins a nearby water body. For the purposes of this study, the watershed refers to areas within or encompassing the Chehalis River Basin (Water Resource Inventory Areas 22 and 23).
Work Group	Comprised of local stakeholders, government officials, Tribe representatives, and others formed to make recommendations to the Governor regarding flood hazard mitigation and aquatic species enhancement projects in the Chehalis River Basin.

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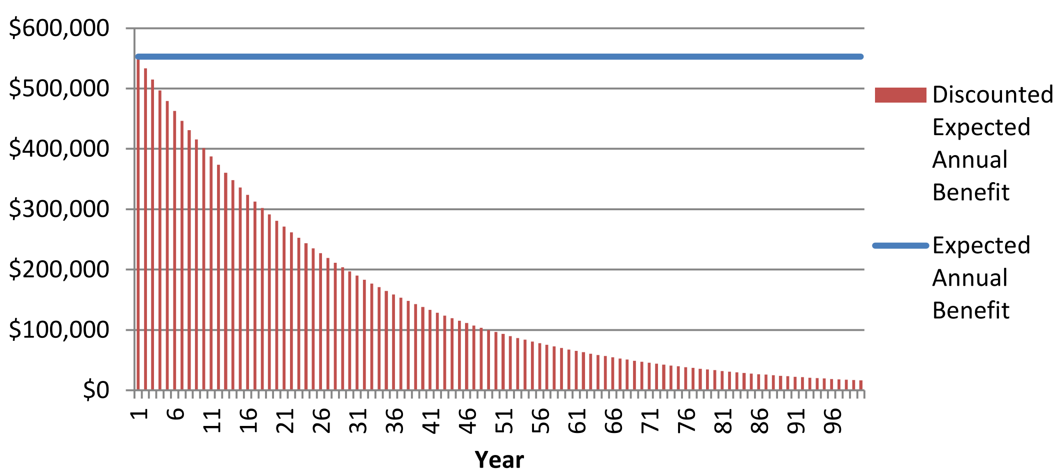
Appendix A: Discount Rates

Introduction

The monetized components in the COA are expressed in current 2014 dollars over the 100-year study period. Even though real 2014 dollars are used in the analysis, a real discount rate will need to be applied to future values to account for the time value of money. A real discount rate is one where inflationary factors are excluded (a risk-free interest rate). A real discount rate represents the premium one would have to pay in order to have a resource today rather than having that resource in the future. Future values are discounted to reflect the time preference for resources.

The specific real discount rates selected for an analysis reflect the time preference for that analysis, or the perspective from which the analysis is conducted. For example, a high discount rate values costs and benefits that occur in the near future higher while costs and benefits that occur in the later years of the study have comparatively less value. Conversely, a relatively low discount rate equalizes the weighting of costs or benefits in the near-term and the future. A discount rate of zero indicates that costs and benefits in the future are just as valuable as costs and benefits in the present (no discounting). Figure A-1 illustrates a fixed annual sum of money given two discount rates: 3.5% and 0%. Figure A-1 illustrates how a 3.5% discount rate places more weight on benefits in the early years. The 0% discount rate places equal weight for values in each year.

Figure A-1
Discounting Example



As such, the choice of which discount rate to use can affect which projects look more favorable in the COA analysis based on the timing of impacts. This appendix describes the selected methodology and assumptions related to the discount rate choice.

Perspective

The real discount rate assumptions vary depending on the perspective from which the analysis is being conducted. It was decided by the Policy Work Group that the COA task would summarize the estimated project costs and impacts from the following three perspectives:

1. State - From the perspective of the State of Washington. All costs and impacts are evaluated based on impacts to the State of Washington.
2. Basin-wide - A regional analysis consisting of Lewis, Grays Harbor, and Thurston counties.
3. Federal - from a national perspective consistent with analyses conducted by the Army Corp of Engineers and that follows the Principles and Guidelines methodology for NED accounts.

The discount rate, or rates, selected for each perspective should reflect the time preference for that perspective. The discount rates selected are discussed in more detail below.

STATE AND BASIN-WIDE

The real discount rates used in the analyses for the State and Basin-wide perspectives are not mandated. However, selecting an appropriate real discount rate, or rates, requires consideration of the affected regions and the respective residents. For example, a real discount rate that is too high may lead to suboptimal choices since benefits and costs in the near-term are valued more than costs and benefits in the later years. The result may be a transfer of wealth from future generations to current generations. Conversely, a discount rate that is too low may result in suboptimal investment by current generations leading to reduced investment from future generations as well.

For this reason, it is recommended that two real discount rate scenarios be analyzed for the State and Basin-wide perspectives. The first discount rate scenario will be based on market borrowing rates. The second discount rate scenario will consist of a lower rate. This lower discount rate scenario will illustrate the trade-off between environmental impacts in the future and non-environmental impacts in the near-term.

Market-Based Discount Rate

The most common risk-free interest rate used in economics analysis is U.S. Treasury Bonds with maturity similar to the time period of the selected study. The COA study period is 100 years; therefore, the longest maturity bond would apply. Currently, the interest rates for a 30-year U.S. Treasury Inflation-Protected Security are 1.36%[38] The OMB reports that the 2014 30-year real Treasury interest rate is 1.9%.[39] It is recommended that an average of these two discount rates is used for the State and Basin-wide studies (1.63%).

Low Discount Rate

A low discount rate scenario of 0% places equal value on dollars paid or received today as dollars paid or received in the future. This low discount rate ensures that environmental impacts realized in the later years of the study are given the same weight as non-environmental impacts realized in the near-term. Because environmental impacts, especially positive impacts, may require significant time in order to be realized, a 0% real discount rate is used so that decision makers can compare Project Alternatives regardless of the timing of costs or benefits.

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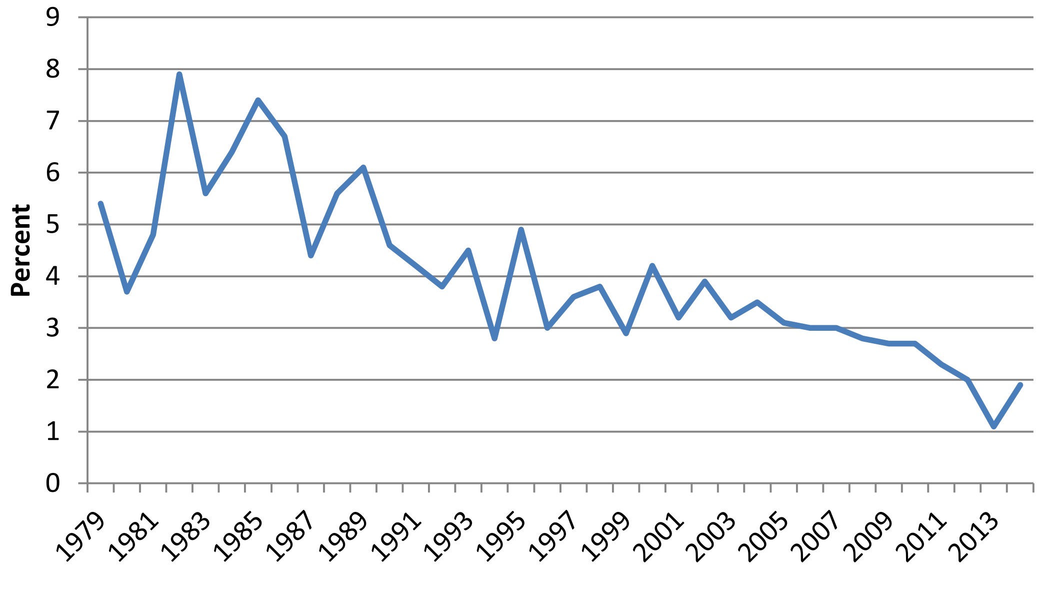
[38] U.S. Department of the Treasury. Daily Treasury Real Yield Curve Rates. March 19, 2014. http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=realyield

[39] Office of Management and Budget. Circular A-94. Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses. December 26, 2013. http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c

High Discount Rate
Current real discount rates are lower than what has been seen historically. Figure A-2 illustrates historic real treasury discount rates.

Figure A-2
Real Treasury Discount Rate



The average real discount rate for the period 1979 through 2013 is 4.08%.[40] Because current discount rates are low, it was suggested that a high discount rate scenario be analyzed as well. Based on historic values, a high discount rate of 7% was also analyzed for the State and Basin-wide perspectives.

FEDERAL PERSPECTIVE

For the Federal Perspective, the real discount rate is mandated annually based on average market yield on interest-bearing marketable securities in the United States that have 15 years or more remaining until maturity. This interest rate is calculated by the U.S. Department of the Treasury (Treasury). The rate may not be raised or lowered by more than one quarter of one percentage point in any year. The Federal discount rate has been reduced or held constant in each year since 1990. Note that because the real discount rate may not be lowered by more than one quarter of one percentage point, significant reductions in interest rates on marketable securities might lag behind the Treasury's calculated rate. When compared to the market rates proposed for the State and Basin perspectives, the Federal perspective rate is higher than the current market-based rates.

The real discount rate used in the National Economic Development (NED) analysis has been set at 3.5 percent for studies conducted in 2014.[41]

[40] 30-year Real Treasury Interest Rates. Office of Management and Budget. Circular A-94. Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses. December 26, 2013. http://www.whitehouse.gov/sites/default/files/omb/assets/a94/dischist-2014.pdf
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SUMMARY

The real discount rates used in this COA vary by study perspective. The State and Basin-wide perspectives do not require a specific discount rate. It is suggested that three discount rate scenarios be developed for these perspectives: a market-based discount rate (1.63%), a social discount rate (0%), and a high discount rate (7%). This range of real discount rates will provide decision makers with the information needed while minimizing any bias toward time preference. The Federal Perspective discount rate is reported Corps at 3.5%; this perspective follows the Principles and Guidelines[42] for NED analysis.

[42] Water Resources Council. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. March 10, 1983.

Appendix B: HAZUS-MH

Introduction

This study uses the FEMA HAZUS-MH flood model (HAZUS) to estimate flood damages in Baseline and Project Alternative scenarios. HAZUS is a widely used software providing standardized methodology for estimating potential losses due to flooding or other natural disasters. HAZUS uses geographic information system (GIS) technology to estimate structural, economic, and social impacts from natural disasters. This is a defensible methodology commonly used by federal, state, and local agencies for planning studies.

As with all loss estimation methodology, there is uncertainty associated with HAZUS. The uncertainty is related to how well regional characteristics and hazard events are defined. In the COA analysis, many of the model inputs are updated with more recent and accurate data compared with the default HAZUS inputs. HAZUS can be used to analyze hazards at various levels of sophistication, where "Level 1" is the least sophisticated and "Level 3" is the most sophisticated requiring the most effort. Previous studies in the Chehalis Basin that have used HAZUS were at a "Level 1" analysis (default building data) with "Level 3" updates to flood hazard data. The updates made in this analysis are consistent with a "Level 2" effort for building data and a "Level 3" for hazard information. Specific updates for this study are described in more detail below as well as in Appendix C.

Local Data

One of the most important inputs for flood modeling is the hydrology data. Through various projects funded by the Chehalis Basin Flood Authority and the State of Washington, a comprehensive hydraulic/hydrology (H&H) model (HEC-RAS) for the Chehalis River Basin has been developed. The HEC-RAS model has been calibrated to the 2009, 2007, and 1996 events. Calibration of the model removes much of the uncertainty related to flood depth and return intervals since the model accurately reproduces historic events. The HEC-RAS model is used to develop flood depth grids under Baseline and Project Alternative scenarios. The flood depth data from the Chehalis Basin hydraulic model is used directly in HAZUS to model 2, 10, 20, 100, and 500 year events in the basin.

Structure inventory characteristics and value is another important input into HAZUS. HAZUS methodology evaluates damage according to averages across census blocks. While averaging data across census blocks results in some uncertainty, the analysis is updated with 2010 County Assessor data for Lewis, Thurston, and Grays Harbor counties. The updated building stock data from the County Assessor limits modeling uncertainty compared with using the default 2000 Census data. The updated 2010 structure data therefore improves HAZUS estimates; however, there is also uncertainty related to the County Assessor data as not all assessor data is completely accurate. However, because HAZUS applies averages across census blocks, the county assessor data can be thought of as a large survey where the results are extrapolated to the population.

In addition, structure first floor elevation data has been updated according to the Structure Survey[43] conducted in the basin. The Structure Survey estimated first floor elevations for residential, commercial, and agricultural

[43] Watershed Sciences & Engineering. Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species – Description of Structures Database/Methodology for Finished Floor Estimation. August 18, 2014 Draft Memorandum.

structures. The survey evaluated 2,882 structures in the 100-year floodplain using Google Street View. An additional 2,630 structure first floor elevations were estimated using statistical averages from the sample of more than 2,800. Based on the large sample size, the results of the survey are accurate at the 99% level of confidence assuming a margin of error of 2%. In addition to this level of uncertainty, the Structure Survey methodology of counting steps was verified with field surveys of 178 structures. The first floor elevations estimated by Google Street View were found to be within 1 foot of actual elevations measured. Therefore, the structure first floor elevations are accurate within a 1-foot error band. This uncertainty is addressed in the risk and uncertainty analysis.

HAZUS Modeling Uncertainty

The above adjustments significantly improve the accuracy of HAZUS results; however, some modeling uncertainty remains. For example, HAZUS estimates losses by census block assuming a small number of buildings. Damage analysis of these small numbers make the Flood Model sensitive to rounding errors.[44]

Discussion

Project Alternative impacts are estimated based on the difference in damage estimates with and without project scenarios. Because HAZUS is used to define damages in both the Baseline and Project Alternative scenarios, estimation errors become unbiased when the difference is taken. For example, if HAZUS were to consistently overestimate damages, the difference in damages between Project Alternatives and the Baseline would be unbiased, or not consistently over or underestimated.

[44] U.S. Department of Homeland Security. Multi-Hazard Loss Estimation Flood Model User Manual. Washington, D.C.

Appendix C: Structures, Content, and Inventory

Introduction

This section describes building characteristic assumptions used in HAZUS to estimate flood damages and consequently how the impacts to structure, content, and inventory are measured. First, default HAZUS data and methodologies are provided. Many of these initial databases and assumptions are updated, as described below.

Building Stock Inventory

In order to determine the damage value to structures due to flooding, an initial assessment of residential and commercial buildings in the flooded area had to be developed. The level of flooding and the damages associated with flooding depend on first floor elevation, square footage of the building, height of the building, occupancy class, and foundation type. The default building stock inventory in HAZUS was developed based on the following sources:

- 2000 Census of Population and Housing
    - Income distribution
    - Occupancy class
    - Square footage
- Dun & Bradstreet Business Population Report (May 2006)
    - Occupancy class
- Department of Energy Housing Characteristics (1993)
    - Square footage
    - Foundation type
    - Number of stories
- Department of Energy, A Look at Residential Energy Consumption (1997)
    - Square footage (updates to 1993 data)
- Department of Energy, A Look at Commercial Buildings in 1995
    - Square footage

The 2000 Census is nearly 15 years old and the building and population characteristics have changed significantly since the 2000 Census. Therefore, the building stock inventory is updated with current County Assessor data for the three counties (Lewis, Grays Harbor, and Thurston). The County Assessor data updates the occupancy class and building square footage data as well.

Residential Structure Characteristics

The HAZUS flood damage estimate model includes home and structure inventories at the census block level. The model assumes that structure types are evenly distributed throughout each census block. Because this study analyzes relatively large regions (city, county, etc.), the results are reasonably reliable given these even distributions. Loss estimates for small study areas are less reliable (for example, one or two census blocks). Residential structures are defined assuming various characteristics including:

- Occupancy Class
- Square footage
- Building height
- Foundation type
- First floor elevation

Each of these is discussed below.

OCCUPANCY CLASS

The residential occupancy classifications include single family, mobile home, and multi-family by number of units. The information is obtained from the Department of Commerce Census of Housing.

SQUARE FOOTAGE

Default square footage is determined based on building type (from census data) and as a function of income. Median income for each census block group is assigned and the square footage calculated based on income ratio. The income ratio is defined as the median income for a census block divided by the median income for the census region. The typical square footage per unit for the Pacific Census Division is shown in Table C-1.

Table C-1
Income Ratios for Pacific Northwest

INCOME RATIO (I_K):	NO BASEMENT SQ. FT.	BASEMENT SQ. FT.
$I_k < 0.5$	1,300	975
$0.5 < I_k < 0.85$	1,500	1,125
$0.85 < I_k < 1.25$	1,700	1,275
$1.25 < I_k < 2.0$	1,900	1,425
$I_k > 2.0$	2,100	1,575

The average home size for homes in the Pacific region is 1,700 square feet without a basement and 1,275 square feet with a basement. This average home size is slightly smaller than what has been found in the Residential Building Stock Assessment (Northwest Energy Efficiency Alliance [NEEA])[45] for the

[45] Northwest Energy Efficiency Alliance. Residential Building Stock Assessment: Single Family Characteristics and Energy Use. October 31, 2012.

entire Pacific Northwest region (Washington, Oregon, Idaho, and Montana); however, these home sizes are consistent with the Lewis County Public Utility District Conservation Potential Assessment conducted in 2009.[46]

Home square footage was updated in the HAZUS model with current County Assessor data.

BUILDING HEIGHT

Table C-2 summarizes the default building height information in HAZUS for the West Coast. The default data is replaced with County Assessor data for this analysis. For reference, data from the NEEA 2012 Residential Building Stock Assessment: Single Family Characteristics and Energy Use[47] are also shown. The building height categories do not directly correlate between the two data sources. It was assumed that a 1.5-story building (NEEA study) is a 1-story building for the purposes of HAZUS. Similarly, a 2.5-story building is a 2-story building. These half stories are measured in the NEEA study as levels above ground; therefore, half stories are finished attics.

Table C-2
Single Family Building Height

BUILDING HEIGHT	HAZUS DEFAULT	NEEA STUDY WASHINGTON	LEWIS COUNTY ASSESSOR
1-Story	68%	67%	95%
2-Story	26%	33%	5%
3-Story	3%	0%	0%
Split-Level	3%	0%	0%

Similar to single family homes, for this analysis the height of multifamily homes is adjusted from the default HAZUS data. The default HAZUS data includes areas such as California, which has high-rise apartments. Lewis County Assessor data is used to update the number of stories for multi-family buildings (see Table C-3).

Table C-3
Multi-family Building Height

BUILDING HEIGHT	HAZUS DEFAULT	LEWIS COUNTY ASSESSOR
1-2 Stories	58%	98.8%
3-4 Stories	25%	1.2%
5+ Stories	17%	0%

[46] Later studies do not report average home square footage. Data was unavailable for Grays Harbor and Thurston Counties. EES Consulting, Inc. Lewis County PUD #1. Conservation Potential Assessment. Kirkland, Washington. October 29, 2009.
[47] Northwest Energy Efficiency Alliance. Residential Building Stock Assessment: Single Family Characteristics and Energy Use. October 31, 2012.

FOUNDATION TYPE

Foundation types are related to first floor elevation data in the HAZUS model. Structure damage curves are applied to the structures in each census block according to foundation type. Table C-4 shows the default HAZUS data for homes on the West Coast. Foundation data was incomplete in the County Assessor data and could not be used. Therefore, foundation types for single family homes are updated based on the NEEA study.

Table C-4
Foundation Type

	HAZUS DEFAULT	NEEA STUDY WASHINGTON[48]
Crawlspace	45%	62%
Basement	13%	27%
Slab	42%	11%

In addition, 221 homes have been raised (placed on piers or pilings) since 2000. Therefore, these homes will be included in census blocks within the 100-year floodplain. Because these homes are included in the structure survey completed by the Project Team, and the structure survey is used to update first floor elevations (discussed below), these homes have been accounted for in the updates to default HAZUS data.

FIRST FLOOR ELEVATION

Directly related to foundation type is the first floor elevation. Table C-5 summarizes the default data in HAZUS. Pre-Firm homes are those that were built prior to the area becoming part of the National Flood Insurance Program (NFIP). Post-FIRM applies to homes built after the area was considered a flooded area.

Table C-5
Riverine Area Base Floor Elevation (Feet)

	PRE-FIRM	POST-FIRM
Pile	7	8
Pier/Post	5	6
Solid Wall	7	8
Basement	4	4
Crawlspace	3	4
Fill	2	2
Slab-on-Grade	1	1

[48] Northwest Energy Efficiency Alliance. Residential Building Stock Assessment: Single Family Characteristics and Energy Use. October 31, 2012.

The Chehalis Project Team completed a structure survey that initially evaluated over 9,000 structures in the 100-year floodplain. Of these structures, those with the highest value were surveyed for first floor elevation. Approximately 2,880 structures in the floodplain were evaluated for first floor elevation. The first floor elevation survey consisted of using Google Street View to estimate first floor elevations by counting steps from the surface elevation. Therefore, in order for a structure to be included in the survey, the structure must be visible from street view. This methodology also assumes that steps are built uniformly or to code. Both the average and minimum above ground elevations were estimated. Table C-6 summarizes the surveyed structures. The average (mean) height above ground is used to calibrate HAZUS inputs. The height above ground from the structure survey is used to update the first floor elevations for residential and commercial buildings in Table C-5.

Table C-6
Residential First Floor Elevation above Ground

BUILDING TYPE	NUMBER	MEDIAN	MEAN
Residential	2,066	2.09	2.42
Manufactured Homes	82	2.62	2.78
Commercial	687	1.48	1.83
Agriculture	47	2.13	2.22

Based on the information from the structure survey, the following assumptions are used in HAZUS (Table C-7):

Table C-7
Riverine Area Base Floor Elevation

	PRE-FIRM FEET	POST-FIRM FEET
Pile	7	8
Pier/Post	5	6
Solid Wall	7	8
Basement	3.8	3.8
Crawlspace	2	2
Fill	2	2
Slab-on-Grade	1	1

Notes:
Table C-7 shows that only the basement and crawlspace first floor elevations needed updating.

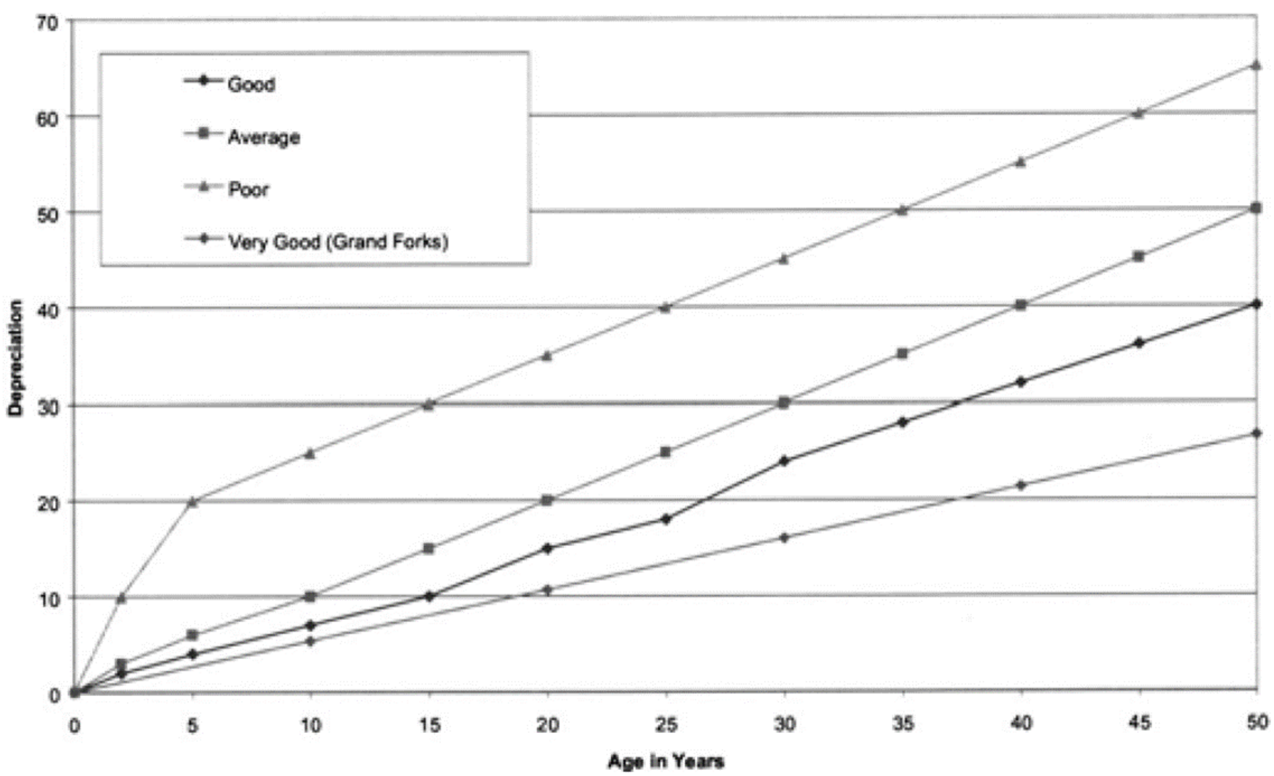
VALUE OF BUILDINGS

In order to determine structure damages from flooding, the value of buildings needs to be determined. In HAZUS, the General Building Stock "dollar exposure" is derived from the square footage values, which are sourced from the U.S. Census Bureau 2000 and Dun & Bradstreet 2002. Recall that the structure square footage data is updated with current County Assessor data. In addition, the values are updated at the same time.

HAZUS provides dollar exposure by building (the structure), contents, inventory, and the total of all three components. HAZUS also provides value based on replacement cost and depreciated replacement cost. The full replacement value is the engineering cost to replace or repair a building. This is not the appraised value or market value and does not include the land value. The depreciated replacement cost is the actual cash value for replacing/repairing a building and its contents. This methodology of using depreciated value tends to more closely reflect the payout by NFIP because age and/or quality of the building is a factor in the reimbursement amounts. Improvements above and beyond the pre-flood condition are paid for by the structure owner and are not costs attributed to flood damage.

Figure C-1 provides the depreciation curves used in HAZUS. If a flooded home is in good condition and 20 years old, the replacement costs are depreciated by approximately 20%. This depreciation reflects that a 20-year home does have some wear and tear. Including the full replacement cost could overestimate the benefit associated with an alternative as the replaced home will be in a better condition than before the flooding. Building condition is determined by census block. Conditions have been updated with current County Assessor data.

Figure C-1
Residential Depreciation Curve



Source: Scawthorn, Charles et al. HAZUS-MH Flood Loss Estimation Methodology. II Damage and Loss Assessment. Natural Hazards Review ASCE May 2006.

Alternatively, the assessed value for the home (structure) can be used without depreciation.

Commercial and Industrial Structure and Content Damages

The HAZUS flood damage estimate model includes home and structure inventories at the census block level. The model assumes that structure types are evenly distributed throughout each census block. Commercial and industrial structures are defined assuming various characteristics including:

- Occupation type
- Square footage
- Building height
- Foundation type
- First Floor elevation

Each of these is discussed below.

OCCUPANCY CLASS

The commercial occupancy classifications include Commercial (retail, wholesale, personal and repair, hospitals, entertainment, etc.), Industrial (classified by Standard Industrial Classification [SIC] codes), Agricultural, Religion/non-profit, Government, and Education. The information is obtained from the Dun & Bradstreet Business Population report (2006).

SQUARE FOOTAGE

The default data in HAZUS uses square footage based on typical building size by occupancy class. The average building size by occupancy class is updated according to square footage data from Dun & Bradstreet for Lewis County. Table C-8 shows the default square footage data from HAZUS. The square footage information is updated based on the County Assessor data. Use of the County Assessor data provides more accurate estimates that are specific to the three counties. Lewis County data is provided in Table C-8 for comparison. Not surprisingly, many of the average building sizes are smaller than the default data. This data reflects the city and town sizes found in Lewis County which primarily have smaller retail shops, hospitals, office buildings etc.

Table C-8
Commercial and Industrial Building Square Footage

OCCUPANCY CODE	OCCUPANCY TYPE	HAZUS DEFAULT	LEWIS COUNTY ASSESSOR
COM1	Retail Trade	110,000	6,340
COM2	Wholesale Trade	30,000	19,977
COM3	Personal and Repair Services	10,000	3,102
COM4	Business/Professional/Technical Services	80,000	3,485
COM5	Depository Institutions	4,100	3,515
COM6	Hospital	55,000	5,290
COM7	Medical Office	7,000	3,762

OCCUPANCY CODE	OCCUPANCY TYPE	HAZUS DEFAULT	LEWIS COUNTY ASSESSOR
COM8	Entertainment/Recreation	5,000	2,770
COM9	Theatres	12,000	5,897
COM10	Parking	145,000	361
IND1	Heavy Industrial	30,000	20,778
IND2	Light Industrial	30,000	16,610
IND3	Food/Drugs/Chemical	45,000	10,279
IND4	Metal/Minerals Processing	45,000	2,722
IND5	High Technology	45,000	905
IND6	Construction	30,000	10,153

BUILDING HEIGHT

Commercial and industrial building height is based on the year built, as show in in Table C-9. HAZUS utilized the Department of Energy's study[49] on commercial building types to develop the building height characteristics. The default building height characteristics for commercial buildings is updated with the County Assessor data.

Table C-9
Commercial and Industrial Building Height

VINTAGE	LOW RISE PERCENT OF TOTAL	MID-RISE PERCENT OF TOTAL	HIGH RISE PERCENT OF TOTAL
1949 or earlier	92	7	1
1950-1959	98	1	1
1960-1969	96	3	1
1670-1979	98	1	1
1980-1989	96	3	1
Post 1990	96	3	1

FOUNDATION OF TYPE AND FIRST FLOOR ELEVATIONS

HAZUS assumes that all commercial and industrial buildings are slab on grade foundations with first floor elevations of 1 foot. The Structure Survey estimated commercial minimum first floor elevations at 1.8 feet. The Structure Survey data is used to calibrate HAZUS input for first floor elevations.

[49] Department of Energy. A Look at Commercial Buildings in 1995 DOE/EIA-0625(97), Washington, D.C., Energy Information Administration Office of Energy Markets and End Use, U.S. Department of Energy, October 1998.

Buildings Flooded Comparison: HAZUS vs. Structure Survey

As part of the structure survey task, the number of buildings damaged for each flood event is estimated. These estimates are compared with HAZUS model runs to calibrate the HAZUS model to the structure survey model. While the structure survey is used to calibrate the HAZUS model, the two models cannot be directly compared. The structure survey methodology evaluates the number of buildings flooded based on individual building data whereas the HAZUS model estimates damages based on Census blocks. In particular, the structure survey includes multiple buildings per parcel whereas the HAZUS model includes one building per parcel. In addition, the structure survey applies 2-foot flood depth grids to each parcel. The HAZUS model applies the average flood depth to each census block. Because of these differences, it is difficult to compare output from the two models.

Summary

HAZUS default building characteristics are verified and updated according to available regional data. Most importantly, building first floor elevations are updated based on the Structure Survey results. These updates will result in an analysis that better reflects the damages observed in the study area from actual flooding events.

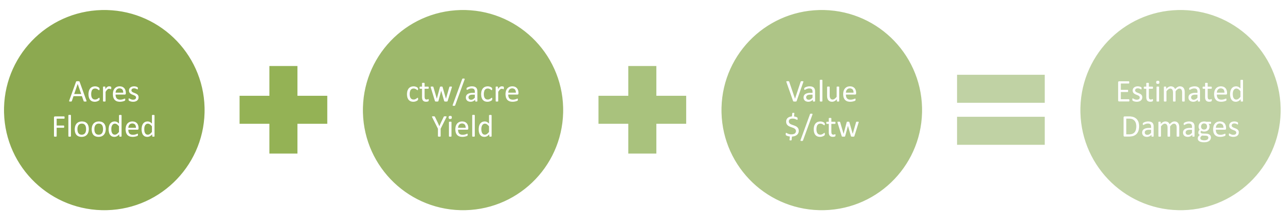
Appendix D: Agriculture

Agricultural damages are estimated for the loss of crops or crop production. Crop damage methodology is described first followed by a discussion of potential livestock losses.

Crop Damage

Crop damages due to flooding arise both when active crops are flooded and damaged as well as when agricultural lands are flooded and cannot be used for a period of time. This section describes the methodology for evaluating damages to crops. Crop damages are estimated for three perspectives: State, Basin-wide, and Federal. The primary difference between the perspectives is the prices used to value crops. Figure D-1 illustrates the crop loss valuation methodology.

Figure D-1
Crop Loss Valuation



Note: ctw = hundredweight is equal to 100 pounds

The valuation methodology is described in more detail below.

Acreage Flooded

The number of acres flooded for each flood event is estimated by HAZUS using flood depth grids developed from the hydrology model. Table D-1 shows the number of agricultural acres flooded under current (Baseline) conditions for each county as estimated by HAZUS. For comparison, it was estimated that more than 10,000 acres of agricultural land in Lewis County alone was flooded in the 2007 flood event (approximately a 200-year event). Because much of the county agriculture is grown near the Chehalis River, flooded acreage is significant throughout the basin.

Table D-1
Agricultural Acreage Flooded by County for Baseline Flood Returns

RETURN INTERVAL	GRAYS HARBOR	LEWIS	THURSTON	TOTAL
2-Year	2,708	6,544	2,220	**11,472**
10-Year	3,309	11,302	3,444	**18,055**
20-Year	3,489	12,926	3,886	**20,301**
100-Year	4,008	15,999	4,627	**24,634**
500-Year	4,246	17,676	4,943	**26,865**

These acres are assigned crop types based on historic crop harvests from the three counties.

CROP DATA

The USDA collects agricultural statistics every few years and completes an agriculture Census every 5 years. The most recent Census of Agriculture was published in May 2014 (2012 Census). NASS database is used to determine the number of acres harvested for each crop type. The acreage harvested is used to determine the share of acres generally committed to a crop type. Acreage harvested for both field crops and vegetables are averaged over the past 3 to 10 years to determine an expected cropping pattern. Crops with very few acres (less than 1 acre) or redacted data entries are excluded. Because crop plantings vary from year to year due to field rotation, prices, and other factors, the historic average acres harvested by crop type provides a normalized cropping pattern.

Crop units are estimated by applying crop yield data to acres harvested for each crop type. Crop yield data is based on the national average yields per acre for the period 2001 to 2011 for vegetables[50] and a 3-year average yield from the NASS database for field crops.

Acres flooded for each crop type are applied to yield per acre to estimate the total number of units (hundredweight or cwt, bushels, or tons) lost due to flooding.

CROP VALUE

Two prices are used to value crop losses. For the Federal perspective, 5-year average normalized prices are used for field crops.[51] The USDA publishes annually normalized prices for field crops; however, not for vegetables. Therefore, a 4-year average national price is used to value vegetable losses.
For the State and Basin-wide perspectives, average historic State level prices are used. When State level prices are unavailable, national prices are used instead.

SUMMARY OF DATA

Tables D-2 through D-7 summarize the data and assumptions for cropping patterns and value for each of the three counties.

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[50] U.S. Department of Agriculture. Agriculture Statistics 2011 and 2012. Chapter IV Statistics of Vegetables and Melons. http://www.nass.usda.gov/Publications/Ag_Statistics/2012/chapter04.pdf
[51] U.S. Department of Agriculture. Economic Research Service. Normalized Prices. http://www.ers.usda.gov/data-products/normalized-prices.aspx#.U5JVwvldV8E

Table D-2
Field Crops: Lewis County

CROP TYPE	ACRES HARVESTED (AVERAGE)	YIELD	UNITS	SHARE OF TOTAL ACREAGE	FEDERAL VALUE $2014/UNIT	STATE VALUE $2014/UNIT
Barley (Grain)	746.5	98.8	Bu/Acre	11%	$3.82	$3.83
Corn (Silage)	842.5	20	tons/Acre	12%	$3.57/Bu	$5.24/Bu
Wheat	1864	76	Bu/Acre	27%	$5.21	$6.23
Peas	205	10	cwt/Acre	3%	$341.25	$238.50
Hay	338.3	2.4	Tons/Acre	5%	$119.00	$162.37
Total Field Crop Acreage	3,996					

Notes:
Bu = Bushel
cwt = hundredweight is equal to 100 pounds

Table D-3
Vegetables: Lewis County

CROP TYPE	ACRES HARVESTED (AVERAGE)	AVERAGE YIELD CWT/ACRE	SHARE OF TOTAL ACREAGE	FEDERAL VALUE $2014/CWT	STATE VALUE $2014/CWT
Snap Beans	105	62	1.5%	$55.85	$55.63
Broccoli	3	148	0.0%	$36.63	$37.13
Cabbage	1	335	0.0%	$16.30	$15.70
Carrots	9	329	0.1%	$27.35	$25.30
Cauliflower	1	172.4	0.0%	$43.03	$41.27
Cucumbers	4	194.3	0.1%	$24.98	$24.98
Lettuce	7	364.4	0.1%	$21.68	$21.68
Onions dry	5	466.1	0.1%	$13.43	$36.50
Bell Peppers	2	313.2	0.0%	$38.40	$38.40
Chile peppers	1	179.7	0.0%	$28.70	$28.70
Potatoes	12	623	0.2%	7.76	7.35
Pumpkins	16	227.9	0.2%	$11.38	$11.38
Spinach	1	158	0.0%	$39.10	$39.10
Squash, Summer	4	156.3	0.0%	$31.95	$31.95
Squash, Winter	1	156.3	0.0%	$31.95	$31.95
Sweet Corn	1,456	188	20.7%	$26.85	$38.40
Tomatoes	2	298.5	0.0%	$44.20	$44.20
Peas, Green	1,407	2.9	0.0%	$341.25	$238.50
Vegetable Acreage	**3,035**				

Table D-4
Field Crops: Grays Harbor County

CROP TYPE	ACRES HARVESTED (AVERAGE)	YIELD	UNITS	SHARE OF TOTAL ACREAGE	FEDERAL VALUE $2014/UNIT	STATE VALUE $2014/UNIT
Barley (Grain)	98	98.8	Bu/Acre	1%	$3.82	$3.83
Corn (Silage)	1,211	20	tons/Acre	9%	$3.57/Bu	$5.24/Bu
Wheat	2,281	76	Bu/Acre	16%	$5.21	$6.23
Oats	35	81	Bu/Acre	0%	$2.29	$2.29
Hay	6,908	2.4	Tons/Acre	50%	$119.00	$162.37
Total Field Crop Acreage	**10,533**					

Notes:
Bu = Bushel

Table D-5
Vegetables: Grays Harbor County

CROP TYPE	ACRES HARVESTED (AVERAGE)	AVERAGE YIELD CWT/ACRE	SHARE OF TOTAL ACREAGE	FEDERAL VALUE $2014/CWT	STATE VALUE $2014/CWT
Snap Beans	105	62	0.1%	$55.85	$55.63
Cabbage	3	335	0.0%	$16.30	$15.70
Carrots	1	329	0.0%	$27.35	$25.30
Cucumbers	9	194.3	0.0%	$24.98	$24.98
Garlic	1	168.6	0.0%	$63.00	$63.00
Lettuce	4	364.4	0.0%	$21.68	$21.68
Potatoes	7	623	0.1%	$7.76	$7.35
Pumpkins	5	227.9	0.2%	$11.38	$11.38
Squash, Winter	2	156.3	0.0%	$31.95	$31.95
Sweet Corn	1	188	15.6%	$26.85	$38.40
Tomatoes	12	298.5	0.0%	$44.20	$44.20
Peas, Green Fresh	16	2.9	0.0%	$341.25	$238.50
Vegetable Acreage	**3,399**				

Notes:
cwt = hundredweight is equal to 100 pounds

Table D-6
Field Crops: Thurston County

CROP TYPE	ACRES HARVESTED (AVERAGE)	YIELD	UNITS	SHARE OF TOTAL ACREAGE	FEDERAL VALUE $2014/UNIT	STATE VALUE $2014/UNIT
Peas	3	10	cwt/Acre	0%	$341.25	$238.50
Hay	10,430	2.4	Tons/Acre	98%	$119.00	$162.37
Total Field Crop Acreage	**10,433**					

Notes: cwt = hundredweight is equal to 100 pounds

Table D-7
Vegetables: Thurston County

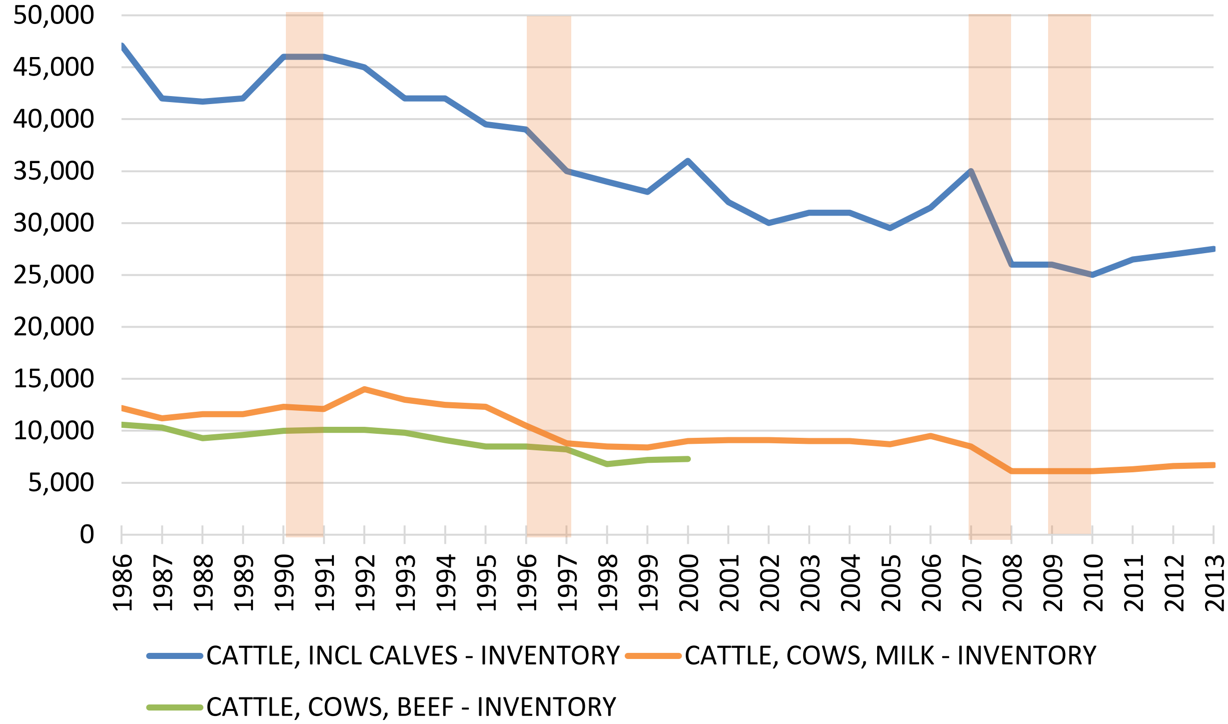
CROP TYPE	ACRES HARVESTED (AVERAGE)	AVERAGE YIELD CWT/ACRE	SHARE OF TOTAL ACREAGE	FEDERAL VALUE $2014/CWT	STATE VALUE $2014/CWT
Snap Beans	9	62	0.1%	$55.85	$55.63
Broccoli	3	148	0.0%	$36.63	$37.13
Cabbage	2	335	0.0%	$16.30	$15.70
Carrots	7	329	0.1%	$27.35	$25.30
Cauliflower	1	172.4	0.0%	$43.03	$41.27
Celery	2	707.5	0.0%	$19.30	$19.30
Cucumbers	9	194.3	0.1%	$24.98	$24.98
Garlic	5	168.6	0.1%	$63.00	$63.00
Lettuce	3	364.4	0.0%	$21.68	$21.68
Onions dry	6	466.1	0.1%	$13.43	$36.50
Potatoes	11	623	0.1%	7.76	7.35
Pumpkins	55	227.9	0.5%	$11.38	$11.38
Spinach	2	158	0.0%	$39.10	$39.10
Squash	7	156.3	0.1%	$31.95	$31.95
Sweet Corn	56	188	0.5%	$26.85	$38.40
Tomatoes	8	298.5	0.1%	$44.20	$44.20
Peas, Green	9	2.9	0.0%	$341.25	$238.50
Vegetable Acreage	**192**				

Notes:
cwt = hundredweight is equal to 100 pounds

Livestock

Recent major flood events have resulted in significant livestock losses. In 2007, it was estimated that 1,600 animals were lost. As a result, five critter pads and two evacuation routes were constructed. The 2009 event, which occurred after these measures were in place, resulted in minimal if any losses; however, the 2009 event was less severe, so it is unclear what changes these measures would make to livestock losses in floods of greater magnitude than the 2009 event. Figure D-2 below illustrates changes in cattle population in Lewis County. The orange-shaded areas indicate years where flood events occurred.

Figure D-2
USDA Survey of Cattle Lewis County[52]



Attempts were made to contact the Lewis County Conservation District regarding livestock impacts and needs assessments. At the time of the report publication, information was not made available for incorporation into the flood reduction impact analysis. In addition, the agriculture analysis was reviewed by the Washington State Dairy Federation (WSDF). At the time of the review, the WSDF was unable to provide additional data to help inform an analysis. Due to lack of data, flood reduction impacts on livestock were not estimated for the five representative flood events and for each Project Alternative.

[52] U.S. Department of Agriculture. National Agricultural Statistics Service. Livestock and Animals for Lewis County, Washington.

Appendix E: Transportation

Interstate 5

The WSDOT prepared a Travel Cost study[53] that estimates the cost of closures on I-5 and highways located in the Chehalis River Basin during a 100-year flood event. This study is used in the COA to estimate the impacts of flood reduction alternatives on I-5 closure costs for each modeled flood event. First, the WSDOT study methodology and results are summarized, followed by how the information is used in the COA analysis.

SUMMARY OF WSDOT STUDY

The Travel Cost study uses available traffic data and surveys to estimate the cost of a 5-day, 3-hour closure on I-5 during the 2007 flood event.

Current traffic volumes through the Twin Cities were estimated based on count locations north and south of the closure area compared to traffic prior to flooding. The total traffic volume is then allocated to different vehicle types (passenger vehicles vs. trucks) as well as trip type. Three trip types were identified:

1. Through traffic
2. Internal/external traffic where trips either end or begin in the Twin Cities
3. Local traffic

Table E-1 summarizes the traffic type assumptions.

Table E-1
Traffic Assumptions

DESTINATION	THROUGH	TWIN CITIES INACCESSIBLE	TWIN CITIES ACCESSIBLE	LOCAL	TOTAL
From North Heading South					
Passenger Vehicles	6,000	6,000	10,000		22,000
Trucks	5,300	500	1,900		7,700
From South Heading North					
Passenger Vehicles	6,000	300	1,200		7,500
Trucks	5,300	300	200		5,800
Local Trips					
Passenger Vehicles				16,340	16,340
Trucks				660	660

Passenger Vehicle Behavior
The behavior for each type of traffic is based on a travel behavior survey conducted in February 2014. The behavior for each type of traffic is based on respondents' answers according to the number of trips taken in a 1-

[53] Hallenbeck, Mark E., Dr. Anne Goodchild, and Jerome Drescher. Travel Costs Associated with Flood Closures of State Highways near Centralia/Chehalis, Washington. Washington State Transportation Center. Draft June 2014.

week period. For example, if a respondent took five or more trips in a 1-week period, it was assumed that the behavior is consistent with local traffic. The survey also asked about trip purpose (recreation, work, shopping, other). The responses are used to assign trip value in the analysis.

Truck Behavior

Truck behavior was determined based on interviews with trucking companies as well as traffic patterns along detour routes.

Trip Costs

The cost for trips not made or trips delayed due to flooding is provided by vehicle type and trip type. For passenger vehicles, the cost for a delay or trip cancellation ranges from $2 to $18 per person per car trip. Through trips are assigned the most value. For trips that have shifted modes, the cost is $184 per person per day for through trips and only $1 per person per day for all other trip types.

The assumed cost for a trip not made by truck ranges from $5 (local) to $42 per truck.

Detour costs are estimated using value of time and the cost of added mileage. Time value ranges from $12/hour for local non-business trips to $22.90/hour for business trips. These values are recommended by the U.S. Department of Transportation. The business trip value of time is consistent with the median family income for the area. Mileage costs are $0.21/mile and $1.10/mile for passenger and truck trips, respectively. These values are based on previous studies and the *AAA Cost of Driving* report.

Vehicle occupancies are based on previous studies.

RESULTS

It was estimated that a 123-hour closure at the Twin Cities would cost $11.5 million. If all through traffic were assumed to use a detour, the total cost increases to $20.6 million. It is noted in the Travel Cost study that the cost of road closure due to flooding may include the cost of all traffic to take alternative routes (Corps). This methodology of assuming all traffic detours is consistent with how I-5 closure costs were estimated in the Phase 2B study.[54]

DISCUSSION

Estimating the dollar damages for I-5 closure due to flooding events in the Twin Cities area is challenging due to the lack of data available. The Travel Cost study assumes different trip types for the traffic estimates within/through the Twin Cities area and these estimates are based on education and experience rather than research. It is important to note that changes to the trip types assumed could significantly change the results of the study. For example, when the costs of the detour are analyzed in an IO model, the full cost of the closure totals $40 million or more when the $20.6 million figure is assumed.

Project Alternative Impacts on I-5

The estimated I-5 closure costs from the WSDOT study are translated into an average dollar/day closure cost. The Federal Perspective assumes the average of WSDOT's estimated $11.5 and $20.6 million range for a 5–day, 3-hour closure. The average cost estimate is used in order to capture lost value due to decisions of some

[54] EES Consulting, Inc. Chehalis River Flood Water Retention Project Phase IIB Feasibility Study. Kirkland, Washington. April 14, 2011.

travelers not to take a detour. The State Perspective assumes the same losses as the Federal Perspective. This assumption may overstate I-5 closure costs from a state perspective if a share of through traffic neither originates in Washington nor has a Washington destination. Finally, the basin-wide perspective assumes the costs associated with local traffic.

The number of days closed is estimated for each Project Alternative and the Baseline for the 2-, 10-, 20-, 100-, and 500-year events based on information provided by the hydraulic model (HEC-RAS). The hours of closure are estimated for several points (cross sections) along I-5. The longest closure estimate among the cross sections is used for each Project Alternative and flood event. For example, if the longest closure is 35 hours at "West of I-5 Across from Green Hill School" for the "With Storage and Airport Levee" Alternative 500-year event, then 35 hours is used as the number of hours the freeway is flooded.

The impact for each alternative is based on the change in days of closure and cost for each day of closure. The annual expected impact is calculated based on flood return interval probability, so the resulting expected annual damage is used directly in the COA.

Rail

Major flood events in the Chehalis River Basin result in floodwaters covering rail lines through the I-5 corridor. Similar to closures of I-5, rail line closures have significant impact on State and Regional economies. These rail lines provide transportation ways for both freight and passenger trains. The rail line through the Twin Cities is classified as a major corridor and is owned by BNSF. Other rails lines in the area include the PSAP line running north out of Centralia and West through Aberdeen, and the Tacoma Rail Mountain Division originating just North of Chehalis and ending in Tacoma.

The BNSF rail line through the Twin Cities is part of a major line connecting Portland and Seattle. This corridor averages 58 freight trains per day as well as 8 Amtrak Cascades trains. Amtrak's Coast Starlight, which connects Los Angeles and Seattle, operates once per day in each direction along this I-5 corridor.[55] One day of closure can affect up to 68 trains.

FREIGHT

Freight traffic in Washington State plays a central role in Washington's interstate and international trade activities. In 2007, rail moved 41% of interstate tonnage (83 million tons), where Washington was either an origin or destination.[56] Half of all rail traffic in 2010 originated out of state consisting primarily of agriculture products and field crops. Much of this freight will be exported from Washington's ports. Similarly, 29% of traffic is through traffic, 16% is outbound, and 4% is intrastate. The WSDOT is forecasting that freight traffic will increase significantly by 2035 from about 115 million tons to more than 250 million tons. WSDOT cites several factors that could affect rail volumes in the future including new bulk exports, changes in global sourcing, larger container ships, economics of rail vs. truck, and fuel costs.

PASSENGER

The passenger trains through the Twin Cities operate on BNSF track. As mentioned above, passenger trains include Amtrak Cascade, Sound commuter trains, and the Coast Starlight (Amtrak). At the state level, ridership trends on the Coast Starlight have been positive since the mid-2000s.[57] WSDOT estimates that the Coast

[55] Washington State Department of Transportation. Washington State 2010-2030 Freight Rail Plan Appendices. December 2009.
[56] Washington State Department of Transportation. Washington State Rail Plan 2013-2035. December 2013.
[57] Washington State Department of Transportation. Washington State Rail Plan 2013-2035. December 2013.

Starlight ridership in Washington and Oregon stations (395,000), which accounts for 30% of total ridership, will increase by 2% annually. Coast Starlight ridership is influenced most strongly by economic conditions, train availability, and population trends.

Intercity Amtrak train ridership (Cascade lines) is driven by population and population density, income, services offered, travel time, schedule and reliability, and cost of competing transportation modes. Amtrak Cascades ridership has tripled since the mid-1990s.[58] Total ridership for all Cascades lines totaled 836,000 in 2012. WSDOT expects a large increase in ridership beginning in 2017 due to service improvements.

DISCUSSION

Attempts were made to contact BNSF regarding closure costs for the railway; however, BNSF did not wish to participate. Discussions with Tacoma Rail revealed that the damages to the rail lines would be minor and estimating the cost of rail closure would be a difficult task and the results would be challenging to defend. Primarily, cost estimation would require a full study similar to what was completed for the I-5 travel cost study where delay costs, operation, maintenance, and repair costs as well as supply chain effects. For reference, each rail car that is delayed is the equivalent of four trucks delayed. The rail detour around the closure is very long, requiring routes as far East as through Walla Walla.

[58] See id.

Appendix F: Cleanup Costs

Introduction

This appendix summarizes the methodology and assumptions used to estimate Project Alternative impacts on cleanup costs after a flood event. Cleanup costs include the labor and materials needed to remove debris and to clean a structure or property after a flood event. The following three components are included in the cleanup cost estimates:

1. Debris removal
2. Building cleanup costs (commercial, residential)
3. Agriculture field cleanup and restoration.

Each of these components is discussed below.

Debris Removal

Flooding results in significant amount of debris generation. The HAZUS model provides the total amount of debris generated from a flood event in tons. Debris is made up of building contents such as furniture, carpeting, flooring, or drywall. HAZUS estimates the amount of debris generated based on the percent damage to a building for each flood event. For buildings with less than 50% damage, the debris model is based on flood depth and occupancy type (residential or commercial).[59] Engineering-based component analysis is used to identify building components requiring replacement and to estimate weight. For buildings that are more than 50% damaged, the building is assumed to be a total loss and will be demolished with no salvage value. With demolition, the debris components include structural components such as wood, concrete, and steel. The final output is tons of debris separated by type: finishes (dry wall, insulation), structural (wood, brick), and foundation (concrete, rebar). The cost to remove debris for each of these components is estimated based on current tipping and junk hauling rates.

DEBRIS REMOVAL COSTS

The cost to dispose of structural, foundation, and woody debris[60] such as tree stumps is generally higher since it requires more truckloads to safely move the heavier material. Table F-1 below summaries a survey conducted for the cost of debris removal in western Washington.

[59] Scawthorn, Charles et al. HAZUS-MH Flood Loss Estimation Methodology. II. Damage and Loss Assessment. Natural Hazards Review. May 2006. Available at: http://www.cs.rice.edu/~devika/evac/papers/Hazus_floodII.pdf

[60] It should be noted that this analysis did not address the reduced environmental benefit of wood removal under selected circumstances

Table F-1
Debris Removal Cost Survey

COMPANY/ENTITY	LOCATION	FINISHES $/TON	STRUCTURAL, FOUNDATION, LARGE WOODY DEBRIS $/TON
All Phase Cleanup[1]	Elma, WA	$203.70	
Lewis County Public Works[2]	Lewis County	$90.00	
Dump It[3]	Puget Sound	$98.96	$123.96
Rubbish Works[4]	Puget Sound	$119.58	
Busby Junk Removal[5]	Puget Sound	$103.13	$150.91
Average		**$123.07**	**$137.43**

Notes:
1. Based on phone conversation with principal of company from March 2014.
2. Includes only disposal fee, no hauling. http://lewiscountywa.gov/solid-waste-disposal-locations-rates-material-accepted
3. http://dump-it.com/cms/index.php?section=4
4. http://www.rubbishworks.com/
5. http://www.busbyjunkremoval.com/pricing.html

Based on Table F-1, the average cost of debris removal for finishes is estimated at $123.07 per ton and the cost to remove heavier debris items is estimated at $137.43 per ton. These costs include removal, transportation, and disposal/recycling. Some items such as old appliances (refrigerators, freezers) may be an additional charge. However, for this study, the cost per ton figures are used since the number of appliances or other special material was not estimated. It is proposed that these figures are used for the expected case.

Building Cleanup Costs

Building cleanup costs include labor costs to clean up floodwaters and to dry out and decontaminate structures. Cleanup costs are valued in $/square foot. A range of $/square foot costs was developed based on a survey of companies serving Washington State. The range in costs reflects that there are several variables that affect cleaning costs including:

- Extent of flooding: depth and square footage affected
- Types of materials damaged: tile, carpet, drywall, plaster, wood
- How long the water has been sitting

EES researched online and called local service companies to ask for a range of cleanup costs for an average 1,500 square foot, single story residential home. Table F-2 below summarizes the responses received.

Table F-2
Survey of Estimated Cleanup Costs

SOURCE[1]	LOW ESTIMATE $/SQ FT	HIGH ESTIMATE $/SQ FT
COIT	$2.33	$3.67
Washington Water Damage & Cleaning Services	$2.00	$26.67
H2O Dry	$5.00	$6.67
Sandrini Restoration	$3.33	$6.67
Median	$3.33	$6.67

Notes:
1. Cost data is based on phone conversations held from February 2014 through March 2014.

It appears that the high estimate from Washington Water Damage and Cleaning Services is an outlier. Median low and high values are shown at the bottom of the table. The use of median values rather than an average results in estimates that are not skewed by outliers. Based on the median values above, $5.00/square foot is used to value cleanup costs in the expected case. For reference, the Phase IIB Study used $4.30/square foot for cleanup costs in 2010 dollars. In addition, low and high estimates are be provided based on the unit costs provided in Table F-2 in the uncertainty analysis.

HAZUS output provides the number of commercial and residential buildings that are damaged during the flood event. The number of buildings is applied to the estimated average square foot by building type. The total cleanup costs for residential will be based on average home size damaged, or the estimated average home size from HAZUS. Damaged commercial and industrial square footage is based on output from HAZUS.

Agriculture Cleanup Costs

Agriculture cleanup costs include labor and material costs used to clean up productive acres of agriculture including debris removal, clay or sand removal,[61] cleaning farm equipment, cleaning or demolition of buildings, flushing irrigation equipment, re-grading, and gully repair. Agriculture cleanup costs are expressed as $/acre of flooded property. The number of agricultural acres flooded is included in HAZUS output.

The Corps estimated in their 2003 report that cleanup costs and field restoration are approximately $286/acre for agriculture (adjusted to 2010 dollars).[62]

Cleanup costs after the 2007 flood event were estimated by the Cowlitz-Wahkiakum Council of Governments (2009). The costs were based on 4,776 acres where significant debris and silt were deposited (note that in 2007, more than 10,000 acres were flooded). Cleanup was estimated at $500 per acre plus another $100 to $260 per acre for re-seeding.[63]

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[61] Any positive effects of soil deposition, such as nutrient renewal (and reduced cost of fertilizer application), were not subtracted from this cleanup cost.
[62] U.S. Army Corps of Engineers. Centralia, Washington, Flood Damage Reduction. Final General Reevaluation Report. Economics Appendix D. June 2003.
[63] Lewis County Flood Disaster Recovery Strategy: January 2009.

Appendix G: Emergency Aid

Introduction

Emergency aid includes Temporary Relocation Assistance and Public Assistance expenditures from FEMA. The 2003 Chehalis Basin study by the Corps calculated these damages based on average emergency expenditures across several locations in the U.S. The claim costs are then increased by 25% to account for contributions from state or local governments. Public Assistance was estimated based on the relationship of Temporary Relocation Assistance to Public Assistance claims throughout the U.S. In the 2003 study, the Corps used a value of 3.01 meaning that Public Assistance expenditures are 3.01 times Temporary Relocation Assistance expenditures.[64] The methodology used by the Corps to estimate emergency costs is based on national data; however, with local data available from the 2007 event, emergency costs can also be estimated based on historic costs.

Temporary Relocation Assistance

HAZUS output includes the number of estimated households displaced from a flood event for each flood scenario. Temporary Relocation Assistance includes financial assistance available for flood victims to rent a temporary place to live or the cost of government housing units when rental properties are not available. In addition short-term lodging expenses are included where homes are damaged but repaired in a shorter amount of time. During the 2007 flood event there were a total of 738 eligible claims for Temporary Relocation Assistance. These claims averaged $3,723 each where rental assistance claims were approximately $3,779 and lodging reimbursement claims averaged $1,917.43 (Nominal $2007).[65] In current 2014 dollars, the average Temporary Relocation Assistance claim is estimated at $4,074.[66] It is recommended that this value be used to estimate damages in 100-year and greater events. For smaller events, the duration and daily cost for relocation will likely be lower. Therefore, a smaller value consisting of just lodging reimbursement is used to value relocation costs in events smaller than 100-year events. Lodging reimbursement is for shorter-term stays cost an average of $2,098 per claim for the 2007 event.

The cost of each claim and the estimated number of claims are multiplied to result in the total expected value of claims. HAZUS output includes the number of estimated households displaced from a flood event.

Public Assistance

FEMA reimburses state and local governments up to 75% of eligible claims for disaster response including debris removal, emergency protective measures, road systems and bridges, water control facilities, public buildings and contents, public utilities, parks, and recreational and other related activities. The 2007 flood event resulted in $14.8 million in Obligated Emergency Public Assistance.[67] Emergency Public Assistance includes work that must be performed to eliminate the immediate threat to life, public health, and safety, and to improve property that

[64] U.S. Army Corps of Engineers. Centralia, Washington, Flood Damage Reduction. Final General Reevaluation Report. Economics Appendix D. June 2003.
[65] Tobert, Mark R. Human Services Program Manager, Emergency Management Division, Washington Military Department. Email dated March 14, 2014.
[66] Based on the GDP implicit price deflator from the St. Louis Federal Reserve. 2007: 97.959 and 2014: 107.204.
[67] Obligated includes only the FEMA portion. FEMA. Washington Severe Storms, Flooding, Landslides, Mudslides (DR-1734). Last updated March 25, 2014. http://www.fema.gov/disaster/1734#tabs-2

is significantly threatened. The ratio of Public Assistance to Temporary Relocation Assistance is $5.39 for each $1 of Temporary Relocation Assistance based on the 2007 event.[68] It is recommended to use this ratio rather than the ratio developed by the Corps in the 2003 study since it is based on recent local experience. An additional 25% is added to account for the non-FEMA portion of Public Assistance.

Discussion

It should be noted that the emergency costs referenced from the 2007 event do not differentiate between costs incurred due to flooding or other storm-related costs such as wind damage, mud, or landslides. However, because the Temporary Relocation Assistance costs are analyzed in units of dollars per claim, and applied to the number of claims estimated by HAZUS directly related to flooding, estimated Temporary Relocation Assistance costs reflect flood-related damages only. Similarly, Public Assistance costs are based on flood-related Temporary Relocation Assistance costs (excluding damages from storm events not related to flooding). Therefore, Public Assistance cost estimates reasonably reflect damages due to only flooding. Low and high emergency aid estimates are estimated by changing the dollar value per claim or altering the ratio of costs for emergency aid.

[68] TRA is $2,747,658.04 and emergency public assistance is $14,815,865.41.

Appendix H: Land Cost

Introduction

The proposed single and MPD dams would require that land be purchased or leased for the purposes of maintaining a reservoir. The reservoir is used for storage of flood waters in both dam scenarios. In the MPD scenario, the reservoir is also used for flow augmentation and hydropower, if economically feasible. This section provides estimates for the land and timber cost associated with the proposed dams and reservoirs.

Timber Value

Timber value depends on a number of factors including the following:

- Regional and statewide prices and market conditions including proximity to lumber mills
- Species, size, and quality of trees
- How much timber is sold and what type of harvesting is done – Larger sales command a higher price per unit of wood. Similarly, the harvest cost (production expense) is factored into the price.
- Site conditions such as distance from nearest road, slope, soil wetness, and whether or not temporary bridges are needed
- State and local timber harvesting management and practices, which can affect how much timber can be removed depending on proximity to streams, local populations, and presence of vulnerable species

Without detailed information on the acreage needed for the reservoir, a market-based approach is used to estimate the $/acre value of land and timber together.

Market Conditions

Current properties for sale in Lewis County are reviewed as well as 2012 sales records. Table H-1 shows a summary of 2011 sales records for timber property sales. Table H-2 shows land currently for sale. These values reflect the land value plus the future stream of net revenue from timber sales.

Table H-1
Timberland Sold in 2011 in Lewis County, WA ($2011)

LOCATION	ACRES	PRICE	$/ACRE	FEATURES	SOURCE
Coal Creek Rd	468.74	$1,440,000	$3,072	Timberland Sold 4/15/2011	County Assessor
Coal Creek Rd	10.84	$25,000	$2,306	Timberland Sold 4/22/2011	County Assessor
Unknown Situs Address	558.23	$2,221,180	$3,979	Timberland Sold 7/5/2011	County Assessor
Poplar Ln	6.63	$50,000	$7,541	Timberland Sold 8/11/2011	County Assessor
Summer Run Dr	96.55	$319,500	$3,309	Timberland Sold 2/28/2011	County Assessor
Unknown Situs Address	396.65	$545,000	$1,374	Timberland Sold 9/16/2011	County Assessor
St Hwy 508	20	$100,000	$5,000	Timberland Sold 4/13/2011	County Assessor
St Hwy 508	234.86	$435,000	$1,852	Timberland Sold 5/5/2011	County Assessor
August Rd	20	$90,000	$4,500	Timberland Sold 12/9/2011	County Assessor
Brown Rd	77.4	$535,000	$6,912	Timberland Sold 3/2/2011	County Assessor
St Hwy 6	78.21	$92,000	$1,176	Timberland Sold 8/11/2011	County Assessor
Radmaker Rd	169.51	$475,000	$2,802	Timberland Sold 11/28/2011	County Assessor
Belville Rd	5	$33,000	$6,600	Timberland Sold 3/3/2011	County Assessor
Droptine Ln	6.02	$33,000	$5,482	Timberland Sold 3/3/2011	County Assessor
Frost Rd	40	$312,500	$7,813	Timberland Sold 6/1/2011	County Assessor
Average			**$4,248**		
Minimum			**$1,176**		
Maximum			**$7,813**		

Table H-2
Land for Sale in Lewis County, WA ($2014)

LOCATION	ACRES	PRICE	$/ACRE	FEATURES	SOURCE
Glenoma	67.7	$135,000	$1,994	Hunting land, natural forest, undeveloped land	Land and Farm
Morton	5	$42,500	$8,500	Undeveloped land, hunting land, natural forest	Land and Farm
Centralia	40.46	$147,000	$3,633	Planted Forest, residential, undeveloped.	Land and Farm
Chehalis	50	$249,000	$4,980	Recreational land, undeveloped land	Land and Farm
Toledo	97.97	$320,000	$3,266	Residential, Forest with 22 year old Douglas fir and red alder	Landwatch
Mossyrock	120	$450,000	$3,750	25 year old Douglas fir and hardwoods	Landwatch
Pe Ell	30	$45,000	$1,500	Undeveloped land, residential land, natural forest	Land and Farm
Toledo	39.69	$169,000	$4,258	Residential land, planted forest, natural forest	Land and Farm
Cinebar	67.85	$175,000	$2,579	Planted Forest, residential, undeveloped.	Land and Farm
Average			**$3,829**		
Minimum			**$1,500**		
Maximum			**$8,500**		

A range of $/acre values is selected based on Tables 1 and 2. In 2014 dollars[69] the low, medium, and high values are $1,221/acre, $4,248/acre, and $8,106/acre.

Reservoir Acres

The inundation area has been estimated by HDR for various pool elevations. It is assumed that the project would purchase acreage consistent with the inundation area where flood storage is maximized plus the dam footprint. Table H-3 summarizes the acreage information provided by HDR.

Table H-3
Acreage Inundated

DAM TYPE	INUNDATION LEVEL AT FLOOD ELEVATION (FT)	INUNDATION AREA AT FLOOD ELEVATION (ACRES)	DAM FOOTPRINT (ACRES)	TOTAL AREA (ACRES)
Roller Compacted Concrete - Flood Retention Only	652.4	1,051.97	3.81	1,055.78
Roller Compacted Concrete - Multipurpose	712.4	1,509.51	7.56	1,517.07
Rock Fill - Multipurpose	712.4	1,501.01	31.1	1,532.11

Total Estimated Land and Timber Cost

The value ranges are applied to the acreage in Table H-4 to determine three estimates for each structure alternative.

Table H-4
Estimated Land and Timber Value

DAM TYPE	ACRES	TOTAL COST		
		LOW ($1,221/ACRE)	MEDIUM ($4,248/ACRE)	HIGH ($8,106/ACRE)
Roller Compacted Concrete - Flood Retention Only	1,055.78	$1,288,593	$4,484,884	$8,558,159
Roller Compacted Concrete - Multipurpose	1,517.07	$1,851,604	$6,444,414	$12,297,378
Rock Fill - Multipurpose	1,532.11	$1,869,960	$6,508,303	$12,419,293

The single purpose project land and timber value are estimated at $1.3 to $8.6 million. The MPD structures' land values range from $1.9 to $12.4 million.

Note that the State of Washington's mitigation policies will require compensatory mitigation for the permanent and temporary impacts of maintaining a reservoir to the various habitat types in the inundated area, via protection or acquisition of habitat elsewhere at a ratio of 1:1 or greater. The costs of implementing compensatory mitigation have not been incorporated into this analysis, but should be anticipated in a future phase.

[69] The 2011 sales prices are adjusted to 2014 dollars using the GDP Implicit Price Deflator. http://research.stlouisfed.org/fred2/series/GDPDEF/

Appendix I: Business Interruption

Business interruption costs include the cost to businesses or landlords for building closure during flood events as well as the cost of delayed re-opening due to damages or relocation. Business interruption costs are composed of four parts:

1. Income (capital-related) Losses
2. Wage Losses
3. Relocation
4. Rental Income Losses

HAZUS calculates each of these losses according to the methodology summarized below.

Income Losses

Income losses are calculated within HAZUS by building occupancy class. The equations used to estimate income losses were developed at the national level and are applied to regional data specific to each flood event. The following variables are analyzed for each occupancy class:

1. Floor area and flood depth
2. Income per day (per square foot)
3. Business loss function (days, or duration of closure)
4. Income recapture factor

Each component is described below.

FLOOR AREA AND FLOOD DEPTH

Floor area by occupancy class has been updated according to 2010 County Assessor data. Flood depth is a based on average flood depth over the relevant census blocks. Flood depth data is provided by the hydraulic modeling (HEC-RAS model) developed for the Chehalis River Basin.

INCOME PER DAY

Income per day per square foot by occupancy class is estimated based on the input data (building square foot by occupancy class) and default regional income data by occupancy class. Income per square foot per day is based on information from the Bureau of Labor Statistics.[70]

BUSINESS LOSS FUNCTION

The duration of business closure is estimated by flood depth and occupancy class. As flood depth increases, restoration times increase. Buildings that are damaged more than 50% (i.e., substantially) must be demolished and rebuilt. The time needed to rebuild a demolished building depends on building location. If the building is located outside of the 100-year floodplain, it is assumed that the business will be open again after 18 months. If

[70] Bureau of Labor Statistics. Industry Productivity & Cost Survey" 2005 and 2006.

the business is located within the 100-year floodplain, the building must be relocated and the time required to reopen is estimated at 24 months.

INCOME RECAPTURE FACTOR

The income recapture factor is a default value in HAZUS for the percent of lost income recaptured after the business reopens. The income recapture factor varies by occupancy class. In addition, as the closure period increases, the income recapture factor decreases. In other words, businesses that are closed for significant periods (more than 6 months) would have lower recapture factors compared with a business closed only a few days.

Wage Losses

Wage losses are calculated in the same way as income losses. Instead of income per square foot per day, wages per square foot per day are calculated. Similarly, instead of the income recapture factor, a wage recapture factor is used.

Relocation Expenses

Relocation expenses include business disruption costs associated for transferring a business and its components to a rental or temporary space. Relocation expenses are estimated only when a structure reaches the 10% threshold for flood damage. Relocation expenses include the following:

1. Floor area by occupancy class and flood depth
2. Percent of building damage by occupancy class and water depth (if greater than 10%)
3. Disruption costs ($/square foot)
4. Recovery time (days) by occupancy and flood depth
5. Percent owner occupied by occupancy class
6. Rental cost ($/square foot/day) by occupancy class

Rental and disruption costs are based on default HAZUS data. These costs were developed in 1994 and updated according to inflation.

Rental Income Losses

Rental Income losses include lost income due to tenants not being able to access a building during a flood event or after a flood event while the building is being cleaned or relocated. Rental income losses are based on the following:

1. Percent owner occupied for occupancy class
2. Floor area of occupancy group
3. Rental cost ($/square foot/day)
4. Recovery Time for occupancy and water depth

Each of these components has been discussed above.

Summary

Business interruption costs are included in the basin-wide Perspective only. From both the State and Federal Perspectives local business loss is a transfer from one region to another, and therefore, a zero-sum game. In the basin-wide Perspective, business interruption impacts are included in the I-O modeling in order to estimate the multiplier effect of Project Alternative impacts on business losses.

Appendix J: Hydropower

Introduction

As part of the dam structure analysis, the Project Team is evaluating the cost-effectiveness of installing a hydropower unit on a MPD alternative. The hydropower unit would produce electricity when water is released under the flow augmentation protocol. The value of the energy produced is made up of three possible components:

1. Energy sold at market prices
2. Renewable energy component
3. Cap and Trade value

The methodology for each of these valuations is described below followed by a summary of the estimated costs for the hydropower component. The economic analysis evaluates the net benefits, or cost-effectiveness of a hydropower plant based on an Expected, Worst Case, and Best Case scenarios. The Worst Case analysis assumes high costs and low value, whereas the Best Case assumes low project costs and high value.

Market Prices

The greatest value from the hydropower unit is the market value of the energy produced. The value varies depending on the timing of output. Generally, production during winter months has the greatest value since the Pacific Northwest electric demand is greatest during this time of year due to building heating loads.

Alternatively, production during the summer months is also valuable since much of the energy produced in the Pacific Northwest is sold to California utilities during this time to help meet air conditioning loads. The monthly diurnal output from the hydropower project is valued at forecast, real Mid-Columbia prices. Mid-Columbia is the nearest and most relevant trading hub. Figure J-1 shows the historic average annual electricity price at Mid-Columbia over the past 10 years.

Figure J-1
Nominal Mid-Columbia Historic Prices[71]

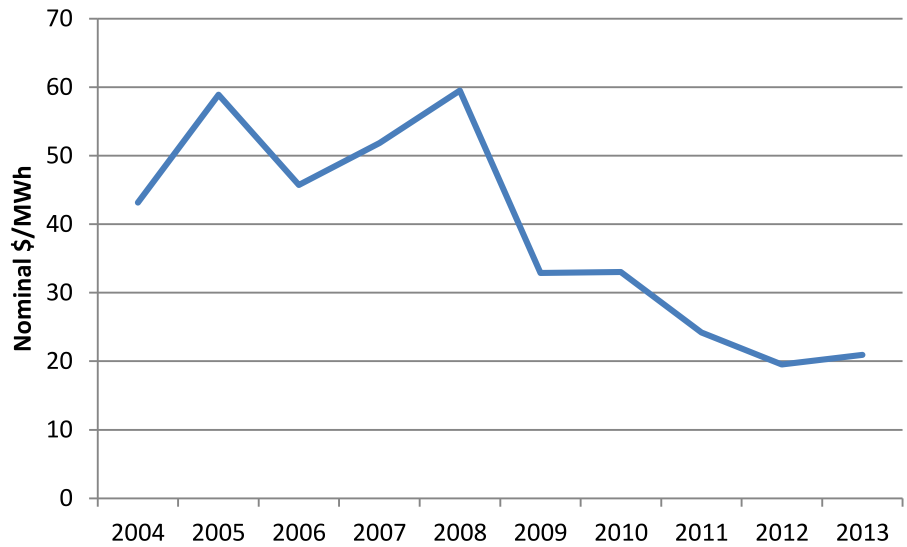
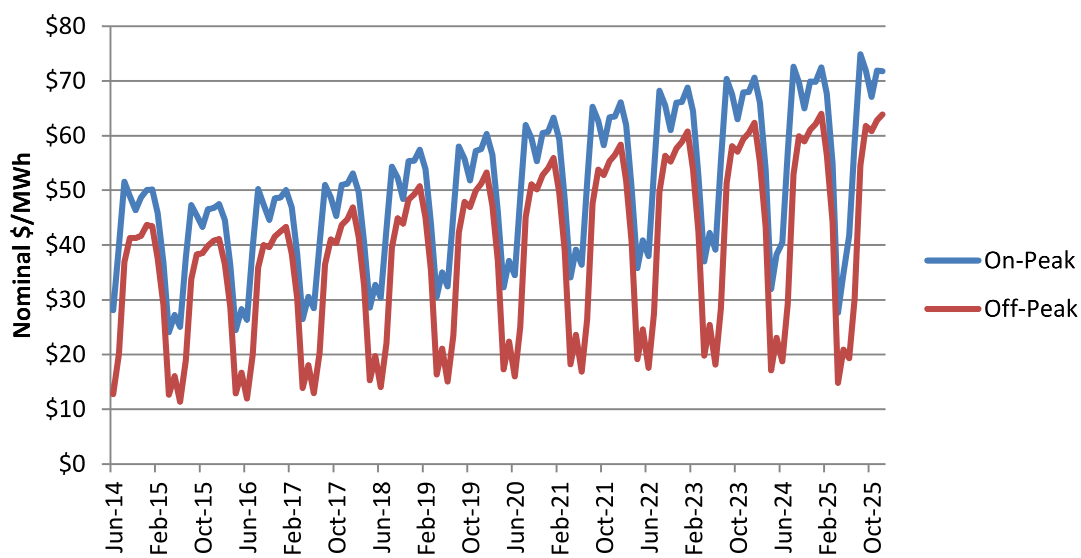


Figure J-2 shows a monthly diurnal price forecast for the period June 2014 through December 2025. On-peak hours are the times with highest electricity usage. Generally, these hours are from 6 am to 10 pm Monday through Saturday. All other times and holidays are considered off-peak periods.

Figure J-2
Nominal Mid-Columbia Price Forecast



The forecast is adjusted to real dollars assuming inflation is 2%. After 2025, the forecast is extended assuming a 1.5% growth rate, or the average growth rate over the forecast period 2014-2025.

[71] Dow Jones & Company, Inc. Mid-Columbia Daily Historic Prices. www.dowjonesnews.com

Renewable Energy

In order to provide a comprehensive examination of the value of the power from the project, an examination of the value as a renewable resource is also undertaken. Because the hydropower unit is incremental to the dam structure, the output from the project may qualify as a renewable under RCW 19.285. In addition, the output may qualify as renewable outside Washington State. However, neither of these circumstances is guaranteed.

The renewable component of the project would be valued separately from the actual energy produced. The unbundled renewable component is referred to as renewable energy credits, or RECs. REC sales in Washington have been around $4-$9 for compliance periods 2008-2013. REC sales for future renewable portfolio standard compliance have sold for $18.50/MWh[72] for purchases beginning in 2016.

As with any commodity, the price of RECs is determined by the supply and demand. REC supply and demand are influenced by many factors, including loads, regulatory framework, development costs, greenhouse gas prices, conservation, and others. In particular, the demand for RECs is driven by both voluntary and compliance markets. It is expected that voluntary markets will have some effect on REC prices over the planning period. Usually, voluntary markets are complementary to compliance markets, utilizing resources that are not eligible compliance RECs due to technology or region.[73] The effect of voluntary markets on compliance REC prices is not included in this study.

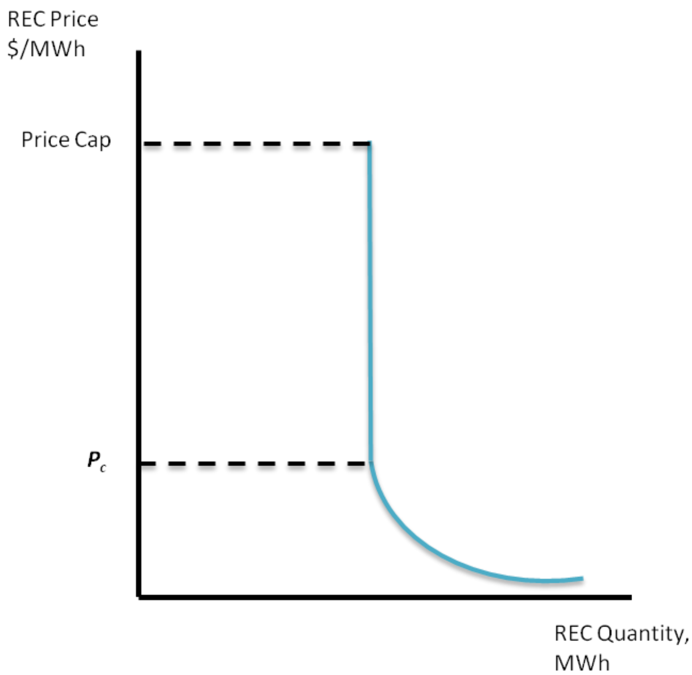
REC DEMAND

The demand for RECs in any given year is, theoretically, perfectly inelastic with respect to price, up to the applicable price cap. The inelasticity of demand is caused by the higher cost of energy from renewable resources compared with conventional energy resources. Since utilities would not purchase renewable energy based on a least-cost analysis, the demand is driven by state mandates. The state-mandated requirements for each year, and subject utility loads, determine the fixed quantity demanded. As long as renewable energy is more costly than conventional energy, utility planners would pay any amount up to the applicable price cap to fulfill RPS requirements. Figure J-3 illustrates a perfectly inelastic demand curve above price P_c where P_c is the price at which renewable energy becomes cost-effective. Zero RECs are demanded when the price is above the price cap.

[72] Based on current market purchases through WREGIS.

[73] Bird, Lori and Elizabeth Lokey. Interaction of Compliance and Voluntary Renewable Energy Markets. National Renewable Energy Laboratory. Technical Report, NREL/TP-670-42096. October 2007.

Figure J-3
Theoretical REC Demand Curve



In the future, the demand for RECs may become less inelastic when the price of renewable resources falls below conventional resources. For example, if high carbon taxes or significant tax credits for renewable resources are enacted, renewable resources may become the least cost alternative.

Regulatory Framework and REC Demand

One of the most prominent factors affecting REC demand is the regulatory framework for each state. Specifically, some states allow trading of unbundled RECs while others require that the energy be physically in-state or require that the energy could be delivered to the state. Also, states such as Washington and California have placed a cap on the price of RECs; therefore, REC prices cannot exceed these upper limits that might vary across states. Further, eligibility requirements may exist that differ from state to state. For example, eligible resource types may vary, as well as the type of project ownership. The demand for RECs, therefore, varies depending on the resource from which the REC originated.

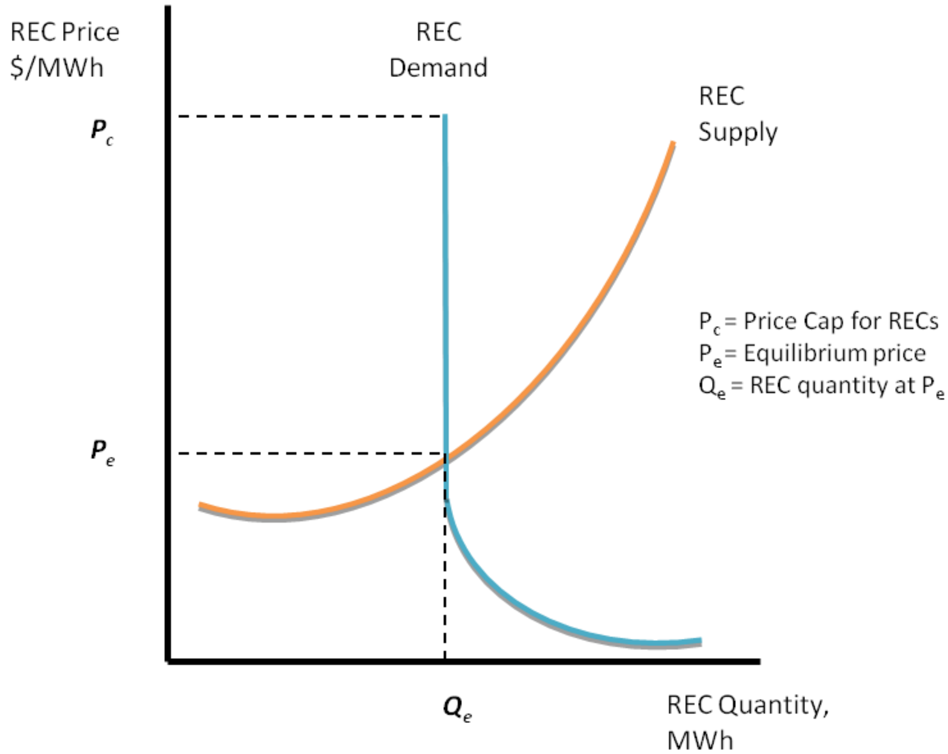
Electric Loads

In addition to regulatory framework, forecasted loads are another important element in the demand for RECs because REC requirements are often determined as a share of electric load. In high load growth scenarios, the demand for RECs increases as the same RPS percentages are applied to higher loads subject to renewable mandates. Therefore, economic development would increase the demand for RECs.

REC Supply

The REC supply curve, on the other hand, has a positive slope. The relationship between the quantities supplied at each REC price is determined by resource development costs and the market price for energy. High energy prices lead to increased cost-effectiveness of renewable resources, resulting in lower or no REC premium. Figure J-4 illustrates the supply and demand for RECs. For prices below any applicable price cap and above P_e, the REC price is determined by the supply. The demand for RECs is determined by RPS standards and loads subject to RPS.

Figure J-4
REC Supply with Inelastic Demand



Least Cost Analysis (Cost of Substitutes)

As mentioned previously, energy from renewable resources is not purchased because it is a least cost resource. Construction and development costs, as well as regulation of the intermittent nature of some resources, have resulted in costs that have been historically higher than conventional resources. Factors that may increase the cost-effectiveness of renewable energy include:

1. Federal, State, or local incentives
2. Technology advances that lower construction costs or resource regulation costs
3. Significant taxes on pollutants such as greenhouse gas (GHG)
4. Increased fuel costs for conventional generation.

Until renewable energy becomes a least-cost resource, the demand curve will exhibit some degree of inelasticity with respect to price. Lowering the cost of development would increase the supply of RECs, driving down the price.

REC PRICE FORECAST

Due to the difficulty of forecasting regulatory changes, the REC price is forecast based on current requirements. For the purposes of this analysis, a forecast of real REC prices was developed based on historic market considerations and current REC sales. A conservative real annual growth rate of 1% is used to forecast $10.00/MWh in 2016 through the end of the study period. While future REC prices are more likely to fluctuate over the study period due to various state compliance periods, the REC price forecast used for the purposes of this analysis is a normalized price that rises slowly over time.

Cap and Trade

Energy generated from the hydropower unit has a market value, renewable attributes of the hydropower generation add additional value, and finally, further value exists under a cap and trade scenario because the plant produces electricity without emitting carbon dioxide. Currently, only entities within the State of California are subject to cap and trade regulations; however, these regulations could become more wide-spread along the West Coast or nationally. Utilities subject to cap and trade can purchase power from the hydroelectric project directly and avoid paying for carbon allowances that would have been paid if the energy came from a natural gas-fired plant or other carbon emitting resource.

The most recent allowance auction in California resulted in a settlement price of $11.34 per allowance for the 2014 vintage. The settlement price for the 2017 vintage was $11.38 per allowance.[74] In order to estimate the cap and trade compliance savings for the hydroelectric resource, it was assumed that a qualifying utility would purchase from the Mid-Columbia market if not from a hydroelectric project. The Environmental Protection Agency (EPA) estimates 0.42 tons of CO_2 per MWh for electricity in the Northwest.[75] Therefore, at $12 per allowance, the non-carbon emitting attribute of the hydro project output is valued at $5.05/MWh.

Currently, there is no cap and trade regulation that applies to Washington State; therefore, in order to realize the value associated with the carbon-free output, the output would need to be sold to California

Hydropower Characteristics

OUTPUT

Hydroelectric output is estimated based on the flow augmentation regime and 4.6 MW rated single reaction Francis turbine. The turbine produces between 2.8 and 4.5 MW of power. The monthly output was calculated for the period 1989 through 2012. During this time, the average net output totaled 23,856 MWh. The lowest and highest net production years are 15,822 and 28,531 MWh respectively. The high output value is used in the Best Case while the low output value is used in the Worst Case.

The incremental costs of the hydropower unit include capital and construction costs, incremental O&M costs, periodic replacement or capital investment needed to keep the plant operating for the full study period, interest during construction, and regulatory and permitting costs.

PROJECT COSTS

Construction costs for the hydropower unit are estimated at $20 to $25 million. These costs include all costs to construct the unit such as capital, infrastructure investments (power lines), regulatory, permitting, contingencies, engineering, and construction management services. Annual O&M costs are estimated at $485,000. These costs include fixed and variable costs to operate and maintain the hydropower unit. In addition, periodic replacement costs are included in the O&M costs. These costs are capital investments needed to keep the plant operating throughout the full study period of 100 years. In addition, IDC was included in the project costs. The IDC assumes that the equal amounts of the project cost are borrowed in each month over the

[74] California Air Resources Board. Quarterly Auction 6 February 2014. Summary Results Report.
http://www.arb.ca.gov/cc/capandtrade/auction/february-2014/results.pdf
[75] Environmental Protection Agency. Emission Factors for Greenhouse Gas Inventories. April 4, 2014.
http://www.epa.gov/climateleadership/documents/emission-factors.pdf

18-month construction period. Table J-1 below summarizes the expected costs as well as Worst Case and Best Case estimates.

Table J-1
Hydropower Project Cost Estimates

($2014)			
	EXPECTED	BEST CASE	WORST CASE
Capital	$22,500,000	$20,000,000	$25,000,000
OM&R[1]	$485,000	$485,000	$485,000
IDC	$623,438	$554,167	$692,708

Notes:
1. Operation, maintenance, and replacement

Economic Analysis

Table J-2 below summarizes the assumptions used in each scenario.

Table J-2
Summary of Assumptions

	EXPECTED CASE	BEST CASE	WORST CASE
Project Costs	$22.5 M	$20 M	$25 M
Output	23,856 MWh/year	$28,531 MWh/year	$15,822 MWh/year
Market Price, Levelized $/MWh	$55.20	$55.20	$55.20
REC Price, $/MWh	NA	$10/MWh	NA
REC Price Escalation, Annual	NA	1%	NA
Cap and Trade Allowance Price	NA	$12/ton	NA

Tables J-3 and J-4 compare the costs and benefits for the three cases. Table J-3 excludes renewable value as well as any value attributed due to cap and trade regulations.

Table J-3
Hydropower Economic Analysis

($2014)			
	EXPECTED	BEST CASE	WORST CASE
Capital	$22,500,000	$20,000,000	$25,000,000
OM&R	$13,410,000	$13,410,000	$13,410,000
IDC	$620,000	$550,000	$690,000
Total Expenses	$36,540,000	$33,970,000	$39,110,000
Market Value	$36,420,000	$44,150,000	$24,430,000
Net Benefit	-$120,000	$10,190,000	-$14,680,000
Benefit/Cost	1.00	1.30	0.62

Table J-4
Hydropower Economic Analysis with Renewable Components

($2014)			
	EXPECTED	BEST CASE	WORST CASE
Capital	$22,500,000	$20,000,000	$25,000,000
OM&R	$13,410,000	$13,410,000	$13,410,000
IDC	$620,000	$550,000	$690,000
Total Expenses	$36,540,000	$33,970,000	$39,110,000
Market Value	$36,420,000	$44,150,000	$24,430,000
RECs	NA	$10,860,000	NA
Carbon Allowances	NA	$9,170,000	NA
Total Value	$36,420,000	$64,180,000	$24,430,000
Net Benefit	-$120,000	$30,220,000	-$14,680,000
Benefit/Cost	1.00	1.74	0.62

Without the renewable components, the project is not cost-effective in the Expected Scenario.

The above analysis does not include environmental impacts of installing a hydropower unit on MPD structure. Identifying and quantifying environmental impacts of the hydropower unit was not part of the project scope. Additional analysis regarding the impact on fish populations in particular is recommended before pursuing a hydropower addition to a flood storage structure.

Risk Analysis

In order to evaluate risk with regard to market price risk, a Monte Carlo simulation was performed on the market price forecast. The Monte Carlo simulation is based on market prices having normal distribution with an average monthly standard deviation of $18.96/MWh and increasing slightly over time. The increasing standard deviation models that uncertainty increases as the forecast period is extended. The probability distribution values are based on historic Mid-Columbia prices for the past 10 years. A high and low price forecast are developed using one standard deviation above and below the mean. The 100-year levelized cost for the high and low market prices are $91.95 and $49.25/MWh, respectively. According to a normal distribution curve, it can be expected that 68.2% of the time, market prices (and subsequent hydropower revenue) will fall between these high and low ranges.

Tables J-5 and J-6 show the results of the economic analysis assuming the high and low market prices.

Table J-5
Hydropower Economic Analysis High Market Prices

($2014)			
	EXPECTED	BEST CASE	WORST CASE
Capital	$22,500,000	$20,000,000	$25,000,000
OM&R	$13,410,000	$13,410,000	$13,410,000
IDC	$620,000	$550,000	$690,000
Total Expenses	$36,540,000	$33,970,000	$39,110,000
Market Value	$60,660,000	$73,750,000	$40,740,000
Net Benefit	$24,130,000	$39,790,000	$1,630,000
Benefit/Cost	1.66	2.17	1.04

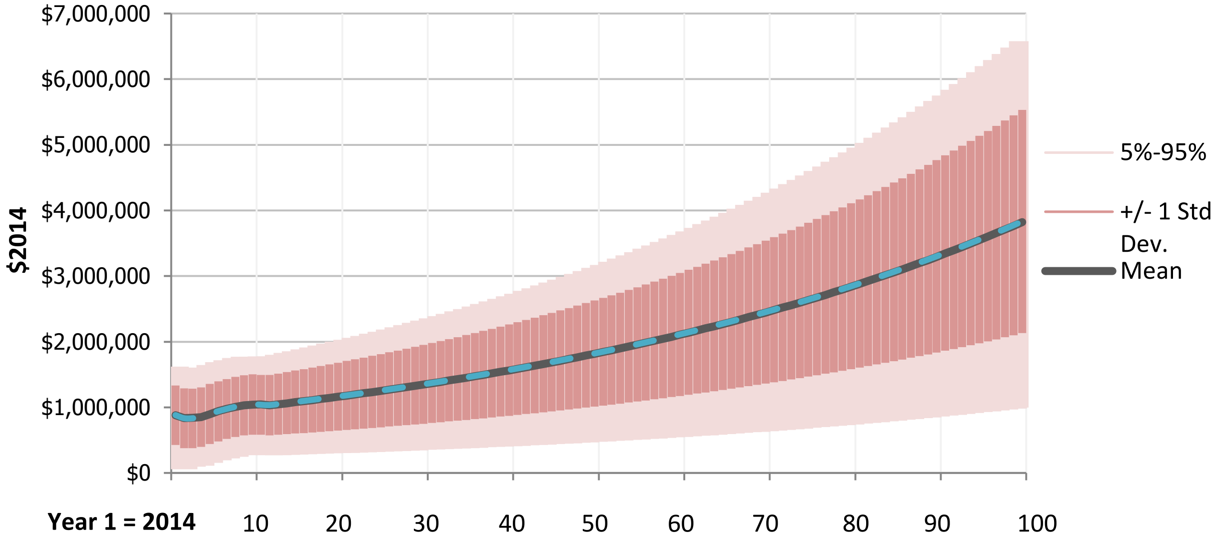
Table J-6
Hydropower Economic Analysis Low Market Prices

($2014)			
	EXPECTED	BEST CASE	WORST CASE
Capital	$22,500,000	$20,000,000	$25,000,000
OM&R	$13,410,000	$13,410,000	$13,410,000
IDC	$620,000	$550,000	$690,000
Total Expenses	$36,540,000	$33,970,000	$39,110,000
Market Value	$17,320,000	$20,830,000	$11,570,000
Net Benefit	-$19,220,000	-$13,140,000	-$27,530,000
Benefit/Cost	0.47	0.61	0.30

With high market prices paired with the Expected output scenario, the hydropower unit is cost-effective.

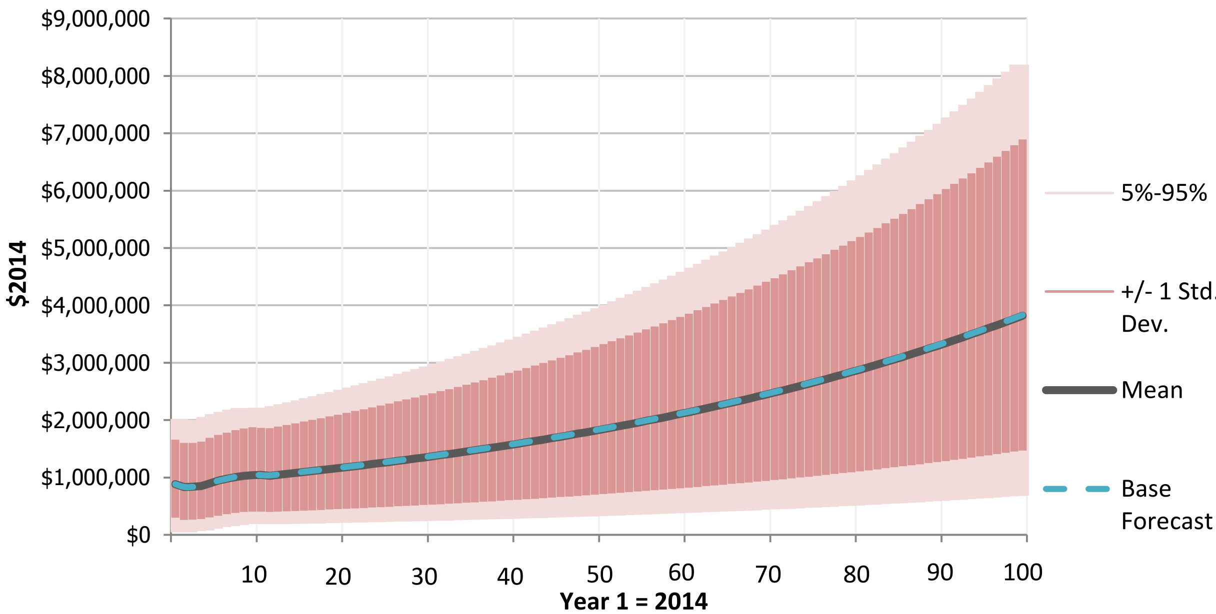
The following figures were developed from a Monte Carlo simulation with 1,000 iterations. Figure J-5 illustrates the revenue risk for the Expected output case over a 100-year planning period. Assuming a discount rate of 3.5%, the net present value of revenue ranges from $9.2 to $65.1 million.

Figure J-5
Revenue Risk with Expected Output Over 100 Years



When output risk is included, the range of revenues increases even more. Figure J-6 illustrates the combined market price risk with output uncertainty.

Figure J-6
Revenue Risk with Output Risk Over 100 Years



When market price risk is combined with the output variation, the net present value of the revenue ranges from $6.4 to $81.2 million over the study period.

Risk Analysis Summary

Based on this analysis, with Expected output, there is a 42% probability that the net present value of the output would at least cover the costs ($39 million in the worst case). Table J-7 summarizes the probability that the hydropower output value will exceed the project costs for each cost scenario.

Table J-7
Probability of Cost-Effectiveness

EXPECTED OUTPUT, DISCOUNT RATE 3.5%			
	EXPECTED	BEST CASE	WORST CASE
Total Project Cost	$36,536,000	$33,967,000	$39,106,000
Probability Net Benefit > 0	52%	58%	42%
Probability Net Benefit < 0	48%	42%	58%

Table J-7 assumes that over the 100-year planning period, the average annual hydropower output will be consistent with the expected values presented earlier. From Table J-7, it is approximately 50% likely that the hydropower output value would exceed the cost of the project.

Appendix K: Environmental Impacts

Scope of Analysis Overview

Habitat enhancement and flood retention facilities change the habitats of aquatic and amphibian species. Quantifying these impacts is a significant challenge in most cases because limitations in data available create challenges when specifying models used to predict changes in population dynamics. For this project, a team of state and consulting biologists assessed the impact on habitats and species populations from different types of flood retention facilities and an ASEP that consists of a variety of enhancement measures in the basin. Their work produced quantitative forecasts of salmonid populations (specifically, spring Chinook, fall Chinook, coho, and steelhead) under a variety of implementation scenarios including implementation of flood retention structure, enhancement action, or a combination of these.[76] Additionally, the ASEP report includes discussions on how enhancement and flood control facilities could impact a wider array of species from a qualitative perspective.

This appendix supplements the brief discussion and data included in the main report related to the economic evaluation of changes in salmonid populations. Specifically, additional information is provided on the standard economic analysis methods and data used to estimate the value of changes in salmonid populations from enhancement actions and flood retention facilities. In the several sections contained in this appendix, discussions are provided on the economic data and methods for estimating changes in value to commercial and recreational fishermen as well as for households who do not fish but value salmonids all the same. This section also covers a separate and detailed economic evaluation of a range of enhancement projects in order to identify which projects generate the greatest value per dollar of investment. In addition, a discussion is also provided on the environmental impacts that cannot be quantified, such as the cultural value of salmonids to Tribal communities, or the impacts of projects on other species populations.

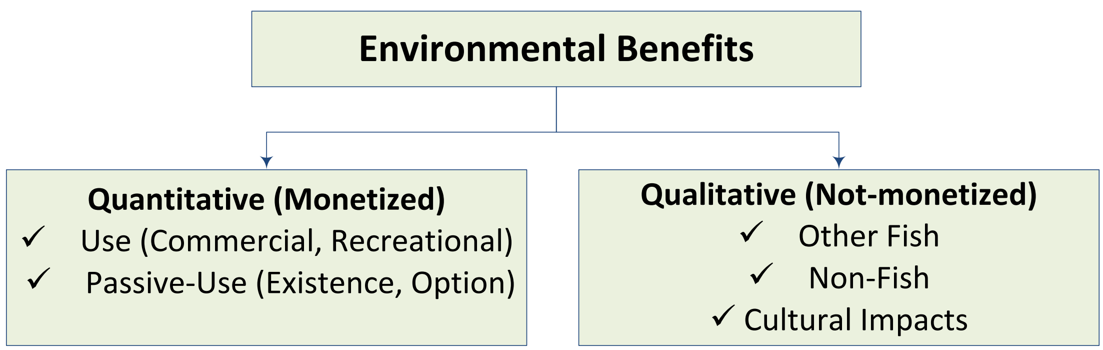
This section on economic benefits covers just one of the two economic measures of changes in fish populations. Economic impacts related to the changes in expenditures, incomes, and output of fishermen that would be attributable to fish population changes are covered in Appendix L. Assessments of economic impacts that relate to changes in expenditures differ from the benefits discussion here because expenditure-related impacts reflect how the fishing industry is integrated into the local and state-level economy. Benefits estimates, in contrast, account for the values that individual fishermen have in their fishing activity. Additional discussion on the difference between economic impacts and economic benefits is contained in Appendix L.

[76] The ASEP group disaggregated its evaluation of salmon, other fish species, and non-fish species based on data availability and ability to forecast species populations. Salmonids are the only fish species that have available population data for forecasting purposes. Several Other Fish and Non-fish species were limited to a qualitative discussion due to a lack of data. Details on the data, assumptions, and models used to estimate salmonid populations are contained in the accompanying ASEP report.

Components of Economic Analyses of Fisheries

An economic valuation of changes in fishery populations considers both quantitative and qualitative types of impacts (see Figure K-1). However, only quantitative outcomes can be included in common project evaluation metrics such as a benefit-cost ratio (BCR) or NPV. Economic valuation of changes in fish populations is determined by the impacts to different stakeholders, including commercial and recreational fishermen as well as others in the state who do not fish but value fisheries-based existence or if they may want the option to fish in the future. Standard methods are used to estimate either benefits or costs[77] to each stakeholder from an increase or decrease in fish populations and harvests. For example, a flood retention facility that prevents adult migration to spawning grounds would reduce stocks of juvenile/young fish and eventually reduce the total population in the Chehalis Basin and its contribution to stocks in estuaries and oceans. Commercial and recreational fishermen would directly bear the costs of these lower populations. The impact is measured in terms of lost profits and reductions in sport trip value, respectively.

Figure K-1
Breakdown of Environmental Benefits Considered



A significant value that cannot be monetized is the cultural value that salmonids provide to tribal communities. The two principal tribes in the area include the Quinault and the Chehalis Tribe. The Quinault, who are located predominantly in the Lower Chehalis Basin and elsewhere around the Puget Sound Area, signed a treaty with the U.S. Government on July 1, 1855. The Chehalis people have historically inhabited the territory from Cloquallum Creek to the upper reaches of the Chehalis River and had a strong river-based economy. The people of the Upper Chehalis rejected as unacceptable the terms of the treaties offered by the U.S. Government, and Chehalis Tribe is regarded as a "non-treaty" tribe. The aquatic resources of the Chehalis Basin are extremely important to both tribes. The estimation of commercial value for these two tribes is not separated from each other in this analysis – all references to Tribes include both the Quinault and Chehalis fishing activities.

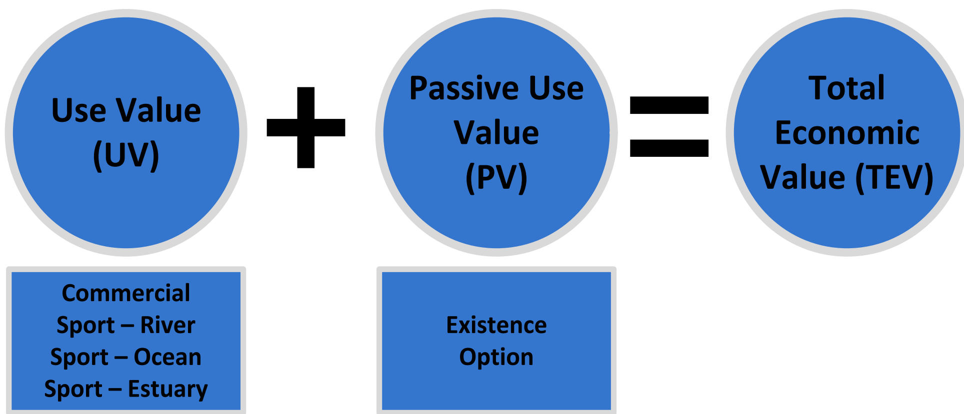
An economic analysis of the importance of salmonid fisheries to these Tribes can be estimated for the commercial activities they undertake. However, the act of fishing and subsistence harvesting is recognized as a cultural way of life that is connected to tribe history and identity. These types of values are beyond economic valuation, which attempts to value choices people make rather than define who a

[77] "Costs" from a negative project impact are evaluated differently from a construction cost. These costs are considered as "negative benefits" and would be subtracted from any positive benefits of a project.

people are. Instead of estimating an economic value of cultural impacts to salmonid population changes, a discussion on key issues is included below for additional consideration beyond economic project evaluation metrics.

Economic theory defines the Total Economic Value (TEV) as a combination of the sum of two categories of value: Use value (UV) and Passive-use value (PV) (Figure K-2). UV is gained by individuals who directly interact with and enjoy the environmental resource, e.g., fishing. In contrast, PV accounts for the value that people place on the sheer existence of fish populations as part of a healthy ecosystem, or perhaps those who seek to retain the option for fishing sometime in the future. The sum of UV and PV is equal to a TEV (Figure K-2).

Figure K-2
Defining a Structure to Total Value for Fish Benefits



UV is derived from both commercial and recreational fishing activity using different methods and is estimated separately for different locations, such as the ocean, estuaries, and river basins. For example:

- **Commercial Fisheries –** Commercial fishery value is estimated from changes in the profits resulting from harvests of salmon populations. In practice, benefits from changes in a population belonging to a particular basin, such as the Chehalis, are estimated using harvest data and net revenues in different States (i.e., Alaska, Oregon, and Washington) and for Treaty/Non-Treaty communities. Total net revenues of fish harvests are computed in each state from the total annual catch (in tons), revenue per ton (derived from wholesale prices), and costs per ton (based often on a percentage of the wholesale price). Fish from the basin that are caught in Canada are considered as a benefit to the United States.
- **Sport Fisheries –** The economic value of sport fishing to anglers is estimated separately for their activities in ocean, estuary, and river waters to account for differences in the frequency, duration and expenditures in fishing in these locations. In the ocean and estuary, fishing generally relies on charter or privately owned boats. In contrast, fishing in a river often occurs in or along the river bank. Sport fishing benefits can include not only fish caught for harvest but also catch and release activities if such management conditions are in place (Anderson and Lee,

2013).[78] Estimating UV for sport fishing depends on the number of anglers per year, their fishing effort (i.e. days of fishing per catch), and the value per day of fishing. Fishing-day values represent an angler's "willingness to pay" (WTP) for fishing and are estimated using standard economic methods, the details of which are discussed below.[79]

The PV of a fishery stems not from fishing but from an individual's interest in the fact that these fish exist, can be caught by someone now or in the future, have a long-standing connection to local cultures, and are significant elements of the ecosystem. Including PV in economic evaluations is heightened when the resource in question is highly valued across society. Salmonids are one such resource since there are many reasons why this species captures the public's attention.[80]

PV is estimated on a per fish basis and the number of fish to which this value is applied is not always clear in the economic studies that estimated PV values. In most economic analyses, though, PV is applied to changes in a total population of adult fish which may be harvested or return to spawn, which includes escapement plus reported harvest.[81] To compute the total number of adult fish, results from fishery biology EDT models (predicted escapement) are adjusted upwards by the ratio of escapement to total returns.

Inclusion of PV into project evaluations is sometimes shown as a separate set of results. For example, Federal guidelines on economic evaluations, as established in the Corps "*Principles and Guidelines"* (1983)*,* do not permit PV to be included as a benefit category because these values do not represent a change to the nation's productivity or market value. At the same time, the state has considered the interests of a wider population as relevant for making decisions that affect these fish, not just those who fish for them. With salmonids, the wide-ranging economic and cultural importance across the state can be a justification for considering a TEV beyond its recreational and commercial catch. Accordingly, in this analysis, results from the Federal Perspective do not include PV, while results from the State Perspective include total benefits with PV and without PV.

Estimation of Economic Value of Changes to Fisheries

Estimation methods differ for each type component of TEV. Common across these estimation methods is that the total value for any change in fish population depends on the number of fish affected and the economic value obtained per fish. The number of fish affected is determined primarily by fishery biologists who model the population response dynamics to changes in management operations, structures, or enhancement activities. Baseline levels of the population are established for individual fisheries (e.g. ocean, estuaries, and river) from historical records and modeling by biologists.

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[78] Catch and release activity can provide value to fishermen but at a lower level than harvest value. In this analysis, the harvest value of fish is applied because declines in fish stocks are not likely to cause management restrictions and because parameters to estimate the UV in this context are not available without making large assumptions.

[79] Economists estimate the value of a resource, such as fish, by a person's WTP. People tend to express a positive WTP for any increase in fish, if this increase generates increased recreational enjoyment or commercial net income from fishing, or simply its existence value. In contrast, if some type of policy or action causes a reduction in fish stocks, the context changes and instead economists seek to understand whether people would have a "willingness to accept (payment)" (WTA) for this decrease. While research has shown that WTA can be significantly larger than WTP, WTA is rarely applied in practice because it is considered less reliable than WTP estimates.

[80] For example, salmonids are a large anadromous species with a long cultural history, they are prized for recreational fishing and consumption, and their populations are broadly indicative of a healthy riverine and oceanic ecosystem.

[81] These adult fish are related to the biological concept of "recruitment," which defines fish that are mature enough to be harvested in commercial, subsistence, or sport fisheries, or to spawn, less any fish that die, prior to spawning, by non-human causes.

The economic value of fish is estimated differently for each stakeholder (e.g., commercial and recreational fishermen, and non-fishermen). For example:

- **Commercial UV –** Estimation of the economic value of commercial catch is straightforward because it is based on the net revenue per fish. This value is obtained from data on revenue per fish using wholesale prices and assumptions on annualized costs to catch these fish. The product of these factors yields an estimate of commercial industry profits. In addition, oftentimes, a long-run average profit is estimated to avoid anomalies from any single year. At the same time, it is necessary to account for any long-run trends in revenues. In this case, a 10-year historical upward trend in real returns (i.e., inflation-adjusted) is observable in the data and this factor is included in estimating future commercial benefits.
- **Sport UV –** This recreational value for fishing in the ocean, estuary, river, or lake is estimated using *non-market* methods such as the Travel Cost Method (TCM) or Contingent Valuation Method (CVM). In either case, questionnaires are used to elicit information from fishermen about the economic aspects of their fishing activities. In a TCM, the costs of fishing include travel (e.g., out-of-pocket costs for transportation, lodging, etc.), site access (e.g., permits, fees, etc.), equipment (e.g., boat, fishing rods, etc.), and time (e.g., during travel and fishing). These costs, which differ for each angler, represent the "price" of fishing. An overall WTP for fishing for all anglers is derived from statistical analyses to explain the number of trips as a function of anglers' travel costs. In a CVM, the WTP is estimated without estimating travel costs by eliciting responses to questions about how many additional trips would be taken if something changed in the resource (e.g., a population change) or access to it. The estimated WTP can exceed the actual expenditures for fishing especially because of the time that an angler spends on the trip.[82] In general, the analytical results assume that, like other market goods that can be purchased, the WTP is a price for fishing that declines with each successive trip. Ultimately, UV valuation parameters combine data on WTP per trip with data on catch rates (e.g., the number of fishing trips until the next fish of a specific species is caught); an estimate can be produced for the implicit WTP per fish.
- **PV –** Similar to Sport UV, PV estimates are obtained through questionnaires to households about their WTP to enhance a fish population through a hypothetical, but realistic, initiative. WTP responses from a stratified sample of households within some geographic area (e.g., a state) are used to estimate the value placed on increased fish populations from all households in that area. In practice, studies to estimate PV alone are difficult to implement, and instead, TEV is often estimated directly and PV is estimated if necessary as a difference between TEV and UV.[83]

[82] Note again that out-of-pocket expenditures during a fishing trip are different but relevant measures of the overall impact of this activity on the economy in terms of numbers of jobs, income, and output.
[83] The difficulty in estimating PV directly stems from issues in the survey protocol in obtaining responses from people who do not fish or consume fish from the affected area. Because of this sampling and surveying problem, it is more straightforward to analytically estimate TEV directly. Note that since benefits are based on UV or TEV, estimates PV alone are not necessary.

Valuation parameters for UV or TEV (the WTP per fishing trip or WTP per fish) can be estimated directly for a specific resource and fishing location, but this approach is not always practical.[84] More commonly, an approach called benefits transfer (BT) is used. In the BT approach, valuation parameters from one site ("existing" site) are applied to estimate value at another site ("policy" site). In this case, the policy site is defined as the Chehalis Basin.[85] Valuation parameters for sport fishing UV and PV overall can be obtained from studies that estimated values in similar locations and for similar types of impacts. The BT approach can be applied for TEV and has been used by Washington State in the past to evaluate project impacts.

Several considerations are required to ensure that BT valuation estimates at the new site are reasonable (e.g., OMB, Circular A-4). For example, there are two broad approaches to benefit transfer: first, a value transfer approach; and second, a function transfer approach. The value transfer approach identifies three possible ways of transferring estimates from the study site to the policy site. Researchers can transfer a single benefit estimate from a study site, several benefit estimates from one or multiple study sites (computed as an average value), or administratively approve estimates. The function transfer approach involves the application of functions, data, and models from the study site to address a similar resource valuation question at the policy site. Functions derived from the study site are tailored to fit the specifics of the policy site. This study utilizes a value transfer approach based on results from studies focused on Washington and Oregon fisheries and have been published since 1980.

Current and Projected Fisheries Populations - Baseline

Current guidelines in fishery management and allocation in fishing access stem from the mid-1970s, when several court cases and regulatory actions reshaped harvest in the Chehalis Basin and elsewhere. In 1974, *United States vs. Washington* reallocated sport and commercial harvest to allow tribal treaty fishing rights to be exercised at usual and accustomed locations and Treaty/Non-Treaty and non-tribal fishermen to harvest up to 50% of the harvestable salmon and steelhead. In 1976, the Magnuson Fishery Conservation and Management Act created the PFMC to set harvest limits and seasons for marine waters representing the exclusive economic zone off the Washington, Oregon, and California coasts (i.e., between 3 and 200 miles off the coasts). Between 1976 and the early 1990s, commercial and charter catches declined significantly and the Grays Harbor fishing fleet declined by more than 50%. Reductions in the abundance and productivity of Pacific Northwest salmon and steelhead stocks led to multiple ESA listings by the late 1990s; however, no ESA listings occurred for salmon or steelhead in the Chehalis River.

Current annual estimated populations of the fish species evaluated in this project (coho, Chinook, and steelhead) in western Washington and Chehalis River Basin are approximately 2.2 million and 89 thousand, respectively. Overall, Chehalis Basin contributes less than 5% to the total population. It is also important to note that current management of Steelhead permits only catch-and-release activity. Table K-1 shows how the Chehalis Basin contributes to total fish populations in Washington State.

[84] New studies to estimate economic values can be time consuming and expensive and can face practical constraints. For example, if the change to the resource is not well defined, it would be difficult to construct a questionnaire that can elicit useful response. More generally, some types of analyses do not require a high level of precision in estimated values.
[85]The site(s) or cases evaluated in existing study(s) are referred to as the "study" site and the site to which values are transferred as the "policy" site. The "policy" site here is the Chehalis River Basin in the state of Washington.

Table K-1
Current Fish Populations by Species in WA (2014)

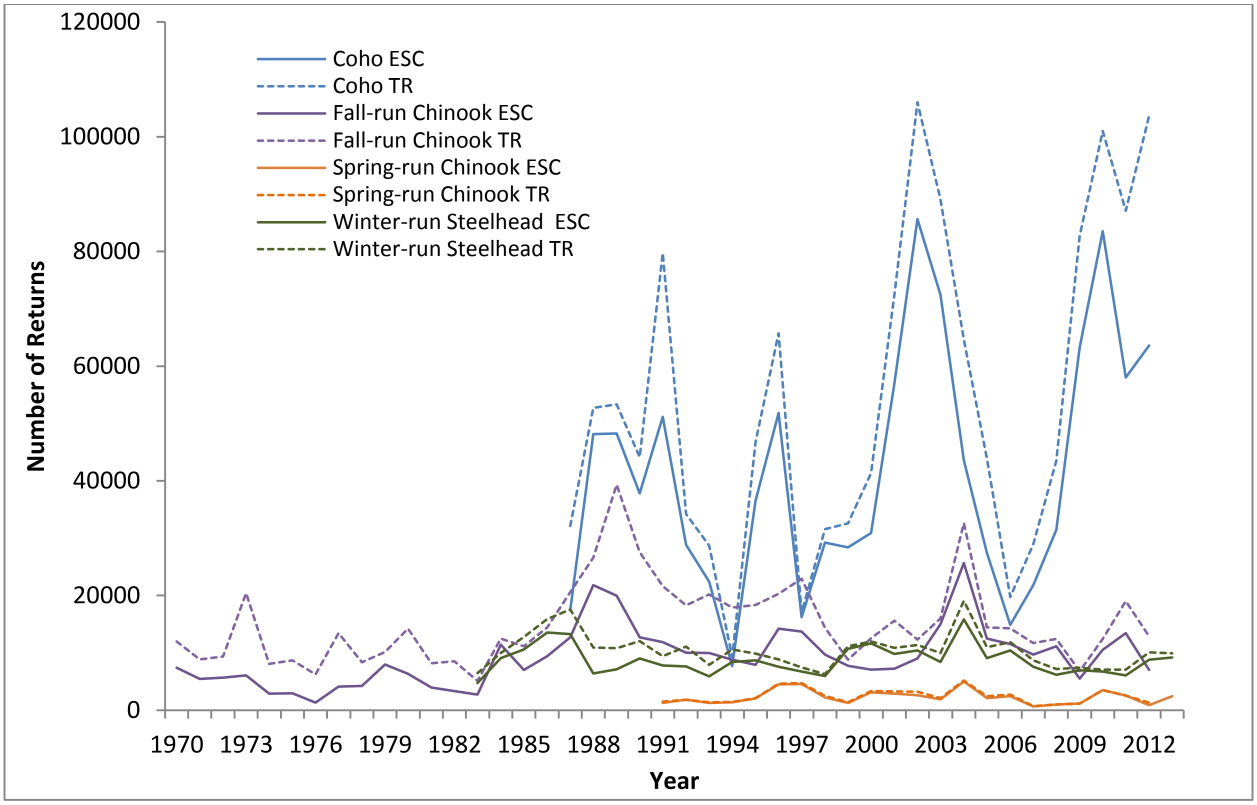
FISH SPECIES	# OF FISH IN OR ORIGINATING FROM CHEHALIS BASIN (2014)	# OF FISH IN WA (2014)	PROPORTION OF WA FISH FROM CHEHALIS
Coho	60,000	721,235	8.3%
Chinook (Spring, Fall)	18,342	1,295,880	1.4%
Steelhead	10,417	200,000	5.2%
Total	88,759	2,217,115	4.0%

Notes:
Source: Last Update - 6/2/2014: 2014 Estimates for total Washington Salmon Populations are provided by Kirt Hughes and Phillips Larry (Washington Department of Fish and Wildlife). The 2014 Reports are located under the listing - 2014 North of Falcon Salmon Pre-Season Forecasts, on this page: http://wdfw.wa.gov/fishing/reports_plants.html.

Biological modeling and forecasts of the change in populations related to flood retention facilities and enhancement projects has been conducted under several baseline conditions including: no growth, managed forests-induced growth, and two climate change scenarios. Key features of these baseline conditions are as follows:

- **No Growth –** Populations are assumed to be stable and unchanging over time. This assumption is supported by recent historical trends that suggest stable populations for most species and even increasing populations for Coho (see Figure K-3).
- **Managed Forests –** Populations are, however, expected to increase over time under a *managed forests* scenario that would account for successes achieved through the Forest Practices Act. Under a *managed forest* scenario, the population would grow asymptotically with or without changes in the basin (e.g., enhancement or flood structure).
- **Climate Change –** Two different climate change scenarios ("Low" and "High") are defined and modeled to evaluate how a series of conceivable conditions related to water temperature and other factors could influence salmonid populations. These scenarios were developed in the ASEP study.

Figure K-3
Recent Spawning Escapement and Total Run Size for Chehalis River Coho Salmon, Fall-run Chinook Salmon, Spring-run Chinook Salmon, and Winter-run Steelhead



Notes:
Date ranges correspond to available data for each species.

The ASEP group used the EDT model to estimate baseline existing conditions of Chehalis salmon populations and the change in population due to a flood retention facility and enhancement actions. In each case, fish population forecasts are predicted to change in some way because of a flood structure or habitat enhancement projects, and the value of this change would be measured relative to the relevant baseline condition. Key assumptions with respect to the impact of flood structures include: (a) Population changes take 4 years to be fully realized for Chinook and steelhead; and (b) Population changes take 2 years to be fully realized for coho. Due to the magnitude of the enhancement efforts, it would take several years to construct all of the projects. It is difficult to predict where and when projects would be implemented because funding sources and quantities are unknown. Therefore, while the benefits are assumed to be realized in the first few years, the actual benefits from the projects would likely take longer to be realized.

Data on baseline populations for no-growth and managed forest scenarios are contained in Table K-2 and the two climate change baseline conditions forecasts are contained in Table K-3. It is assumed that these adult salmon and steelhead represent the biological concept of recruitment (i.e., fish mature enough to be exploitable from commercial, subsistence, or sport fisheries, or to spawn, minus the fish that die prior to spawning by non-human causes). Future populations may deviate from predicted values for a variety of reasons. In this analysis it is assumed that the management of the Pacific salmon fisheries would continue to follow historical actions to maintain populations.[86]

Table K-2
Baseline Fisheries Population Forecasts – No Growth and Managed Forest Scenarios

SCENARIO	SPECIES	CURRENT	FUTURE	PERCENT CHANGE
Baseline with No Growth				
	Spring Chinook	2,448	2,448	0.0%
	Fall Chinook	15,894	15,894	0.0%
	Steelhead	10,417	10,417	0.0%
	Coho	60,000	60,000	0.0%
Baseline with Managed Forests				
	Spring Chinook	2,448	2,935	19.9%
	Fall Chinook	15,894	17,217	8.3%
	Steelhead	10,417	11,825	13.5%
	Coho	60,000	69,984	16.6%

Table K-3
Baseline Fisheries Population Forecasts – Climate Change Scenarios

SCENARIO	SPECIES	CURRENT	FUTURE	PERCENT CHANGE
Baseline with Low Climate Change				
	Spring Chinook	2,448	358	-85.4%
	Fall Chinook	15,894	15,679	-1.4%
	Steelhead	10,417	8,173	-21.5%
	Coho	60,000	40,112	-33.1%
Baseline with High Climate Change				
	Spring Chinook	2,448	-	-100.0%
	Fall Chinook	15,894	13,007	-18.2%
	Steelhead	10,417	4,634	-55.5%
	Coho	60,000	16,810	-72.0%

Commercial fisheries harvest about 90% and 80% of Chinook and coho, respectively (see Table K-4). Tribal commercial harvests (including treaty and non-treaty tribes) occur in Grays Harbor and Chehalis Basin amount to nearly 80% and 75% of Chinook and coho. Sport fishing harvests primarily occur in Grays Harbor. Data on harvests from other states is applied to determine a weighted average value of fish originating from the Chehalis Basin.

[86] For example, it is assumed that these species would not be listed under an Endangered Species Act because of this project.

Table K-4
Proportion of Catch by Fishery and Type of Fisherman

		OCEAN		GRAYS HARBOR		RIVER	TRIBAL (TREATY/ NON-TREATY)[1]	
		COMMERCIAL	SPORT	COMMERCIAL	SPORT	SPORT	COMMERCIAL	TOTAL
Chinook								
	BC	4.4%	1.0%	0.0%	0.0%	0.0%	0.0%	**5.4%**
	AK	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	**3.8%**
	WA	0.1%	0.8%	2.2%	5.9%	2.3%	79.5%	**90.8%**
	OR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.0%**
	Total	**8.4%**	**1.8%**	**2.2%**	**5.9%**	**2.3%**	**79.5%**	**100.0%**
Coho								
	BC	0.1%	0.04%	0.0%	0.0%	0.0%	0.0%	**0.14%**
	AK	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.1%**
	WA	0.1%	0.3%	6.0%	5.3%	14.4%	73.5%	**99.5%**
	OR	0.01%	0.1%	0.0%	0.0%	0.0%	0.0%	**0.11%**
	Total	**0.4%**	**0.4%**	**6.0%**	**5.3%**	**14.4%**	**73.5%**	**100.0%**

Notes:
1. This category combines the benefits to The Quinault Indian Nation "Treaty" and Chehalis Tribe "Non-treaty"

Description of Project Options and Costs

Project implementation options that have been modeled by fish biologists include two types of facilities (i.e., flood retention and MPD). The flood retention designs include impacts to 50% of upstream habitat as well as alternative designs that affect 25% and 100% of upstream habitat, respectively. In addition, fish impact models evaluated a series of enhancement actions. Some of these enhancement options differ with respect to the level of riparian area that is restored and the proportion of river reaches where enhancement could occur. Other enhancement projects are related to the installation of large woody material (LWM) in streams, modification of culverts to permit passage of fish, and some off-channel enhancement actions. In all, the following enhancement projects were evaluated:

- **NMF-Riparian20/50 –** Increase the modeled riparian attributes by 20% in the non-managed forests in 50% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.
- **NMF-Riparian60/50 –** Increase the modeled riparian attributes by 60% in the non-managed forests in 50% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.
- **NMF-Riparian20/75 –** Increase the modeled riparian attributes by 20% in the non-managed forests in 75% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.

- **NMF-Riparian60/75 –** Increase the modeled riparian attributes by 60% in the non-managed forests in 75% of Spring Chinook spawning reaches. Potential examples of actions that would be included are removal of invasive vegetation, riparian plantings, and preservation of existing good riparian areas.
- **NMF-LWM50/50 –** Increase the modeled instream wood attributes by 50% in 50% of Spring Chinook spawning reaches. Examples include log cribs, installation of log jams, root wads, and wood structure to trap gravel and/or sediment.
- **NMF-LWM50/75 –** Increase the modeled instream wood attributes by 50% in 75% of Spring Chinook spawning reaches. Examples include log cribs, installation of log jams, root wads, and wood structure to trap gravel and/or sediment.
- **Culvert100 –** Passage at all artificial barriers = 100% Remove the 169 barriers that are in the EDT model to allow access above the barriers.
- **Off-Channel –** Restore side-channel habitat by re-connecting disconnected ox-bows to main channels and restore adjacent riparian habitats.

In all of these cases, it is assumed that baseline fish populations are stable in the future and the watershed is in a *non-managed forest* regime.

Table K-5 provides a brief description of these project implementation options, and more information is contained in the ASEP report.

Table K-5
List of Enhancement Options and Costs

PROJECT NAME	DESCRIPTION
Baseline	Post flood conditions, Non-rated culverts=100% passage; without managed forests (except in Combinations)
STRUCTURES	
FRO50, FRO25, FRO100	Flood retention only affects 50%, 25% and 100% of habitat
Multipurpose	Multi-purpose dam, full reservoir
ENHANCEMENT	
Riparian20/50	Restore riparian by 20% in 50% of reaches
Riparian60/50	Restore riparian by 60% in 50% of reaches
Riparian20/75	Restore riparian by 20% in 75% of reaches
Riparian60/75	Restore riparian by 60% in 75% of reaches
LWM50/50	Restore LWM by 50% in 50% of reaches
LWM50/75	Restore LWM by 50% in 75% of reaches
Culvert100	Passage at all artificial barriers = 100%

In addition to evaluating the effect of individual projects, some scenarios evaluated a combination of projects that could be implemented. Table K-6 indicates the actual projects in each combination by an *X* under each option. For example, the Low Enhancement Only scenario contained the enhancement projects Riparian20/50, LWM50/50, Culvert100, and Off-channel. For the Low Enhancement + FRO50 scenario, these same projects were included along with FRO50. The impact of these combinations is discussed below.

Table K-6
Definition of Structure and Enhancement Option Combinations

SCENARIO	ENHANCEMENT OPTION						STRUCTURE		
	NMF-RIPARIAN20/50	NMF-RIPARIAN60/50	NMF-RIPARIAN20/75	NMF-RIPARIAN60/75	NMF-LWM50/50	NMF-LWM50/75	CULVERT100	FRO50	MULTIPURPOSE
Low Enhancement Only	X				X		X		
High Enhancement Only				X		X	X		
Low Enhancement+ FRO50	X				X		X	X	
Low Enhancement+ Multi	X				X		X		X
High Enhancement+ FRO50				X		X	X	X	
High Enhancement+ Multi				X		X	X		X

High-level estimates for the capital costs of enhancement projects have been estimated as a range of values. These costs are shown below in Table K-7. Costs for different types of flood control facilities are discussed elsewhere in Dam Design Study.[87]

Table K-7
Enhancement Action Capital Cost Summary ($M)

Project Name	Total with Contingency[1]	Annual O&M Costs[2]	Total Costs - Federal @3.5%	Total Costs - State @1.63%
NMF-LWM50/50	$17.55	$0.10	$18.34	$18.42
NMF-LWM50/75	$27.80	$0.14	$28.99	$29.11
NMF-Riparian20/50	$43.24	$0.22	$45.04	$45.22
NMF-Riparian20/75	$64.86	$0.32	$67.55	$67.83
NMF-Riparian60/50	$43.24	$0.22	$45.04	$45.22
NMF-Riparian60/75	$64.86	$0.32	$67.55	$67.83
Culverts 100	$29.97	$0.16	$31.28	$31.42
Low Enhancement	$90.76	$0.47	$94.66	$95.06
High Enhancement	$122.63	$063	$127.83	$128.35

Notes:
1. Includes 30% contingency
2. O&M is required for 10 years following project implementation.

Impact of Project Options on Fish Populations

The following tables summarize the results of population changes due to the implementation of a flood retention facility or habitat rehabilitation project. Table K-8 indicates the total impacts on each fish

[87] HDR, Inc. Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species. Dam Design Technical Memorandum. Draft March 2014.

species for either a FRO50 or Multipurpose structure. Based on ASEP modeling, the impacts to spring Chinook differ considerably between the structure designs in that there is an 8% decline for FRO50 and a 6.5% increase for the MPD option. Steelhead populations on the other hand would be worse off with the MPD option.

Table K-8
Fish Population Changes with Structure (% Change from Projected Populations)

SPECIES	% CHANGE IN FISH POPULATION WITH FRO50	% CHANGE IN FISH POPULATION WITH MULTIPURPOSE
Spring Chinook	-8.1%	6.5%
Fall Chinook	-1.1%	0.3%
Steelhead	-4.0%	-7.4%
Coho	-1.9%	-0.6%
Total	**-2.1%**	**-1.1%**

Table K-9 presents the changes in populations for each fish species due to enhancement actions. Among fish species, spring Chinook is the most responsive to enhancement, which would see population increases from 12% to over 160% for all actions besides culverts. Impacts to coho populations would also be significant for each enhancement action, just not quite as large an impact as spring Chinook.

Table K-9
Fish Population Changes with Enhancement, % Change from Projected Populations

SPECIES	LWM 50/50	LWM 50/75	RIPARIAN 20/50	RIPARIAN 20/75	RIPARIAN 60/50	RIPARIAN 60/75	CULVERTS 100
Spring Chinook	12.1%	31.3%	22.6%	52.8%	104.8%	164.9%	0.0%
Fall Chinook	2.2%	4.8%	4.0%	7.6%	10.5%	19.1%	0.8%
Steelhead	3.2%	5.7%	4.7%	7.7%	12.8%	20.6%	8.2%
Coho	7.8%	11.8%	8.8%	13.4%	26.5%	40.5%	8.6%
Total	**6.4%**	**10.3%**	**7.8%**	**12.8%**	**24.2%**	**37.8%**	**6.9%**

Finally, Table K-10 presents the effects on each fish species from some combination of a flood retention structure and one or more enhancement actions, as defined in Table K-6. While structures caused an overall reduction in fish populations (with the exception of a MPD structure on Chinook), the combination of structures and enhancement actions all enhanced fish populations. The largest overall effect is observed for spring Chinook. The combination of enhancement projects also increases fish populations above any single action, as shown in Table K-9. However, the impact of the sum of single enhancement actions is not equal to the combination of these actions.

Table K-10
Fish Population Changes with Combined Structure and Enhancement, % Change from Projected Populations

SPECIES	LOW RIPARIAN ENHANCEMENT	HIGH RIPARIAN ENHANCEMENT	FR050 + LOW ENHANCEMENT	MULTIPURPOSE + LOW ENHANCEMENT	FRO50 + HIGH ENHANCEMENT	MULTIPURPOSE + HIGH ENHANCEMENT
Spring Chinook	49.6%	184.3%	21.9%	25.8%	164.7%	109.7%
Fall Chinook	8.4%	25.2%	6.5%	5.8%	22.8%	17.9%
Steelhead	14.3%	34.6%	9.7%	3.1%	32.1%	19.3%
Coho	23.0%	60.9%	19.7%	17.1%	58.5%	49.4%
Total	**20.1%**	**54.8%**	**16.2%**	**13.7%**	**51.9%**	**41.9%**

Estimated annual changes in fish populations by species due to structure or enhancement options can be computed from the data on: (a) future baseline fish populations by species (Table K-2); (b) the proportions caught in each fishery (Table K-4); and (c) the percentage change in population because of a structure (Table K-8), enhancement action (Table K-9), or combined action (Table K-10).[88] Several examples are provided below for options on structures, enhancement, and combined actions to provide a perspective on the potential magnitude of benefits of GI. Steelhead are not caught in oceans and estuaries, only in rivers, and thus do not appear in commercial cells in Table K-4.

Table K-11
Total Change in Fish Populations – FRO50

SPECIES	COMMERCIAL				SPORT			
	OCEAN	GRAYS HARBOR	TREATY / NON-TREATY[1]	TOTAL	OCEAN	GRAYS HARBOR	RIVER	TOTAL
Spring Chinook	-17	-4	-158	-179	-4	-12	-5	-20
Fall Chinook	-15	-4	-140	-158	-3	-10	-4	-17
Steelhead							-414	-414
Coho	-5	-66	-817	-888	-5	-59	-159	-223
Total	**-36**	**-74**	**-1115**	**-1225**	**-11**	**-81**	**-582**	**-674**

Table K-12
Total Change in Fish Populations – Multipurpose

SPECIES	COMMERCIAL	SPORT

[88] The estimated change in fish populations for combined structure and restoration actions is computed relative to a managed forest scenario baseline since managed forest conditions were assumed in the forecast for combined actions and managed forests conditions are part of this project.

	OCEAN	GRAYS HARBOR	TREATY / NON-TREATY[1]	TOTAL	OCEAN	GRAYS HARBOR	RIVER	TOTAL
Spring Chinook	13	3	126	143	3	9	4	16
Fall Chinook	4	1	38	43	1	3	1	5
Steelhead							-414	-414
Coho	-2	-23	-282	-307	-2	-20	-55	-77
Total	16	-18	-118	-121	2	-8	-464	-471

Similar results are shown for all of the options including ones for High Enhancement (Table K-13), Low Enhancement (

Table K-14), and combined structure and enhancement (Table K-15). These data indicate that in some cases, the impact on fisheries is small (e.g., change in commercial harvest of 1 in Grays Harbor due to a flood retention structure) and in others, the impact is relatively large (e.g., growth in Treaty/Non-Treaty Harvest of coho due to a NMF-Riparian60/75 enhancement action).

Table K-13
Total Change in Fish Populations – Riparian60/75

	COMMERCIAL				SPORT			
SPECIES	OCEAN	GRAYS HARBOR	TREATY / NON-TREATY[1]	TOTAL	OCEAN	GRAYS HARBOR	RIVER	TOTAL
Spring Chinook	337	88	3211	3636	71	236	94	401
Fall Chinook	254	66	2417	2737	53	178	71	302
Steelhead							2145	2145
Coho	105	1452	17869	19425	102	1289	3488	4879
Total	696	1605	23497	25798	226	1703	5798	7728

Table K-14
Total Change in Fish Populations –Riparian20/50

SPECIES	COMMERCIAL				SPORT			
	OCEAN	GRAYS HARBOR	TREATY / NON-TREATY[1]	TOTAL	OCEAN	GRAYS HARBOR	RIVER	TOTAL
Spring Chinook	46	12	440	498	10	32	13	55
Fall Chinook	52	14	499	566	11	37	15	62
Steelhead							486	486
Coho	23	315	3881	4219	22	280	758	1060
Total	121	341	4820	5282	43	349	1271	1663

Table K-15
Total Change in Fish Populations – Combined Low Enhancement + FRO50

SPECIES	COMMERCIAL				SPORT			
	OCEAN	GRAYS HARBOR	TREATY / NON-TREATY[1]	TOTAL	OCEAN	GRAYS HARBOR	RIVER	TOTAL
Spring Chinook	60	16	572	647	13	42	17	71
Fall Chinook	93	24	887	1004	20	65	26	111
Steelhead							1148	1148
Coho	60	825	10153	11037	58	732	1982	2772
Total	213	865	11611	12688	90	840	3172	4102

Notes:
1 This category combines the benefits to The Quinault Indian Nation "Treaty" and Chehalis Tribe "Non-treaty"

Estimation of Commercial Use Values

Estimated benefits (or costs) in commercial fisheries accrue from increases (or decreases) in fish populations (as shown in Table K-11 through Table K-15) and the market returns to fishermen. Several commercial fisheries would be affected by flood control structures and enhancement actions, including:

- Ocean-caught Chinook and coho salmon
- Grays Harbor-caught Chinook and coho
- Treaty/Non-Treaty-caught Chinook and coho

The method for computing economic values of population changes is common across these fisheries. However, accounting for costs and benefits depends on the regional perspective. For example:

- **Federal Perspective –** Based on USACE Principles and Guidelines, NED benefits from commercial fishing include the harvest of all Chehalis-sourced salmon but exclude those allocated to Canada.
- **State Perspective –** Commercial benefits would include Washington-only harvests of Chehalis-origin salmonids in the Ocean and Grays Harbor.

COMPUTATIONAL APPROACH

Benefits are computed as the sum of net economic value resulting from Chehalis Basin originating salmon harvested by marine fisheries operations. Net economic value is estimated using standard assumptions on the computation of profits from the commercial fishery. In economic analyses, this value represents the creation of wealth for fishermen, either from the State or Federal Perspectives. Total net economic value is the sum of profits across states and fish types for all fish harvested in a given year. Total net economic value framed as an equation looks like the following:

$$UV_{Comm} = \sum_{ijt} \pi_{ijt} * \Delta Q_{ijt}$$

where UV_{Comm} is commercial use value that is computed as a sum of the profits earned per fish π_{ijt}, and the change in the quantity of fish harvested, ΔQ_{ijt}, for each sovereignty (i.e., U.S. or Tribe) (i)[89], U.S. state (j), and year (t) where and when they are caught. An additional factor, g_t , accounts for long-run trends in harvest revenue that could influence prices in the future. Over the past ten years, growth in revenue has been about 2% annually in real, inflation-adjusted terms. This factor is included in the computation of future commercial value of salmonid harvests.

Average profit per fish has been estimated using historical data available from the PFMC and Washington Department of Fish and Wildlife (WDFW). A structure and logic diagram (Figure K-4) outlines the variables used to derive an estimate of average profit and the units associated with them. Key inputs are the total nominal revenue of fish harvested, dressed pounds landed, and numbers of fish harvested per year. Computations of net revenue are determined for each State. Average values are generated by weighting them based on the proportion of Chehalis-origin catch.

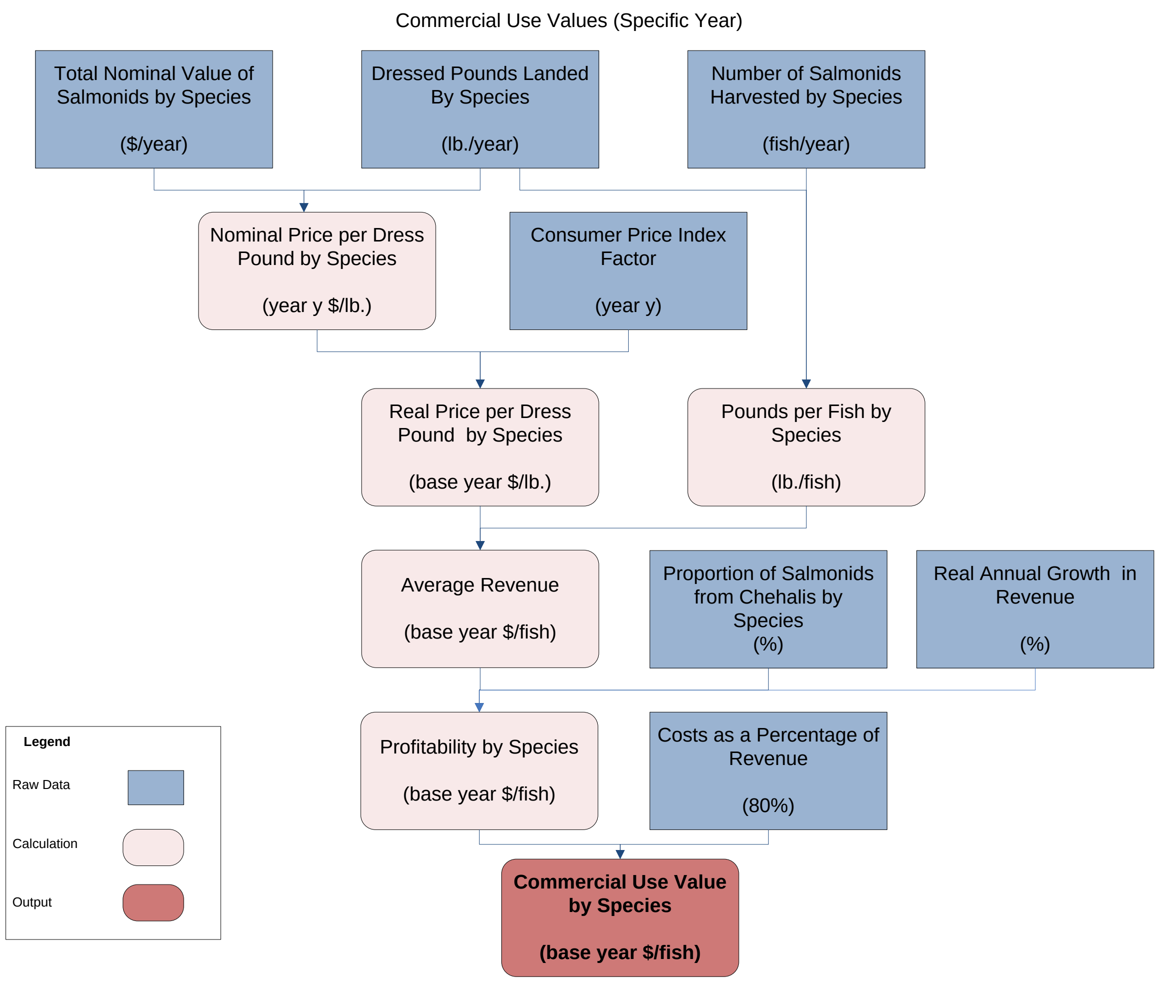
BIOLOGICAL ASSUMPTIONS

Changes in commercial fisheries harvests assume that fishery management strategies remain the same. Even if a commercial fishery harvest trend exists, no attempt was made to derive that trend and extrapolate it into the future condition. As a result, the current proportions of fish caught in different locations are the same as what is projected to be the case in the future. The proportion of each salmon species harvested by location is derived from historical data from WDFW on the landed catch of salmon that originate from the Chehalis Basin. This percentage is computed as the ratio of total commercial harvest by sovereignty and state to the total number of harvested fish for all purposes (commercial and

[89] Net revenues to Canadian firms are excluded.

sport). As discussed previously, estimated changes in fish populations by location are presented in Table K-11 through Table K-15.
Changes are related to baseline and changed population relative to implantation of a structure, enhancement, or combined action.

Figure K-4
Commercial Use Value Calculations, Structure and Logic Diagram



COMMERCIAL FISHING VALUE DATA

This section presents estimated real revenue per fish for Chehalis-origin fish that are caught in several states (Oregon, Washington, and Alaska). Profit assumes that costs are approximately 80% of gross revenues.[90] Calculations follow the method discussed above. The last column presents estimated revenues from Chehalis-origin fish separately for coho and Chinook in Table K-16 and Table K-17.

[90] Yakima River Basin Integrated Plan Study, ECONorthwest, 2012

Table K-16
Coho Profitability[2]

STATE	YEAR	NOMINAL REVENUE ($1,000S)	REAL REVENUE ($1,000S)1	DRESSED POUNDS LANDED (1,000S)	# OF FISH HARVESTED	NOMINAL PRICE PER DRESSED POUND	REAL PRICE PER DRESSED POUND[1]	POUNDS PER FISH	NOMINAL REVENUE PER FISH	REAL PROFIT PER FISH[1]
Oregon	2009	267	285	131	21968	2.04	2.18	5.96		
	2010	16	16	7	1038	2.29	2.29	6.74		
	2011	5	5	3	464	1.67	1.67	6.47		
	2012	8	9	4	625	2.00	2.25	6.40		
	2013	7	7	2	426	3.50	3.50	4.69		
	Revenue average[3]					1.88	2.06	6.46	12.05	13.35
	Profit average[3]								9.64	10.68
Washington	2009	276	294	136	20055	2.03	2.16	6.78		
	2010	32	34	15	2104	2.13	2.27	7.13		
	2011	35	37	17	3053	2.06	2.18	5.57		
	2012	35	36	18	3268	1.94	2.00	5.51		
	2013	67	67	31	6041	2.16	2.16	5.13		
	Revenue average[3]					1.78	1.93	6.45	11.48	12.42
	Profit average[3]								9.18	9.94
Alaska	2009	17615	18764	16770	2635000	1.05	1.12	6.36		
	2010	24735	26281	19444	2578000	1.27	1.35	7.54		
	2011	17524	18525	13766	2305000	1.27	1.35	5.97		
	2012	19579	20138	13311	2084000	1.47	1.51	6.39		
	2013	23410	23410	19987	3504000	1.17	1.17	5.70		
	Revenue average[3]					1.24	1.35	6.59	8.19	8.88
	Profit average[3]								6.55	7.10

Notes:

1. Nominal prices have been converted to 2014 dollars using the Consumer Price Index for the respective year value
2. Data obtained from Pacific Fisheries Management Council (2013) Stock Assessment and Fisheries Evaluation Reports (SAFE), Review of 2013 Ocean Salmon Fisheries, Chapter IV – Socioeconomic Assessment of the 2013 Ocean Salmon Fisheries http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/review-of-2013-ocean-salmon-fisheries/
3. Revenue and profit averages are computed as a five-year weighted average.

Table K-17
Chinook Profitability[2]

STATE	YEAR	NOMINAL REVENUE ($1,000S)	REAL REVENUE ($1,000S)[1]	DRESSED POUNDS LANDED (1,000S)	# OF FISH HARVESTED	NOMINAL PRICE PER DRESSED POUND	REAL PRICE PER DRESSED POUND[1]	POUNDS PER FISH	NOMINAL REVENUE PER FISH	REAL PROFIT PER FISH[1]
Oregon	2009	77	82	15	1149	5.13	5.47	13.05		
	2010	2775	2921	506	39433	5.48	5.77	12.83		
	2011	2385	2473	402	32081	5.93	6.15	12.53		
	2012	4263	4325	741	73096	5.75	5.84	10.14		
	2013	7598	7598	1291	112596	5.89	5.89	11.47		
	Revenue average[3]					4.34	4.78	11.32	49.09	54.06
	Profit average[3]								39.27	43.24
Washington	2009	893	951	155	12316	5.76	6.14	12.59		
	2010	3083	3245	522	45099	5.91	6.22	11.57		
	2011	1652	1705	322	26902	5.13	5.30	11.97		
	2012	2323	2356	435	36855	5.34	5.42	11.80		
	2013	2771	2771	450	40090	6.16	6.16	11.22		
	Revenue average[3]					4.66	4.95	12.40	57.78	61.39
	Profit average[3]								46.23	49.11
Alaska	2009	11970	12747	3759	267000	3.18	3.39	14.08		
	2010	15772	16601	3742	260000	4.21	4.44	14.39		
	2011	18358	18947	4612	344000	3.98	4.11	13.41		
	2012	16030	16258	3629	278000	4.42	4.48	13.05		
	2013	17423	17423	2601	200000	6.70	6.70	13.01		
	Revenue average[3]					3.66	3.96	14.25	52.20	56.41
	Profit average[3]								41.76	45.13

Notes:
1. Nominal prices have been converted to 2014 dollars using the Consumer Price Index for the respective year value.
2. Data obtained from Pacific Fisheries Management Council (2013) Stock Assessment and Fisheries Evaluation Reports (SAFE), Review of 2013 Ocean Salmon Fisheries, Chapter IV – Socioeconomic Assessment of the 2013 Ocean Salmon Fisheries http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/review-of-2013-ocean-salmon-fisheries/
3. Revenue and profit averages are computed as a five-year weighted average.

Table K-18 shows the estimation of the commercial value of Treaty/Non-Treaty harvested fish. The procedure for estimating real value per fish is the same as for commercial activities in each state;

however, the final values here are not weighted since all Treaty/Non-Treaty-caught fish come from the Chehalis Basin.[91]

Table K-18
Treaty/Non-Treaty Fishery Profitability[2]

SPECIES	ROW LABEL	NOMINAL VALUE ($1,000S)	REAL VALUE ($1,000S)	ROUND POUNDS LANDED (1,000S)	NOMINAL PRICE PER DRESSED POUND	REAL PRICE PER DRESSED POUND	POUNDS PER FISH	NOMINAL VALUE PER FISH	REAL VALUE PER FISH
Spring-run Chinook salmon	2009	$745	$809	247	$3.02	$3.28			
	2010	$2,534	$2,708	666	$3.81	$4.07			
	2011	$1,843	$1,909	526	$3.50	$3.63			
	2012	$996	$1,010	207	$4.81	$4.88			
	2013	$964	$964	208	$4.63	$4.63			
Revenue 10-year wtd average					$3.57	$3.80	15.05	$53.73	$57.14
Profit 10-year wtd average								$42.99	**$45.71**
Fall-run Chinook Salmon	2009	$1,391	$1,510	1,383	$1.01	$1.09			
	2010	$2,246	$2,400	1,887	$1.19	$1.27			
	2011	$3,522	$3,648	1,892	$1.86	$1.93			
	2012	$2,059	$2,089	1,124	$1.83	$1.86			
	2013	$5,302	$5,302	2,778	$1.91	$1.91			
Revenue 10-year wtd average					$1.39	$1.48	17.92	$24.86	$26.52
Profit 10-year wtd average								$19.89	**$21.22**
Coho Salmon	2009	$49	$53	70	$0.70	$0.76			
	2010	$53	$57	42	$1.27	$1.36			
	2011	$262	$271	183	$1.43	$1.48			
	2012	$47	$48	34	$1.39	$1.41			
	2013	$115	$115	98	$1.17	$1.17			
Revenue 10-year wtd average					$0.96	$1.02	11.43	$10.95	$11.66
Profit 10-year wtd average								$8.76	**$9.32**

Notes:
1. Nominal prices have been converted to 2014 dollars using the Consumer Price Index for the respective year value
2. Data obtained from Pacific Fisheries Management Council (2013) Stock Assessment and Fisheries Evaluation Reports (SAFE), Review of 2013 Ocean Salmon Fisheries, Chapter IV – Socioeconomic Assessment of the 2013 Ocean Salmon Fisheries http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/review-of-2013-ocean-salmon-fisheries/
3. Revenue and profit averages are computed as a five-year weighted average.

In order to sum benefits for multiple states, the profit for each state was weighted by the proportion among states where Chehalis-origin fish are caught for commercial harvest purposes. Thus, the sum of the products of weighted profit per state and quantity of fish per state are the total profits for all states

[91] This assumes that all fish counted in this estimate are used for commercial purposes. Fish used for tribal subsistence purposes would be accounted for separately.

(see Table K-4 and Table K-17). Note that fish caught by Treaty and Non-Treaty Tribes are not weighted since all are caught in WA State waters.

Table K-19
Commercial Fishing Use Values

STATE	SPECIES	% OF TOTAL STATES ONLY	10-YEAR WEIGHTED AVERAGE PROFIT ($/FISH)	10-YEAR WEIGHTED AVERAGE (PROFIT) WEIGHED BY DISTRIBUTION ($/FISH)
Coho salmon	Oregon	0%	$10.59	$0.02
	Washington	99%	$9.94	$9.82
	Alaska	1%	$7.10	$0.07
	Total[2]	100%	N/A	$9.91
Chinook salmon	Oregon	0%	$42.81	$0.00
	Washington	37%	$49.11	$18.25
	Alaska	63%	$45.13	$28.36
	Total[1]	100%	N/A	$46.61

Estimation of Sport Use Values – Ocean and Grays Harbor

COMPUTATIONAL APPROACH

Benefits from sport fishing for salmonids in either Grays Harbor or ocean fisheries are estimated using a similar process but with different valuation data. In each case, the value of a fish to an angler is derived from an economic valuation of the time and expenditures trip to catch each fish. The economic value of a fish is above and beyond the expenditures alone to go fishing and reflects an angler's interests by accounting for the time and expense of taking a trip. Data about fishing trips is converted into an economic measure of an angler's willingness-to-pay (WTP) for a trip, which is defined as the marginal, or incremental, value of taking an additional trip. For all fishermen, WTP expresses the collective value of going fishing and adheres to standard economic assumptions that a person's WTP for fishing trips declines as more trips are taken. The overall sum of WTP for each angler reveals a total use value for all trips that are taken.

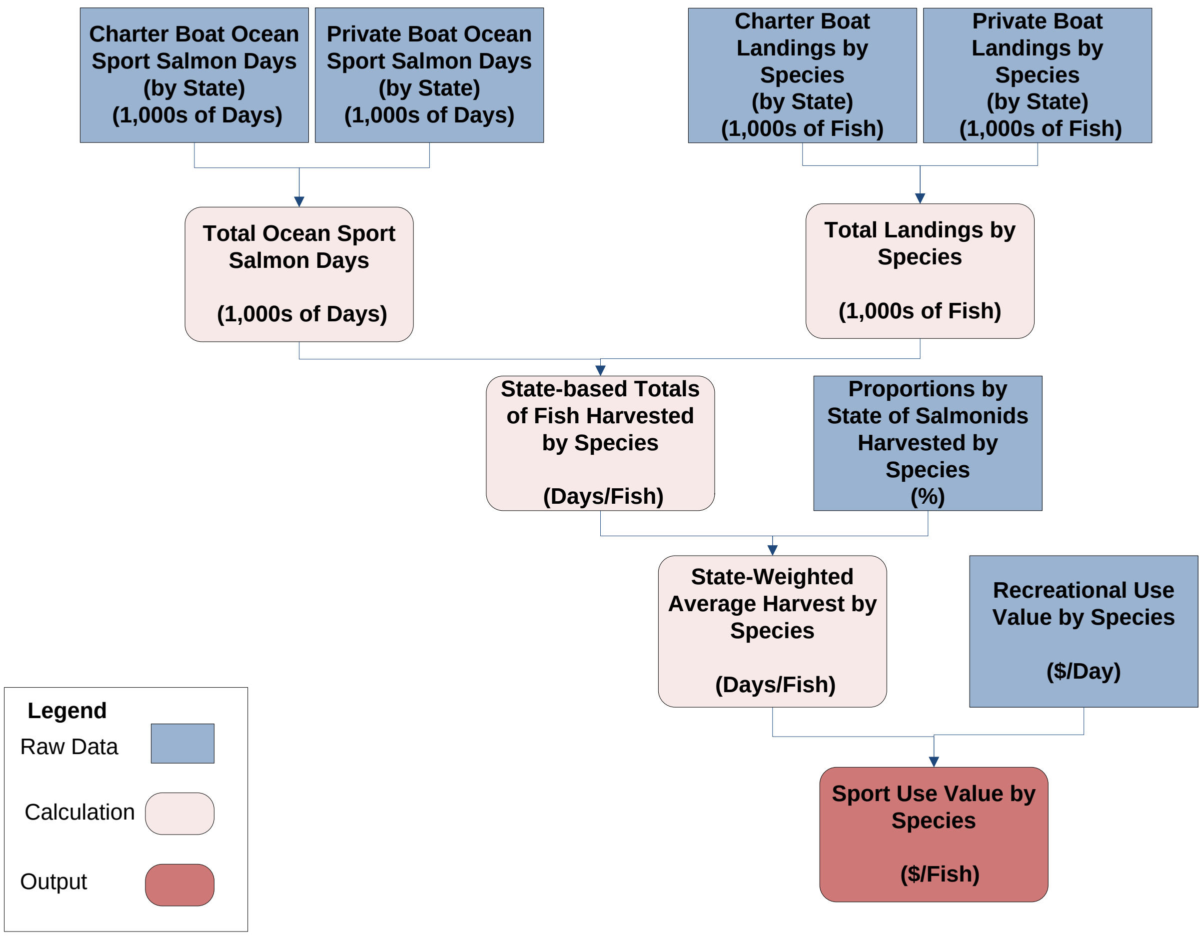
The value of fish originating from the Chehalis Basin and caught in ocean and Grays Harbor fisheries is developed from information about all potential sport fisheries and the proportion of fish that are caught in these fisheries. The equation below describes the total value for ocean and Grays Harbor fisheries:

$$UV_{Sport-O,E} = \sum_{ijt} v_{ijt} * \Delta Q_{ijt}$$

where $UV_{Sport-O,E}$ is the sport use value for fishing in ocean or estuary that is computed as the WTP per fish v_{ijt}, and the change in the quantity of fish harvested, ΔQ_{ijt}, for each fishery (ocean or Grays Harbor) (i), US state (j), and year (t) where and when they are caught. The inputs into these calculations are presented below and are followed with the estimated benefits.

Economic valuations of fish have been estimated using economic studies. Similar to commercial catch, it is necessary to estimate the number of days (or trips), landings by type of vessel, and origin of species caught in each fishery. These data determine the catch rate (i.e. the number of days until a fish is caught) that is specifically attributable to Chehalis fish, which in this case is 0.9 for all salmonid species. A key difference with commercial use value is that sport fishing value is determined from additional data on the recreational value per day. The key data in the computations are presented in the structure and logic diagram in Figure K-5.

Figure K-5
Sport Use Value Calculations – Ocean and Estuary, Structure and Logic Diagram



BIOLOGICAL ASSUMPTIONS

Sport fisheries harvests are estimated by applying a percentage of salmon harvest for Chehalis-origin fish for coho and Chinook to the respective fish population forecasts. For fish caught in oceanic fisheries, the same proportions of Chehalis-origin fish caught in commercial activities are assumed to apply to sport catch. The proportions of fish from the Chehalis Basin that are caught in the ocean are derived from historical data from WDFW. All fish caught in Grays Harbor are assumed to have originated from the Chehalis Basin. Estimated changes in fish population by location are discussed above; a sample of changes is shown in Table K-11 through K-14. Changes in populations are relative to the Baseline and the implantation of a structure, enhancement or combined action.

OCEAN AND GRAYS HARBOR SPORT USE VALUE DATA

A number of economic studies exist to estimate the value of fishing to anglers in oceanic and estuarine habitats (see Annotated Bibliography at the end of this appendix for more information). Rarely though are the data produced in the specific location where a new study, such as this one, is being conducted. For instance, the Integrated Master Plan for the Yakima River Basin relied upon several studies from the 1980s to estimate the average value per day of $82.60 for Chinook and $50.88 for coho. Similarly, in an evaluation of a dam removal for the Klamath River, NOAA researchers evaluated studies from a variety of sources and ended up producing a site-specific value of approximately $152 per angler day for parts of California and Oregon. Also, a recent evaluation of the value of improvements on the Rogue River determined that ocean sport use value was $71/day. While these studies show that it is common practice in economics to apply results from one study to another in a *benefit transfer method,* the level of confidence that the results are correct can be low.

This analysis, however, can rely on a very recent, relevant, and high quality study by Anderson and Lee (2013) to evaluate the value of sport fishing in Washington ocean and estuary waters. The Anderson and Lee report surveyed anglers about their fishing activities and interests. They elicited responses to questions about their WTP for fish under different contexts including the: fishery location (oceanic or estuary fisheries), species (Chinook or coho), type of fish (wild or hatchery), size of fish (small, medium and large, by weight depending on the type of species) and management system (harvest or release). This broad and robust set of results enables the selection of anglers' WTP that is specific to the context whereby anglers would express a WTP that is relevant to this study.

In this study, a specific set of results from Anderson and Lee (2013) are applied. In particular, it is assumed the expected WTP for Chinook and coho caught in each location is derived from estimates for medium-sized wild fish that can be harvested. The actual weight of the medium-sized fish depends on the species. Values for hatchery fish and fish that must be released would not be relevant for this study because the impacted fish are those that spawn far up stream and a change in fish population would change the number of fish that can be caught. The only other data that will be used from this study include the WTP values for small and large fish since these values can provide a perspective on the uncertainty in WTP for any fish that may be caught. Table K-20 presents the values for small, medium and large size catch in each water body.

Table K-20
Use Value Parameter for Ocean and Grays Harbor Harvests

SPECIES	OCEAN			GRAYS HARBOR		
	MEDIUM SIZE	SMALL SIZE	LARGE SIZE	MEDIUM SIZE	SMALL SIZE	LARGE SIZE
Chinook salmon	$82.60	$55.35	$106.37	$100.11	$67.81	$127.83
Coho salmon	$50.88	$35.45	$58.36	$62.44	$43.80	$71.41

Notes:
Source: Untangling the Recreational Value of Wild and Hatchery Salmon, Anderson and Lee, *Marine Resource Economics*, 2013.

Estimation of Sport Use Values - River

COMPUTATIONAL APPROACH

The value of sport fishing for salmonids in the Chehalis Basin is estimated similarly to ocean and estuary sport fishing. For example, the economic value of fishing in the river is above and beyond the expenditures and derived from economic analyses of WTP for additional trips (see Appendix P for more information). But, in this case, all fish caught in the basin are assumed, reasonably, to be from the basin. Estimates on catch effort are simplified in this case because data on different types of vessels are not required since anglers often use their own smaller boats, or fish from or by the riverbank. Instead, data on catch rate per species is required. Catch rate is defined as the number of days until a particular species of fish is caught. Oftentimes, an angler catches a fish in any particular fish, but since this analysis is focused on salmonids, it is the catch rate for these fish that is required for the analysis. Estimates of catch rates per species are derived from data provide by WDFW.

A reduced form of the equation for estimating the value of fishing in the Chehalis Basin is:

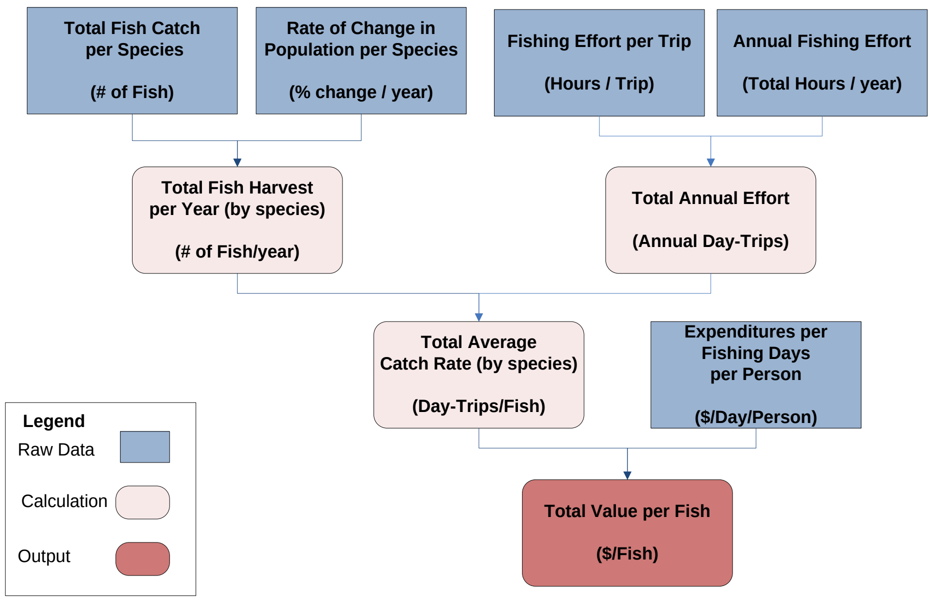
$$UV_{Sport-R} = \sum_t v_t * \Delta Q_t$$

where $UV_{Sport-R}$ is the sport use value for fishing in the river basin that is computed as the WTP per trip v_t, and the change in the quantity of fish harvested from all trips, ΔQ_t, to the river in year (t). The number of trips accounts for the product of total fish caught and the inverse of the catch rate, or the number of fish caught per trip. This value is integrated into the results obtained from the literatures. More details on these calculations are presented in the structure and logic diagram below.

Sport fisheries harvests from rivers are estimated by applying the proportions of salmonids harvested in rivers, as opposed to other water bodies. The proportions of fish caught in the Chehalis Basin are assumed to come from the basin, and harvest rates are derived from historical data from WDFW. Estimated changes in fish population caught in rivers are discussed in the section above and a sample of population changes are shown in Table K-12 through K-16.

Population changes are relative to the Baseline and implantation of a structure, enhancement or combined action.

Figure K-6
Sport Use Value Calculations – River, Structure and Logic Diagram



RIVER SPORT USE VALUE DATA

Table K-21 provides the valuation parameters for this study that have been derived as an average from several published papers from Olsen et al (1991), Meyer et al. (1983), and Olsen and Richards (1992). These papers provided WTP values for different species and locations. A full review of these papers is discussed at the end of this appendix. The average use values by species are computed from available data on WTP per trip and data on the number of fish caught per trip. These values are ultimately more conservative measures of value compared to the values used in the Yakima Basin Study. Differences between the values for Chehalis Basin and the Yakima Basin Study stem from the higher single average value of $77.24 per day that was used in Yakima as well as a lower number of average fish caught per fishing day. The reason for the difference in value per day is that for the Chehalis study, results from Meyer et al (1983) are included rather than a study from the Sacramento River in California considered in the Yakima River. These values represent a more conservative valuation assessment for recreational fishing in rivers. Note that the average use value for Steelhead is adjusted downward from the originally estimated values in these papers because Steelhead is a catch and release fishery. The downward adjustment applies the average percentage difference in harvest versus catch and release for Chinook and coho salmon as reported in Anderson and Lee (2013).

Table K-21
River Sport Fishing Use Values

	OLSEN ET AL (1991) (COLUMBIA RIVER BASIN; OR AND WA)	MEYER ET AL. (1983) (COLUMBIA RIVER BASIN; OR)	OLSEN AND RICHARDS (1992) (ROGUE RIVER; OR)	AVERAGE USE VALUE ($/FISH)	YAKIMA STUDY AVERAGE USE VALUES
Spring Chinook	$62.91	$294.02		$178.47	$761
Fall Chinook	$62.91	$220.52	$116.49	$133.31	$429
Coho	$62.91	$220.52		$141.72	$429
Steelhead	$60.48	$163.84	$50.26	$91.53	NA

Estimation of Passive-Use Values

COMPUTATIONAL APPROACH

Estimation of total economic values in WA has been implemented over the past several years by applying results from a 1999 study by Layton, Brown and Plummer (LBP). The LBP study estimates a total economic value of hypothetical programs that would increase the populations of fish in several different fisheries across the state. One of these fisheries, migratory fish in western Washington and Puget Sound, is applicable to the fish impacted by Chehalis Basin actions. While LBP (1999) was not published in an academic journal, it has been widely applied in projects that may impact fish in the state. For instance, the recently completed Yakima River Basin Integrated Water Resource Management Plan used LBP (1999) includes a total value based on LBP and this value had a critical influence in determining that the project's benefits exceeded costs.[92] The LBP (1999) analysis is relevant for assessing total use value for structure and enhancement actions in Chehalis Basin as well. The analysis would account for the changes in lower or higher populations that may take place over the next 20 years.

LBP (1999) estimated values by implementing a contingent valuation study that entailed carefully constructed questions about their WTP for a program (i.e., a yes or no choice), through a specific surcharge amount on their monthly water/utility bills. The sampling protocol varied the magnitude of household payment levels and as well as the level of increases in historical, current and future fish populations. For example, half of all respondents were asked to react to a case when future fish populations would remain stable and the rest faced a scenario of declining populations at historical levels. Questionnaire responses were statistically analyzed to determine average WTP for different fisheries and fish population outlook scenarios.

Applicability of LBP valuation for fish populations in this analysis is reasonable but some additional considerations are required. According to guidelines established by the U.S. Office of Management and Budget (OMB), the results of one study can be applied to the context of another if the nature of the study and sites are relatively similar.[93] For example, the two sites and contexts must be similar with

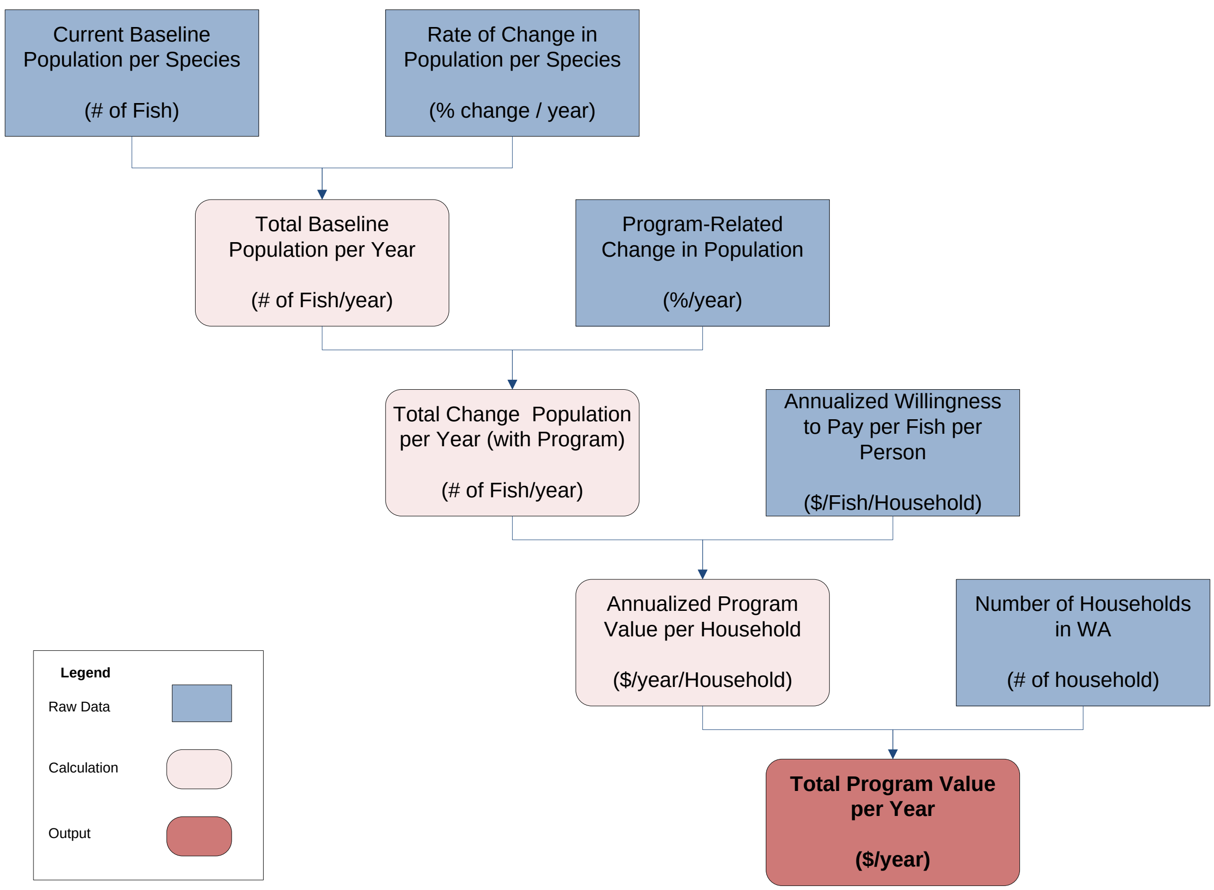
[92] Benefits of the project associated with passive use were over 910 times larger than the estimated use-value. Without including passive use value, the total benefits would not exceed total costs.
[93] OMB has established guidelines related to the process of 'benefits transfer' in OMB Circular A-4. Benefit transfer is the application of results from one or more studies to a new site.

respect to the scope, location, and population affected, as well as policy change and property rights (at least with respect to measure of WTP or WTA). In addition, the existing analysis must be based on reliable data and fully document the results. It is under these considerations that the State of Washington actually accepted the use of the LBP for valuation purposes in the state.[94]

The PV valuation parameter for this analysis can be computed from the LBP results (Figure K-7). This parameter is computed in terms of the annual willingness to pay per household per fish. The value itself is a direct function of the percentage change in number of fish in a specific fishery, such as migratory fish in western Washington, as well as the baseline population forecast, and specifically whether it is stable or falling. In this case, it is assumed that the population forecast is stable. As such, since the number of fish affected in the Chehalis Basin is small relative to the total population of migratory fish in western Washington, a marginal value per fish per household is based on LBP results from the linearized portion of the estimated WTP function. Results are then scaled up across all households in Washington.

Figure K-6 illustrates the PV valuation methodology.

Figure K-7
Passive Use Value Calculations, Structure and Logic Diagram



[94] It may be noted that LBP (1999) estimated increases in population whereas this project requires estimates of the value for increases and decreases in populations. However, because these changes are relatively small, no adjustment for a WTA is undertaken for cases when populations decline. Instead, a threshold analysis for fish populations will be conducted.

BIOLOGICAL ASSUMPTIONS

TEV depends on the percentage change in total fish population under various alternatives. Total fish populations in Chehalis as a percentage of the total WA State populations are between 1% and 8% depending on the species. Overall, the Chehalis Basin contributes less than 5% of total salmonids to the state (as shown in Table K-1). The changes caused by either a flood retention facility or enhancement action would be a fraction of the total WA migratory fish and accordingly a minimum value is applied.

PASSIVE USE VALUE DATA

LBP (1999) indicate that WA households express different WTPs for different types of fish and in different fisheries, and under different baseline population conditions. In each case, a higher value per fish was estimated when future populations were projected to decline over time and a lower value was attributed to long-term stability in populations. For small changes in fish (i.e., population changes 5% or less), a single value per fish is estimated; higher rates of change in fish populations would have a declining value per fish for increasingly larger changes in fish. For the Chehalis analysis, a small change in population and a long term stable baseline is assumed resulting in an annual WTP of $2,232 per fish for all 2.6 million Washington households, or about $0.0009 annually per fish.

Estimated Economic Values from Multiple Perspectives

When evaluating alternatives, understanding the perspective of the stakeholders and decision makers is crucial to developing a useful study. For this study, stakeholders include not only the local community in the Chehalis Basin, but also stakeholders consist of entities that may provide funding for an alternative in the future. Two perspectives are described in more detail below as they apply to the environmental valuation:

- **Federal –** Federal agencies, such as the Corps of Engineers and the Bureau of Reclamation evaluate projects from a national perspective. These agencies examine the change in impact on a national level. For example, local business losses may not be included in the analysis as other businesses outside the basin may experience increased economic activity from flooding in the basin. The Federal Perspective would include all impacts to the nation including impacts on the local Tribes.
- **State –** For the purposes of this study, the regional perspective is defined as the geographic area of the State of Washington (State Perspective). The regional perspective is needed to provide supporting information when requesting funding from the state. This perspective explores the impact of each alternative on the State of Washington and tribal lands located within Washington.

An additional perspective is considered for other benefit categories which relates to Basin-wide impacts. With respect to environmental impacts, there is no appreciable difference between the basin-wide and State Perspectives since data are not available to determine the residential location of commercial or recreational fishermen. Also, with respect to passive use values, we present total benefits with and without this category to reflect the multiple perspectives on this value. A PV was not computed for only Basin-wide residents, but this factor would likely be small because the number of households in the area would be well under 5% of the state population.

From an analytical perspective, there are only a few differences between the Federal and State analyses. First, as stated above, Federal guidelines exclude consideration of the PV in the measure of total benefits. They are, however, included in the analysis of State benefits since this category has been applied to previous projects and is based on the interests of State households. A second difference is that the Federal Perspective applies a real discount rate of 3.5%, again based on federal guidelines. This rate is higher than the 1.63% rate used at the state level. A lower discount rate places greater value on future benefits and costs (see Appendix A for more on discounting assumptions).

FEDERAL PERSPECTIVE RESULTS

Table K-22 presents the total estimated Federal Perspective commercial and sport UV benefits for each of the options for implementation of a structure, enhancement action, or combined actions. In all cases, the recreational benefits are larger in magnitude than commercial benefits, even though the number of fish harvested by commercial activities is significantly greater (see Table K-11 through Table K-15). Recall that in the previous discussion and data, commercial values of coho and Chinook are about $10 and $47 per fish, whereas recreational activity amounts to over $50 and $80 for these fish in the ocean and Grays Harbor estuary and over $125 in rivers, after accounting for the WTP per trip and number of trips until a fish is caught.

These results indicate that between the structures, the FRO50 causes a larger loss in value compared to the MPD structure because in the MPD design, Chinook and coho populations would actually increase. The most beneficial enhancement alone is the NMF-Riparian60/75 option because of its significant coverage in impact throughout the watershed. This option is one of the options included in a “High Riparian Enhancement” action. For combination actions, the fish modeling revealed that fish populations overall are more responsive to combinations of High Enhancement and Flood Retention, rather than High Enhancement paired with the MPD facility. Accordingly, the largest benefits among combination options come from the FRO50 + High Enhancement action. These benefits are marginally smaller than a combination of enhancement benefits alone.

Table K-22
Estimated Federal Benefits – Structure, Enhancement and Combination Actions ($Million)

PROJECT	COMMERCIAL	SPORT	TOTAL
FRO50	($0.52)	($0.90)	($1.42)
Multipurpose	$0.05	($0.37)	($0.32)
Enhancement Actions			
NMF-LWM50/50	$1.55	$3.21	$4.76
NMF-LWM50/75	$2.72	$5.02	$7.74
NMF-Riparian20/50	$2.06	$3.77	$5.83
NMF-Riparian20/75	$3.61	$5.94	$9.55
NMF-Riparian60/50	$6.66	$11.52	$18.18
NMF-Riparian60/75	$10.59	$17.77	$28.36
Culverts 100	$1.32	$3.53	$4.85
Combination Actions			
Low Riparian Enhancement	$5.13	$9.96	$15.09

High Riparian Enhancement	$15.04	$27.09	$42.13
FRO50 + Low Enhancement	$3.93	$8.27	$12.20
Multipurpose + Low Enhancement	$3.54	$7.07	$10.60
FRO50 + High Enhancement	$14.07	$25.85	$39.92
Multipurpose + High Enhancement	$11.19	$21.35	$32.54

Table K-23 provides a breakout of the benefits by area and category. For example, commercial benefits are broken out by US Ocean, and Treaty/Non-treaty. As indicated above the results show that FR050 causes a larger loss compared with a MPD facility. The highest losses are to Treaty/Non-treaty commercial fishing which represent the largest allocation of fish and river sport fishing. The enhancement actions would benefit Treaty/Non-treaty fisheries and river sport fishing the most (assuming fisheries allocations are unchanged).

Table K-23
Detailed Estimates of Federal Benefits by Location ($Million)

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014							
	COMMERCIAL			SPORT			
PROJECT	US OCEAN	TREATY/NON-TREATY[1]	TOTAL	US OCEAN	GRAYS HARBOR	RIVER	TOTAL
Baseline with Dam - FRO50	($0.05)	($0.47)	($0.52)	($0.01)	($0.15)	($0.73)	($0.90)
Multipurpose	$0.01	$0.04	$0.05	$0.00	($0.00)	($0.36)	($0.37)
Enhancement Actions							
NMF-LWM50/50	$0.14	$1.41	$1.55	$0.03	$0.51	$2.67	$3.21
NMF-LWM50/75	$0.27	$2.46	$2.72	$0.06	$0.85	$4.11	$5.02
NMF-Riparian20/50	$0.20	$1.86	$2.06	$0.05	$0.64	$3.09	$3.77
NMF-Riparian20/75	$0.37	$3.24	$3.61	$0.08	$1.08	$4.78	$5.94
NMF-Riparian60/50	$0.66	$6.00	$6.66	$0.15	$2.03	$9.34	$11.52
NMF-Riparian60/75	$1.07	$9.52	$10.59	$0.24	$3.18	$14.35	$17.77
Culverts 100	$0.11	$1.21	$1.32	$0.03	$0.48	$3.02	$3.53
Combination Actions							
Low Riparian Enhancement	$0.49	$4.64	$5.13	$0.11	$1.62	$8.22	$9.96
High Riparian Enhancement	$1.48	$13.56	$15.04	$0.34	$4.63	$22.12	$27.09
FRO50 + Low Enhancement	$0.37	$3.57	$3.93	$0.09	$1.29	$6.89	$8.27
Multipurpose + Low Enhancement	$0.33	$3.20	$3.54	$0.08	$1.14	$5.84	$7.07
FRO50 + High Enhancement	$1.38	$12.70	$14.07	$0.31	$4.37	$21.17	$25.85
Multipurpose + High Enhancement	$1.08	$10.12	$11.19	$0.25	$3.54	$17.56	$21.35

Notes:
1. This category combines the benefits to The Quinault Indian Nation "Treaty" and Chehalis Tribe "Non-treaty."

BENEFIT COST ANALYSES OF ENHANCEMENT ACTIONS

The benefits discussed above in Table K-22 and Table K-23 are combined with costs estimates in Table K-24 to estimate benefit/cost ratios and net benefits. The benefit cost ratios and net benefits related to enhancement combined with flood retention options are not shown here. The impacts of those alternatives need to be combined with the cost estimates for flood retention for meaningful comparison. Those findings are presented instead in the main report alongside the enhancement alternatives, For those findings refer to **Error! Reference source not found.** (Section 8) in the main eport.

Table K-24 shows that the performance metrics for the enhancement actions are less than 1 (benefit/cost ratio) and negative for all enhancement actions. Even though the enhancement actions do not have benefits exceeding the costs of investment, the metrics still allow for a general ranking of the enhancement actions. NMF-Riparian60/75 and NMF-Riparian60/50 have the highest returns on average benefit per dollar invested (benefit/cost).

Table K-24
Benefit-Cost Analysis of Enhancement Actions – Federal Perspective ($Million)

PROJECT	PROJECT COSTS	PROJECT IMPACT	NET BENEFIT	BENEFIT/COST RATIO
formula	*a*	*b*	*c = b-a*	*d=b/a*
Enhancement Actions				
NMF-LWM50/50	$18.34	$4.76	($13.58)	0.26
NMF-LWM50/75	$28.99	$7.74	($21.25)	0.27
NMF-Riparian20/50	$45.04	$5.83	($39.20)	0.13
NMF-Riparian20/75	$67.55	$9.55	($58.01)	0.14
NMF-Riparian60/50	$45.04	$18.18	($26.86)	0.40
NMF-Riparian60/75	$67.55	$28.36	($39.20)	0.42
Culverts 100	$31.28	$4.85	($26.43)	0.16
Combination Actions				
Low Riparian Enhancement	$94.66	$15.09	($79.57)	0.16
High Riparian Enhancement	$127.83	$42.13	($85.70)	0.33

STATE PERSPECTIVE

Table K-25 presents the total estimated State perspective benefits by category for structure, enhancement action, or combined action options. In all cases, the benefits from a State Perspective are larger than the Federal Perspective because the discount rate is lower under the State Perspective. In addition, the State Perspective also considers the inclusion of PV which would accrue to all state households. The results under the column "Total Value" include PV whereas "Total without Passive Use" exclude this value.

Similar to the Federal Perspective results, there are higher numbers of fish losses from FRO50 compared to the MPD alternative thereby causing a larger reduction in economic benefits. In addition, the NMF-

Riparian60/75 option is also the highest enhancement project and the FRO50 and High Enhancement generates the highest level of benefits of all combined projects. High Enhancement alone generates the highest benefits across all projects.

In contrast to the Federal Perspective results, when accounting for Total Economic Value, the passive use component significantly magnifies the losses and gains by an order of magnitude in most cases. This increase in value represents the interests of households across the state with regard to larger salmonid populations.

Table K-25
Estimated State Benefits – Structure, Enhancement and Combination Actions ($Million)

PROJECT	COMMERCIAL	SPORT	TOTAL WITHOUT PASSIVE USE	TOTAL VALUE
Baseline with Dam - FRO50	($0.92)	($1.63)	($2.55)	($98.50)
Multipurpose	$0.07	($0.67)	($0.60)	($46.68)
Enhancement Actions				
NMF-LWM50/50	$2.79	$5.82	$8.61	$302.33
NMF-LWM50/75	$4.87	$9.10	$13.97	$489.61
NMF-Riparian20/50	$3.68	$6.84	$10.53	$370.81
NMF-Riparian20/75	$6.42	$10.78	$17.21	$601.92
NMF-Riparian60/50	$11.89	$20.89	$32.78	$1,134.34
NMF-Riparian60/75	$18.87	$32.24	$51.11	$1,773.61
Culverts 100	$2.40	$6.39	$8.79	$327.59
Combination Actions				
Low Riparian Enhancement	$9.40	$18.44	$27.84	$953.04
High Riparian Enhancement	$27.44	$50.10	$77.54	$2,630.17
FRO50 + Low Enhancement	$7.23	$15.31	$22.54	$771.41
Multipurpose + Low Enhancement	$6.50	$13.09	$19.59	$649.02
FRO50 + High Enhancement	$25.69	$47.80	$73.49	$2,493.14
Multipurpose + High Enhancement	$20.47	$39.46	$59.92	$2,018.49

A more detailed breakout of benefits from the State Perspective is shown in Table K-26. The highest losses are to river sport fishing which as discussed above and are driven by the high WTP placed on fishing experience in the Chehalis Basin. The enhancement actions would benefit Treaty/Non-treaty fisheries and river sport fishing the more than the other actions (assuming fisheries allocations were unchanged).

Table K-26
Detailed Estimates of State Benefits by Location ($Million)

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014								
PROJECT	COMMERCIAL				SPORT			
	OCEAN	GRAYS HARBOR	TREATY/NON-TREATY[1]	TOTAL	OCEAN	GRAYS HARBOR	RIVER	TOTAL
Baseline with dam - FRO50	($0.00)	($0.06)	($0.86)	($0.92)	($0.02)	($0.28)	($1.33)	($1.63)
Multipurpose	$0.00	($0.00)	$0.07	$0.07	$0.00	($0.01)	($0.67)	($0.67)
Enhancement Actions								
NMF-LWM50/50	$0.00	$0.20	$2.59	$2.79	$0.05	$0.92	$4.84	$5.82
NMF-LWM50/75	$0.01	$0.34	$4.53	$4.87	$0.10	$1.55	$7.46	$9.10
NMF-Riparian20/50	$0.00	$0.25	$3.42	$3.68	$0.07	$1.17	$5.60	$6.84
NMF-Riparian20/75	$0.01	$0.43	$5.99	$6.42	$0.13	$1.97	$8.68	$10.78
NMF-Riparian60/50	$0.01	$0.81	$11.07	$11.89	$0.24	$3.70	$16.95	$20.89
NMF-Riparian60/75	$0.02	$1.27	$17.58	$18.87	$0.38	$5.82	$26.04	$32.24
Culverts 100	$0.00	$0.19	$2.21	$2.40	$0.04	$0.86	$5.48	$6.39
Combination Actions								
Low Riparian Enhancement	$0.01	$0.66	$8.73	$9.40	$0.18	$3.03	$15.23	$18.44
High Riparian Enhancement	$0.03	$1.88	$25.53	$27.44	$0.54	$8.64	$40.92	$50.10
FRO50 + Low Enhancement	$0.01	$0.52	$6.70	$7.23	$0.13	$2.40	$12.77	$15.31
Multipurpose + Low Enhancement	$0.01	$0.46	$6.03	$6.50	$0.12	$2.13	$10.83	$13.09
FRO50 + High Enhancement	$0.03	$1.77	$23.88	$25.69	$0.50	$8.14	$39.16	$47.80
Multipurpose + High Enhancement	$0.03	$1.43	$19.01	$20.47	$0.39	$6.59	$32.47	$39.46

BENEFIT COST ANALYSES OF ENHANCEMENT ACTIONS

The benefits discussed above in Table K-25 and Table K-26 are combined with costs estimates in Table K-7 to estimate benefit/cost ratios and net benefits. The benefit cost ratios and net benefits related to the enhancement actions combined with flood retention options are not shown here. The impacts of those alternatives need to be combined with the cost estimates for flood retention for meaningful comparison. Those findings are presented in the main report alongside the enhancement alternatives. For those findings refer to **Error! Reference source not found.** in the main report (Section 6). Table K-27 presents the findings without passive use values while Table K-28 provides the performance metrics when passive use values are counted.

Results from the State Perspective mirror those in the Federal Perspective when passive use values are excluded. Performance metrics for the enhancement actions are less than 1 (benefit/cost ratio) and are negative for all enhancement actions. Even though the enhancement actions do not have benefits exceeding the costs of investment, the metrics still allow for a general ranking of the enhancement actions.

Table K-27
Benefit-Cost Analysis of Enhancement Actions without Passive Use Value – State Perspective ($Million)

PROJECT	PROJECT COSTS	PROJECT IMPACT	NET BENEFIT	BENEFIT/COST RATIO
formula	*a*	*b*	*c = b-a*	*d=b/a*
Enhancement Actions				
NMF-LWM50/50	$18.42	$8.61	($9.81)	0.47
NMF-LWM50/75	$29.11	$13.97	($15.14)	0.48
NMF-Riparian20/50	$45.22	$10.53	($34.69)	0.23
NMF-Riparian20/75	$67.83	$17.21	($50.62)	0.25
NMF-Riparian60/50	$45.22	$32.78	($12.44)	0.72
NMF-Riparian60/75	$67.83	$51.11	($16.71)	0.75
Culverts 100	$31.42	$8.79	($22.62)	0.28
Combination Actions				
Low Riparian Enhancement	$95.06	$27.84	($67.21)	0.29
High Riparian Enhancement	$128.35	$77.54	($50.81)	0.60

As expected, including passive use values in the results significantly increases benefits from enhancement actions by several orders of magnitude. Reviewing the changes, NMF-Riparian60/75 and NMF-Riparian60/50 have the highest returns on average benefit per dollar invested (benefit/cost). High Riparian Enhancement is the combination suite with the greatest return per dollar invested.

Table K-28
Benefit-Cost Analysis of Enhancement Actions with Passive Use Value – State Perspective ($Million)

PROJECT	PROJECT COSTS	PROJECT IMPACT	NET BENEFIT	BENEFIT/COST RATIO
formula	*a*	*b*	*c = b-a*	*d=b/a*
Enhancement Actions				
NMF-LWM50/50	$18.42	$302.33	$283.91	16.41
NMF-LWM50/75	$29.11	$489.61	$460.50	16.82
NMF-Riparian20/50	$45.22	$370.81	$325.59	8.20
NMF-Riparian20/75	$67.83	$601.92	$534.09	8.87
NMF-Riparian60/50	$45.22	$1,134.34	$1,089.12	25.09
NMF-Riparian60/75	$67.83	$1,773.61	$1,705.78	26.15
Culverts 100	$31.42	$327.59	$296.17	10.43
Combination Actions				
Low Riparian Enhancement	$95.06	$953.04	$857.98	10.03
High Riparian Enhancement	$128.35	$2,630.17	$2,501.82	20.49

Additional Discussion

QUALITATIVE IMPACTS FOR NON-SALMONID SPECIES

Other fish (non-salmonid) and non-fish species are impacted by the Project Alternatives and enhancement actions. In particular, impacts on Other Fish and Non-fish species correlate with changes in habitat.

In general, results of model studies indicated that all dam alternatives reduced off-channel habitat resulting in negative effects on semi-aquatic species. Stream flow was found to be more limiting in the Upper Chehalis River reaches compared with lower reaches for non-salmonid (other fish) species based on PHABSIM model studies. Also, low flows during the drier summer months appeared to be a limiting factor for several species. Given the importance of flow and the currently poor understanding of non-salmonid (other fish) in the basin, additional data are needed to corroborate these modeled findings. Most non-salmonid species modeled, including the western toad, small and largemouth bass, largescale sucker, and speckled dace generally sustained declines in habitat in response to the MPD alternatives. However, there were both increases and decreases in modeled habitat depending on species and life stage. It is important to note that very little is known about non-salmonid aquatic and semi-aquatic (e.g., amphibians and beaver) species in the basin and more information is needed to support more detailed effects analyses in the future.

Furthermore, the biological studies found that available information on Other Fish and Non-fish Species is too sparse to precisely direct enhancement activities that will positively benefit them. It is expected that enhancement projects that benefit juvenile coho salmon in side-channel habitat are likely to benefit the entire suite of Key Non-fish Species that occur in side-channel habitats (namely, northern red-legged frog, Oregon spotted frog, western pond turtle, North American beaver, and, if present, western toad). Juvenile coho co-evolved with these species, and limited information reveals that they can be abundant there where coho are present (Henning 2004; Henning and Schirato 2006). Nonetheless, the Other Fish and Non-fish Species' responses to enhancement approaches of any kind carry uncertainty because their responses have been so rarely tracked. For this reason, it will be crucial to track the response of Other Fish and Non-fish Species in enhancement projects involving juvenile coho salmon in side-channel habitats so that the results can adaptively modify future enhancement efforts, when needed.

IMPACTS OF FLOOD RETENTION ON IN-CHANNEL HABITAT FOR OTHER FISH AND NON-FISH SPECIES

Under current (Baseline) conditions, Physical Habitat Simulation (PHABSIM) modeled flows were found to reflect species' life histories and life stage requirements. Also, low flows during the drier summer months appeared to be a limiting factor for several species as well as preferable for others. Pacific lamprey (*Lampetra tridentata*) spawn in late spring and early summer and summer low flows follow spawning, so the lamprey life history is synchronized with hydrology. Spawning appeared to be limited by flow during the spring and summer months; however, Pacific lamprey rearing was not limited by flow. Largemouth bass (*Micropterus salmoides*) habitat was not limited by flow and smallmouth bass (*Micropterus dolomieu*) habitat was only limited by flow from the Newaukum River to the Skookumchuck River during the summer months. Speckled dace (*Rhinichthys osculus*) habitat generally was greatest at low flow and therefore was not limited by flow. Largescale sucker (*Catostomus macrocheilus*) habitat was not limited by flow upstream of the Newaukum River confluence; however, mountain whitefish spawning and rearing habitat was limited by flow upstream of the Newaukum River.

The FRO alternative was not modeled, as it had little effect on flows except during short-term flood events and especially during the summer low-flow period. Under the proposed Multipurpose Dam Alternative, changes in flow resulted in both increases and decreases of habitat for Other Fish and Non-fish Species, depending on species and life stage. Most species modeled, including the western toad (*Bufo boreas*), both bass species, largescale sucker, and speckled dace generally sustained declines in habitat. Mountain whitefish and Pacific lamprey sustained more increases than decreases in habitat across all reaches examined. Any reductions in in-stream habitat have the potential to contribute to the local or regional extirpation of state or federally sensitive, candidate, or listed species (e.g., the State Sensitive Olympic mudminnow, the State Endangered western pond turtle, and the State Endangered and Federally Threatened Oregon spotted frog). Further, for the Multipurpose Dam Alternative, in addition to the potential direct loss of breeding habitat within the footprint of the reservoir, an increase in summer base flows has the potential to delay or eliminate breeding for the instream-breeding western toad downstream of the dam. Loss of instream habitat may have some potential to be regained via changes in the operational flows of the dam and within the operational capacity of the dam.

IMPACTS OF FLOOD RETENTION ON OFF-CHANNEL HABITAT FOR OTHER FISH AND NON-FISH SPECIES

The Key Species identified from the Other Fish and Non-fish groups that occupy off-channel habitat in the Chehalis River at any life stage include Olympic mudminnow (*Novumbra hubbsi*), Pacific lamprey, speckled dace, largemouth bass, riffle sculpin (*Cottus gulosus*), reticulate sculpin (*Cottus perplexus*), largescale sucker, northern red-legged frog (*Rana aurora*), Oregon spotted frog (*Rana pretiosa*), western toad, western pond turtle, and north American beaver (*Castor canadensis*).

Translating water surface elevations at different flood levels into creation and maintenance of off-channel habitat for species dependent on those habitats is difficult and limited by a lack of information on inundation patterns associated with peak flows (e.g., timing, magnitude, periodicity, etc.) and how these patterns influence the creation and maintenance aquatic habitat. This difficulty led to using a correlative model that indexed habitat change as a function of inundation. For the purposes of this analysis, any of the key species examined that could occupy off-channel habitat such as oxbows and wetlands were considered to require such habitat during at least one life stage, and any changes in inundation were assumed to reflect relative changes in habitat.

Overall, the correlative model used to evaluate habitat changes for off-channel species revealed a marked decline in available habitat downstream of the either dam alternative at all flood levels modeled (500-, 100-, 20-, and 10-year events) except for the 2-year event. The decline was due to a loss of habitat that resulted from decreases of inundation. Declines in habitat were most pronounced in reaches nearest to the proposed dam site. Hence, the implementation of dam alternatives will reduce habitat for off-channel utilizing species or life stages, such as juvenile coho salmon, the State Sensitive Olympic mudminnow, the State Endangered western pond turtle, and the State Endangered and Federally Threatened Oregon spotted frog. For state or federally sensitive, candidate, or listed species, reductions in habitat have the potential to increase risk to these species.

Along with native species, non-native species occupying off-channel habitats, such as largemouth bass, could be negatively affected by loss of habitat associated with water retention alternatives as well. As they compete for food and spawning habitat with native fishes, and prey on native fishes, this negative impact of habitat reduction could positively benefit native fishes. On the other hand, a decrease in off-channel habitat for all these species would concentrate their presence in remaining off-channel acreage, which would increase pressure of predation on native species. As a consequence, interpretation of the outcome of changes in inundation at this stage of analysis was ambiguous where non-native aquatic predators, especially fishes, are present.

Climate change is generally anticipated to have negative effects on cold-adapted species and benefit warm-adapted species. Based on PHABSIM modeling for Other Fish and Non-Fish Species, this also appeared to be the case in the Chehalis Basin. That modeling projected to have variable but positive effects on Pacific lamprey, largemouth bass, smallmouth bass, speckled dace, largescale sucker, and western toad spawning and/or rearing habitat. In contrast, climate change substantially reduced both spawning and rearing habitat for mountain whitefish:

- Stream flow was found to be more limiting in the Upper Chehalis River reaches than lower reaches for non-salmonid (other fish) species based on PHABSIM model studies. Also, low flows during the drier summer months appeared to be a limiting factor for several species. Given the importance of flow and the currently poor understanding of non-salmonid (other fish) in the basin, additional data are needed to corroborate these modeled findings.
- Most non-salmonid species modeled, including the western toad, small and largemouth bass, largescale sucker, and speckled dace generally sustained declines in habitat in response to all dam alternatives. However, there were both increases and decreases in modeled habitat depending on species and life stage. It is important to note that very little is known about non-salmonid aquatic and semi-aquatic (e.g., amphibian) species in the basin and more information is needed to support more detailed effects analyses in the future.

- In general, results of model studies indicated that all dam alternatives reduced off-channel habitat, which would result in negative effects on semi-aquatic species.
- The current modeled results suggest that climate change will lead to a major decline for all salmon and steelhead and the extirpation of spring-run Chinook salmon in particular in the basin. Given the severity and potential implications of these results, a more in-depth climate change risk assessment is warranted. Any future work should incorporate climate change as a major component of the analysis.
- Results of combining habitat enhancement and dam alternatives suggested that the relative benefit was strongest for spring-run Chinook salmon, in part because this run was targeted. Enhancement actions focused on other species will produce somewhat different results. However, the magnitude and/or specific benefits from the models should be interpreted with caution because of the need to test and validate some of the key assumptions about the interactions between enhancement and dam effects.
- Based on EDT and SHIRAZ modeled results, placing flood reduction structures in the watershed exacerbated the negative effects of climate change, leading to the extirpation of several sub-populations in the basin. The MPD Alternative did reduce impacts from climate scenarios on spring-run Chinook salmon, and to a lesser extent on winter-run steelhead. However, as mentioned earlier the for spring-run Chinook salmon results were predicated on the assumption that salmon will not seek and locate cold water refugia in the absence of a dam.
- In general and based on EDT modeled results, when habitat enhancement, dam alternatives and future climate scenarios were combined, enhancement had to be effective and extensive (i.e., the High Enhancement alternative) to overcome the effects of future climate scenarios and dam alternatives.

IMPACTS OF ENHANCEMENT ACTIONS ON OTHER FISH SPECIES

In Section 3 of the ASEP, descriptions of the habitat requirements of the Other Fish Species and factors that may be limiting different life stages are provided in general terms, along with a list of potential enhancement actions that could be used to address the limiting factors. The discussion is further expanded by focusing on the types of enhancement actions needed to address the limiting factors.

Eleven fish species exist in this grouping: Pacific lamprey, white sturgeon, chum salmon, eulachon, speckled dace, largescale sucker, reticulate sculpin, riffle sculpin, Olympic mudminnow, largemouth bass, and smallmouth bass. Of the three broad groups of organisms being evaluated in ASEP (salmonids, Non-fishes, and Other Fishes), the Other Fish groups have the least amount of information on their life history and habitat requirements. In many cases, the factors limiting a population and the types of enhancement actions required are unknown.

The types of enhancement actions discussed above for Other Fishes can be organized into the following categories:

- **Salmon Enhancement projects would be positive to neutral for Other Fish species:** For species with life stage requirements similar to salmon, projects that improve salmon habitats would be neutral or perhaps positive for some other species as well. For example, speckled dace spawn in gravel substrate at the tail-outs of pools and in riffles. Enhancement actions for salmon that reduce silt loading and increase in-channel habitat complexity will benefit speckled dace spawning as well. Speckled dace adults reside in mainstem pools. Enhancement actions for salmon to increase in-channel habitat complexity will benefit adult speckled dace as well. This could include placement of LWM, ELJs, boulders, etc. Large scale sucker fry and pacific lamprey larvae occupy silty backwater habitats on the mainstem and in tributaries. They require depositional areas protected from high velocity current during summer. These are successional habitats, where changes in sediment transport (deposition and flushing) could change the rate of succession and connectivity. Projects that construct or maintain backwater-rearing habitats for salmon will benefit large scale sucker fry and Pacific Lamprey larvae rearing.
- **Enhancement projects for some species would be similar to salmon projects:** Enhancement projects that benefit other species of salmon and steelhead will likely benefit chum salmon as well, with the exception of projects aimed at rearing of juvenile salmon. Limiting factors for chum salmon are largely restricted to spawning and incubation, with flood scour and superimposition (crowding of redds) being the two factors most likely to limit them. Enhancement projects that address scour such as controlling flooding and in-channel structures, and projects that reduce superimposition of redds by expanding access to or constructing additional spawning habitat will benefit chum salmon.
- **Enhancement projects that maintain the current frequency and duration of flows to reduce fine sediment accumulations and maintain the current mosaic of habitat types**: Projects that address these attributes could potentially benefit a number of species and life stages. This includes adult Pacific lamprey and speckled dace that require appropriately sized and clean gravel substrate at pool tail outs and in riffles, and adult large scale suckers that reside in pool habitat.
- **Enhancement projects that provide off channel habitat and connectivity to these habitats:** Largescale sucker fry and Pacific lamprey larvae occupy silty backwater habitats on the mainstem and in tributaries. They require depositional areas protected from high velocity current during summer. These are successional habitats, where changes in sediment transport (deposition and flushing) could change the rate of succession and connectivity. Projects that construct or maintain backwater-rearing habitats will benefit largescale sucker fry and Pacific lamprey larvae rearing.
- **Enhancement projects that maintain access to mainstem foraging areas:** Adult white sturgeon are thought to move into the lower mainstem Chehalis River from Grays Harbor to forage. Catch records indicate that the majority of their distribution extends upstream as far as the Black River. For these foraging migrations to be successful, the fish need access to main channel reaches and self-sustaining populations of key food resources. They are not spawning in the river and can enter the river in any season. Therefore, projects that maintain water quality in the mainstem and access to upstream mainstem reaches should benefit white sturgeon.
- **Enhancement projects that maintain access to spawning habitat:** This is a generic requirement for all species, but in this context it refers specifically to chum salmon. As with other salmon species, chum salmon are able to spawn in shallow water and diverse channel habitats.

Enhancement actions that will benefit chum salmon include improving access to spawning areas through barrier removal, improving the quality of spawning habitat, maintaining flows over redds sufficient for flushing and oxygenating gravels, and enhancing riparian vegetation to maintain bank stability and decrease sloughing of banks and siltation.

Enhancement projects that maintain adequate quantity of spawning habitat and substrate type: Freshwater limiting factors for eulachon are largely restricted to river conditions and spawning, with a lack of appropriate sand and pea-sized gravel substrate being the most likely limiting factor. Eulachon are present in the mainstem Chehalis River, as well as the Wynoochee and Satsop rivers. Once juveniles emerge from the substrate, they are flushed out of the natal reach with river flow. Enhancement actions that maintain an adequate quantity of sand and pea-sized gravel areas for spawning will benefit eulachon.

- **Enhancement projects that involve control of non-native predators through targeted removals:** For Olympic mudminnow, removal of non-native predators, such as largemouth and smallmouth bass, from oxbow lakes and side-channel habitats, will benefit the species. This might be accomplished by targeted harvest of predator species through changes in harvest regulations (season length and daily catch limits), fishing derbies and reward programs, and selected trapping. However, the effectiveness of these approaches on Olympic mudminnow is untested, and responses to their application are uncertain. Hence, any attempts at their application should involve monitoring that can adaptively track the results and provide direction to improve any future attempts at applications. A large part of this uncertainty is based on whether the locations targeted for enhancement are associated with the in-stream main channel Chehalis that is non-native dominated, and whether side-channel reconnection is also part of the enhancement. If the in-stream main channel Chehalis is not non-native-dominated, then non-native removal would likely be a success if side-channel reconnection is also part of the enhancement. If the in-stream main channel Chehalis is non-native-dominated, then the success of non-native removal would be uncertain if side-channel reconnection is part of the enhancement. In the latter instance, it would be critically important to adaptively track (monitor) the results of the enhancement action. The creation of preferred habitats for species will reduce the potential for further contractions of their distribution and range.

Based on existing information, our ability to quantify the potential benefits of these actions to most Other Fish Species is limited, as enhancement science has focused on culturally and economically important fish species, such as salmon. As pointed out in Chapter 5 of the ASEP report, available information on the species discussed here is too sparse to inform population trends or, in many cases, to identify their ecological constraints. Therefore, a critical and necessary precursor to enhancement actions on most Other Fish species is inventory of aquatic habitats to understand where they occur in the basin and the status of their populations. Even after habitats, sites, or projects for potential enhancement actions are identified, it is crucial that their application be monitored, because of the uncertainty associated with responses, especially for Other Fish species that occupy side-channel habitats, where almost no data exist. This will ensure that attempted enhancements can contribute meaningfully to future efforts, should they not succeed.

IMPACTS OF ENHANCEMENT ACTIONS ON NON-FISH SPECIES

To an even greater degree than for Other Fish Species, available information on Non-fish Species is too sparse to precisely direct enhancement activities that will positively benefit them, particularly since the balance of the Non-fish Species occur in the most ignored macrohabitat of the floodplain, the side-channel/low-flow habitats. The critical first step in attempting to apply any enhancement actions on these species is a distributional inventory to identify where they still occur in the basin, as uncertainty exists as to whether some Non-fish Species are still present. For example, uncertainty exists about whether Oregon spotted frog and western pond turtle occur in side-channel habitats associated with the main channel Chehalis River. As side-channel habitat in which the Non-fish Species may be present is almost entirely (over 97%) on private lands, conducting such an inventory will require a private landowner liaison that is particularly effective in facilitating partnerships. Further, the inventory should not only be able to identify where Non-fish Species may be present, but the status of their populations and their likely limiting factors (non-natives or habitat conditions). Once these have begun to be identified, focused habitat-, species-, and project-specific enhancement actions can begin to be designed and implemented. The following sections provide a description of potential habitat enhancement activities that could begin to be addressed for Non-fish Species once the aforementioned inventory has begun to identify sites and conditions appropriate for these activities. As with Olympic mudminnow and other Non-fish species that occupy side-channel habitats, the effectiveness of a number of these enhancement approaches is poorly tested on Non-fish Species, so responses to their application are uncertain. Hence, any attempts at their application should incorporate monitoring that can adaptively track the results and provide direction to improve any future enhancement attempts. Potential enhancement activities were identified based on a review of existing information and coordination with WDFW (Hayes 2014).

Additionally, enhancement projects that benefit juvenile coho salmon in side-channel habitat are likely to benefit the entire suite of Key Non-fish Species that occur in side-channel habitats (namely, northern red-legged frog, Oregon spotted frog, western pond turtle, North American beaver, and, if present, western toad). Juvenile coho co-evolved with these species, and limited information reveals that they can be abundant there where coho are present (Henning 2004; Henning and Schirato 2006). Nonetheless, the Non-fish Species' responses to enhancement approaches of any kind carry uncertainty because their responses have been so rarely tracked. For this reason, it will be crucial to track the response of Non-fish Species in enhancement projects involving juvenile coho salmon in side-channel habitats so that the results can adaptively modify future enhancement efforts, when needed.

Northern Red-legged Frog

Potential enhancement activities in the Chehalis Basin for northern red-legged frog includes preserving existing suitable upland forest habitat adjacent to aquatic habitat, restoring degraded upland forest habitat, and removing or suppressing warm water exotic species that prey on northern red-legged frogs.

Preserving existing quality upland forest habitat adjacent to aquatic habitats used by northern red legged frogs would be a beneficial enhancement activity for this species, as research indicates the quality of terrestrial habitat (specifically as a function of area) has a greater impact on the northern red-legged frog populations than the aquatic habitat (WDFW unpublished data). Restoring degraded upland forest habitat by removing non-native invasive vegetation, allowing woody material to accumulate by promoting a multi-age tree canopy that can mature, and promoting a dense understory vegetation of native species (especially with sword fern [*Polystichum munitum*] and/or snowberry [*Symphiocarpus albus*] that shelter northern red-legged frog invertebrate food resources; Hayes 2008, WDFW unpublished data). Acquisitions to allow riparian forest maturation may help in restoring degraded forest, but an active enhancement schedule will be needed to remove aggressive forest canopy and understory exotic shrubs and vines ranging from sweet (or bird) cherry (*Prunus avium*) to English holly (*Ilex aquifolium*) and English ivy (*Hedera helix*). Moreover, if nearby sources of these aggressively invasive exotics exist; a long-term cost will include a vigilance program to eliminate them if they begin to reappear, as long as nearby sources exist.

Removal of exotic fish species, especially centrarchid fishes (basses and sunfishes) and ictalurid catfishes (bullheads) that prey on northern red-legged frogs would also be a beneficial enhancement activity based on their known negative effects (Kiesecker and Blaustein 1998, Adams et al. 2003). However, this activity does present a management conflict, because these non-native fish species are recreational game species managed by WDFW. This enhancement option would require a policy decision by state government agencies about the management approach, and cooperation from the warm water fish program within WDFW. Assuming that the management conflict can be resolved, methods do exist, such as rotenone application, to eliminate fish from a circumscribed body of water. Implementing such applications would have to occur during the seasonal interval when the side-channel habitat is disconnected, and at locations where few or no native non-target species would be affected.

Additionally, reappearance of these undesirable exotic fishes during seasonal intervals where the side-channel habitat becomes reconnected to the stream would have to be considered in the context of reinvading potentially proximate sources. If elimination of exotic fish is not an option, habitat modification to disfavor the target exotic fish species could be considered, with actions tailored to the habitat requirements of the target exotic species being addressed. Whether actions are implemented will also depend on the risks of these alterations to Native Fish and Non-fish Species.

Removing American bullfrogs from northern red-legged frog habitat does not present the management conflict that the removal of exotic fish species presents, but bullfrog removal does present several challenges, such as efficiency of removal methods and costs associated with committing to the long-term management and monitoring that would be necessary to confirm its effectiveness (Adams and Pearl 2007). Bullfrog removal has the potential to be effective in small circumscribed wetlands, but vigilance against recolonization is a perpetual cost if proximate sources exist (Adams and Pearl 2007). However, northern red-legged frog species are less vulnerable to bullfrog predation than other frog species because they spend less time in aquatic habitats, where adult bullfrogs typically remain, compared to terrestrial habitats. As a consequence, management of American bullfrogs would be a lesser priority than management of exotic fishes, as far as the northern red-legged frog is concerned.

Western Toad

Potential enhancement activities in the Chehalis Basin for western toad include preserving existing off-channel habitat, with western toad breeding habitat features such as shallow depths, low-flows, and open water conditions; removal of nonnative, invasive vegetation that form dense emergent thickets; eliminating open water habitat; and preserving or restoring upland prairie habitat adjacent to suitable aquatic breeding habitat.

Suitable stillwater breeding habitat for western toad, which is open and typically unvegetated, appears to be limited within the basin, and may be restricted to the seasonal appearance of such habitat in the in-stream main channel Chehalis River. Limited data suggest that the lack of such suitable habitat in side-channel areas associated with the river's main channel largely reflects the establishment of dense stands of invasive reed, which often creates dense monocultures that eliminate open water habitat. Removal of invasive vegetation from aquatic habitats that provide known or potential western toad habitat would restore or create habitat conditions for the species. Several vegetation management options for reed canary grass removal exist (Hayes et al. 2013). These include livestock grazing, herbicide application, mulching, and solarization. All these options must be well planned, as improper implementation can create conditions that would be detrimental to western toad or other aquatic species. Appropriate permits are also often required for activities within or near aquatic habitat. Proper herbicide application in aquatic habitats, under the jurisdiction of the Washington State Department of Ecology, requires following strict permit requirements for the type of herbicide, time of year applied, and quantities used. Livestock can over-graze, compact soils and degrade water quality with waste, so grazing intensity and frequency has to be adjusted to levels appropriate to the habitat addressed. Solarization involves the placement of shade cloth over areas where reed canary grass needs elimination. Less problematic ecologically than either grazing or herbicide application, solarization has dimension (implementation limits the size of treated unit[s] potentially treatable), timing (warm-season requirement for effectiveness at Pacific Northwest latitudes), and land use considerations (land use cannot have interfering [disturbance] conditions) that would limit its application.

Since loss of the processes that create side-channel habitat is suspect (see section 4.2), projects that create new side-channel habitat could provide breeding and rearing habitat for western toad. Such projects are likely to be successful within the movement range of any local western toad populations because western toad is known to be able to rapidly colonize such novel habitats (Crisafulli et al. 2005). However, given that the processes for maintaining the novel habitat at the new locations may not exist, maintaining these habitats at an early stage of succession will be a long-term cost associated with their creation if they are expected to function as western toad breeding and rearing habitat.

For western toad, enhancement actions focused exclusively on breeding habitat may be insufficient to guarantee success, because of the western toad requirement for juxtaposed suitable (open) upland non-breeding habitat. This juxtaposition must also involve an upland habitat piece of sufficient size, because toads generally move between 500 meters to 2 kilometers into uplands from their aquatic breeding habitat. Hence, enhancement actions that addressed breeding habitat must also consider whether suitable upland non-breeding habitat that has a patch size that encompasses the aforementioned upland dispersal size range exists, and if not, the proximate upland habitat will require enhancement to some level of suitability. Enhancement of unsuitable habitat that is covered by dense forest, shrub, or graminoid will require vegetation removal and implementation of some process to maintain the habitat in an early graminoid-dominated successional stage. Vegetation removal methods are diverse, but selection of the method should be compatible with the faunal assemblage that co-exists with western toads.

Oregon Spotted Frog

Potential enhancement activities in the Chehalis Basin for Oregon spotted frog includes removal of warm water exotic species that prey on Oregon spotted frogs, removal of non-native invasive vegetation that degrades or eliminates aquatic habitat, and preserving or restoring open canopy conditions adjacent to aquatic habitats that provide known or potential breeding habitat for Oregon spotted frog. Removal of exotic warm water predators to assist Oregon spotted frogs presents the same problems described in the earlier section addressing northern red-legged frogs (see Section 5.4.1). However, removal of these species is much more important for Oregon spotted frogs because their entirely aquatic habitat places them in contact with this suite of predators year-round. Though untested, habitat manipulation to create conditions that simply disfavor exotic warm water predators is unlikely to be successful in maintaining populations of Oregon spotted frogs that may exist in the basin. Moreover, the USFWS will view such habitat manipulation as too great a risk to take with any Oregon spotted frogs that may remain in the Chehalis system.

In Washington State, invasive reed canary grass often develops dense monocultures, which alters, degrades or eliminates breeding habitat for Oregon spotted frog (Kapust et al. 2012). Reed canary grass vegetation management in Oregon spotted frog habitat has been used successfully to enhance breeding habitat (Kapust et al. 2012, WDFW unpublished data), so some kind of vegetation management scheme could be applied to reed canary grass. Vegetation management options are discussed in the immediately previous section addressing western toad.

Preserving or restoring open canopy conditions adjacent to aquatic habitats that Oregon spotted frog inhabit may also be important. The Oregon spotted frog is a warm water marsh specialist, so shading may reduce habitat quality. This is important in the context of potential conflicts with certain categories of salmonid enhancement efforts in which tree and shrub plantings have occurred in seasonal or permanent wetlands with the intent of shading water to promote cooling. Hence, this kind of potential conflict between Oregon spotted frog and salmonid enhancement efforts will have to be considered on a case-by-case basis, but it is likely that policy will favor enhancement actions for the Federally Listed frog over salmonids, which are not currently listed.

Coastal Tailed Frog

Identifying potential enhancement activities in the Chehalis Basin for coastal tailed frog is limited by data gaps in existing literature on the species habitat needs, particularly within the Chehalis Basin. Preservation of second growth to mature upland coniferous forest adjacent to stream channels as a source of LWM appears to be the most likely beneficial enhancement activity. Less understood are the potential benefits to coastal tailed frog for enhancement activities influencing stream temperature and the quality of forest habitat adjacent to stream systems. Additional research is necessary to accurately identify the benefits to coastal tailed frog from potential enhancement activities.

Allowing second-growth coniferous forest to mature in uplands adjacent to medium to small streams would provide an ongoing source of LWM that would contribute to formation of step-pool habitat, an important habitat feature for coastal tailed frog (Jackson et al. 2007). This approach would likely only be effective for coastal tailed frogs in the headwaters portion of the basin as they appear to be absent from lower elevations. Moreover, its contribution is likely to be much more significant in Non-fish-bearing streams, since those streams possess a 50-foot (17-meter), two-sided riparian buffer on as little as 50% of that portion of the stream network, based on current forestry practices rules under the state Forests and Fish Habitat Conservation Plan. More specifically, its contribution is likely to be more significant in non-fish-bearing streams that are temperature labile because they have intrinsically low-flow volumes and groundwater inputs do not modulate their temperatures. Additionally, preservation of suitable forested habitat in the upper reaches of stream systems would likely benefit several in-stream and riparian-dwelling amphibian species, as well as a variety of other wildlife species utilizing those habitats. Allowing second-growth coniferous forest to mature would either require acquisition (purchase) of private forest lands for this purpose or negotiation with private landowners to exclude target areas from harvest. The latter is unlikely to occur if ownership remains private.

Van Dyke's Salamander

Potential enhancement activities in the Chehalis Basin for Van Dyke's salamander include preservation of quality riparian habitat that includes conditions for LWM recruitment that maintains a stream of LWM over time sufficient to ensure enough LWM in an intermediate stage of decay appropriate for utilization by Van Dyke's salamander.

Van Dyke's salamander is a riparian specialist (Jones 1999) that is relatively sedentary and appears to have a low upper temperature tolerance (Blessing et al. 1999, Jones 1999) that may limit its ability to survive in or colonize disturbed habitats. Similar to tailed frog, allowing second-growth coniferous forest to mature in uplands adjacent to medium- to small-sized streams would provide riparian habitat that Van Dyke's salamander would be able to utilize and an ongoing source of LWM that may be important for its nesting (Blessing et al. 1999). Approaches to allowing second-growth coniferous forest to mature were discussed under the section above for coastal tailed frog. Though not experimentally examined, retaining dead and downed woody material may also contribute to providing both nesting and moist refuge micro-habitats, an effect that likely translates to other terrestrial salamander species as well.

Western Pond Turtle

Potential enhancement activities in the Chehalis Basin for western pond turtle includes removal of warm water exotic species that prey on western pond turtle hatchlings, preservation of prairie habitat, enhancement of prairie habitat by removing nonnative invasive vegetation, and LWM placement in off channel or shallow open water habitat. As no information currently exists regarding the presence of western pond turtle within the floodplain of the main channel Chehalis River, confirming presence of this species is an important precursor in targeting enhancement activities.

If western pond turtles are found in side-channel habitats containing exotic warm water predators, removal of exotic species that prey on western pond turtle would present an important enhancement activity. As with Oregon spotted frog, habitat manipulation to create conditions that simply disfavor exotic warm water predators is unlikely to allow western pond turtle hatchlings to survive because of their highly aquatic habit and shallow-water habitat needs that would place them in frequent contact with some of these aquatic exotic predators. Approaches to and issues with removing different exotic aquatic predators were in the earlier section addressing northern red-legged frog.

Similar to western toad, enhancement actions for western pond turtle that focused exclusively on the aquatic habitat may not suffice to guarantee success, because of the western pond turtle requirement for juxtaposed suitable (open) upland habitat for nesting. western pond turtles require well-insulated upland habitat (that is, open and largely unvegetated) large enough to encompass typical movement distances (up to 400 meters) from the aquatic habitat. Hence, enhancement actions that address the non-breeding aquatic habitat must also consider whether suitable upland breeding habitat exists that has a patch size large enough to accommodate the nesting movement range, and if no patches of sufficient size exist, then the upland habitat would require enhancement to some level of suitability. Approaches to restoring open terrestrial habitat were discussed under western toad (see Section 5.4.2). western pond turtles also have the added requirement of a suitable nesting substrate, which is a well-drained soil in which to excavate the nest (Holland 1994). Hence, if enhancement of open terrestrial habitat is needed in upland landscapes where soil types are a mosaic over relatively small scales, evaluating the suitability of the soil where enhancement is occurring may be needed.

The frequently limited availability of LWM in the Chehalis Basin is likely to translate to limited availability of LWM in some side-channel habitats. At the latitude of the Chehalis system, presence of aquatic LWM in side-channel habitats may be critically important to the western pond turtles to enable them to adequately raise their body temperatures (Holland 1994). This is especially important for digestion, adequate growth in juveniles, and proper yolking of eggs in adult females (Holland 1994). Hence, in LWM-limited side-channel habitats, LWM placement would provide basking habitat for western pond turtles that would properly support these biological functions. Moreover, encouraging forest to mature adjacent to these western pond turtle aquatic habitats would provide a continued source of LWM.

North American Beaver

Identifying potential enhancement activities in the Chehalis Basin for North American beaver is limited by data gaps in existing literature on the species presence within the Chehalis Basin. Additional research is necessary to accurately identify the benefits to North American beaver from potential enhancement activities. In general, preserving quality riparian habitat with deciduous trees, especially cottonwoods and willows (which are a preferred food resource for beaver), or restoring degraded riparian habitat would benefit beaver, as well as several of the aforementioned amphibian species and other wildlife. However, as North American beaver is side-channel habitat-focused, some of the previous suggestions for enhancement of other Non-fish Species in side-channel habitats will favor beaver even where beaver is not necessarily targeted. In particular, those that involve enhancement of deciduous riparian forest, which would affect food resources where cottonwoods, willows, and selected riparian shrubs (such as red osier dogwood) are involved, and would affect dam building resources where most woody riparian species are involved.

CLIMATE CHANGE SCENARIOS

The purpose of this climate change analysis was to provide decision makers with information on how projected changes associated with climate may affect species in the future. The climate change analysis conducted in the ASEP considered the impacts of climate change projections from the CIG at the University of Washington. The analysis conducted in the ASEP analysis considered changes to three parameters: water temperature, stream flow, and sea level. The general findings from the climate change analysis suggest changes in quantity, timing, and intensity of precipitation that will translate into changes in flow and perhaps changes in the frequency of flow change. Additionally, projections for the Chehalis Basin anticipate less change in stream flow compared to snow-dominated systems. By mid-century rainfall events are projected to become more severe, summer stream flows are projected to decrease and annual variability will continue to cause some periods that are abnormally wet, and others that are abnormally dry. For more information on the detailed findings from how ASEP modeled climate change and the resulting impacts on species refer to the ASEP report and ASEP impacts report.

The findings from the ASEP evaluation (impacts to salmonids) were combined with the benefit cost inputs discussed above and evaluated in the federal and state perspective. The findings are summarized in the following tables. The ASEP group did not evaluate the impacts on all enhancement alternatives, but instead considered the impact of climate change on the best performing enhancement measure assuming that the other alternatives would be more adversely affected. As such summarized findings include: FR050; MPD; Low and High Enhancement; NMF-Riparian60/75; FR050 combined with Low and High Enhancement; and MPD combined with low and high enhancement. Each alternative is presented under the low and high climate change scenarios.

FEDERAL PERSPECTIVE CLIMATE CHANGE FINDINGS

The impacts of climate change on the Federal Perspective benefits analysis are shown below in Table K-29, Table K-30, and Table K-31. The results show that FR050 has larger losses under both climate change scenarios. However, as noted previously under baseline conditions, when FR050 is combined with High Enhancement it is the better performing alternative.

Table K-29
Estimated Federal Benefits – Climate Change Scenarios ($Million)

	COMMERCIAL	SPORT	TOTAL
Low Climate Change			
Baseline with Dam - FRO50	($0.42)	($0.76)	($1.18)
NMF-Riparian60/75	$15.23	$24.61	$39.84
Multipurpose	$0.14	($0.25)	($0.11)
Low Enhancement	$7.45	$14.72	$22.17
High Enhancement	$21.40	$38.98	$60.38
FRO50 + Low Enhancement	$4.37	$9.14	$13.51
Multipurpose + Low Enhancement	$4.43	$8.17	$12.60
FRO50 + High Enhancement	$21.66	$40.07	$61.74
Multipurpose + High Enhancement	$15.90	$31.10	$46.99
High Climate Change			
Baseline with Dam - FRO50	($0.23)	($0.40)	($0.63)
NMF-Riparian60/75	$13.86	$22.88	$36.74
Multipurpose	$0.24	($0.02)	$0.22
Low Enhancement	$7.77	$16.05	$23.81
High Enhancement	$21.13	$39.39	$60.53
FRO50 + Low Enhancement	$3.86	$7.83	$11.69
Multipurpose + Low Enhancement	$3.44	$6.62	$10.06
FRO50 + High Enhancement	$19.97	$37.81	$57.78
Multipurpose + High Enhancement	$14.78	$29.67	$44.45

Table K-30
Detailed Estimates of Federal Benefits by Location ($Million)

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014							
	COMMERCIAL			SPORT			
	US OCEAN	TREATY/NON-TREATY[1]	TOTAL	US OCEAN	GRAYS HARBOR	RIVER	TOTAL
Low Climate Change							
Baseline with Dam - FRO50	($0.04)	($0.38)	($0.42)	($0.01)	($0.13)	($0.63)	($0.76)
NMF-Riparian60/75	$1.55	$13.69	$15.23	$0.34	$4.51	$19.76	$24.61
Multipurpose	$0.02	$0.12	$0.14	$0.00	$0.02	($0.28)	($0.25)
Low Enhancement	$0.71	$6.74	$7.45	$0.17	$2.37	$12.18	$14.72
High Enhancement	$2.10	$19.31	$21.40	$0.48	$6.61	$31.89	$38.98
FRO50 + Low Enhancement	$0.41	$3.97	$4.37	$0.10	$1.43	$7.61	$9.14
Multipurpose + Low Enhancement	$0.43	$4.00	$4.43	$0.10	$1.37	$6.70	$8.17
FRO50 + High Enhancement	$2.11	$19.55	$21.66	$0.48	$6.73	$32.86	$40.07
Multipurpose + High Enhancement	$1.51	$14.38	$15.90	$0.35	$5.07	$25.68	$31.10
High Climate Change							
Baseline with Dam - FRO50	($0.02)	($0.21)	($0.23)	($0.01)	($0.07)	($0.33)	($0.40)
NMF-Riparian60/75	$1.40	$12.46	$13.86	$0.31	$4.13	$18.44	$22.88
Multipurpose	$0.03	$0.21	$0.24	$0.01	$0.05	($0.08)	($0.02)
Low Enhancement	$0.73	$7.04	$7.77	$0.17	$2.51	$13.37	$16.05
High Enhancement	$2.06	$19.08	$21.13	$0.47	$6.58	$32.35	$39.39
FRO50 + Low Enhancement	$0.37	$3.49	$3.86	$0.09	$1.24	$6.50	$7.83
Multipurpose + Low Enhancement	$0.33	$3.11	$3.44	$0.08	$1.09	$5.45	$6.62
FRO50 + High Enhancement	$1.93	$18.04	$19.97	$0.44	$6.25	$31.12	$37.81
Multipurpose + High Enhancement	$1.40	$13.39	$14.78	$0.33	$4.75	$24.59	$29.67

Notes:
1. This category combines the benefits to The Quinault Indian Nation "Treaty" and Chehalis Tribe "Non-treaty"

Climate change has minimal impact on the benefit/cost ratios. As with the baseline conditions, enhancement actions have benefit/cost ratios less than one indicating that on their own, they do not provide sufficient economic value to cover their costs. High Enhancement continues to be the best performing combination suite of enhancement actions.

Table K-31
Benefit-Cost Analysis – Federal Perspective ($Million)

PROJECT	PROJECT COSTS	PROJECT IMPACT	NET BENEFIT	BENEFIT/COST RATIO
formula	*a*	*b*	*c = b-a*	*d=b/a*
Low Climate Change				
Baseline with Dam - FRO50	$0.00	($1.18)	($1.18)	-
NMF-Riparian60/75	$87.01	$39.84	($47.17)	0.46
Multipurpose	$0.00	($0.11)	($0.11)	-
Low Enhancement	$94.66	$22.17	($72.49)	0.23
High Enhancement	$127.83	$60.38	($67.44)	0.47
FRO50 + Low Enhancement	$94.66	$13.51	($81.15)	0.14
Multipurpose + Low Enhancement	$94.66	$12.60	($82.06)	0.13
FRO50 + High Enhancement	$127.83	$61.74	($66.09)	0.48
Multipurpose + High Enhancement	$127.83	$46.99	($80.84)	0.37
High Climate Change				
Baseline with Dam - FRO50	$0.00	($0.63)	($0.63)	-
NMF-Riparian60/75	$87.01	$36.74	($50.28)	0.42
Multipurpose	$0.00	$0.22	$0.22	-
Low Enhancement	$94.66	$23.81	($70.85)	0.25
High Enhancement	$127.83	$60.53	($67.30)	0.47
FRO50 + Low Enhancement	$94.66	$11.69	($82.97)	0.12
Multipurpose + Low Enhancement	$94.66	$10.06	($84.60)	0.11
FRO50 + High Enhancement	$127.83	$57.78	($70.04)	0.45
Multipurpose + High Enhancement	$127.83	$44.45	($83.38)	0.35

State Perspective Climate Change Findings

The impacts of climate change on the state perspective benefits analysis are shown below in Table K-32, Table K-33. Table K-34 and Table K-35 present benefit/cost ratios with and without passive use values. Similar to Federal results, the higher numbers of fish losses from FRO50 compared to the Multi-purpose Dam Alternative cause a larger reduction in economic benefits. In addition, NMF-Riparian60/75 option is also the highest enhancement project and the FRO50 and High Enhancement generates the highest level of benefits of all combined projects. High Enhancement alone generates the highest benefits across all projects.

Table K-32
Estimated State Benefits – Climate Change Scenarios ($Million)

	COMMERCIAL	SPORT	TOTAL WITHOUT PASSIVE USE	TOTAL VALUE
Low Climate Change				
Baseline with Dam - FRO50	($0.80)	($1.51)	($2.31)	($80.76)
NMF-Riparian60/75	$30.59	$49.98	$80.57	$2,263.74
Multipurpose	$0.20	($0.61)	($0.41)	($29.97)
Low Enhancement	$15.20	$30.56	$45.76	$1,285.19
High Enhancement	$43.60	$80.94	$124.55	$3,440.13
FRO50 + Low Enhancement	$8.17	$17.23	$25.40	$848.28
Multipurpose + Low Enhancement	$8.55	$15.66	$24.21	$758.93
FRO50 + High Enhancement	$45.02	$84.76	$129.78	$3,458.90
Multipurpose + High Enhancement	$32.43	$64.66	$97.09	$2,675.04
High Climate Change				
Baseline with Dam - FRO50	($0.45)	($0.84)	($1.28)	($41.26)
NMF-Riparian60/75	$26.95	$45.16	$72.11	$2,160.34
Multipurpose	$0.30	($0.27)	$0.02	$1.34
Low Enhancement	$15.90	$33.78	$49.68	$1,388.27
High Enhancement	$42.81	$81.74	$124.55	$3,484.35
FRO50 + Low Enhancement	$6.67	$13.53	$20.21	$781.18
Multipurpose + Low Enhancement	$5.90	$11.29	$17.19	$658.43
FRO50 + High Enhancement	$40.57	$78.54	$119.11	$3,323.59
Multipurpose + High Enhancement	$29.45	$60.62	$90.07	$2,590.66

Table K-33
Detailed Estimates of State Benefits by Location ($Million)

PROJECT ALTERNATIVE IMPACT NET PRESENT VALUE $2014								
	COMMERCIAL				SPORT			
	OCEAN	GRAYS HARBOR	TREATY/NON-TREATY[1]	TOTAL	OCEAN	GRAYS HARBOR	RIVER	TOTAL
Low Climate Change								
Baseline with Dam - FRO50	($0.00)	($0.05)	($0.74)	($0.80)	($0.02)	($0.25)	($1.25)	($1.51)
NMF-Riparian60/75	$0.04	$2.03	$28.52	$30.59	$0.62	$9.29	$40.07	$49.98
Multipurpose	$0.00	$0.01	$0.19	$0.20	$0.01	$0.03	($0.64)	($0.61)
Low Enhancement	$0.02	$1.07	$14.10	$15.20	$0.29	$4.93	$25.34	$30.56
High Enhancement	$0.05	$3.01	$40.54	$43.60	$0.85	$13.79	$66.30	$80.94
FRO50 + Low Enhancement	$0.01	$0.59	$7.57	$8.17	$0.15	$2.71	$14.38	$17.23
Multipurpose + Low Enhancement	$0.01	$0.58	$7.96	$8.55	$0.17	$2.68	$12.81	$15.66
FRO50 + High Enhancement	$0.06	$3.12	$41.85	$45.02	$0.87	$14.31	$69.57	$84.76
Multipurpose + High Enhancement	$0.04	$2.30	$30.09	$32.43	$0.61	$10.55	$53.50	$64.66
High Climate Change								
Baseline with Dam - FRO50	($0.00)	($0.03)	($0.41)	($0.45)	($0.01)	($0.14)	($0.69)	($0.84)
NMF-Riparian60/75	$0.03	$1.80	$25.12	$26.95	$0.55	$8.24	$36.37	$45.16
Multipurpose	$0.00	$0.01	$0.28	$0.30	$0.01	$0.06	($0.34)	($0.27)
Low Enhancement	$0.02	$1.14	$14.74	$15.90	$0.30	$5.25	$28.23	$33.78
High Enhancement	$0.05	$2.98	$39.78	$42.81	$0.83	$13.65	$67.26	$81.74
FRO50 + Low Enhancement	$0.01	$0.47	$6.19	$6.67	$0.13	$2.18	$11.23	$13.53
Multipurpose + Low Enhancement	$0.01	$0.41	$5.48	$5.90	$0.11	$1.90	$9.28	$11.29
FRO50 + High Enhancement	$0.05	$2.83	$37.68	$40.57	$0.78	$13.00	$64.76	$78.54
Multipurpose + High Enhancement	$0.04	$2.11	$27.31	$29.45	$0.55	$9.67	$50.40	$60.62

Notes:
1. This category combines the benefits to The Quinault Indian Nation "Treaty" and Chehalis Tribe "Non-treaty"

Table K-34
Benefit-Cost Analyses without Passive Use Value – State Perspective ($Million)

PROJECT	PROJECT COSTS	PROJECT IMPACT	NET BENEFIT	BENEFIT/COST RATIO
formula	*a*	*b*	*c = b-a*	*d=b/a*
Low Climate Change				
Baseline with Dam - FRO50	$0.00	($2.31)	($2.31)	-
NMF-Riparian60/75	$87.29	$80.57	($6.71)	0.92
Multipurpose	$0.00	($0.41)	($0.41)	-
Low Enhancement	$95.06	$45.76	($49.30)	0.48
High Enhancement	$128.35	$124.55	($3.81)	0.97
FRO50 + Low Enhancement	$95.06	$25.40	($69.65)	0.27
Multipurpose + Low Enhancement	$95.06	$24.21	($70.84)	0.25
FRO50 + High Enhancement	$128.35	$129.78	$1.43	1.01
Multipurpose + High Enhancement	$128.35	$97.09	($31.27)	0.76
High Climate Change				
Baseline with Dam - FRO50	$0.00	($1.28)	($1.28)	-
NMF-Riparian60/75	$87.29	$72.11	($15.18)	0.83
Multipurpose	$0.00	$0.02	$0.02	-
Low Enhancement	$95.06	$49.68	($45.38)	0.52
High Enhancement	$128.35	$124.55	($3.80)	0.97
FRO50 + Low Enhancement	$95.06	$20.21	($74.85)	0.21
Multipurpose + Low Enhancement	$95.06	$17.19	($77.87)	0.18
FRO50 + High Enhancement	$128.35	$119.11	($9.24)	0.93
Multipurpose + High Enhancement	$128.35	$90.07	($38.28)	0.70

Table K-35
Benefit-Cost Analysis with Passive Use Value – State Perspective ($Million)

PROJECT	PROJECT COSTS	PROJECT IMPACT	NET BENEFIT	BENEFIT/COST RATIO
formula	*a*	*b*	*c = b-a*	*d=b/a*
Low Climate Change				
Baseline with Dam - FRO50	$0.00	($80.76)	($80.76)	-
NMF-Riparian60/75	$87.29	$2,263.74	$2,176.45	25.93
Multipurpose	$0.00	($29.97)	($29.97)	-
Low Enhancement	$95.06	$1,285.19	$1,190.14	13.52
High Enhancement	$128.35	$3,440.13	$3,311.78	26.80
FRO50 + Low Enhancement	$95.06	$848.28	$753.23	8.92
Multipurpose + Low Enhancement	$95.06	$758.93	$663.87	7.98
FRO50 + High Enhancement	$128.35	$3,458.90	$3,330.54	26.95

PROJECT	PROJECT COSTS	PROJECT IMPACT	NET BENEFIT	BENEFIT/COST RATIO
formula	*a*	*b*	*c = b-a*	*d=b/a*
Multipurpose + High Enhancement	$128.35	$2,675.04	$2,546.69	20.84
High Climate Change				
Baseline with Dam - FRO50	$0.00	($41.26)	($41.26)	-
NMF-Riparian60/75	$87.29	$2,160.34	$2,073.05	24.75
Multipurpose	$0.00	$1.34	$1.34	-
Low Enhancement	$95.06	$1,388.27	$1,293.21	14.60
High Enhancement	$128.35	$3,484.35	$3,356.00	27.15
FRO50 + Low Enhancement	$95.06	$781.18	$686.12	8.22
Multipurpose + Low Enhancement	$95.06	$658.43	$563.37	6.93
FRO50 + High Enhancement	$128.35	$3,323.59	$3,195.23	25.89
Multipurpose + High Enhancement	$128.35	$2,590.66	$2,462.30	20.18

RISK AND UNCERTAINTY

Key drivers of uncertainty in the environmental analysis include monetary values of fish and fish populations. For the monetary values of fish, low, median, and high values were determined for each variable. More specifically, commercial fish values are driven by exogenous market conditions and trends. The salmon fisheries are managed by the Pacific Fisheries Management Council (PFMC). It is assumed that market prices would be in response to the relative demand for and supply of wild caught salmon (non-farmed) as set by PFMC and their available substitutes. The values used in the model were determined using an average of historical values which accounts for recent trends in the commercial production of salmon. Ranges for commercial salmon values were established based on the historical high and low. However, these values do not account for the uncertainty that may result from a closed fishery due to low fish escapement or an endangered species act listing.

A benefits transfer approach was used with sport and passive use values. Using estimated values from existing literature introduces multiple sources of uncertainty related to: the age of the study, the site characteristics and scale of the transfer study, and fish species types. The ocean sport value is the most site appropriate with values as recent as 2013. Ranges were established based on characteristics cited in the study. River sport values are based on a sampling of several studies with ranges based on the low and high values from the sample. The tables below present total estimated Federal and State Perspective costs and use values for structure, enhancement action, or combined actions and under no climate change and climate change scenarios (“Low” and “High”). Low, median, and high values of costs and use values impacts are provided.

The fish populations for the salmonid and steelhead populations were estimated using the EDT model. Uncertainty ranges and distributions around the fish populations could not be estimated given the limits of the EDT modeling. The fish populations represent an expected value in the overall analysis. Uncertainty in the outcomes for enhancement and impacts of the dams were evaluated with low and high fish response scenarios as shown in the enhancement action descriptions.

For use values benefits, the results in the tables below indicate that the most beneficial enhancement action is the NMF-Riparian60/75 option because of its significant coverage through the watershed. This option is one of the options included in a "High Riparian Enhancement" action. Among combination options, the largest benefits come from the FRO50 + High Enhancement action as fish modeling revealed that overall, fish populations are more responsive to combinations of High Enhancement and Flood.

Table K-36
Uncertainty Costs and Use Values Impacts – Federal Perspective ($ Million)

	COSTS			USE VALUES IMPACTS		
	Expected	Low	High	Expected	Low	High
Baseline with Dam - FRO50	$0.00	$0.00	$0.00	($1.42)	($0.88)	($2.91)
Multipurpose	$0.00	$0.00	$0.00	($0.32)	($0.15)	($0.84)
Enhancement Actions						
NMF-LWM50/50	$18.34	$12.84	$24.80	$4.76	$2.86	$10.39
NMF-LWM50/75	$28.99	$19.86	$39.89	$7.74	$4.73	$16.48
NMF-Riparian20/50	$45.04	$26.68	$65.56	$5.83	$3.57	$12.39
NMF-Riparian20/75	$67.55	$40.02	$98.39	$9.55	$5.93	$19.81
NMF-Riparian60/50	$45.04	$26.68	$65.56	$18.18	$11.21	$38.16
NMF-Riparian60/75	$67.55	$40.02	$98.39	$28.36	$17.57	$59.13
Culverts 100	$31.28	$21.43	$42.83	$4.85	$2.82	$10.98
Combination Actions						
Low Riparian Enhancement	$94.66	$60.95	$133.19	$15.09	$9.15	$32.38
High Riparian Enhancement	$127.83	$81.32	$181.10	$42.13	$25.83	$89.11
FRO50 + Low Enhancement	$94.66	$60.95	$133.19	$12.20	$7.31	$26.65
Multipurpose + Low Enhancement	$94.66	$60.95	$133.19	$10.60	$6.39	$23.04
FRO50 + High Enhancement	$127.83	$81.32	$181.10	$39.92	$24.40	$84.82
Multipurpose + High Enhancement	$127.83	$81.32	$181.10	$32.54	$19.76	$69.83
Low Climate Change						
Baseline with Dam - FRO50	$0.00	$0.00	$0.00	($1.18)	($0.73)	($2.44)
Multipurpose	$0.00	$0.00	$0.00	($0.11)	($0.01)	($0.44)
NMF-Riparian60/75	$87.01	$51.77	$126.26	$39.84	$24.77	$82.44
Low Enhancement	$94.66	$60.95	$133.19	$22.17	$13.39	$47.74
High Enhancement	$127.83	$81.32	$181.10	$60.38	$36.88	$128.12
FRO50 + Low Enhancement	$94.66	$60.95	$133.19	$13.51	$8.10	$29.46
Multipurpose + Low Enhancement	$94.66	$60.95	$133.19	$12.60	$7.69	$26.78
FRO50 + High Enhancement	$127.83	$81.32	$181.10	$61.74	$37.60	$131.51
Multipurpose + High Enhancement	$127.83	$81.32	$181.10	$46.99	$28.38	$101.42
High Climate Change						
Baseline with Dam - FRO50	$0.00	$0.00	$0.00	($0.63)	($0.39)	($1.29)
Multipurpose	$0.00	$0.00	$0.00	$0.22	$0.19	$0.26
NMF-Riparian60/75	$87.01	$51.77	$126.26	$36.74	$22.79	$76.29

	COSTS			USE VALUES IMPACTS		
Low Enhancement	$94.66	$60.95	$133.19	$23.81	$14.29	$51.67
High Enhancement	$127.83	$81.32	$181.10	$60.53	$36.86	$128.92
FRO50 + Low Enhancement	$94.66	$60.95	$133.19	$11.69	$7.05	$25.29
Multipurpose + Low Enhancement	$94.66	$60.95	$133.19	$10.06	$6.11	$21.64
FRO50 + High Enhancement	$127.83	$81.32	$181.10	$57.78	$35.10	$123.50
Multipurpose + High Enhancement	$127.83	$81.32	$181.10	$44.45	$26.77	$96.29

Table K-37
Uncertainty Costs and Use Values Impacts – State Perspective ($ Million)

	COSTS			USE VALUES IMPACTS		
	Expected	Low	High	Expected	Low	High
Baseline with Dam - FRO50	$0.00	$0.00	$0.00	($2.55)	($1.58)	($5.27)
Multipurpose	$0.00	$0.00	$0.00	($0.60)	($0.28)	($1.55)
Enhancement Actions						
NMF-LWM50/50	$18.42	$12.87	$24.95	$8.61	$5.15	$18.81
NMF-LWM50/75	$29.11	$19.91	$40.11	$13.97	$8.50	$29.83
NMF-Riparian20/50	$45.22	$26.74	$65.93	$10.53	$6.41	$22.42
NMF-Riparian20/75	$67.83	$40.11	$98.95	$17.21	$10.64	$35.85
NMF-Riparian60/50	$45.22	$26.74	$65.93	$32.78	$20.11	$69.06
NMF-Riparian60/75	$67.83	$40.11	$98.95	$51.11	$31.50	$107.00
Culverts 100	$31.42	$21.49	$43.12	$8.79	$5.10	$19.90
Combination Actions						
Low Riparian Enhancement	$95.06	$61.10	$134.00	$27.84	$16.81	$59.91
High Riparian Enhancement	$128.35	$81.50	$182.17	$77.54	$47.32	$164.51
FRO50 + Low Enhancement	$95.06	$61.10	$134.00	$22.54	$13.45	$49.33
Multipurpose + Low Enhancement	$95.06	$61.10	$134.00	$19.59	$11.76	$42.67
FRO50 + High Enhancement	$128.35	$81.50	$182.17	$73.49	$44.71	$156.59
Multipurpose + High Enhancement	$128.35	$81.50	$182.17	$59.92	$36.24	$128.93
Low Climate Change						
Baseline with Dam - FRO50	$0.00	$0.00	$0.00	($2.31)	($1.41)	($4.80)
Multipurpose	$0.00	$0.00	$0.00	($0.41)	($0.14)	($1.23)
NMF-Riparian60/75	$87.29	$51.86	$126.82	$80.57	$49.92	$167.12
Low Enhancement	$95.06	$61.10	$134.00	$45.76	$27.50	$98.96
High Enhancement	$128.35	$81.50	$182.17	$124.55	$75.69	$265.38
FRO50 + Low Enhancement	$95.06	$61.10	$134.00	$25.40	$15.17	$55.51
Multipurpose + Low Enhancement	$95.06	$61.10	$134.00	$24.21	$14.77	$51.26
FRO50 + High Enhancement	$128.35	$81.50	$182.17	$129.78	$78.68	$277.56

	COSTS			USE VALUES IMPACTS		
	Expecte d	Low	High	Expected	Low	High
Multipurpose + High Enhancement	$128.35	$81.50	$182.17	$97.09	$58.34	$210.46
High Climate Change						
Baseline with Dam - FRO50	$0.00	$0.00	$0.00	($1.28)	($0.79)	($2.68)
Multipurpose	$0.00	$0.00	$0.00	$0.02	$0.11	($0.31)
NMF-Riparian60/75	$87.29	$51.86	$126.82	$72.11	$44.54	$150.21
Low Enhancement	$95.06	$61.10	$134.00	$49.68	$29.63	$108.38
High Enhancement	$128.35	$81.50	$182.17	$124.55	$75.42	$266.64
FRO50 + Low Enhancement	$95.06	$61.10	$134.00	$20.21	$12.16	$43.71
Multipurpose + Low Enhancement	$0.10	$61.10	$134.00	$17.19	$10.41	$36.94
FRO50 + High Enhancement	$128.35	$81.50	$182.17	$119.11	$71.96	$255.78
Multipurpose + High Enhancement	$128.35	$81.50	$182.17	$90.07	$53.91	$196.19

THRESHOLD ANALYSIS

A threshold analysis was performed to determine the sensitivity of results relative to changes in estimated fish populations. The analysis examines, from a "break-even" perspective, the number of fish it would take to cause benefits to equal costs and then assess this number of fish relative to the estimated number of fish from the EDT analysis.[95]

In this analysis, only environmental benefits are compared against enhancement costs. The analysis requires the computation of environmental benefits per fish for all species and each project option. The analysis does not differentiate fish species because of the aggregated level of this analysis. The formula below is used to obtain break-even net benefits (i.e., benefits minus costs):

$$\left(\frac{\textbf{Environmental Benefits}}{\textbf{Fish}}\right) \times \textbf{Fish} - \textbf{Restoration Costs} = \mathbf{0}$$

Separate analyses are conducted for benefits with and without passive-use values and for both the State and Federal Perspectives. In addition, this analysis is performed for each of the enhancement projects along with the flood control structures. In cases where the originally estimated net benefits are greater than zero (i.e., the project is economically justified), the threshold analysis determines the number and percentage of fewer fish that would be required to break-even. On the other hand if the costs exceed benefits, this analysis determines the additional number of fish that would be required.

The results are contained in a series of tables from Table K-38 to K-42. The tables below indicate the percentage of expected population change needed to obtain a BCR of 1 for each enhancement alternative. Results for use values are presented for State and Federal Perspectives. Passive use values results are presented for State Perspective only. The first three tables focus on the results for enhancement actions only and cover the state, federal, and state with Passive Use value results. The

[95] Adjusted net benefits are equal to zero for each project alternative.

last two tables implement the threshold analysis for the impact of flood control structures on fish populations only.

The threshold analysis results largely indicate that the economic implications of the original results are fairly robust. That is, it would take a large change in numbers of fish to alter an economically justified project (with positive net benefits) to one that was not justified and vice versa. For example, fish populations from the NMF-Riparian20/50 scenario for Federal Perspective (use value impacts) in Table K-39 would have to be about 17 times greater than what is currently estimated in order to break-even. Whereas at the state level, and by including passive use values, the fish populations for the NMF-Riparian60/75 scenario would have to decline by over 90% to result in the project not being justified. The results for the flood control structures indicate that a smaller percentage change in fish populations could change the economic justification of the project. The results vary by type of structure and state and federal contexts.

Table K-38
Threshold Analysis for State Perspective – Use Value ($Million unless specified)

Project	Enhancement Costs	Project Impact	Change in Population Estimates	Project Impact ($/fish)	Adjusted Project Impact	Adjusted Change in Population Estimates	Change in Fish population needed	% of Expected Population Change to Obtain BCR = 1
formula	*a*	*b*	*c*	*d=b/c*	*e=a*	*f=(e*c)/b*	*g=f-c*	*h=(f/c)-1*
Enhancement Actions								
NMF-LWM50/50	$18.42	$8.61	5,644	$1,525	$18.42	12,077	6,433	114%
NMF-LWM50/75	$29.11	$13.97	9,182	$1,522	$29.11	19,129	9,946	108%
NMF-Riparian20/50	$45.22	$10.53	6,946	$1,515	$45.22	29,840	22,894	330%
NMF-Riparian20/75	$67.83	$17.21	11,340	$1,517	$67.83	44,701	33,360	294%
NMF-Riparian60/50	$45.22	$32.78	21,480	$1,526	$45.22	29,631	8,151	38%
NMF-Riparian60/75	$67.83	$51.11	33,525	$1,525	$67.83	44,489	10,964	33%
Culverts 100	$31.42	$8.79	6,157	$1,428	$31.42	22,001	15,843	257%
Combination Actions								
Low Riparian Enhancement	$95.06	$27.84	17,860	$1,559	$95.06	60,973	43,112	241%
High Riparian Enhancement	$128.35	$77.54	48,660	$1,594	$128.35	80,548	31,888	66%

Table K-39
Threshold Analysis for Federal Perspective – Use Value

Project	Enhancement Costs	Project Impact	Change in Population Estimates	Project Impact ($/fish)	Adjusted Project Impact	Adjusted Change in Population Estimates	Change in Fish population needed	% of Expected Population Change to Obtain BCR = 1
formula	*a*	*b*	*c*	*d=b/c*	*e=a*	*f=(e*c)/b*	*g=f-c*	*h=(f/c)-1*
Enhancement Actions								
NMF-LWM50/50	$18.34	$4.76	5,644	$844	$18.34	21,726	16,082	285%
NMF-LWM50/75	$28.99	$7.74	9,182	$843	$28.99	34,375	25,192	274%
NMF-Riparian20/50	$45.04	$5.83	6,946	$840	$45.04	53,626	46,681	672%
NMF-Riparian20/75	$67.55	$9.55	11,340	$842	$67.55	80,233	68,893	608%
NMF-Riparian60/50	$45.04	$18.18	21,480	$846	$45.04	53,213	31,733	148%
NMF-Riparian60/75	$67.55	$28.36	33,525	$846	$67.55	79,869	46,343	138%
Culverts 100	$31.28	$4.85	6,157	$788	$31.28	39,706	33,549	545%
Combination Actions								
Low Riparian Enhancement	$94.66	$15.09	17,860	$845	$94.66	112,043	94,183	527%
High Riparian Enhancement	$127.83	$42.13	48,660	$866	$127.83	147,633	98,973	203%

Table K-40
Threshold Analysis for State Perspective – Total Value

Project	Enhancement Costs	Project Impact	Change in pop. estimates	Project Impact ($/fish)	Adjusted Project Impact	Adj. Change in Population Estimates	Change in Fish Population Needed	% of Expected Population Change to Obtain BCR = 1
formula	*a*	*b*	*c*	*d=b/c*	*e=a*	*f=(e*c)/b*	*g=f-c*	*h=(f/c)-1*
Enhancement Actions								
NMF-LWM50/50	$18.42	$302.33	5,644	$53,565	$18.42	344	(5,300)	-94%
NMF-LWM50/75	$29.11	$489.61	9,182	$53,320	$29.11	546	(8,636)	-94%
NMF-Riparian20/50	$45.22	$370.81	6,946	$53,387	$45.22	847	(6,099)	-88%
NMF-Riparian20/75	$67.83	$601.92	11,340	$53,078	$67.83	1,278	(10,062)	-89%
NMF-Riparian60/50	$45.22	$1,134.34	21,480	$52,810	$45.22	856	(20,623)	-96%
NMF-Riparian60/75	$67.83	$1,773.61	33,525	$52,903	$67.83	1,282	(32,243)	-96%
Culverts 100	$31.42	$327.59	6,157	$53,202	$31.42	591	(5,567)	-90%
Combination Actions								
Low Riparian Enhancement	$95.06	$953.04	17,860	$53,361	$95.06	1,781	(16,079)	-90%
High Riparian Enhancement	$128.35	$2,630.17	48,660	$54,052	$128.35	2,375	(46,286)	-95%

Project Alternatives[96] (separated from enhancement actions)

[96] The tables below look at flood control costs for different types of projects without enhancement.

Table K-41
Threshold Analysis for State Perspective ($Million unless specified)

Project	Flood Control Costs	Impacts (Environmental and non-environmental)			Change in Population Est.	Project Impact ($/fish)	Adj. Project Impacts	Adj. Change in Population Est.	Change in Fish Population Needed	% of Expected Population Change to Obtain BCR = 1
formula	*a*	*Flood Damage Reduction- b*	*Env. Use Values- c*	*Total Impacts d=b+c*	*e*	*f=d/e*	*g=a*	*h=(g*e)/d*	*i=h-e*	*j*
Combined with Low Restoration										
I-5 Project Alternative Variations										
I-5 Project + Airport Levee	$187.16	$100.28	$27.84	$128.12	17,860	$7,174	$187.16	26,090	8230	46%
I-5 Project + Airport Levee + Flood Proofing	$274.41	$235.55	$27.84	$263.39	17,860	$14,748	$274.41	18,607	747	4%
Upper Chehalis Storage Alternative Variations										
Storage + Airport Levee										
Flood Retention RCC	$428.32	$608.96	$22.54	$631.50	14,415	$43,810	$428.32	9,777	-4638	-32%
Multipurpose RCC with CHTR Fish Passage	$558.53	$608.96	$19.59	$628.55	12,144	$51,758	$558.53	10,791	-1353	-11%
Multipurpose RCC with Conventional Fishway	$586.82	$608.96	$19.59	$628.55	12,144	$51,758	$586.82	11,338	-806	-7%
Multipurpose Rockfill with Experimental Fishway	$769.84	$608.96	$19.59	$628.55	12,144	$51,758	$769.84	14,874	2730	22%
Storage + Airport Levee + Flood Proofing										
Flood Retention RCC	$477.32	$650.99	$22.54	$673.52	14,415	$46,725	$477.32	10,215	-4199	-29%
Multipurpose RCC with CHTR Fish Passage	$607.53	$650.99	$19.59	$670.57	12,144	$55,219	$607.53	11,002	-1142	-9%
Multipurpose RCC with Conventional Fishway	$635.82	$650.99	$19.59	$670.57	12,144	$55,219	$635.82	11,515	-629	-5%
Multipurpose Rockfill with Experimental Fishway	$818.84	$650.99	$19.59	$670.57	12,144	$55,219	$818.84	14,829	2685	22%
Storage + I-5 Project Alternative Variations										
Storage + I-5 Project + Airport Levee										
Flood Retention RCC	$499.70	$657.47	$22.54	$680.01	14,415	$47,175	$499.70	10,592	-3822	-27%
Multipurpose RCC with CHTR Fish Passage	$629.91	$657.47	$19.59	$677.06	12,144	$55,753	$629.91	11,298	-846	-7%
Multipurpose RCC with Conventional Fishway	$658.21	$657.47	$19.59	$677.06	12,144	$55,753	$658.21	11,806	-338	-3%
Multipurpose Rockfill with Experimental Fishway	$841.23	$657.47	$19.59	$677.06	12,144	$55,753	$841.23	15,088	2945	24%
Storage + I-5 Project + Airport Levee + Flood Proofing										
Flood Retention RCC	$546.45	$710.02	$22.54	$732.56	14,415	$50,821	$546.45	10,753	-3662	-25%
Multipurpose RCC with CHTR Fish Passage	$676.66	$710.02	$19.59	$729.61	12,144	$60,080	$676.66	11,263	-881	-7%
Multipurpose RCC with Conventional Fishway	$704.96	$710.02	$19.59	$729.61	12,144	$60,080	$704.96	11,734	-410	-3%
Multipurpose Rockfill with Experimental Fishway	$887.98	$710.02	$19.59	$729.61	12,144	$60,080	$887.98	14,780	2636	22%
Combined with High Restoration										
I-5 Project Alternative Variations										
I-5 Project + Airport Levee	$220.46	$100.28	$77.54	$177.82	48,660	$3,654	$220.46	60,329	11668	24%
I-5 Project + Airport Levee + Flood Proofing	$307.71	$235.55	$77.54	$313.09	48,660	$6,434	$307.71	47,824	-836	-2%

Upper Chehalis Storage Alternative Variations										
Storage + Airport Levee										
Flood Retention RCC	$461.62	$608.96	$73.49	$682.45	46,110	$14,801	$461.62	31,189	-14921	-32%
Multipurpose RCC with CHTR Fish Passage	$591.83	$608.96	$59.92	$668.88	37,188	$17,987	$591.83	32,904	-4284	-12%
Multipurpose RCC with Conventional Fishway	$620.12	$608.96	$59.92	$668.88	37,188	$17,987	$620.12	34,477	-2711	-7%
Multipurpose Rockfill with Experimental Fishway	$803.14	$608.96	$59.92	$668.88	37,188	$17,987	$803.14	44,652	7464	20%
Storage + Airport Levee + Flood Proofing										
Flood Retention RCC	$510.62	$650.99	$73.49	$724.48	46,110	$15,712	$510.62	32,498	-13611	-30%
Multipurpose RCC with CHTR Fish Passage	$640.83	$650.99	$59.92	$710.91	37,188	$19,117	$640.83	33,522	-3666	-10%
Multipurpose RCC with Conventional Fishway	$669.12	$650.99	$59.92	$710.91	37,188	$19,117	$669.12	35,002	-2186	-6%
Multipurpose Rockfill with Experimental Fishway	$852.14	$650.99	$59.92	$710.91	37,188	$19,117	$852.14	44,576	7388	20%
Storage + I-5 Project Alternative Variations										
Storage + I-5 Project + Airport Levee										
Flood Retention RCC	$533.00	$657.47	$73.49	$730.97	46,110	$15,853	$533.00	33,622	-12488	-27%
Multipurpose RCC with CHTR Fish Passage	$663.21	$657.47	$59.92	$717.40	37,188	$19,291	$663.21	34,379	-2809	-8%
Multipurpose RCC with Conventional Fishway	$691.51	$657.47	$59.92	$717.40	37,188	$19,291	$691.51	35,846	-1342	-4%
Multipurpose Rockfill with Experimental Fishway	$874.53	$657.47	$59.92	$717.40	37,188	$19,291	$874.53	45,333	8145	22%
Storage + I-5 Project + Airport Levee + Flood Proofing										
Flood Retention RCC	$579.75	$710.02	$73.49	$783.51	46,110	$16,992	$579.75	34,119	-11991	-26%
Multipurpose RCC with CHTR Fish Passage	$709.96	$710.02	$59.92	$769.94	37,188	$20,704	$709.96	34,291	-2897	-8%
Multipurpose RCC with Conventional Fishway	$738.26	$710.02	$59.92	$769.94	37,188	$20,704	$738.26	35,658	-1530	-4%
Multipurpose Rockfill with Experimental Fishway	$921.28	$710.02	$59.92	$769.94	37,188	$20,704	$921.28	44,497	7309	20%

Table K-42
Threshold Analysis for Federal Perspective

Project	Total Cost	Impacts (Environmental and Non-environmental)			Change in Population Est.	Project Impact ($/fish)	Adj. Project Impacts	Adj. Change in Population Est.	Change in Fish Population Needed	% of Expected Population Change to Obtain BCR = 1
formula	*a*	*Flood Damage Reduction- b*	*Env. Use Values- c*	*Total Impacts d=b+c*	*e*	*f=d/e*	*g=a*	*h=(g*e)/d*	*i=h-e*	*j*
Combined with Low Restoration										
I-5 Project Alternative Variations										
I-5 Project + Airport Levee	$188.17	$56.57	$15.09	$71.66	17,860	$4,012	$188.17	46,899	29039	163%
I-5 Project + Airport Levee + Flood Proofing	$275.42	$108.51	$15.09	$123.60	17,860	$6,921	$275.42	39,798	21937	123%
Upper Chehalis Storage Alternative Variations										
Storage + Airport Levee										

Project	Total Cost	Impacts (Environmental and Non-environmental)			Change in Population Est.	Project Impact ($/fish)	Adj. Project Impacts	Adj. Change in Population Est.	Change in Fish Population Needed	% of Expected Population Change to Obtain BCR = 1
formula	*a*	*Flood Damage Reduction-b*	*Env. Use Values- c*	*Total Impacts d=b+c*	*e*	*f=d/e*	*g=a*	*h=(g*e)/d*	*i=h-e*	*j*
Flood Retention RCC	$416.01	$377.45	$12.20	$389.65	14,415	$27,032	$416.01	15,390	975	7%
Multipurpose RCC with CHTR Fish Passage	$531.86	$377.45	$10.60	$388.05	12,144	$31,954	$531.86	16,644	4500	37%
Multipurpose RCC with Conventional Fishway	$563.99	$377.45	$10.60	$388.05	12,144	$31,954	$563.99	17,650	5506	45%
Multipurpose Rockfill with Experimental Fishway	$745.15	$377.45	$10.60	$388.05	12,144	$31,954	$745.15	23,319	11176	92%
Storage + Airport Levee + Flood Proofing										
Flood Retention RCC	$465.01	$401.08	$12.20	$413.28	14,415	$28,671	$465.01	16,219	1804	13%
Multipurpose RCC with CHTR Fish Passage	$580.86	$401.08	$10.60	$411.69	12,144	$33,901	$580.86	17,134	4990	41%
Multipurpose RCC with Conventional Fishway	$612.99	$401.08	$10.60	$411.69	12,144	$33,901	$612.99	18,082	5938	49%
Multipurpose Rockfill with Experimental Fishway	$794.15	$401.08	$10.60	$411.69	12,144	$33,901	$794.15	23,426	11282	93%
Storage + I-5 Project Alternative Variations										
Storage + I-5 Project + Airport Levee										
Flood Retention RCC	$488.60	$400.87	$12.20	$413.08	14,415	$28,657	$488.60	17,050	2636	18%
Multipurpose RCC with CHTR Fish Passage	$604.45	$400.87	$10.60	$411.48	12,144	$33,883	$604.45	17,839	5695	47%
Multipurpose RCC with Conventional Fishway	$636.58	$400.87	$10.60	$411.48	12,144	$33,883	$636.58	18,787	6643	55%
Multipurpose Rockfill with Experimental Fishway	$817.74	$400.87	$10.60	$411.48	12,144	$33,883	$817.74	24,134	11990	99%
Storage + I-5 Project + Airport Levee + Flood Proofing										
Flood Retention RCC	$535.35	$430.43	$12.20	$442.63	14,415	$30,707	$535.35	17,434	3020	21%
Multipurpose RCC with CHTR Fish Passage	$651.20	$430.43	$10.60	$441.03	12,144	$36,317	$651.20	17,931	5787	48%
Multipurpose RCC with Conventional Fishway	$683.33	$430.43	$10.60	$441.03	12,144	$36,317	$683.33	18,816	6672	55%
Multipurpose Rockfill with Experimental Fishway	$864.49	$430.43	$10.60	$441.03	12,144	$36,317	$864.49	23,804	11660	96%
Combined with High Restoration										
I-5 Project Alternative Variations										
I-5 Project + Airport Levee	$188.17	$56.57	$15.09	$71.66	17,860	$4,012	$188.17	46,899	29039	163%
I-5 Project + Airport Levee + Flood Proofing	$275.42	$108.51	$15.09	$123.60	17,860	$6,921	$275.42	39,798	21937	123%
Upper Chehalis Storage Alternative Variations										
Storage + Airport Levee										
Flood Retention RCC	$416.01	$377.45	$12.20	$389.65	14,415	$27,032	$416.01	15,390	975	7%
Multipurpose RCC with CHTR Fish Passage	$531.86	$377.45	$10.60	$388.05	12,144	$31,954	$531.86	16,644	4500	37%
Multipurpose RCC with Conventional Fishway	$563.99	$377.45	$10.60	$388.05	12,144	$31,954	$563.99	17,650	5506	45%
Multipurpose Rockfill with Experimental Fishway	$745.15	$377.45	$10.60	$388.05	12,144	$31,954	$745.15	23,319	11176	92%
Storage + Airport Levee + Flood Proofing										

Project	Total Cost	Impacts (Environmental and Non-environmental)			Change in Population Est.	Project Impact ($/fish)	Adj. Project Impacts	Adj. Change in Population Est.	Change in Fish Population Needed	% of Expected Population Change to Obtain BCR = 1
formula	*a*	*Flood Damage Reduction- b*	*Env. Use Values- c*	*Total Impacts d=b+c*	*e*	*f=d/e*	*g=a*	*h=(g*e)/d*	*i=h-e*	*j*
Flood Retention RCC	$465.01	$401.08	$12.20	$413.28	14,415	$28,671	$465.01	16,219	1804	13%
Multipurpose RCC with CHTR Fish Passage	$580.86	$401.08	$10.60	$411.69	12,144	$33,901	$580.86	17,134	4990	41%
Multipurpose RCC with Conventional Fishway	$612.99	$401.08	$10.60	$411.69	12,144	$33,901	$612.99	18,082	5938	49%
Multipurpose Rockfill with Experimental Fishway	$794.15	$401.08	$10.60	$411.69	12,144	$33,901	$794.15	23,426	11282	93%
Storage + I-5 Project Alternative Variations										
Storage + I-5 Project + Airport Levee										
Flood Retention RCC	$488.60	$400.87	$12.20	$413.08	14,415	$28,657	$488.60	17,050	2636	18%
Multipurpose RCC with CHTR Fish Passage	$604.45	$400.87	$10.60	$411.48	12,144	$33,883	$604.45	17,839	5695	47%
Multipurpose RCC with Conventional Fishway	$636.58	$400.87	$10.60	$411.48	12,144	$33,883	$636.58	18,787	6643	55%
Multipurpose Rockfill with Experimental Fishway	$817.74	$400.87	$10.60	$411.48	12,144	$33,883	$817.74	24,134	11990	99%
Storage + I-5 Project + Airport Levee + Flood Proofing										
Flood Retention RCC	$535.35	$430.43	$12.20	$442.63	14,415	$30,707	$535.35	17,434	3020	21%
Multipurpose RCC with CHTR Fish Passage	$651.20	$430.43	$10.60	$441.03	12,144	$36,317	$651.20	17,931	5787	48%
Multipurpose RCC with Conventional Fishway	$683.33	$430.43	$10.60	$441.03	12,144	$36,317	$683.33	18,816	6672	55%
Multipurpose Rockfill with Experimental Fishway	$864.49	$430.43	$10.60	$441.03	12,144	$36,317	$864.49	23,804	11660	96%

ANNOTATED BIBLIOGRAPHY - VALUATION PARAMETERS

OVERVIEW OF LITERATURE REVIEW

A number of economic analyses that have estimated use and passive use values have been reviewed to determine their applicability in estimating values of changes in fish populations from the Chehalis Basin. These analyses include individual published papers with a purely research purpose and others that used the results of this research to estimate the economic value of fishing at a different site altogether – an approach called *benefit transfer*. A key aspect of benefit transfer is the selection of studies and their published results for economic valuation at a new site. Guidelines have been established for Benefit Transfer by the U.S. Office of Management and Budget (OMB) as well as the U.S. Environmental Protection Agency (EPA).

For the analysis of fish populations from the Chehalis Basin, a comprehensive review of potentially applicable studies has been conducted to ensure a high level of due diligence in selecting the most appropriate studies for estimating the economic value for these population changes. The determination of applicability of a study to the Chehalis Basin adopted standards established by OMB and EPA and led to the consideration of several factors including:

a) **Regional differentiation –** Studies performed in the Pacific Northwest
b) **Site-level similarities –** Studies conducted for rivers, estuaries, and ocean waters separately in areas similar to the Chehalis Basin and WA coast
c) **Species-level similarities –** Studies developed separate estimates of economic value for different types of salmonid species.
d) **Study quality –** Studies conducted since 1980 were considered as potential candidates since these studies would have been more likely to have been conducted using better analytical and survey methods.
e) **Precedence in practice –** Studies that have been included in similar analyses in the Pacific Northwest.

These criteria led to the rejection of a number of potentially applicable studies for use in estimating values for the Chehalis Basin. While it is certainly the case that no single study or set of studies matches the context of the projects under consideration for the Chehalis Basin, there are many studies that were deemed to be altogether a poor match based on federal benefit transfer guidelines.

A starting point for gathering information on potentially applicable studies entailed a review of a publicly available database of fish valuation literature (Rosenberger, 2011) and similar studies which compiled research to estimate economic values (e.g., ECONorthwest, 2009 and 2012). The Rosenberger (2011) database contains over 350 documents of economic valuation studies that estimated the use value of recreation activities in the U.S. and Canada from 1958 to 2006, totaling 2,703 estimates in per person per activity day, adjusted to 2010 USD. The data is differentiated by activity types, resource type, and primary species sought. These recreation use value estimates are measured on a consistent basis in terms of net willingness-to-pay for recreational access to specific sites, or for certain activities at broader geographic scales (e.g., state or province, national) in per person per activity day units.

The ECONorthwest (2009) report, which is reviewed below, provides a listing of potentially relevant studies that were reviewed for an economic analysis of salmonids in the Rogue River. In addition to document reviews, direct consultations were also undertaken with academic economists, and economists from US Bureau of

Reclamation (BOR) and US National Oceanic and Atmospheric Administration (NOAA) who have conducted studies of their own.

The ECONorthwest (2012) study is a particularly relevant as a precedent because its analysis contributed to the Yakima River Basin Integrated Water Resource Management Plan. Its benefit transfer approach implemented findings from the U.S. Bureau of Reclamation (2008). In that analysis, separate studies were used to derive values for sport fishing in rivers and ocean waters. For river sport fishing, three studies were used including: (a) a commonly cited analysis of use and nonuse values associated with salmon in ocean and Columbia River by Olsen et al. (1991); (b) a study from Olsen and Richards (1992) on the value of salmon populations in the Rogue River in Oregon; and (c) a report by Gallo (2003) who applied a travel-cost model to estimate values associated with salmon populations on the Sacramento River in California. Ocean sport values included Olsen et al. (1991) along with Jones and Stokes (1987), who conducted a survey in 1986-7 of Juneau, Alaska, area anglers using sophisticated random utility travel-cost models. After assessing each of these studies and discussing this report with staff economists from BOR, it was determined that a more updated analysis would be more relevant for the Chehalis Basin. In particular, studies from outside OR and WA would be excluded, namely Gallo (2003) and Jones and Stokes (1987).

In addition, the literature review for the Chehalis project revealed that a new analysis of fishing value in ocean waters and estuaries that was not available at the time that U.S. Bureau of Reclamation (2008) prepared its report. This study by Anderson and Lee (2013) provides the best estimates to date for these waters and has been applied for Chehalis salmonids instead of Olsen et al. (1991).

In the sections that follow, several papers that have been used in this analysis are summarized depending on their relevance for sport values for river, oceanic / estuary, passive use, and other benefit transfer studies.

RIVER SPORT

Olsen et al. (1991)

Olsen, Richards, and Scott (1991) conducted a contingent valuation study where they estimate non-use and sport fishing values per year for doubling salmon/steelhead populations in the Columbia River Basin, from 2.5 million to 5 million. Surveys were conducted by telephone. Each household was requested to respond to whether they would pay a surcharge on their utility bill for the cost to enhance these populations. Data were collected from both user and nonuser[97] households in the Pacific Northwest. The final sample consists of approximately 1,400 households with half of them identified as users and the other half as nonusers.

The authors report results for three categories of households. In 2013 dollars, they estimate that on average, households that do not fish for salmon and steelhead are willing to pay $49.80 ($26.51 in 1989 dollars) annually for the doubling of fish populations. Second, they report a mean annual WTP of $109.45 ($58.26 in 1989 dollars) per year for households that currently do not fish but may go fishing in the future. Last but not least, households that currently fish for anadromous species are willing to pay $139.32 ($74.16 in 1989 dollars) per year.

Olsen and Richards (1991)

Olsen and Richards conducted a contingent valuation survey on the Rogue River in Oregon. This survey evaluated the use value associated with doubling salmon population on the Rogue River. In 2013$, they attribute on average a value of $116.49 per fall chinook and $91.06 per steelhead.

[97] Nonusers are households that are not involved in sport or commercial fisheries.

Meyer, Brown, and Hsiao (1983)

Meyer et al (1983) conducted a study that analyzes differential values for sport fisheries for salmon and steelhead in the Columbia River Basin. Their analysis accounted for different characteristics of location, species, and catch success. The authors analyze the results of an existing data collected by Brown, Sorhus, and Gibbs[98] (1980) salt and fresh-water sport fisheries for salmon and steelhead in Oregon. Surveys were sent to a sample of 9,000 anglers in Oregon. The survey consisted of a questionnaire, which was mailed to anglers in order to obtain information about their expenditures and fishing activities on a quarterly basis.

Meyer et al (1983) used more sophisticated statistical methods and integrated the catch rate into trip decisions. Their results recommend the following values per Columbia River enhanced sport fish: $294.02 ($104 in 1980$) for spring chinook, $220.52 ($78 in 1980$) for fall chinook and coho, and $296.85 ($105 in 1980$) for steelhead. They suggest that a more comprehensive analysis would further refine the results.

OCEAN AND ESTUARY SPORT FISHING

Anderson and Lee (2013)

Anderson and Lee (2013) conduct a comprehensive assessment of anglers' preferences for wild and hatchery salmon. They asked elicited responses about their WTP for fish under different contexts including the: fishery location (oceanic or estuary fisheries), species (Chinook or coho), type of fish (wild or hatchery), size of fish (small, medium and large, by weight depending on the type of species) and management system (harvest or release). This broad and robust set of results enables the selection of anglers' WTP that is specific to the context whereby anglers would express a WTP that is relevant to this study.

The authors find differences between the recreational values for wild and hatchery salmon. These differences are statistically significant. Furthermore, WTP values for wild king salmon that can be retained are lower than the corresponding values for hatchery king salmon. This indicates that, across species and sizes, anglers are more likely to release wild salmon than hatchery salmon. The authors investigate further by integrating their econometric model with creel survey data obtained from state sampling programs in order to conduct policy simulations. This approach is illustrated with scenarios that change the bag limit and catch rates for king salmon in Washington. Anderson and Lee evaluate results for various policy changes as well including hatchery vs. wild catch and catch level limits. Because of the comprehensiveness of this study for different types of fish and fishing activity, the results can be reasonably applied to recreational use values for Washington Ocean and Grays Harbor (Washington Inside) in 2013 dollars per fish for each species.[99] The WTP for medium-sized fish per species are used as a proxy value.

PASSIVE USE VALUE

Layton, Brown, and Plummer (1999)

Layton, Brown, and Plummer (1999) conducted a study to estimate the total economic value associated with potential future increases in fish populations in Washington. Findings from Eastern Washington

[98] W.G. Brown, C.N. Sorhus, and K.C. Gibbs. 1980. *Estimated Expenditures by Sport Anglers and Net Economic Values of Steelhead for Specified Fisheries in the Pacific Northwest.* Department of Agricultural Resource Economics, Oregon State University, 1980.

[99] WTP values for wild silver catch in the paper are used for coho in the BCA Model. For chinook, refer to wild king catch. These estimates come from Table 3 of the paper.

and Columbia River migratory fish (i.e., salmon and steelhead originating from Eastern Washington and the Columbia River Basin) were used in this study.

Surveys were sent to households including data on historical fish populations, current fish populations as of 1999, and projected future populations 20 years from date of survey. A total of 2,819 surveys were mailed to randomly selected households. The researchers received 1,917 responses. Eighty-four percent of these responses were used in the study. Half of these responses assumed a stable baseline fish population and the other half assumed a declining baseline fish population. Based on migratory fish data100, past population was estimated at 8 million. By 1999, fish population had plummeted to 2 million, thus representing a 75 percent decline. Future population could either remain stable at 2 million or decrease by 75 percent. Assuming a decrease, the authors report a population of 500,000 fish 20 years after the survey. Furthermore, various programs with different impacts on future fish populations were presented to respondents in order to estimate households' willingness to pay (WTP) for improvements in fish populations over the next 20 years.

The authors find that households are willing to pay more when baseline fish populations are projected to decline than when they would remain stable. For the enhancement program where baseline population remains stable, households are willing to pay approximately $127 (2013 dollars) per year for 20 years for a 20 percent increase in salmon population. However, if baseline population is projected to decline, households would be willing to pay twice as much for a 20 percent increase in salmon population. Additionally, households' average annual WTP increases at a decreasing rate, suggesting that households would pay more for small increases in future populations rather than for large increases.

BENEFIT TRANSFER STUDIES

ECONorthwest (2009)

This report describes the method and data to estimate the value of salmon and steelhead in the Wild & Scenic Rogue River. Salmonids from the Rogue River support commercial fishing, sport fishing, and non-use values. The Rogue River report considered the following studies to determine reasonable recreational values for different species and fishery locations, derived from salmon fishing there.

Table K-43
Recreational Values for Different Species and Fishery Locations

Study	Location	Species	Study Method	WTP Per Fish (2013$)
Olsen et al., 1990	WA. Ocean	Salmon	CVM	$71.45
Meyer et al., 1983	OR. Ocean	Steelhead	TCM	$173.38
Olsen et al., 1990	OR. Coastal	Steelhead	CVM	$110.02
Olsen & Richards, 1992	Rogue River	Fall Chinook	CVM	$116.44
Meyer et al., 1983	Rogue River	Fall Chinook	TCM	$64.09
Meyer Resources, 1987	S.F Bay / Sacramento & San Joaquin Rivers	Chinook	CVM	$769.21
Meyer Resources, 1987	CA. State	Chinook	CVM	$345.34
Meyer Resources, 1987	North Coast Streams	Chinook	CVM	$345.34

[100] Only one result of the Study - EW/Columbia Migratory Fish (CM). Other data for Freshwater Fish and Saltwater is directly in Layton's paper.

Study	Location	Species	Study Method	WTP Per Fish (2013$)
Olsen et al., 1990	WA Freshwater	Salmon	CVM	$63.06
Meyer Resources, 1985	Sacramento and San Joaquin Rivers	Salmon	TCM	$340.16
Meyer et al., 1983	Columbia River	Salmon	TCM	$224.96
Olsen et al., 1990	Columbia River	Salmon	CVM	$78.45
Meyer et al., 1983	Oregon	Steelhead	TCM	$263.67
Olsen & Richards, 1992	Rogue River	Steelhead	CVM	$144.01
Meyer et al., 1983	Rogue & Illinois	Steelhead	TCM	$234.68
Meyer Resources, 1985	Sacramento and San Joaquin Rivers	Steelhead	TCM	$1006.89
Meyer Resources, 1986	CA. State	Steelhead	TCM	$1,022.21
Donnelly et al., 1985	ID. State	Steelhead	CVM	$47.23
Meyer et al, 1983	Columbia River	Steelhead	TCM	$359.84
Olsen et al., 1990	Columbia River	Steelhead	CVM	$227.50
Olsen & Richards, 1992	Rogue River	Half-Pounder	CVM	$18.80
Olsen & Richards, 1992	Rogue River	Steelhead	CVM	$38.04

Notes:
Source: ECONorthwest compilation of various studies

Table K-42 below summarizes the estimated annual WTP by sport anglers for Rogue River salmon that were derived from these studies.

Table K-44
Estimated Annual WTP per Fish

Species	Catch Location	Estimated 2007 Catch	WTP Per Fish (2013$)
Coho salmon	Ocean	6,488	$71.91
	River	1,200	$176.40
Chinook salmon	Ocean	5,355	$71.91
	River	15,988	$260.65
Steelhead	Ocean	1,040	$141.56
	River	4,165	$335.93
Total Sport Fishing		34,236	

Notes:
Source: ECONorthwest analysis of results from studies presented in the previous table and data from Oregon Department of Fish and Wildlife (http://www.dfw.state.or.us/resources/fishing/sportcatch.asp)

Ultimately, ECONorthwest (2009) finds that recreational use and passive use values are significantly larger than commercial value. For example, the value obtained from doubling Rogue River salmon would include:

- Commercial salmon fishery is not less than $1.53 million annually
- Sports salmon fishery is not less than $17.99 million annually
- Using Loomis (1999), the total economic value (including passive use value) of all Rogue River salmon and steelhead runs is approximately $1.70 billion

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Appendix L: Economic Development Impacts

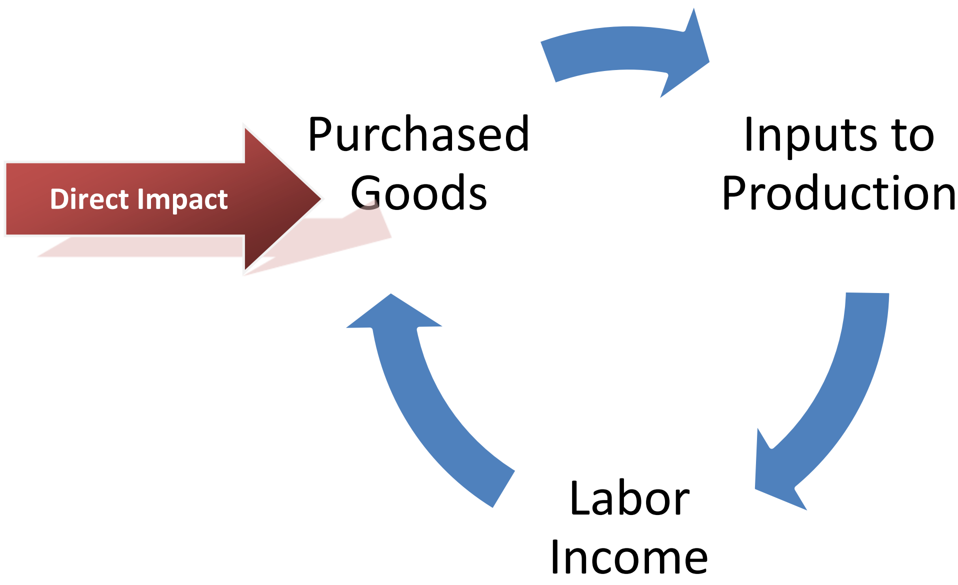
Introduction

So far, the analyses of Project Alternative impacts to flooding damages has accounted only for direct damages. However, in addition to direct damages, indirect or induced effects can also be calculated. These effects account for additional impacts not directly affected by flooding. For example, when a retail store closes due to a flood event (temporarily or permanently), impacts to industries inside and outside the study region are realized when the closed store reduces its purchase of goods from its suppliers. This section describes the general methodology behind input-output (IO) modeling as well as the models selected for modeling indirect and induced effects for each perspective (State or Basin-wide). Note that the Principles and Guidelines methodology for the Federal Perspective would not include economic multiplier effects from IO modeling since these effects primarily measure transfers between regions within the nation.

Input-Output Modeling

IO modeling is a quantitative analysis representing relationships (dependence) between industries in an economy. IO models are based on the implicit assumption that each basic sector has a multiplier, or ripple, effect on the wider economy because each sector purchases goods and services to support that sector. IO modeling estimates the inter-industry transactions and uses those transactions to estimate the economic impacts of any change to the economy. Figure L-1 illustrates a multiplier effect in an economy.

Figure L-1
Impact Analysis



IO models are made up of matrices of multipliers between each industry present in an economy. Each column shows how an industry is dependent on other industries for both its inputs to production and outputs. The tables of multipliers can be used to estimate the effects in changes in spending for various industries, household consumption, or labor income. Both positive and negative impacts can be measured using IO modeling. IO modeling produces results broken down into several categories. Each of these is described below:

- **Direct Effects –** Increased purchases of inputs used to produce final goods and services purchased by residents. Direct effects are the input values in an IO model, or first round effects.
- **Indirect Effects –** Value of inputs used by firms affected by direct effects (inputs). Economic activity that supports direct effects.
- **Induced Effects –** Results of Direct and Indirect effects (calculated using multipliers). Represents economic activity from household spending.
- **Total Effects –** Sum of Direct, Indirect, and Induced effects.
- **Total Output –** Value of all goods and services produced by industries.
- **Value Added –** Total Output less value of inputs, or the Net Benefit/Impact to an economy.
- **Employment –** Number of additional/reduced full time employment resulting from direct effects.

This study uses value added and employment figures to represent the total additional economic impact for each Project Alternative.

USE OF IMPACT ANALYSIS

Economic impact analysis is a widely used methodology for public agencies and state and local governments when making decisions regarding projects, policies, or investments.[101] In addition, private businesses may use

[101] Day, Frances. Principles of Impact Analysis & IMPLAN Applications. IMPLAN Group LLC. Huntersville, NC.

impact analysis to demonstrate their impact on an economy or the effects of changes in business practices or location.

CHEHALIS FLOOD HAZARD MITIGATION: TYPES OF IMPACTS

The economic consequences of flood damage over time includes both positive and negative impacts. Negative impacts include the direct damages immediately following an event. Positive impacts include the effects of recovery and reconstruction.[102] Some studies have asserted that the short-term impacts from a natural disaster are negligible compared with the long-term impacts of recovery.[103] The IO analysis in this study is based on the understanding that natural disasters are best avoided for the benefit of long-term economic growth. While some discussion is provided for the trade-off between monetized positive and negative impacts, a general recognition also exists that reduction of flood hazard risk is a better service to long-term economic growth.

The IO analyses in this study are conducted using previously prepared IO models. This methodology is consistent with many other studies that have evaluated regional impacts from natural disasters using previously prepared IO models. However, this methodology ignores the time lag effect for the positive and negative economic effects following a disaster. In order to mitigate for this shortcoming, economic impacts are reported separately depending on the type of impact. For example, structure damages have immediate negative consequences followed by positive impacts from repair and reconstruction. Therefore, IO results are presented with and without structure damage.

Five types of impacts are modeled in the IO analyses. These are described below.

PROJECT EXPENDITURES

When funded from outside sources, project costs are circulated within the local economy creating additional value. If a project is funded by the state, then the costs would not be counted since the project cost would not change the state budget. Rather, a project funded in the Chehalis Basin would reduce the funds available for projects outside of the basin. Therefore, no additional economic activity is created when state funding is utilized. However, if the project is funded federally from grants or similar mechanisms, then additional economic activity could be included from project expenditures. Similarly, local funding within the basin would not promote additional economic activity; however, funding at the state or federal level would result in additional economic growth.

PHYSICAL PROPERTY DAMAGE REDUCTION

Damage reduction resulting from the implementation of Project Alternatives refers to the reduced damages to physical property and reduced labor requirement to clean up after a flood event. Other studies[104] have modeled damage reduction as an increase in income for medium households. Because damage reduction impacts can be viewed as both sources of economic growth as well as reductions in income, these damages are reported separately in the results.

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[102] Ishikawa, Yoshimi and Toshitaka Katada. Analysis of the Economic Impacts of a Natural Disaster Using Interregional Input-Output Tables for the Affected Region: A Case Study of the Tokai Flood of 2000 in Japan. 2006 Intermediate Input-Output Modeling.
[103] Ishikawa, Yoshimi, 2006.
[104] Sheets, Keith. Traditional Uses of Input-Output Models in Watershed Programs Planned under Principles and Guidelines. USDA Natural Resources Conservation Service. Lincoln, Nebraska. August 1998.

BUSINESS LOSS REDUCTION

In the basin-wide Perspective, business interruption losses are estimated. These losses are included in the IO analysis as changes in industry (lost revenue). Since income recapture factors (see Appendix I) are already included in the business interruption loss estimates, no further adjustments are made before including these losses in the basin-wide IO model. Similarly, avoided I-5 closures are included in the both the State- and Basin-wide perspective IO modeling.

LOST HOUSEHOLD INCOME

When a home is flooded, residents are not only faced with the cleanup and reconstruction costs but they may also incur lost wages for cleanup and management of repair. This lost income is not calculated in the COA framework unless included as part of a business closure. In general, calculating lost household income resulting from a natural disaster is difficult and is therefore left out of IO analyses. This study has not included these losses; therefore, the flood reduction impacts from the Project Alternatives may be underestimated. It is important to note that while these losses are not included in the COA, the exclusion is not likely to change the relative ranking of the Project Alternatives.

OTHER PROJECT IMPACTS

Other project impacts include effects on commercial and sport fishing. The fish population projections and estimated value of fish populations are estimated. The change in fisheries value is included in the IO analysis to account for possible economic activity changes resulting from fish population changes.

Selected Models

Washington State (Office of Financial Management [OFM]) periodically updates a State IO model. The OFM model was reviewed and it was found that it excludes various input parameters viewed as important in this study. For example, the OFM model does not easily incorporate changes to labor income, household income, or government expenditures. Therefore, IMPLAN models were selected for both the state and Basin IO analyses.

IMPLAN Model

The IMPLAN is a software program comprised of regional data sets developed by MIG Inc. One of IMPLAN's strengths is that the regional data sets are based on data representing regional economies including U.S. Bureau of Labor Statistics (BLS) Covered Employment and Wages program; U.S. Bureau of Economic Analysis (BEA) Regional Economic Information System program; U.S. Bureau of Economic Analysis Benchmark I/O Accounts of the U.S.; BEA Output estimates; BLS Consumer Expenditure Survey; U.S. Census Bureau County Business Patterns Program; U.S. Census Bureau Decennial Census and Population Surveys; U.S. Bureau Economic Censuses and Surveys; and the U.S. Department of Agriculture Census.

IMPLAN includes over 400 industries as well as local and federal taxing agencies, local government expenditures, labor and wage income, and personal expenditures. The IMPLAN model is an iterative model where the effects measured in IMPLAN are the results of multiple rounds. Multiplier effects are calculated until only the transfers that occur outside of the region are affected.

MODEL LIMITATIONS

IMPLAN has several limitations including:

- The model estimates impacts best for years closest to the year for which the model is constructed. The study period for the Chehalis Basin Flood Hazard Mitigation study is 100 years. Over that time industries are likely to shift and have considerable changes in industry interdependence.
- The model assumes a fixed employment-to-output ratio at the industry level and uses these ratios to calculate employment impacts. As labor productivity changes over time, these ratios will become less representative of the state economy. Similarly, changes in the economy affect output but not the mix of inputs to production.
- Local supply is perfectly elastic meaning that no capacity limitations exist. This model limitation is less important for relatively small impacts that do not affect equilibrium prices. This study has not considered price effects for implementation of any of the proposed Project Alternatives.
- The time needed to realize the economic impacts is not specified.

These limitations are generally consistent with other IO modeling approaches.

STATE PERSPECTIVE

The State IMPLAN model is used to estimate the value added for each Project Alternative. Employment numbers are also reported as the number of full time employees added or reduced as a result of a Project Alternative. Expected annual avoided or reduced flood damages are used as inputs to the model. The output measures the additional economic activity resulting from the expected avoided damages. In addition, the monetized effect on state fisheries is included and reported separately. The following inputs are included in the State IMPLAN model:

- Avoided or reduced flood damages
- Structure, content, inventory damages
    - Transportation delays
    - Agriculture losses
    - Cleanup Costs
    - State share of Emergency Aid
- Monetized impacts on State Fisheries
- Project Expenditures

The following impacts are not included in the IO analysis for the State Perspective:

- Vehicle Loss
- Business Interruption
- FEMA share of Public Assistance

Project costs are included from the State Perspective; however, if any of these projects are funded by the state, the IO analysis should exclude project costs. In particular, if these projects are funded by the state, those funds could not be allocated to some other purpose and the impacts to the state as a whole are zero. Because a funding decision has not been made, impacts resulting from project costs are included but are reported separately.

The output from the model represents the expected value added and additional employment that result in the impacts estimated over the study period. The timing of these additional impacts is not defined and could extend beyond the 100-year study period.

BASIN-WIDE PERSPECTIVE

Three county level IO models are combined to produce a Basin-wide IO model. The following inputs are included in the basin-wide IO model:

- Project Expenditures
- Avoided or reduced flood damages on an annual expected basis
  - Structure, content, inventory damages
  - Local transportation delays
  - Agriculture losses
  - Cleanup costs
  - Business interruption
- Monetized impacts on local fisheries

The following impacts are not included in the IO analysis for the basin-wide Perspective:

- Vehicle loss

The output from the model represents the expected value added and employment given the project expenditures as well as the 100-year net present value of expected damages and losses.

State IO Results

Table L-1
State Input-Output Results

	DIRECT IMPACTS MILLIONS	TOTAL VALUE ADDED MILLIONS	MULTIPLIER	EMPLOYMENT	BENEFIT/COST RATIO
I-5 Project + Airport Levee + Floodproofing					
I-5 Closure	$22	$21	2.0	258	1.3
Project Costs (Excluding Enhancement)	$192	$197	2.0	2,120	2.2
Flood Damage Reduction	$175	$140	1.8	1,537	1.9
Low Enhancement (project costs + impacts)	$123	$121	2.0	1,406	1.3
High Enhancement (project costs + impacts)	$206	$200	2.0	2,292	1.6
Total with Low Enhancement	$511	$679	2.3	7,613	3.3
Total with High Enhancement	$594	$558	1.9	6,207	2.7
Flood Retention RCC with CHTR + Airport Levee + Floodproofing					
I-5 Closure	$16	$16	2.0	202	1.6
Project Costs (Excluding Enhancement)	$530	426	1.8	4,777	2.7
Flood Damage Reduction	$382	$342	1.9	3,884	2.5
Low Enhancement (project costs + impacts)	$120	$116	2.0	1,344	1.6
High Enhancement (project costs + impacts)	$203	$196	2.0	2,248	1.8
Total with Low Enhancement	$1,048	$1,096	2.0	12,455	3.7
Total with High Enhancement	$1,131	$980	1.9	11,111	3.3
Multipurpose RCC with CHTR + Airport Levee + Floodproofing					
I-5 Closure	$16	$16	2.0	202	1.2
Project Costs (Excluding Enhancement)	$530	426	1.8	4,777	2.0
Flood Damage Reduction	$512	$432	1.8	4,930	2.0
Low Enhancement (project costs + impacts)	$122	$114	1.9	1,315	1.3
High Enhancement (project costs + impacts)	$205	$183	1.9	2,105	1.4
Total with Low Enhancement	$1,180	$1,171	2.0	13,329	3.0
Total with High Enhancement	$1,263	$1,057	1.8	12,014	2.8

	DIRECT IMPACTS MILLIONS	TOTAL VALUE ADDED MILLIONS	MULTIPLIER	EMPLOYMENT	BENEFIT/COST RATIO
Multipurpose RCC with Conventional Fishway+ Airport Levee + Floodproofing					
I-5 Closure	$16	$16	2.0	202	1.2
Project Costs (Excluding Enhancement)	$530	426	1.8	4,777	1.9
Flood Damage Reduction	$541	$468	1.9	5,346	2.0
Low Enhancement (project costs + impacts)	$122	$114	1.9	1,315	1.2
High Enhancement (project costs + impacts)	$205	$183	1.9	2,105	1.3
Total with Low Enhancement	$1,209	$1,024	1.8	11,640	2.7
Total with High Enhancement	$1,292	$1,093	1.8	12,430	2.7
Multipurpose Rockfill with Experimental Fishway+ Airport Levee + Floodproofing					
I-5 Closure	$16	$16	2.0	202	0.9
Project Costs (Excluding Enhancement)	$530	426	1.8	4,777	1.4
Flood Damage Reduction	$724	$641	1.9	7,351	1.7
Low Enhancement (project costs + impacts)	$122	$114	1.9	1,315	1.0
High Enhancement (project costs + impacts)	$205	$183	1.9	2,105	1.0
Total with Low Enhancement	$1,392	$1,197	1.9	13,645	2.3
Total with High Enhancement	$1,475	$1,266	1.9	14,435	2.3
Flood Retention RCC with CHTR + I-5 Project +Airport Levee + Floodproofing					
I-5 Closure	$21	$21	2.0	262	1.6
Project Costs (Excluding Enhancement)	$568	457	1.8	5,169	2.5
Flood Damage Reduction	$463	424	1.9	4,835	2.4
Low Enhancement (project costs + impacts)	$120	$116	2.0	1,344	1.5
High Enhancement (project costs + impacts)	$203	$196	2.0	1,344	1.7
Total with Low Enhancement	$1,172	$1,018	1.9	11,610	3.1
Total with High Enhancement	$1,255	$1,098	1.9	11,610	3.2
Multipurpose RCC with CHTR + I-5 Project + Airport Levee + Floodproofing					
I-5 Closure	$21	$21	2.0	262	1.2
Project Costs (Excluding Enhancement)	$568	457	1.8	5,169	2.0
Flood Damage Reduction	$594	$516	1.9	5,904	2.1

	DIRECT IMPACTS MILLIONS	TOTAL VALUE ADDED MILLIONS	MULTIPLIER	EMPLOYMENT	BENEFIT/COST RATIO
Low Enhancement (project costs + impacts)	$122	$114	1.9	1,315	1.2
High Enhancement (project costs + impacts)	$205	$183	1.9	2,105	1.3
Total with Low Enhancement	$1,304	$1,108	1.8	12,650	2.7
Total with High Enhancement	$1,387	$1,177	1.8	13,440	2.7
Multipurpose RCC with Conventional Fishway+ I-5 Project+ Airport Levee + Floodproofing					
I-5 Closure	$21	$21	2.0	262	1.2
Project Costs (Excluding Enhancement)	$568	457	1.8	5,169	1.9
Flood Damage Reduction	$622	$552	1.9	6,320	2.0
Low Enhancement (project costs + impacts)	$122	$114	1.9	1,315	1.2
High Enhancement (project costs + impacts)	$205	$183	1.9	2,105	1.3
Total with Low Enhancement	$1,333	$1,144	1.9	13,066	2.6
Total with High Enhancement	$1,416	$1,213	1.9	13,856	2.6
Multipurpose Rockfill with Experimental Fishway + I-5 Project + Airport Levee + Floodproofing					
I-5 Closure	$21	$21	2.0	262	0.9
Project Costs (Excluding Enhancement)	$568	457	1.8	5,169	1.4
Flood Damage Reduction	$805	$725	1.9	8,326	1.8
Low Enhancement (project costs + impacts)	$122	$114	1.9	1,315	0.9
High Enhancement (project costs + impacts)	$205	$183	1.9	2,105	1.0
Total with Low Enhancement	$1,516	$1,317	1.9	15,072	2.3
Total with High Enhancement	$1,599	$1,386	1.9	15,862	2.3

Basin-wide IO Results

Table L-2
Basin-wide Input-Output Results

	DIRECT IMPACTS MILLIONS	TOTAL VALUE ADDED MILLIONS	MULTIPLIER	EMPLOYMENT	BENEFIT/COST RATIO
I-5 Project + Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$5	$3.2	1.7	47	1.1
Project Costs (Excluding Enhancement)	$192	$139	1.7	1,905	1.8
Flood Damage Reduction	$175	$134	1.8	1,873	1.8
Low Enhancement (project costs + impacts)	$123	$83	1.7	1,317	1.1
High Enhancement (project costs + impacts)	$206	$140	1.7	2,208	1.4
Total with Low Enhancement	$495	$499	2.0	7,349	2.6
Total with High Enhancement	$578	$416	1.7	6,032	2.2
Flood Retention RCC with CHTR + Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$8	$4	1.5	54	1.6
Project Costs (Excluding Enhancement)	$530	$307	1.6	3,946	2.4
Flood Damage Reduction	$382	$230	1.6	3,522	2.2
Low Enhancement (project costs + impacts)	$120	$79	1.7	1,255	1.6
High Enhancement (project costs + impacts)	$203	$137	1.7	2,161	1.7
Total with Low Enhancement	$1,040	$757	1.7	10,938	3.0
Total with High Enhancement	$1,123	$678	1.6	9,683	2.7
Multipurpose RCC with CHTR + Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$8	$4	1.5	54	1.2
Project Costs (Excluding Enhancement)	$530	$307	1.6	3,946	1.8
Flood Damage Reduction	$512	$291	1.6	4,497	1.7
Low Enhancement (project costs + impacts)	$122	$77	1.6	1,225	1.2
High Enhancement (project costs + impacts)	$205	$127	1.6	2,007	1.3
Total with Low Enhancement	$1,172	$679	1.6	11,728	2.2
Total with High Enhancement	$1,255	$729	1.6	10,503	2.2

	DIRECT IMPACTS MILLIONS	TOTAL VALUE ADDED MILLIONS	MULTIPLIER	EMPLOYMENT	BENEFIT/COST RATIO
Multipurpose RCC with Conventional Fishway+ Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$8	$4	1.5	54	1.1
Project Costs (Excluding Enhancement)	$530	$307	1.6	3,946	1.7
Flood Damage Reduction	$541	$314	1.6	4,875	1.7
Low Enhancement (project costs + impacts)	$122	$77	1.6	1,225	1.2
High Enhancement (project costs + impacts)	$205	$127	1.6	2,007	1.2
Total with Low Enhancement	$1,201	$703	1.6	10,100	2.1
Total with High Enhancement	$1,284	$753	1.6	10,882	2.2
Multipurpose Rockfill with Experimental Fishway+ Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$8	$4	1.5	54	0.8
Project Costs (Excluding Enhancement)	$530	$307	1.6	3,946	1.2
Flood Damage Reduction	$724	$428	1.6	6,699	1.4
Low Enhancement (project costs + impacts)	$122	$77	1.6	1,225	0.9
High Enhancement (project costs + impacts)	$205	$127	1.6	2,007	1.0
Total with Low Enhancement	$1,384	$816	1.6	11,924	1.8
Total with High Enhancement	$1,467	$866	1.6	12,706	1.8
Flood Retention RCC with CHTR + I-5 Project +Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$9	$5	1.5	64	1.5
Project Costs (Excluding Enhancement)	$568	$329	1.6	4,258	2.2
Flood Damage Reduction	$463	$284	1.6	4,386	2.1
Low Enhancement (project costs + impacts)	$120	$79	1.7	1,255	1.4
High Enhancement (project costs + impacts)	$203	$137	1.7	2,161	1.5
Total with Low Enhancement	$1,160	$696	1.6	9,963	2.5
Total with High Enhancement	$1,243	$754	1.6	10,869	2.6
Multipurpose RCC with CHTR + I-5 Project + Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$9	$5	1.5	64	1.2
Project Costs (Excluding Enhancement)	$568	$329	1.6	4258	1.7
Flood Damage Reduction	$594	$344	1.6	5,360	1.8

	DIRECT IMPACTS MILLIONS	TOTAL VALUE ADDED MILLIONS	MULTIPLIER	EMPLOYMENT	BENEFIT/COST RATIO
Low Enhancement (project costs + impacts)	$122	$77	1.6	1,225	1.2
High Enhancement (project costs + impacts)	$205	$127	1.6	2,007	1.2
Total with Low Enhancement	$1,293	$754	1.6	10,907	2.1
Total with High Enhancement	$1,376	$804	1.6	11,689	2.2
Multipurpose RCC with Conventional Fishway+ I-5 Project+ Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$9	$5	1.5	64	1.1
Project Costs (Excluding Enhancement)	$568	$329	1.6	4,258	1.6
Flood Damage Reduction	$622	$368	1.6	5,738	1.7
Low Enhancement (project costs + impacts)	$122	$77	1.6	1,225	1.1
High Enhancement (project costs + impacts)	$205	$127	1.6	2,007	1.2
Total with Low Enhancement	$1,321	$778	1.6	11,285	2.1
Total with High Enhancement	$1,404	$828	1.6	12,067	2.1
Multipurpose Rockfill with Experimental Fishway + I-5 Project + Airport Levee + Floodproofing					
I-5 Closure, Business Interruption	$9	$5	1.5	64	0.9
Project Costs (Excluding Enhancement)	$568	$329	1.6	4,258	1.3
Flood Damage Reduction	$805	$482	1.6	7,563	1.5
Low Enhancement (project costs + impacts)	$122	$77	1.6	1,225	0.9
High Enhancement (project costs + impacts)	$205	$127	1.6	2,007	0.9
Total with Low Enhancement	$1,504	$892	1.6	13,110	1.8
Total with High Enhancement	$1,587	$942	1.6	13,892	1.8

Appendix M: Climate Change

Introduction

Flood damage reduction impacts for two climate change scenarios are analyzed in this study. Climate change scenarios were also analyzed in the environmental analysis; however, the climate change scenarios evaluated under the environmental studies differ from the climate change scenarios analyzed in the hydraulic modeling or the water retention studies. The climate change analysis conducted in the ASEP considered changes to water temperature, stream flows and sea level. The climate change for the non-environmental analysis only addressed change in hydrology due to climate change. The climate change analysis for the environmental impacts can be found in Appendix K. Table K-29 provide the result for the Federal perspective and Table K-32 provides the result for the State and Basin perspectives.

The first climate change scenario evaluated for the non-environmental impacts was an 18% increase in river flows evenly distributed across the basin.[105] The second was a 90% increase in river flows also evenly distributed across the basin.[106] The hydraulic modeling for each climate change scenario was conducted assuming the storage capacity as depicted in the COA report. The dam design team evaluated the costs and configurations for larger dams to coincide with the climate change scenarios; however, the COA analysis does not evaluate these alternative structure storage capabilities. Therefore, the COA evaluates the climate change scenarios assuming the flood water storage capacity determined from the current hydrology in the basin.

Methodology

The climate change scenarios are modeled such that the increases in river flows are experienced over the full 100-year study period. Because the study period for the climate change scenarios are the same as the primary analysis of alternatives, their results can be compared. Hydrology data corresponding to the scenarios are modeled in HAZUS to develop new flood damage estimates for each Project Alternative. Although climate change hydrology is assumed for the full study period, it is unlikely that the hydrology would be observed in the near term since it would require years of transition to the possible future modeled. In order to evaluate climate change scenarios where basin hydrology is progressively changing over the study period, 100 years of hydrology data would be required for each climate change scenario and each Project Alternative. The result would be at least 4,000 sets of hydrology data and the equivalent number of HAZUS runs for flood damage reduction estimation. In addition, the timing of the changes in hydrology would need to be known. Since the climate change scenarios are associated with substantial uncertainty as to the timing of hydrology changes and modeling these changes would require significant work, the COA made the simplifying assumption that climate change hydrology would be the same across the 100-year study time line.

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[105] Snover, A.K et al. 2013. Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers. State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle.
[106] Salathé, E., et al. 2014: Estimates of 21st Century Flood Risk in the Pacific Northwest Based on Regional Climate Change Simulations. J. Hydrometeor. doi: 10.1175/JHM-D-13-0123.1, in press.

KEY ASSUMPTIONS

Project Alternative impacts are modeled in the expected case as well as two climate change scenarios given the following key assumptions.

- It is assumed that the floodplain usage is the same 100 years from now as it is today. Changes to the floodplain use are not modeled (growth, out migration, etc.). This is a greatly simplifying assumption given the anticipated human population growth and development in the basin.
- Similarly, changes to floodplain usage are not modeled in either the Baseline or in Project Alternative scenarios. For example, changes in types of agricultural production are not modeled as a result of either changes in hydrology or with the construction of a flood water storage facility.
- All costs and impacts are evaluated in current 2014 dollars without inflation. No attempt was made to forecast changes in real dollars over the study period; therefore, real changes in prices are not modeled.

The above assumptions are important to keep in mind when interpreting the economic results of the climate change modeling. Specific considerations are further discussed below.

18% INCREASE IN RIVER FLOWS

This scenario is a conservative to modest level climate change scenario. An 18% increase in river flows translates to approximately a 30% increase in building and content damages in the Baseline compared with a no climate change scenario. This increase in damages increases the expected annual impact of the Project Alternatives. Therefore, except for the enhancement projects, the Project Alternatives with negative net benefits have positive net benefits related to non-environmental impacts under a climate change scenario.

90% INCREASE IN RIVER FLOWS

The 90% climate change scenario dramatically increases the probability of a severe flood event. For example, the current 100-year event would close I-5 for approximately 5 days. Under the 90% climate change scenario, a 10-year flood closes I-5 for approximately 5 days. Project Alternative impacts for the current 100-year condition are realized much more frequently under the 90% climate change scenario: 1 in 10 vs. 1 in 100 years. Therefore, on an expected annual basis, the Project Alternative impacts are much higher.

Additionally, the larger flood events under this climate change scenario affect many more buildings. Therefore, any flood reduction alternative, would impact more buildings under the climate change scenario resulting in greater benefits.

With the much greater risk of major floods, the floodplain would likely change significantly. This analysis does not reflect how the floodplain might change in the 90% Climate Change Scenario. If a 90% increase in river flows were realized, many households and businesses would likely relocate outside of the basin as the risk of substantial loss is increased.

Summary

The effect of the climate change scenarios is an increase in Project Alternative net benefits. The 90% climate change scenario has the greatest impact on net benefits; however, caution should be used when interpreting the results as the floodplain would likely change significantly as the risk of major events increases and anticipated human population growth and development, which would likely undergo major shifts, was not incorporate with the impact calculation. Increases in river flows from climate change will result in Project Alternatives becoming more cost-effective; however, at some point the floodplain usage will change as a result of the increased flood risk, and the modeling results are no longer applicable. Changes in floodplain usage are also foreseeable in the 18% climate change scenario; however, the point at which changes would occur (due to an increase in perceived risk of flooding and associated losses) has not been evaluated.

Results

Tables M-1 through M-6 summarize the economic results of the climate change scenarios modeled for flood reduction only. Note that while environmental enhancement actions are included in the results, the impacts and project costs have not changed from the Expected Case presented in the COA report; the tables assume no impact to enhancement project impacts from climate change.

Table M-1
State Perspective 18% Climate Change Scenario

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)[107]	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Flood Proofing Only	$195	$0	$92	$104	2.1
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement	$873	$28	$289	$612	3.1
I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement	$873	$78	$322	$628	2.9
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,058	$20	$477	$600	2.3
Multipurpose RCC with CHTR Fish Passage	$1,058	$19	$608	$469	1.8
Multipurpose RCC with Conventional Fishway	$1,058	$19	$636	$441	1.7
Multipurpose Rockfill with Experimental Fishway	$1,058	$19	$819	$258	1.3
Storage + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,058	$71	$511	$618	2.2
Multipurpose RCC with CHTR Fish Passage	$1,058	$59	$641	$476	1.7
Multipurpose RCC with Conventional Fishway	$1,058	$59	$669	$448	1.7
Multipurpose Rockfill with Experimental Fishway	$1,058	$59	$852	$265	1.3
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,151	$20	$559	$613	2.1
Multipurpose RCC with CHTR Fish Passage	$1,151	$19	$689	$481	1.7
Multipurpose RCC with Conventional Fishway	$1,151	$19	$717	$453	1.6
Multipurpose Rockfill with Experimental Fishway	$1,151	$19	$900	$270	1.3
Storage + I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,151	$71	$592	$630	2.1
Multipurpose RCC with CHTR Fish Passage	$1,151	$59	$722	$488	1.7
Multipurpose RCC with Conventional Fishway	$1,151	$59	$750	$460	1.6
Multipurpose Rockfill with Experimental Fishway	$1,151	$59	$933	$277	1.3

[107] Please note that the environmental impact is basecase impacts and do not incorporate climate change. For climate change estimates for environmental impacts, please refer to Table K-32 and Appendix K.

Table M-2
State Perspective 90% Climate Change Scenario

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)[108]	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Flood Proofing Only	$362	$0	$92	$271	4.0
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement	$901	$28	$289	$640	3.2
I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement	$901	$78	$322	$657	3.0
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,137	$20	$477	$1,680	4.5
Multipurpose RCC with CHTR Fish Passage	$2,137	$19	$608	$1,549	3.5
Multipurpose RCC with Conventional Fishway	$2,137	$19	$636	$1,520	3.4
Multipurpose Rockfill with Experimental Fishway	$2,137	$19	$819	$1,337	2.6
Storage + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,137	$71	$511	$1,697	4.3
Multipurpose RCC with CHTR Fish Passage	$2,137	$59	$641	$1,556	3.4
Multipurpose RCC with Conventional Fishway	$2,137	$59	$669	$1,527	3.3
Multipurpose Rockfill with Experimental Fishway	$2,137	$59	$852	$1,344	2.6
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,280	$20	$559	$1,741	4.1
Multipurpose RCC with CHTR Fish Passage	$2,280	$19	$689	$1,610	3.3
Multipurpose RCC with Conventional Fishway	$2,280	$19	$717	$1,582	3.2
Multipurpose Rockfill with Experimental Fishway	$2,280	$19	$900	$1,399	2.6
Storage + I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,280	$71	$592	$1,759	4.0
Multipurpose RCC with CHTR Fish Passage	$2,280	$59	$722	$1,617	3.2
Multipurpose RCC with Conventional Fishway	$2,280	$59	$750	$1,589	3.1
Multipurpose Rockfill with Experimental Fishway	$2,280	$59	$933	$1,406	2.5

[108] Please note that the environmental impact is basecase impacts and do not incorporate climate change. For climate change estimates for environmental impacts please refer to Table K-32 and Appendix K.

Table M-3
Basin Perspective 18% Climate Change Scenario

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)[109]	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Flood Proofing Only	$195	$0	$92	$104	2.1
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement	$849	$28	$289	$587	3.0
I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement	$849	$78	$322	$604	2.9
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,031	$20	$477	$574	2.2
Multipurpose RCC with CHTR Fish Passage	$1,031	$19	$608	$442	1.7
Multipurpose RCC with Conventional Fishway	$1,031	$19	$636	$414	1.7
Multipurpose Rockfill with Experimental Fishway	$1,031	$19	$819	$231	1.3
Storage + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,031	$71	$511	$591	2.2
Multipurpose RCC with CHTR Fish Passage	$1,031	$59	$641	$449	1.7
Multipurpose RCC with Conventional Fishway	$1,031	$59	$669	$421	1.6
Multipurpose Rockfill with Experimental Fishway	$1,031	$59	$852	$238	1.3
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,125	$20	$559	$587	2.1
Multipurpose RCC with CHTR Fish Passage	$1,125	$19	$689	$456	1.7
Multipurpose RCC with Conventional Fishway	$1,125	$19	$717	$427	1.6
Multipurpose Rockfill with Experimental Fishway	$1,125	$19	$900	$244	1.3
Storage + I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,125	$71	$592	$605	2.0
Multipurpose RCC with CHTR Fish Passage	$1,125	$59	$722	$463	1.6
Multipurpose RCC with Conventional Fishway	$1,125	$59	$750	$434	1.6
Multipurpose Rockfill with Experimental Fishway	$1,125	$59	$933	$251	1.3

[109] Please note that the environmental impact is basecase impacts and do not incorporate climate change. For climate change estimates for environmental impacts, please refer to Table K-32 and Appendix K.

Table M-4
Basin Perspective 90% Climate Change Scenario

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)[110]	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Flood Proofing Only	$362	$0	$92	$271	4.0
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement	$780	$28	$289	$518	2.8
I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement	$780	$78	$322	$535	2.7
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,018	$20	$477	$1,561	4.3
Multipurpose RCC with CHTR Fish Passage	$2,018	$19	$608	$1,429	3.4
Multipurpose RCC with Conventional Fishway	$2,018	$19	$636	$1,401	3.2
Multipurpose Rockfill with Experimental Fishway	$2,018	$19	$819	$1,218	2.5
Storage + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,018	$71	$511	$1,578	4.1
Multipurpose RCC with CHTR Fish Passage	$2,018	$59	$641	$1,437	3.2
Multipurpose RCC with Conventional Fishway	$2,018	$59	$669	$1,408	3.1
Multipurpose Rockfill with Experimental Fishway	$2,018	$59	$852	$1,225	2.4
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,161	$20	$559	$1,622	3.9
Multipurpose RCC with CHTR Fish Passage	$2,161	$19	$689	$1,491	3.2
Multipurpose RCC with Conventional Fishway	$2,161	$19	$717	$1,463	3.0
Multipurpose Rockfill with Experimental Fishway	$2,161	$19	$900	$1,280	2.4
Storage + I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$2,161	$71	$592	$1,640	3.8
Multipurpose RCC with CHTR Fish Passage	$2,161	$59	$722	$1,498	3.1
Multipurpose RCC with Conventional Fishway	$2,161	$59	$750	$1,470	3.0
Multipurpose Rockfill with Experimental Fishway	$2,161	$59	$933	$1,287	2.4

[110] Please note that the environmental impact is basecase impacts and do not incorporate climate change. For climate change estimates for environmental impacts please refer to table K-32 and Appendix K.

Table M-5
Federal Perspective 18% Climate Change Scenario

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)[111]	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Flood Proofing Only	$110	$0	$92	$18	1.2
Low Enhancement Only	$0	$15	$95	-$80	0.2
High Enhancement Only	$0	$42	$128	-$86	0.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement	$508	$15	$290	$233	1.8
I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement	$508	$42	$324	$226	1.7
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$622	$11	$465	$168	1.4
Multipurpose RCC with CHTR Fish Passage	$622	$10	$581	$52	1.1
Multipurpose RCC with Conventional Fishway	$622	$10	$613	$20	1.0
Multipurpose Rockfill with Experimental Fishway	$622	$10	$794	-$162	0.8
Storage + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$622	$39	$498	$163	1.3
Multipurpose RCC with CHTR Fish Passage	$622	$32	$614	$40	1.1
Multipurpose RCC with Conventional Fishway	$622	$32	$646	$8	1.0
Multipurpose Rockfill with Experimental Fishway	$622	$32	$827	-$173	0.8
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$674	$11	$548	$137	1.2
Multipurpose RCC with CHTR Fish Passage	$674	$10	$663	$20	1.0
Multipurpose RCC with Conventional Fishway	$674	$10	$696	-$12	1.0
Multipurpose Rockfill with Experimental Fishway	$674	$10	$877	-$193	0.8
Storage + I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$674	$39	$581	$131	1.2
Multipurpose RCC with CHTR Fish Passage	$674	$32	$697	$9	1.0
Multipurpose RCC with Conventional Fishway	$674	$32	$729	-$23	1.0
Multipurpose Rockfill with Experimental Fishway	$674	$32	$910	-$204	0.8

[111] Please note that the environmental impact is basecase impacts and do not incorporate climate change. For climate change estimates for environmental impacts, please refer to Table K-29 and Appendix K.

Table M-6
Federal Perspective 90% Climate Change Scenario

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)[112]	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Flood Proofing Only	$204	$0	$92	$112	2.2
Low Enhancement Only	$0	$15	$95	-$80	0.2
High Enhancement Only	$0	$42	$128	-$86	0.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement	$433	$15	$290	$158	1.5
I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement	$433	$42	$324	$152	1.5
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,206	$11	$465	$751	2.6
Multipurpose RCC with CHTR Fish Passage	$1,206	$10	$581	$635	2.1
Multipurpose RCC with Conventional Fishway	$1,206	$10	$613	$603	2.0
Multipurpose Rockfill with Experimental Fishway	$1,206	$10	$794	$422	1.5
Storage + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,206	$39	$498	$746	2.5
Multipurpose RCC with CHTR Fish Passage	$1,206	$32	$614	$624	2.0
Multipurpose RCC with Conventional Fishway	$1,206	$32	$646	$592	1.9
Multipurpose Rockfill with Experimental Fishway	$1,206	$32	$827	$411	1.5
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Flood Proofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,286	$11	$548	$749	2.4
Multipurpose RCC with CHTR Fish Passage	$1,286	$10	$663	$633	2.0
Multipurpose RCC with Conventional Fishway	$1,286	$10	$696	$601	1.9
Multipurpose Rockfill with Experimental Fishway	$1,286	$10	$877	$420	1.5
Storage + I-5 Alternative + Airport Levee + Flood Proofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$1,286	$39	$581	$744	2.3
Multipurpose RCC with CHTR Fish Passage	$1,286	$32	$697	$622	1.9
Multipurpose RCC with Conventional Fishway	$1,286	$32	$729	$590	1.8
Multipurpose Rockfill with Experimental Fishway	$1,286	$32	$910	$408	1.4

[112] Please note that the environmental impact is basecase impacts and do not incorporate climate change. For climate change estimates for environmental impacts, please refer to Table K-29 and Appendix K.

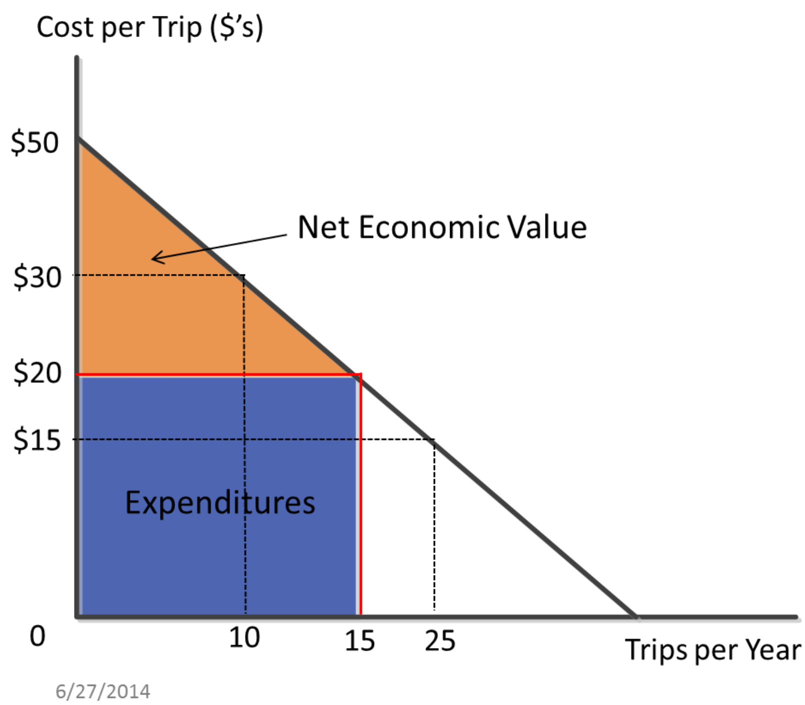
Appendix N: Economic Primer

Economic Benefits and Economic Impacts

An often-confused and misunderstood aspect in the evaluation of impacts of a project are the differences between a benefits-cost analysis (BCA) and economic impact analysis (EIA). A direct relationship exists between BCA (the valuation of changes in societal welfare) and EIA (changes in expenditures) where their combination form a complete measure of economic benefits.

The conceptual basis for the link between EIA and BCA is illustrated in the Figure N-1. The figure portrays an individual's willingness to pay for recreational at various market prices. The traditional downward sloping curve shows the persons marginal willingness to pay for additional trips or put simply that each additional trip is valued less than the previous trip. Thus, the lower the cost of the trip, the more trips the angler will take up to the market price of $20. At a market price of $20 the person will take 15 trips. The expenditures associated with this price times quantity (20 times 15) is $300.

Figure N-1
Willingness to Pay



Beyond the market price, the person will not take more than 15 trips because the cost of the trips exceeds their value for the additional trips. This is shown at 25 trips where the person's value for those 10 additional trips is $15 dollars but the market price is $20.

Economic benefits exist between 0 and 15 trips where the person would have been willing to spend more on the trips they did take. This is shown at 10 trips where the person was willing to pay as much as $30 on those trips. The difference between what was actually paid and what the individuals was willing to pay is the economic value (orange triangle) or $225. BCA focuses on changes in total economic value or the sum of the area above the market price and below the demand curve. For example, a project which would reduce the cost of trips to $15 would result in additional trips taken and an improvement in the person's net economic value to $437.50. The economic benefit is then $437.50 minus $225 or $212.50.

Economic impact analysis focuses on the expenditures resulting from the project. In this example the individual takes 15 trips at $20 for a total expenditure of $300. With the improvement in the cost of trips the individual would take 25 trips at $15 for a total expenditure of $375. Hence, the economic impacts of the project are the increase in expenditures by $75.

Benefit-cost Ratios

The COA analysis compares both Project Alternative net benefits as well as benefit/cost ratios. The benefit/cost ratios include project impacts in the numerator (positive or negative) and project implementation costs in the denominator (the costs needed in order to implement the project). This methodology compares project expenditures with project impacts; however, any negative impacts are included in the denominator, resulting in slightly higher benefit-cost ratios compared with including negative project impacts in the denominator. Due to the Project Alternative Impacts being largely positive, the methodology presented in the COA report does not influence whether or not a project is cost-effective. The net benefits for projects that are cost-effective (benefit/cost ratio greater than 1) are positive and vice versa. However, for completeness, economic benefit/cost ratios are shown in Table N-1 below where negative impacts are included in the denominator. In many cases, the benefit/cost ratios are unchanged. The results would be similar for the basin-wide and Federal Perspectives.

Table N-1
State Perspective Benefit/Cost Ratio Comparison

	NET IMPACTS/ PROJECT COSTS	POSITIVE IMPACTS/ (COST+NEGATIVE IMPACTS)
Floodproofing Only	1.6	1.6
Low Enhancement Only	0.3	0.3
High Enhancement Only	0.6	0.6
I-5 Project Alternative Variations		
I-5 Project + Airport Levee	0.9	0.9
I-5 Project + Airport Levee + Floodproofing	1.2	1.2
I-5 Project + Airport Levee + High Enhancement	0.8	0.8
I-5 Project + Airport Levee + Low Enhancement	0.6	0.6
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	1.0	1.0
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	0.9	0.9
Upper Chehalis Storage Alternative Variations		
Storage + Airport Levee		
Flood Retention RCC with CHTR Fish Passage	1.8	1.8
Multipurpose RCC with CHTR Fish Passage	1.3	1.3
Multipurpose RCC with Conventional Fishway	1.2	1.2
Multipurpose Rockfill with Experimental Fishway	0.9	0.9
Storage + Airport Levee + Floodproofing		

	NET IMPACTS/ PROJECT COSTS	POSITIVE IMPACTS/ (COST+NEGATIVE IMPACTS)
Flood Retention RCC with CHTR Fish Passage	1.7	1.7
Multipurpose RCC with CHTR Fish Passage	1.3	1.3
Multipurpose RCC with Conventional Fishway	1.2	1.2
Multipurpose Rockfill with Experimental Fishway	0.9	0.9
Storage + Airport Levee + High Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.5	1.5
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.1	1.1
Multipurpose Rockfill with Experimental Fishway	0.8	0.8
Storage + Airport Levee + Low Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.5	1.5
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.1	1.1
Multipurpose Rockfill with Experimental Fishway	0.8	0.8
Storage + Airport Levee + Floodproofing + High Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.4	1.4
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.1	1.1
Multipurpose Rockfill with Experimental Fishway	0.8	0.8
Storage + Airport Levee + Floodproofing + Low Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.4	1.4
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.1	1.1
Multipurpose Rockfill with Experimental Fishway	0.8	0.8
Storage + I-5 Project Alternative Variations		
Storage + I-5 Project + Airport Levee		
Flood Retention RCC with CHTR Fish Passage	1.6	1.6
Multipurpose RCC with CHTR Fish Passage	1.2	1.2
Multipurpose RCC with Conventional Fishway	1.1	1.1
Multipurpose Rockfill with Experimental Fishway	0.9	0.9
Storage + I-5 Project + Airport Levee + Floodproofing		
Flood Retention RCC with CHTR Fish Passage	1.5	1.5
Multipurpose RCC with CHTR Fish Passage	1.2	1.2
Multipurpose RCC with Conventional Fishway	1.1	1.1
Multipurpose Rockfill with Experimental Fishway	0.9	0.9
Storage + I-5 Project + Airport Levee + High Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.3	1.3
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.0	1.0
Multipurpose Rockfill with Experimental Fishway	0.8	0.8
Storage + I-5 Project + Airport Levee + Low Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.3	1.3
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.0	1.0
Multipurpose Rockfill with Experimental Fishway	0.8	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.3	1.3

	NET IMPACTS/ PROJECT COSTS	POSITIVE IMPACTS/ (COST+NEGATIVE IMPACTS)
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.0	1.0
Multipurpose Rockfill with Experimental Fishway	0.8	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement		
Flood Retention RCC with CHTR Fish Passage	1.3	1.3
Multipurpose RCC with CHTR Fish Passage	1.1	1.1
Multipurpose RCC with Conventional Fishway	1.0	1.0
Multipurpose Rockfill with Experimental Fishway	0.8	0.8

Appendix O: Detailed Results

This Appendix provides detailed results. The COA analysis included the three Project Alternatives presented in the main report. In addition, several other scenarios have been modeled. The scenarios include the following:

- Floodproofing Only
- Low Enhancement Only
- High Enhancement Only
- I-5 Project plus Airport Levee
- I-5 Project, Airport Levee, and Floodproofing
- I-5 Project, Airport Levee, and Low Enhancement
- I-5 Project, Airport Levee, and High Enhancement
- Alternative 1: I-5 Project, Airport Levee, Floodproofing, and Low Enhancement
- Alternative 1: I-5 Project, Airport Levee, Floodproofing, and High Enhancement
- Upper Chehalis Storage plus Airport Levee
- Upper Chehalis Storage, Airport Levee, and Floodproofing
- Upper Chehalis Storage, Airport Levee, and Low Enhancement
- Upper Chehalis Storage, Airport Levee, and High Enhancement
- Alternative 2: Upper Chehalis Storage, Floodproofing, Airport Levee, and Low Enhancement
- Alternative 2: Upper Chehalis Storage, Floodproofing, Airport Levee, and High Enhancement
- Upper Chehalis Storage, I-5 Project, Airport Levee, and Floodproofing
- Upper Chehalis Storage, I-5 Project, Airport Levee, and Low Enhancement
- Upper Chehalis Storage, I-5 Project, Airport Levee, and High Enhancement
- Alternative 3: Upper Chehalis Storage, I-5 Project, Floodproofing, Airport Levee, and Low Enhancement
- Alternative 3: Upper Chehalis Storage, I-5 Project, Floodproofing, Airport Levee, and High Enhancement

Note that Upper Chehalis Storage may include four different dam configurations including a Flood Control Only option with upstream fish passage and three MPD dams with various fish passage options.

State Perspective

EXPECTED CONDITIONS 1.63% DISCOUNT RATE

Table O-1
State Perspective Flood Reduction Impacts

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE, MILLIONS ($2014)							
	STORAGE + AIRPORT LEVEE	I-5 PROJECT + AIRPORT LEVEE	STORAGE + I-5 PROJECT + AIRPORT LEVEE	FLOODPROOFING ONLY	STORAGE + FLOODPROOFING + AIRPORT LEVEE	I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE	STORAGE + I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE
Flood Reduction Impacts							
Structure	$142.0	$10.6	$150.1	$64.1	$150.3	$49.3	$158.3
Content	$222.7	$12.7	$231.5	$64.8	$247.9	$89.0	$256.4
Inventory	$21.1	$7.1	$26.6	$4.6	$24.9	$14.1	$29.3
Public Assistance	$52.9	$17.6	$63.9	$0.0	$52.9	$17.6	$63.9
Temporary Relocation Assistance	$7.9	$2.6	$9.5	$0.0	$7.9	$2.6	$9.5
Cleanup Costs: Debris	$21.4	$5.3	$12.8	$7.1	$18.1	$12.2	$26.9
Cleanup Costs: Structures	$8.8	$4.5	$12.2	$7.1	$16.7	$10.8	$14.7
Cleanup Costs: Agriculture Fields	$16.1	$0.0	$16.2	$0.0	$16.1	$0.0	$16.2
Cleanup Costs: Agriculture Re-seeding	$5.8	$0.0	$5.8	$0.0	$5.8	$0.0	$5.8
I-5 Transportation Delay	$16.2	$20.7	$21.0	$0.0	$16.2	$20.7	$21.0
Agriculture: Crop Damage	$49.7	-$0.1	$60.0	$0.0	$49.7	-$0.1	$60.0
Vehicle Damage	$44.5	$19.3	$48.1	$0.0	$44.5	$19.3	$48.1
Subtotal	**$609.0**	**$100.3**	**$657.5**	**$147.6**	**$651.0**	**$235.6**	**$710.0**

Table O-2
State Perspective Flood Reduction Impacts

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE, MILLIONS ($2014)							
	STORAGE + AIRPORT LEVEE	I-5 PROJECT + AIRPORT LEVEE	STORAGE + I-5 PROJECT + AIRPORT LEVEE	FLOODPROOFING ONLY	STORAGE + FLOODPROOFING + AIRPORT LEVEE	I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE	STORAGE + I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE
Flood Reduction Impacts							
Structure	$279.9	$51.4	$316.1	$357.0	$615.3	$448.6	$586.4
Content	$493.1	$121.7	$550.6	$1,130.1	$1,497.5	$1,265.6	$1,454.4
Inventory	$21.1	$7.1	$26.6	$4.6	$24.9	$14.1	$29.3
Public Assistance	$52.9	$17.6	$63.9	$0.0	$52.9	$17.6	$63.9
Temporary Relocation Assistance	$7.9	$2.6	$9.5	$0.0	$7.9	$2.6	$9.5
Cleanup Costs: Debris	$21.4	$5.3	$12.8	$7.1	$18.1	$12.2	$26.9
Cleanup Costs: Structures	$8.8	$4.5	$12.2	$7.1	$16.7	$10.8	$14.7
Cleanup Costs: Agriculture Fields	$16.1	$0.0	$16.2	$0.0	$16.1	$0.0	$16.2
Cleanup Costs: Agriculture Re-seeding	$5.8	$0.0	$5.8	$0.0	$5.8	$0.0	$5.8
I-5 Transportation Delay	$16.2	$20.7	$21.0	$0.0	$16.2	$20.7	$21.0
Agriculture: Crop Damage	$49.7	-$0.1	$60.0	$0.0	$49.7	-$0.1	$60.0
Vehicle Damage	$44.5	$19.3	$48.1	$0.0	$44.5	$19.3	$48.1
Subtotal	**$1,017.3**	**$250.2**	**$1,142.7**	**$1,505.9**	**$2,365.5**	**$1,811.3**	**$2,336.1**

Table O-3
State Perspective Results with Depreciated Values

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
PROJECT ALTERNATIVE	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$100	$0	$107	-$7	0.9
I-5 Project + Airport Levee + Floodproofing	$236	$0	$194	$41	1.2
I-5 Project + Airport Levee + High Enhancement	$100	$78	$235	-$57	0.8
I-5 Project + Airport Levee + Low Enhancement	$100	$28	$202	-$74	0.6
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$236	$78	$322	-$9	1.0
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$236	$28	$289	-$26	0.9
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					
Flood Retention RCC	$609	-$3	$333	$273	1.8
Multipurpose RCC with CHTR Fish Passage	$609	-$1	$463	$145	1.3
Multipurpose RCC with Conventional Fishway	$609	-$1	$492	$117	1.2
Multipurpose Rockfill with Experimental Fishway	$609	-$1	$675	-$66	0.9
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$651	-$3	$382	$266	1.7
Multipurpose RCC with CHTR Fish Passage	$651	-$1	$512	$138	1.3
Multipurpose RCC with Conventional Fishway	$651	-$1	$541	$110	1.2
Multipurpose Rockfill with Experimental Fishway	$651	-$1	$724	-$73	0.9
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$609	$71	$462	$218	1.5
Multipurpose RCC with CHTR Fish Passage	$609	$59	$592	$76	1.1
Multipurpose RCC with Conventional Fishway	$609	$59	$620	$48	1.1
Multipurpose Rockfill with Experimental Fishway	$609	$59	$803	-$135	0.8
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$609	$20	$428	$201	1.5
Multipurpose RCC with CHTR Fish Passage	$609	$19	$558	$70	1.1
Multipurpose RCC with Conventional Fishway	$609	$19	$586	$42	1.1

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
PROJECT ALTERNATIVE	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Multipurpose Rockfill with Experimental Fishway	$609	$19	$769	-$141	0.8
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$651	$71	$511	$211	1.4
Multipurpose RCC with CHTR Fish Passage	$651	$59	$641	$69	1.1
Multipurpose RCC with Conventional Fishway	$651	$59	$669	$41	1.1
Multipurpose Rockfill with Experimental Fishway	$651	$59	$852	-$142	0.8
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$651	$20	$477	$194	1.4
Multipurpose RCC with CHTR Fish Passage	$651	$19	$608	$62	1.1
Multipurpose RCC with Conventional Fishway	$651	$19	$636	$34	1.1
Multipurpose Rockfill with Experimental Fishway	$651	$19	$819	-$149	0.8
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$657	-$3	$417	$238	1.6
Multipurpose RCC with CHTR Fish Passage	$657	-$1	$547	$110	1.2
Multipurpose RCC with Conventional Fishway	$657	-$1	$575	$82	1.1
Multipurpose Rockfill with Experimental Fishway	$657	-$1	$758	-$101	0.9
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$710	-$3	$463	$244	1.5
Multipurpose RCC with CHTR Fish Passage	$710	-$1	$594	$116	1.2
Multipurpose RCC with Conventional Fishway	$710	-$1	$622	$87	1.1
Multipurpose Rockfill with Experimental Fishway	$710	-$1	$805	-$96	0.9
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$657	$71	$545	$183	1.3
Multipurpose RCC with CHTR Fish Passage	$657	$59	$675	$42	1.1
Multipurpose RCC with Conventional Fishway	$657	$59	$704	$13	1.0
Multipurpose Rockfill with Experimental Fishway	$657	$59	$887	-$170	0.8
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$657	$20	$512	$166	1.3
Multipurpose RCC with CHTR Fish Passage	$657	$19	$642	$34	1.1
Multipurpose RCC with Conventional Fishway	$657	$19	$670	$6	1.0
Multipurpose Rockfill with Experimental Fishway	$657	$19	$853	-$177	0.8

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
PROJECT ALTERNATIVE	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$710	$71	$592	$189	1.3
Multipurpose RCC with CHTR Fish Passage	$710	$59	$722	$47	1.1
Multipurpose RCC with Conventional Fishway	$710	$59	$750	$19	1.0
Multipurpose Rockfill with Experimental Fishway	$710	$59	$933	-$164	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$710	$20	$559	$171	1.3
Multipurpose RCC with CHTR Fish Passage	$710	$19	$689	$40	1.1
Multipurpose RCC with Conventional Fishway	$710	$19	$717	$12	1.0
Multipurpose Rockfill with Experimental Fishway	$710	$19	$900	-$171	0.8

Table O-4
State Perspective Results with Replacement Values

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$1,506	$0	$92	$1,414	16.5
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$250	$0	$107	$143	2.3
I-5 Project + Airport Levee + Floodproofing	$1,811	$0	$194	$1,617	9.3
I-5 Project + Airport Levee + High Enhancement	$250	$78	$235	$93	1.4
I-5 Project + Airport Levee + Low Enhancement	$250	$28	$202	$76	1.4
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$1,811	$78	$322	$1,566	5.9
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$1,811	$28	$289	$1,550	6.4
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Flood Retention RCC	$1,017	-$3	$333	$681	3.0
Multipurpose RCC with CHTR Fish Passage	$1,017	-$1	$463	$553	2.2
Multipurpose RCC with Conventional Fishway	$1,017	-$1	$492	$525	2.1
Multipurpose Rockfill with Experimental Fishway	$1,017	-$1	$675	$342	1.5
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$2,366	-$3	$382	$1,981	6.2
Multipurpose RCC with CHTR Fish Passage	$2,366	-$1	$512	$1,852	4.6
Multipurpose RCC with Conventional Fishway	$2,366	-$1	$541	$1,824	4.4
Multipurpose Rockfill with Experimental Fishway	$2,366	-$1	$724	$1,641	3.3
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$1,017	$71	$462	$627	2.4
Multipurpose RCC with CHTR Fish Passage	$1,017	$59	$592	$485	1.8
Multipurpose RCC with Conventional Fishway	$1,017	$59	$620	$456	1.7
Multipurpose Rockfill with Experimental Fishway	$1,017	$59	$803	$273	1.3
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,017	$20	$428	$609	2.4
Multipurpose RCC with CHTR Fish Passage	$1,017	$19	$558	$478	1.9
Multipurpose RCC with Conventional Fishway	$1,017	$19	$586	$450	1.8
Multipurpose Rockfill with Experimental Fishway	$1,017	$19	$769	$267	1.3
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$2,366	$71	$511	$1,926	4.8
Multipurpose RCC with CHTR Fish Passage	$2,366	$59	$641	$1,784	3.8
Multipurpose RCC with Conventional Fishway	$2,366	$59	$669	$1,756	3.6
Multipurpose Rockfill with Experimental Fishway	$2,366	$59	$852	$1,573	2.8
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$2,366	$20	$477	$1,908	5.0
Multipurpose RCC with CHTR Fish Passage	$2,366	$19	$608	$1,777	3.9
Multipurpose RCC with Conventional Fishway	$2,366	$19	$636	$1,749	3.8
Multipurpose Rockfill with Experimental Fishway	$2,366	$19	$819	$1,566	2.9
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$1,143	-$3	$417	$723	2.7
Multipurpose RCC with CHTR Fish Passage	$1,143	-$1	$547	$595	2.1

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Multipurpose RCC with Conventional Fishway	$1,143	-$1	$575	$567	2.0
Multipurpose Rockfill with Experimental Fishway	$1,143	-$1	$758	$384	1.5
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$2,336	-$3	$463	$1,870	5.0
Multipurpose RCC with CHTR Fish Passage	$2,336	-$1	$594	$1,742	3.9
Multipurpose RCC with Conventional Fishway	$2,336	-$1	$622	$1,714	3.8
Multipurpose Rockfill with Experimental Fishway	$2,336	-$1	$805	$1,531	2.9
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$1,143	$71	$545	$669	2.2
Multipurpose RCC with CHTR Fish Passage	$1,143	$59	$675	$527	1.8
Multipurpose RCC with Conventional Fishway	$1,143	$59	$704	$498	1.7
Multipurpose Rockfill with Experimental Fishway	$1,143	$59	$887	$315	1.4
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,143	$20	$512	$651	2.3
Multipurpose RCC with CHTR Fish Passage	$1,143	$19	$642	$520	1.8
Multipurpose RCC with Conventional Fishway	$1,143	$19	$670	$491	1.7
Multipurpose Rockfill with Experimental Fishway	$1,143	$19	$853	$308	1.4
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$2,336	$71	$592	$1,815	4.1
Multipurpose RCC with CHTR Fish Passage	$2,336	$59	$722	$1,673	3.3
Multipurpose RCC with Conventional Fishway	$2,336	$59	$750	$1,645	3.2
Multipurpose Rockfill with Experimental Fishway	$2,336	$59	$933	$1,462	2.6
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$2,336	$20	$559	$1,798	4.2
Multipurpose RCC with CHTR Fish Passage	$2,336	$19	$689	$1,666	3.4
Multipurpose RCC with Conventional Fishway	$2,336	$19	$717	$1,638	3.3
Multipurpose Rockfill with Experimental Fishway	$2,336	$19	$900	$1,455	2.6

EXPECTED CONDITIONS 7% DISCOUNT RATE

Table O-5
State Perspective Results 7% Discount Rate

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 7% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$43	$0	$92	-$49	0.5
Low Enhancement Only	$0	$7	$94	-$87	0.1
High Enhancement Only	$0	$20	$127	-$107	0.2
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$29	$0	$112	-$83	0.3
I-5 Project + Airport Levee + Floodproofing	$48	$0	$199	-$151	0.2
I-5 Project + Airport Levee + High Enhancement	$29	$20	$239	-$190	0.2
I-5 Project + Airport Levee + Low Enhancement	$29	$7	$206	-$170	0.2
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$48	$20	$326	-$258	0.2
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$48	$7	$293	-$238	0.2
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					
Flood Retention RCC	$177	-$1	$321	-$145	0.5
Multipurpose RCC with CHTR Fish Passage	$177	$0	$430	-$253	0.4
Multipurpose RCC with Conventional Fishway	$177	$0	$465	-$288	0.4
Multipurpose Rockfill with Experimental Fishway	$177	$0	$649	-$472	0.3
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$189	-$1	$370	-$181	0.5
Multipurpose RCC with CHTR Fish Passage	$189	$0	$479	-$290	0.4
Multipurpose RCC with Conventional Fishway	$189	$0	$514	-$325	0.4
Multipurpose Rockfill with Experimental Fishway	$189	$0	$698	-$509	0.3
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$177	$18	$448	-$253	0.4
Multipurpose RCC with CHTR Fish Passage	$177	$15	$557	-$365	0.3
Multipurpose RCC with Conventional Fishway	$177	$15	$592	-$400	0.3
Multipurpose Rockfill with Experimental Fishway	$177	$15	$776	-$584	0.2
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$177	$5	$415	-$233	0.4
Multipurpose RCC with CHTR Fish Passage	$177	$5	$524	-$343	0.3

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 7% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Multipurpose RCC with Conventional Fishway	$177	$5	$560	-$378	0.3
Multipurpose Rockfill with Experimental Fishway	$177	$5	$744	-$562	0.2
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$189	$18	$497	-$289	0.4
Multipurpose RCC with CHTR Fish Passage	$189	$15	$606	-$401	0.3
Multipurpose RCC with Conventional Fishway	$189	$15	$641	-$437	0.3
Multipurpose Rockfill with Experimental Fishway	$189	$15	$825	-$621	0.2
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$189	$5	$464	-$270	0.4
Multipurpose RCC with CHTR Fish Passage	$189	$5	$573	-$379	0.3
Multipurpose RCC with Conventional Fishway	$189	$5	$608	-$414	0.3
Multipurpose Rockfill with Experimental Fishway	$189	$5	$792	-$598	0.2
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$191	-$1	$408	-$218	0.5
Multipurpose RCC with CHTR Fish Passage	$191	$0	$517	-$327	0.4
Multipurpose RCC with Conventional Fishway	$191	$0	$553	-$362	0.3
Multipurpose Rockfill with Experimental Fishway	$191	$0	$737	-$546	0.3
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$206	-$1	$455	-$250	0.5
Multipurpose RCC with CHTR Fish Passage	$206	$0	$564	-$358	0.4
Multipurpose RCC with Conventional Fishway	$206	$0	$599	-$393	0.3
Multipurpose Rockfill with Experimental Fishway	$206	$0	$783	-$577	0.3
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$191	$18	$535	-$326	0.4
Multipurpose RCC with CHTR Fish Passage	$191	$15	$644	-$438	0.3
Multipurpose RCC with Conventional Fishway	$191	$15	$680	-$473	0.3
Multipurpose Rockfill with Experimental Fishway	$191	$15	$864	-$657	0.2
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$191	$5	$502	-$306	0.4
Multipurpose RCC with CHTR Fish Passage	$191	$5	$611	-$416	0.3
Multipurpose RCC with Conventional Fishway	$191	$5	$647	-$451	0.3
Multipurpose Rockfill with Experimental Fishway	$191	$5	$831	-$635	0.2

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 7% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$206	$18	$582	-$358	0.4
Multipurpose RCC with CHTR Fish Passage	$206	$15	$691	-$470	0.3
Multipurpose RCC with Conventional Fishway	$206	$15	$726	-$505	0.3
Multipurpose Rockfill with Experimental Fishway	$206	$15	$910	-$689	0.2
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$206	$5	$549	-$338	0.4
Multipurpose RCC with CHTR Fish Passage	$206	$5	$658	-$447	0.3
Multipurpose RCC with Conventional Fishway	$206	$5	$693	-$482	0.3
Multipurpose Rockfill with Experimental Fishway	$206	$5	$877	-$666	0.2

EXPECTED CONDITIONS 0% DISCOUNT RATE

Table O-6
State Perspective Results 0% Discount Rate

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 0% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$300	$0	$92	$209	3.3
Low Enhancement Only	$0	$59	$95	-$36	0.6
High Enhancement Only	$0	$165	$129	$36	1.3
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$204	$0	$106	$98	1.9
I-5 Project + Airport Levee + Floodproofing	$600	$0	$193	$407	3.1
I-5 Project + Airport Levee + High Enhancement	$204	$165	$235	$134	1.6
I-5 Project + Airport Levee + Low Enhancement	$204	$59	$201	$62	1.3
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$600	$165	$322	$443	2.4
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$600	$59	$289	$371	2.3
Upper Chehalis Storage Alternative Variations					

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 0% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Storage + Airport Levee					
Flood Retention RCC	$1,238	-$5	$369	$864	3.3
Multipurpose RCC with CHTR Fish Passage	$1,238	-$1	$536	$701	2.3
Multipurpose RCC with Conventional Fishway	$1,238	-$1	$556	$681	2.2
Multipurpose Rockfill with Experimental Fishway	$1,238	-$1	$748	$489	1.7
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$1,324	-$5	$418	$900	3.2
Multipurpose RCC with CHTR Fish Passage	$1,324	-$1	$585	$738	2.3
Multipurpose RCC with Conventional Fishway	$1,324	-$1	$605	$718	2.2
Multipurpose Rockfill with Experimental Fishway	$1,324	-$1	$797	$525	1.7
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$1,238	$151	$498	$891	2.8
Multipurpose RCC with CHTR Fish Passage	$1,238	$126	$665	$700	2.1
Multipurpose RCC with Conventional Fishway	$1,238	$126	$685	$679	2.0
Multipurpose Rockfill with Experimental Fishway	$1,238	$126	$877	$487	1.6
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,238	$43	$464	$817	2.8
Multipurpose RCC with CHTR Fish Passage	$1,238	$40	$631	$648	2.0
Multipurpose RCC with Conventional Fishway	$1,238	$40	$651	$628	2.0
Multipurpose Rockfill with Experimental Fishway	$1,238	$40	$843	$436	1.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$1,324	$151	$547	$928	2.7
Multipurpose RCC with CHTR Fish Passage	$1,324	$126	$714	$736	2.0
Multipurpose RCC with Conventional Fishway	$1,324	$126	$734	$716	2.0
Multipurpose Rockfill with Experimental Fishway	$1,324	$126	$926	$524	1.6
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$1,324	$43	$514	$853	2.7
Multipurpose RCC with CHTR Fish Passage	$1,324	$40	$680	$684	2.0
Multipurpose RCC with Conventional Fishway	$1,324	$40	$701	$664	1.9
Multipurpose Rockfill with Experimental Fishway	$1,324	$40	$893	$472	1.5
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$1,337	-$5	$452	$880	2.9

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 0% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Multipurpose RCC with CHTR Fish Passage	$1,337	-$1	$618	$718	2.2
Multipurpose RCC with Conventional Fishway	$1,337	-$1	$639	$697	2.1
Multipurpose Rockfill with Experimental Fishway	$1,337	-$1	$831	$505	1.6
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$1,444	-$5	$498	$940	2.9
Multipurpose RCC with CHTR Fish Passage	$1,444	-$1	$665	$778	2.2
Multipurpose RCC with Conventional Fishway	$1,444	-$1	$685	$757	2.1
Multipurpose Rockfill with Experimental Fishway	$1,444	-$1	$877	$565	1.6
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$1,337	$151	$581	$907	2.6
Multipurpose RCC with CHTR Fish Passage	$1,337	$126	$747	$716	2.0
Multipurpose RCC with Conventional Fishway	$1,337	$126	$767	$696	1.9
Multipurpose Rockfill with Experimental Fishway	$1,337	$126	$960	$504	1.5
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,337	$43	$547	$833	2.5
Multipurpose RCC with CHTR Fish Passage	$1,337	$40	$714	$664	1.9
Multipurpose RCC with Conventional Fishway	$1,337	$40	$734	$644	1.9
Multipurpose Rockfill with Experimental Fishway	$1,337	$40	$926	$451	1.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$1,444	$151	$627	$968	2.5
Multipurpose RCC with CHTR Fish Passage	$1,444	$126	$794	$776	2.0
Multipurpose RCC with Conventional Fishway	$1,444	$126	$814	$756	1.9
Multipurpose Rockfill with Experimental Fishway	$1,444	$126	$1,006	$564	1.6
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$1,444	$43	$594	$893	2.5
Multipurpose RCC with CHTR Fish Passage	$1,444	$40	$761	$724	2.0
Multipurpose RCC with Conventional Fishway	$1,444	$40	$781	$704	1.9
Multipurpose Rockfill with Experimental Fishway	$1,444	$40	$973	$512	1.5

Basin-wide Perspective

EXPECTED CONDITIONS 1.63% DISCOUNT RATE

Table O-7
Basin-wide Perspective Flood Reduction Impacts

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE, MILLIONS ($2014), MILLIONS							
	STORAGE + AIRPORT LEVEE	I-5 PROJECT + AIRPORT LEVEE	STORAGE + I-5 PROJECT + AIRPORT LEVEE	FLOODPROOFING ONLY	STORAGE + FLOODPROOFING + AIRPORT LEVEE	I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE	STORAGE + I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE
Flood Reduction Impacts							
Structure	$142.0	$10.6	$150.1	$64.1	$150.3	$49.3	$158.3
Content	$222.7	$12.7	$231.5	$64.8	$247.9	$89.0	$256.4
Inventory	$21.1	$7.1	$26.6	$4.6	$24.9	$14.1	$29.3
Public Assistance	$52.9	$17.6	$63.9	$0.0	$52.9	$17.6	$63.9
Temporary Relocation Assistance	$7.9	$2.6	$9.5	$0.0	$7.9	$2.6	$9.5
Cleanup Costs: Debris	$21.4	$5.3	$12.8	$7.1	$18.1	$12.2	$26.9
Cleanup Costs: Structures	$8.8	$4.5	$12.2	$7.1	$16.7	$10.8	$14.7
Cleanup Costs: Agriculture Fields	$16.1	$0.0	$16.2	$0.0	$16.1	$0.0	$16.2
Cleanup Costs: Agriculture Re-seeding	$5.8	$0.0	$5.8	$0.0	$5.8	$0.0	$5.8
I-5 Transportation Delay	$3.0	$3.9	$3.9	$0.0	$3.0	$3.9	$3.9
Agriculture: Crop Damage	$49.7	-$0.1	$60.0	$0.0	$49.7	-$0.1	$60.0
Vehicle Damage	$44.5	$19.3	$48.1	$0.0	$44.5	$19.3	$48.1
Business Interruption	$5.1	$0.9	$5.2	$0.0	$5.1	$0.9	$5.2
Subtotal	**$600.9**	**$84.3**	**$645.6**	**$147.6**	**$642.9**	**$219.6**	**$698.1**

Table O-8
Basin-wide Perspective Flood Reduction Impacts

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE, MILLIONS ($2014), MILLIONS							
	STORAGE + AIRPORT LEVEE	I-5 PROJECT + AIRPORT LEVEE	STORAGE + I-5 PROJECT + AIRPORT LEVEE	FLOODPROOFING ONLY	STORAGE + FLOODPROOFING + AIRPORT LEVEE	I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE	STORAGE + I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE
Flood Reduction Impacts							
Structure	$279.9	$51.4	$316.1	$357.0	$615.3	$448.6	$586.4
Content	$493.1	$121.7	$550.6	$1,130.1	$1,497.5	$1,265.6	$1,454.4
Inventory	$21.1	$7.1	$26.6	$4.6	$24.9	$14.1	$29.3
Public Assistance	$52.9	$17.6	$63.9	$0.0	$52.9	$17.6	$63.9
Temporary Relocation Assistance	$7.9	$2.6	$9.5	$0.0	$7.9	$2.6	$9.5
Cleanup Costs: Debris	$21.4	$5.3	$12.8	$7.1	$18.1	$12.2	$26.9
Cleanup Costs: Structures	$8.8	$4.5	$12.2	$7.8	$17.8	$11.5	$14.7
Cleanup Costs: Agriculture Fields	$16.1	$0.0	$16.2	$0.0	$16.1	$0.0	$16.2
Cleanup Costs: Agriculture Re-seeding	$5.8	$0.0	$5.8	$0.0	$5.8	$0.0	$5.8
I-5 Transportation Delay	$3.0	$3.9	$3.9	$0.0	$3.0	$3.9	$3.9
Agriculture: Crop Damage	$49.7	-$0.1	$60.0	$0.0	$49.7	-$0.1	$60.0
Vehicle Damage	$44.5	$19.3	$48.1	$0.0	$44.5	$19.3	$48.1
Business Interruption	$5.1	$0.9	$5.2	$0.0	$5.1	$0.9	$5.2
Subtotal	**$1,009.2**	**$234.2**	**$1,130.8**	**$1,506.6**	**$2,358.5**	**$1,796.0**	**$2,324.3**

Table O-9
Basin-wide Perspective Results with Depreciated Values

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$84	$0	$107	-$23	0.8
I-5 Project + Airport Levee + Floodproofing	$220	$0	$194	$25	1.1
I-5 Project + Airport Levee + High Enhancement	$84	$78	$235	-$73	0.7
I-5 Project + Airport Levee + Low Enhancement	$84	$28	$202	-$90	0.6
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$220	$78	$322	-$25	0.9
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$220	$28	$289	-$42	0.9
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					
Flood Retention RCC	$596	-$3	$333	$260	1.8
Multipurpose RCC with CHTR Fish Passage	$596	-$1	$463	$132	1.3
Multipurpose RCC with Conventional Fishway	$596	-$1	$492	$103	1.2
Multipurpose Rockfill with Experimental Fishway	$596	-$1	$675	-$80	0.9
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$643	-$3	$382	$258	1.7
Multipurpose RCC with CHTR Fish Passage	$643	-$1	$512	$130	1.3
Multipurpose RCC with Conventional Fishway	$643	-$1	$541	$102	1.2
Multipurpose Rockfill with Experimental Fishway	$643	-$1	$724	-$81	0.9
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$596	$71	$462	$205	1.4
Multipurpose RCC with CHTR Fish Passage	$596	$59	$592	$63	1.1
Multipurpose RCC with Conventional Fishway	$596	$59	$620	$35	1.1
Multipurpose Rockfill with Experimental Fishway	$596	$59	$803	-$148	0.8
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$596	$20	$428	$188	1.4
Multipurpose RCC with CHTR Fish Passage	$596	$19	$558	$57	1.1
Multipurpose RCC with Conventional Fishway	$596	$19	$586	$28	1.0
Multipurpose Rockfill with Experimental Fishway	$596	$19	$769	-$155	0.8

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$643	$71	$511	$203	1.4
Multipurpose RCC with CHTR Fish Passage	$643	$59	$641	$61	1.1
Multipurpose RCC with Conventional Fishway	$643	$59	$669	$33	1.0
Multipurpose Rockfill with Experimental Fishway	$643	$59	$852	-$150	0.8
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$643	$20	$477	$186	1.4
Multipurpose RCC with CHTR Fish Passage	$643	$19	$608	$54	1.1
Multipurpose RCC with Conventional Fishway	$643	$19	$636	$26	1.0
Multipurpose Rockfill with Experimental Fishway	$643	$19	$819	-$157	0.8
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$646	-$3	$417	$226	1.5
Multipurpose RCC with CHTR Fish Passage	$646	-$1	$547	$98	1.2
Multipurpose RCC with Conventional Fishway	$646	-$1	$575	$70	1.1
Multipurpose Rockfill with Experimental Fishway	$646	-$1	$758	-$113	0.9
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$698	-$3	$463	$232	1.5
Multipurpose RCC with CHTR Fish Passage	$698	-$1	$594	$104	1.2
Multipurpose RCC with Conventional Fishway	$698	-$1	$622	$76	1.1
Multipurpose Rockfill with Experimental Fishway	$698	-$1	$805	-$107	0.9
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$646	$71	$545	$171	1.3
Multipurpose RCC with CHTR Fish Passage	$646	$59	$675	$30	1.0
Multipurpose RCC with Conventional Fishway	$646	$59	$704	$1	1.0
Multipurpose Rockfill with Experimental Fishway	$646	$59	$887	-$182	0.8
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$646	$20	$512	$154	1.3
Multipurpose RCC with CHTR Fish Passage	$646	$19	$642	$23	1.0
Multipurpose RCC with Conventional Fishway	$646	$19	$670	-$6	1.0
Multipurpose Rockfill with Experimental Fishway	$646	$19	$853	-$189	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Flood Retention RCC	$698	$71	$592	$177	1.3
Multipurpose RCC with CHTR Fish Passage	$698	$59	$722	$35	1.0
Multipurpose RCC with Conventional Fishway	$698	$59	$750	$7	1.0
Multipurpose Rockfill with Experimental Fishway	$698	$59	$933	-$176	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$698	$20	$559	$160	1.3
Multipurpose RCC with CHTR Fish Passage	$698	$19	$689	$28	1.0
Multipurpose RCC with Conventional Fishway	$698	$19	$717	$0	1.0
Multipurpose Rockfill with Experimental Fishway	$698	$19	$900	-$183	0.8

Table O-10
Basin-wide Perspective Results with Replacement Values

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$1,506	$0	$92	$1,414	16.5
Low Enhancement Only	$0	$28	$95	-$67	0.3
High Enhancement Only	$0	$78	$128	-$51	0.6
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$234	$0	$107	$127	2.2
I-5 Project + Airport Levee + Floodproofing	$1,795	$0	$194	$1,601	9.2
I-5 Project + Airport Levee + High Enhancement	$234	$78	$235	$77	1.3
I-5 Project + Airport Levee + Low Enhancement	$234	$28	$202	$60	1.3
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$1,795	$78	$322	$1,550	5.8
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$1,795	$28	$289	$1,534	6.3
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					
Flood Retention RCC	$1,004	-$3	$333	$668	3.0
Multipurpose RCC with CHTR Fish Passage	$1,004	-$1	$463	$540	2.2
Multipurpose RCC with Conventional Fishway	$1,004	-$1	$492	$512	2.0
Multipurpose Rockfill with Experimental Fishway	$1,004	-$1	$675	$329	1.5
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$2,357	-$3	$382	$1,973	6.2
Multipurpose RCC with CHTR Fish Passage	$2,357	-$1	$512	$1,844	4.6
Multipurpose RCC with Conventional Fishway	$2,357	-$1	$541	$1,816	4.4
Multipurpose Rockfill with Experimental Fishway	$2,357	-$1	$724	$1,633	3.3
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$1,004	$71	$462	$613	2.3
Multipurpose RCC with CHTR Fish Passage	$1,004	$59	$592	$472	1.8
Multipurpose RCC with Conventional Fishway	$1,004	$59	$620	$443	1.7
Multipurpose Rockfill with Experimental Fishway	$1,004	$59	$803	$260	1.3
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,004	$20	$428	$596	2.4
Multipurpose RCC with CHTR Fish Passage	$1,004	$19	$558	$465	1.8
Multipurpose RCC with Conventional Fishway	$1,004	$19	$586	$437	1.7
Multipurpose Rockfill with Experimental Fishway	$1,004	$19	$769	$254	1.3

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$2,357	$71	$511	$1,918	4.8
Multipurpose RCC with CHTR Fish Passage	$2,357	$59	$641	$1,776	3.8
Multipurpose RCC with Conventional Fishway	$2,357	$59	$669	$1,748	3.6
Multipurpose Rockfill with Experimental Fishway	$2,357	$59	$852	$1,565	2.8
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$2,357	$20	$477	$1,900	5.0
Multipurpose RCC with CHTR Fish Passage	$2,357	$19	$608	$1,769	3.9
Multipurpose RCC with Conventional Fishway	$2,357	$19	$636	$1,741	3.7
Multipurpose Rockfill with Experimental Fishway	$2,357	$19	$819	$1,558	2.9
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$1,131	-$3	$417	$711	2.7
Multipurpose RCC with CHTR Fish Passage	$1,131	-$1	$547	$583	2.1
Multipurpose RCC with Conventional Fishway	$1,131	-$1	$575	$555	2.0
Multipurpose Rockfill with Experimental Fishway	$1,131	-$1	$758	$372	1.5
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$2,324	-$3	$463	$1,858	5.0
Multipurpose RCC with CHTR Fish Passage	$2,324	-$1	$594	$1,730	3.9
Multipurpose RCC with Conventional Fishway	$2,324	-$1	$622	$1,702	3.7
Multipurpose Rockfill with Experimental Fishway	$2,324	-$1	$805	$1,519	2.9
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$1,131	$71	$545	$657	2.2
Multipurpose RCC with CHTR Fish Passage	$1,131	$59	$675	$515	1.8
Multipurpose RCC with Conventional Fishway	$1,131	$59	$704	$487	1.7
Multipurpose Rockfill with Experimental Fishway	$1,131	$59	$887	$303	1.3
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,131	$20	$512	$639	2.2
Multipurpose RCC with CHTR Fish Passage	$1,131	$19	$642	$508	1.8
Multipurpose RCC with Conventional Fishway	$1,131	$19	$670	$479	1.7
Multipurpose Rockfill with Experimental Fishway	$1,131	$19	$853	$296	1.3
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					

EXPECTED, REPLACEMENT VALUES 100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Flood Retention RCC	$2,324	$71	$592	$1,803	4.0
Multipurpose RCC with CHTR Fish Passage	$2,324	$59	$722	$1,662	3.3
Multipurpose RCC with Conventional Fishway	$2,324	$59	$750	$1,633	3.2
Multipurpose Rockfill with Experimental Fishway	$2,324	$59	$933	$1,450	2.6
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$2,324	$20	$559	$1,786	4.2
Multipurpose RCC with CHTR Fish Passage	$2,324	$19	$689	$1,654	3.4
Multipurpose RCC with Conventional Fishway	$2,324	$19	$717	$1,626	3.3
Multipurpose Rockfill with Experimental Fishway	$2,324	$19	$900	$1,443	2.6

EXPECTED CONDITIONS 7% DISCOUNT RATE

Table O-11
Basin-wide Perspective Results 7% Discount Rate

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 7% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$43	$0	$92	-$49	0.5
Low Enhancement Only	$0	$7	$94	-$87	0.1
High Enhancement Only	$0	$20	$127	-$107	0.2
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$24	$0	$112	-$88	0.2
I-5 Project + Airport Levee + Floodproofing	$43	$0	$199	-$156	0.2
I-5 Project + Airport Levee + High Enhancement	$24	$20	$239	-$195	0.2
I-5 Project + Airport Levee + Low Enhancement	$24	$7	$206	-$174	0.2
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$43	$20	$326	-$263	0.2
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$43	$7	$293	-$243	0.2
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					
Flood Retention RCC	$173	-$1	$321	-$148	0.5

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 7% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Multipurpose RCC with CHTR Fish Passage	$173	$0	$430	-$257	0.4
Multipurpose RCC with Conventional Fishway	$173	$0	$465	-$292	0.4
Multipurpose Rockfill with Experimental Fishway	$173	$0	$649	-$476	0.3
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$187	-$1	$370	-$184	0.5
Multipurpose RCC with CHTR Fish Passage	$187	$0	$479	-$292	0.4
Multipurpose RCC with Conventional Fishway	$187	$0	$514	-$328	0.4
Multipurpose Rockfill with Experimental Fishway	$187	$0	$698	-$511	0.3
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$173	$18	$448	-$256	0.4
Multipurpose RCC with CHTR Fish Passage	$173	$15	$557	-$368	0.3
Multipurpose RCC with Conventional Fishway	$173	$15	$592	-$404	0.3
Multipurpose Rockfill with Experimental Fishway	$173	$15	$776	-$588	0.2
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$173	$5	$415	-$237	0.4
Multipurpose RCC with CHTR Fish Passage	$173	$5	$524	-$346	0.3
Multipurpose RCC with Conventional Fishway	$173	$5	$560	-$382	0.3
Multipurpose Rockfill with Experimental Fishway	$173	$5	$744	-$566	0.2
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$187	$18	$497	-$292	0.4
Multipurpose RCC with CHTR Fish Passage	$187	$15	$606	-$404	0.3
Multipurpose RCC with Conventional Fishway	$187	$15	$641	-$439	0.3
Multipurpose Rockfill with Experimental Fishway	$187	$15	$825	-$623	0.2
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$187	$5	$464	-$272	0.4
Multipurpose RCC with CHTR Fish Passage	$187	$5	$573	-$381	0.3
Multipurpose RCC with Conventional Fishway	$187	$5	$608	-$417	0.3
Multipurpose Rockfill with Experimental Fishway	$187	$5	$792	-$600	0.2
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$187	-$1	$408	-$222	0.5
Multipurpose RCC with CHTR Fish Passage	$187	$0	$517	-$330	0.4
Multipurpose RCC with Conventional Fishway	$187	$0	$553	-$365	0.3

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 7% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Multipurpose Rockfill with Experimental Fishway	$187	$0	$737	-$549	0.3
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$203	-$1	$455	-$253	0.4
Multipurpose RCC with CHTR Fish Passage	$203	$0	$564	-$362	0.4
Multipurpose RCC with Conventional Fishway	$203	$0	$599	-$397	0.3
Multipurpose Rockfill with Experimental Fishway	$203	$0	$783	-$581	0.3
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$187	$18	$535	-$330	0.4
Multipurpose RCC with CHTR Fish Passage	$187	$15	$644	-$442	0.3
Multipurpose RCC with Conventional Fishway	$187	$15	$680	-$477	0.3
Multipurpose Rockfill with Experimental Fishway	$187	$15	$864	-$661	0.2
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$187	$5	$502	-$310	0.4
Multipurpose RCC with CHTR Fish Passage	$187	$5	$611	-$419	0.3
Multipurpose RCC with Conventional Fishway	$187	$5	$647	-$454	0.3
Multipurpose Rockfill with Experimental Fishway	$187	$5	$831	-$638	0.2
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$203	$18	$582	-$361	0.4
Multipurpose RCC with CHTR Fish Passage	$203	$15	$691	-$473	0.3
Multipurpose RCC with Conventional Fishway	$203	$15	$726	-$508	0.3
Multipurpose Rockfill with Experimental Fishway	$203	$15	$910	-$692	0.2
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$203	$5	$549	-$341	0.4
Multipurpose RCC with CHTR Fish Passage	$203	$5	$658	-$451	0.3
Multipurpose RCC with Conventional Fishway	$203	$5	$693	-$486	0.3
Multipurpose Rockfill with Experimental Fishway	$203	$5	$877	-$670	0.2

EXPECTED CONDITIONS 0% DISCOUNT RATE

Table O-12
Basin-wide Perspective Results 0% Discount Rate

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 0% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$300	$0	$92	$209	3.3
Low Enhancement Only	$0	$59	$95	-$36	0.6
High Enhancement Only	$0	$165	$129	$36	1.3
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$171	$0	$106	$66	1.6
I-5 Project + Airport Levee + Floodproofing	$568	$0	$193	$375	2.9
I-5 Project + Airport Levee + High Enhancement	$171	$165	$235	$102	1.4
I-5 Project + Airport Levee + Low Enhancement	$171	$59	$201	$29	1.1
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$568	$165	$322	$411	2.3
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$568	$59	$289	$339	2.2
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					
Flood Retention RCC	$1,212	-$5	$369	$837	3.3
Multipurpose RCC with CHTR Fish Passage	$1,212	-$1	$536	$674	2.3
Multipurpose RCC with Conventional Fishway	$1,212	-$1	$556	$654	2.2
Multipurpose Rockfill with Experimental Fishway	$1,212	-$1	$748	$462	1.6
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$1,307	-$5	$418	$884	3.1
Multipurpose RCC with CHTR Fish Passage	$1,307	-$1	$585	$721	2.2
Multipurpose RCC with Conventional Fishway	$1,307	-$1	$605	$701	2.2
Multipurpose Rockfill with Experimental Fishway	$1,307	-$1	$797	$509	1.6
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$1,212	$151	$498	$864	2.7
Multipurpose RCC with CHTR Fish Passage	$1,212	$126	$665	$673	2.0
Multipurpose RCC with Conventional Fishway	$1,212	$126	$685	$653	2.0
Multipurpose Rockfill with Experimental Fishway	$1,212	$126	$877	$461	1.5
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,212	$43	$464	$790	2.7
Multipurpose RCC with CHTR Fish Passage	$1,212	$40	$631	$622	2.0

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 0% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Multipurpose RCC with Conventional Fishway	$1,212	$40	$651	$601	1.9
Multipurpose Rockfill with Experimental Fishway	$1,212	$40	$843	$409	1.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$1,307	$151	$547	$911	2.7
Multipurpose RCC with CHTR Fish Passage	$1,307	$126	$714	$720	2.0
Multipurpose RCC with Conventional Fishway	$1,307	$126	$734	$699	2.0
Multipurpose Rockfill with Experimental Fishway	$1,307	$126	$926	$507	1.5
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$1,307	$43	$514	$836	2.6
Multipurpose RCC with CHTR Fish Passage	$1,307	$40	$680	$667	2.0
Multipurpose RCC with Conventional Fishway	$1,307	$40	$701	$647	1.9
Multipurpose Rockfill with Experimental Fishway	$1,307	$40	$893	$455	1.5
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$1,313	-$5	$452	$856	2.9
Multipurpose RCC with CHTR Fish Passage	$1,313	-$1	$618	$693	2.1
Multipurpose RCC with Conventional Fishway	$1,313	-$1	$639	$673	2.1
Multipurpose Rockfill with Experimental Fishway	$1,313	-$1	$831	$481	1.6
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$1,420	-$5	$498	$916	2.8
Multipurpose RCC with CHTR Fish Passage	$1,420	-$1	$665	$753	2.1
Multipurpose RCC with Conventional Fishway	$1,420	-$1	$685	$733	2.1
Multipurpose Rockfill with Experimental Fishway	$1,420	-$1	$877	$541	1.6
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$1,313	$151	$581	$883	2.5
Multipurpose RCC with CHTR Fish Passage	$1,313	$126	$747	$692	1.9
Multipurpose RCC with Conventional Fishway	$1,313	$126	$767	$672	1.9
Multipurpose Rockfill with Experimental Fishway	$1,313	$126	$960	$479	1.5
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$1,313	$43	$547	$808	2.5
Multipurpose RCC with CHTR Fish Passage	$1,313	$40	$714	$640	1.9
Multipurpose RCC with Conventional Fishway	$1,313	$40	$734	$619	1.8
Multipurpose Rockfill with Experimental Fishway	$1,313	$40	$926	$427	1.5

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 0% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$1,420	$151	$627	$943	2.5
Multipurpose RCC with CHTR Fish Passage	$1,420	$126	$794	$752	1.9
Multipurpose RCC with Conventional Fishway	$1,420	$126	$814	$732	1.9
Multipurpose Rockfill with Experimental Fishway	$1,420	$126	$1,006	$540	1.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$1,420	$43	$594	$868	2.5
Multipurpose RCC with CHTR Fish Passage	$1,420	$40	$761	$700	1.9
Multipurpose RCC with Conventional Fishway	$1,420	$40	$781	$679	1.9
Multipurpose Rockfill with Experimental Fishway	$1,420	$40	$973	$487	1.5

Federal Perspective

EXPECTED CONDITIONS 3.5% DISCOUNT RATE

Table O-13
Federal Perspective Flood Reduction Impacts

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE, MILLIONS ($2014)							
	STORAGE + AIRPORT LEVEE	I-5 PROJECT + AIRPORT LEVEE	STORAGE + I-5 PROJECT + AIRPORT LEVEE	FLOODPROOFING ONLY	STORAGE + FLOODPROOFING + AIRPORT LEVEE	I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE	STORAGE + I-5 PROJECT + FLOODPROOFING + AIRPORT LEVEE
Flood Reduction Impacts							
Structure	$79.9	$5.9	$84.4	$36.0	$84.6	$18.7	$89.0
Content	$125.2	$7.1	$130.2	$36.4	$139.4	$35.9	$144.2
Inventory	$11.8	$4.0	$14.9	$2.6	$14.0	$7.0	$16.5
Public Assistance	$29.8	$9.9	$36.0	$0.0	$29.8	$9.9	$36.0
Temporary Relocation Assistance	$4.4	$1.5	$5.3	$0.0	$4.4	$1.5	$5.3
Cleanup Costs: Debris	$12.0	$3.0	$7.2	$4.0	$10.2	$6.8	$15.2
Cleanup Costs: Structures	$4.9	$2.5	$6.8	$4.0	$9.4	$6.1	$8.3
Cleanup Costs: Agriculture Fields	$9.1	$0.0	$9.1	$0.0	$9.1	$0.0	$9.1
Cleanup Costs: Agriculture Re-seeding	$3.3	$0.0	$3.3	$0.0	$3.3	$0.0	$3.3
I-5 Transportation Delay	$9.1	$11.7	$11.8	$0.0	$9.1	$11.7	$11.8
Agriculture: Crop Damage	$62.9	$0.1	$64.8	$0.0	$62.9	$0.1	$64.8
Vehicle Damage	$25.0	$10.9	$27.0	$0.0	$25.0	$10.9	$27.0
Subtotal	**$377.5**	**$56.6**	**$400.9**	**$83.0**	**$401.1**	**$108.5**	**$430.4**

Table O-14
Federal Perspective Results with Depreciated Values

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Floodproofing Only	$83	$0	$92	-$8	0.9
Low Enhancement Only	$0	$15	$95	-$80	0.2
High Enhancement Only	$0	$42	$128	-$86	0.3
I-5 Project Alternative Variations					
I-5 Project + Airport Levee	$57	$0	$109	-$52	0.5
I-5 Project + Airport Levee + Floodproofing	$109	$0	$196	-$87	0.6
I-5 Project + Airport Levee + High Enhancement	$57	$42	$236	-$138	0.4
I-5 Project + Airport Levee + Low Enhancement	$57	$15	$203	-$132	0.4
I-5 Project + Airport Levee + Floodproofing + High Enhancement	$109	$42	$324	-$173	0.5
I-5 Project + Airport Levee + Floodproofing + Low Enhancement	$109	$15	$290	-$167	0.4
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee					
Flood Retention RCC	$377	-$1	$321	$55	1.2
Multipurpose RCC with CHTR Fish Passage	$377	$0	$437	-$60	0.9
Multipurpose RCC with Conventional Fishway	$377	$0	$469	-$92	0.8
Multipurpose Rockfill with Experimental Fishway	$377	$0	$650	-$273	0.6
Storage + Airport Levee + Floodproofing					
Flood Retention RCC	$401	-$1	$370	$29	1.1
Multipurpose RCC with CHTR Fish Passage	$401	$0	$486	-$85	0.8
Multipurpose RCC with Conventional Fishway	$401	$0	$518	-$118	0.8
Multipurpose Rockfill with Experimental Fishway	$401	$0	$699	-$299	0.6
Storage + Airport Levee + High Enhancement					
Flood Retention RCC	$377	$39	$449	-$33	0.9
Multipurpose RCC with CHTR Fish Passage	$377	$32	$565	-$155	0.7
Multipurpose RCC with Conventional Fishway	$377	$32	$597	-$187	0.7
Multipurpose Rockfill with Experimental Fishway	$377	$32	$778	-$369	0.5
Storage + Airport Levee + Low Enhancement					
Flood Retention RCC	$377	$11	$416	-$28	0.9
Multipurpose RCC with CHTR Fish Passage	$377	$10	$532	-$145	0.7
Multipurpose RCC with Conventional Fishway	$377	$10	$564	-$177	0.7
Multipurpose Rockfill with Experimental Fishway	$377	$10	$746	-$358	0.5

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC	$401	$39	$498	-$59	0.9
Multipurpose RCC with CHTR Fish Passage	$401	$32	$614	-$181	0.7
Multipurpose RCC with Conventional Fishway	$401	$32	$646	-$213	0.7
Multipurpose Rockfill with Experimental Fishway	$401	$32	$827	-$394	0.5
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$401	$11	$465	-$53	0.9
Multipurpose RCC with CHTR Fish Passage	$401	$10	$581	-$169	0.7
Multipurpose RCC with Conventional Fishway	$401	$10	$613	-$202	0.7
Multipurpose Rockfill with Experimental Fishway	$401	$10	$794	-$383	0.5
Upper Chehalis Storage and I-5 Alternative Variations					
Storage + I-5 Project + Airport Levee					
Flood Retention RCC	$401	-$1	$406	-$7	1.0
Multipurpose RCC with CHTR Fish Passage	$401	$0	$522	-$122	0.8
Multipurpose RCC with Conventional Fishway	$401	$0	$554	-$154	0.7
Multipurpose Rockfill with Experimental Fishway	$401	$0	$735	-$335	0.5
Storage + I-5 Project + Airport Levee + Floodproofing					
Flood Retention RCC	$430	-$1	$453	-$24	0.9
Multipurpose RCC with CHTR Fish Passage	$430	$0	$569	-$139	0.8
Multipurpose RCC with Conventional Fishway	$430	$0	$601	-$171	0.7
Multipurpose Rockfill with Experimental Fishway	$430	$0	$782	-$352	0.5
Storage + I-5 Project + Airport Levee + High Enhancement					
Flood Retention RCC	$401	$39	$534	-$95	0.8
Multipurpose RCC with CHTR Fish Passage	$401	$32	$650	-$217	0.7
Multipurpose RCC with Conventional Fishway	$401	$32	$682	-$249	0.6
Multipurpose Rockfill with Experimental Fishway	$401	$32	$863	-$430	0.5
Storage + I-5 Project + Airport Levee + Low Enhancement					
Flood Retention RCC	$401	$11	$501	-$89	0.8
Multipurpose RCC with CHTR Fish Passage	$401	$10	$617	-$206	0.7
Multipurpose RCC with Conventional Fishway	$401	$10	$649	-$238	0.6
Multipurpose Rockfill with Experimental Fishway	$401	$10	$830	-$419	0.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					

EXPECTED, DEPRECIATED VALUES 100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE	ENVIRONMENTAL (USE VALUES)	PROJECT COSTS	NET BENEFIT	BENEFIT/COST
Flood Retention RCC	$430	$39	$581	-$112	0.8
Multipurpose RCC with CHTR Fish Passage	$430	$32	$697	-$234	0.7
Multipurpose RCC with Conventional Fishway	$430	$32	$729	-$266	0.6
Multipurpose Rockfill with Experimental Fishway	$430	$32	$910	-$447	0.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC	$430	$11	$548	-$106	0.8
Multipurpose RCC with CHTR Fish Passage	$430	$10	$663	-$223	0.7
Multipurpose RCC with Conventional Fishway	$430	$10	$696	-$255	0.6
Multipurpose Rockfill with Experimental Fishway	$430	$10	$877	-$436	0.5

State Perspective: Uncertainty Analysis

Table O-15
Summary Results Expected Impact, Low Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$61	-$33	0.5
High Enhancement Only	$0	$78	$82	-$4	1.0
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$236	$28	$245	$19	1.1
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$236	$78	$265	$48	1.2
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$20	$377	$294	1.8
Multipurpose RCC with CHTR Fish Passage	$651	$19	$486	$184	1.4
Multipurpose RCC with Conventional Fishway	$651	$19	$510	$160	1.3
Multipurpose Rockfill with Experimental Fishway	$651	$19	$669	$1	1.0
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$71	$397	$325	1.8
Multipurpose RCC with CHTR Fish Passage	$651	$59	$507	$204	1.4
Multipurpose RCC with Conventional Fishway	$651	$59	$531	$180	1.3
Multipurpose Rockfill with Experimental Fishway	$651	$59	$690	$21	1.0
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$20	$448	$282	1.6
Multipurpose RCC with CHTR Fish Passage	$710	$19	$557	$172	1.3
Multipurpose RCC with Conventional Fishway	$710	$19	$581	$148	1.3
Multipurpose Rockfill with Experimental Fishway	$710	$19	$740	-$11	1.0
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$71	$468	$313	1.7

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Multipurpose RCC with CHTR Fish Passage	$710	$59	$578	$192	1.3
Multipurpose RCC with Conventional Fishway	$710	$59	$601	$168	1.3
Multipurpose Rockfill with Experimental Fishway	$710	$59	$761	$9	1.0

Table O-16
Summary Results Expected Impact, High Cost

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$134	-$106	0.2
High Enhancement Only	$0	$78	$182	-$105	0.4
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$236	$28	$339	-$75	0.8
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$236	$78	$387	-$74	0.8
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$20	$588	$83	1.1
Multipurpose RCC with CHTR Fish Passage	$651	$19	$744	-$74	0.9
Multipurpose RCC with Conventional Fishway	$651	$19	$788	-$118	0.9
Multipurpose Rockfill with Experimental Fishway	$651	$19	$997	-$327	0.7
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$651	$71	$636	$86	1.1
Multipurpose RCC with CHTR Fish Passage	$651	$59	$792	-$82	0.9
Multipurpose RCC with Conventional Fishway	$651	$59	$836	-$126	0.8
Multipurpose Rockfill with Experimental Fishway	$651	$59	$1,045	-$335	0.7
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$20	$679	$51	1.1
Multipurpose RCC with CHTR Fish Passage	$710	$19	$835	-$106	0.9
Multipurpose RCC with Conventional Fishway	$710	$19	$879	-$150	0.8
Multipurpose Rockfill with Experimental Fishway	$710	$19	$1,088	-$359	0.7
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$710	$71	$727	$54	1.1
Multipurpose RCC with CHTR Fish Passage	$710	$59	$883	-$114	0.9
Multipurpose RCC with Conventional Fishway	$710	$59	$927	-$158	0.8
Multipurpose Rockfill with Experimental Fishway	$710	$59	$1,136	-$367	0.7

Table O-17
Summary Results Low Impact, Expected Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$86	$0	$82	$4	1.1
Low Enhancement Only	$0	$17	$95	-$78	0.2
High Enhancement Only	$0	$47	$128	-$81	0.4
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$158	$17	$289	-$114	0.6
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$158	$47	$322	-$117	0.6
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$478	$12	$477	$13	1.0
Multipurpose RCC with CHTR Fish Passage	$478	$11	$608	-$118	0.8
Multipurpose RCC with Conventional Fishway	$478	$11	$636	-$146	0.8
Multipurpose Rockfill with Experimental Fishway	$478	$11	$819	-$329	0.6
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$478	$43	$511	$11	1.0
Multipurpose RCC with CHTR Fish Passage	$478	$36	$641	-$127	0.8
Multipurpose RCC with Conventional Fishway	$478	$36	$669	-$155	0.8
Multipurpose Rockfill with Experimental Fishway	$478	$36	$852	-$338	0.6
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$505	$12	$553	-$36	0.9
Multipurpose RCC with CHTR Fish Passage	$505	$11	$683	-$167	0.8
Multipurpose RCC with Conventional Fishway	$505	$11	$712	-$195	0.7
Multipurpose Rockfill with Experimental Fishway	$505	$11	$895	-$378	0.6
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$505	$43	$587	-$38	0.9
Multipurpose RCC with CHTR Fish Passage	$505	$36	$717	-$176	0.8
Multipurpose RCC with Conventional Fishway	$505	$36	$745	-$204	0.7
Multipurpose Rockfill with Experimental Fishway	$505	$36	$928	-$387	0.6

Table O-18
Summary Results Low Impact, Low Cost

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$86	$0	$82	$4	1.1
Low Enhancement Only	$0	$17	$61	-$44	0.3
High Enhancement Only	$0	$47	$82	-$34	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$158	$17	$245	-$70	0.7
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$158	$47	$265	-$60	0.8
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$478	$12	$377	$113	1.3
Multipurpose RCC with CHTR Fish Passage	$478	$11	$486	$4	1.0
Multipurpose RCC with Conventional Fishway	$478	$11	$510	-$20	1.0
Multipurpose Rockfill with Experimental Fishway	$478	$11	$669	-$180	0.7
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$478	$43	$397	$124	1.3
Multipurpose RCC with CHTR Fish Passage	$478	$36	$507	$8	1.0
Multipurpose RCC with Conventional Fishway	$478	$36	$531	-$16	1.0
Multipurpose Rockfill with Experimental Fishway	$478	$36	$690	-$175	0.7
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$505	$12	$448	$69	1.2
Multipurpose RCC with CHTR Fish Passage	$505	$11	$557	-$40	0.9
Multipurpose RCC with Conventional Fishway	$505	$11	$581	-$64	0.9
Multipurpose Rockfill with Experimental Fishway	$505	$11	$740	-$223	0.7
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$505	$43	$468	$80	1.2
Multipurpose RCC with CHTR Fish Passage	$505	$36	$578	-$36	0.9
Multipurpose RCC with Conventional Fishway	$505	$36	$601	-$60	0.9
Multipurpose Rockfill with Experimental Fishway	$505	$36	$761	-$219	0.7

Table O-19
Summary Results Low Impacts, High Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$86	$0	$82	$4	1.1
Low Enhancement Only	$0	$17	$134	-$117	0.1
High Enhancement Only	$0	$47	$182	-$135	0.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$158	$17	$339	-$164	0.5
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$158	$47	$387	-$182	0.5
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$478	$12	$588	-$98	0.8
Multipurpose RCC with CHTR Fish Passage	$478	$11	$744	-$255	0.7
Multipurpose RCC with Conventional Fishway	$478	$11	$788	-$298	0.6
Multipurpose Rockfill with Experimental Fishway	$478	$11	$997	-$507	0.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$478	$43	$636	-$115	0.8
Multipurpose RCC with CHTR Fish Passage	$478	$36	$792	-$278	0.6
Multipurpose RCC with Conventional Fishway	$478	$36	$836	-$322	0.6
Multipurpose Rockfill with Experimental Fishway	$478	$36	$1,045	-$531	0.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$505	$12	$679	-$162	0.8
Multipurpose RCC with CHTR Fish Passage	$505	$11	$835	-$318	0.6
Multipurpose RCC with Conventional Fishway	$505	$11	$879	-$362	0.6
Multipurpose Rockfill with Experimental Fishway	$505	$11	$1,088	-$571	0.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$505	$43	$727	-$179	0.8
Multipurpose RCC with CHTR Fish Passage	$505	$36	$883	-$342	0.6
Multipurpose RCC with Conventional Fishway	$505	$36	$927	-$386	0.6
Multipurpose Rockfill with Experimental Fishway	$505	$36	$1,136	-$595	0.5

Table O-20
Summary Results High Impacts, Expected Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$234	$0	$108	$126	2.2
Low Enhancement Only	$0	$60	$95	-$35	0.6
High Enhancement Only	$0	$165	$128	$36	1.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$337	$60	$289	$108	1.4
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$337	$165	$322	$179	1.6
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$824	$44	$477	$391	1.8
Multipurpose RCC with CHTR Fish Passage	$824	$41	$608	$257	1.4
Multipurpose RCC with Conventional Fishway	$824	$41	$636	$229	1.4
Multipurpose Rockfill with Experimental Fishway	$824	$41	$819	$46	1.1
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$824	$151	$511	$465	1.9
Multipurpose RCC with CHTR Fish Passage	$824	$127	$641	$310	1.5
Multipurpose RCC with Conventional Fishway	$824	$127	$669	$282	1.4
Multipurpose Rockfill with Experimental Fishway	$824	$127	$852	$99	1.1
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$895	$44	$567	$371	1.7
Multipurpose RCC with CHTR Fish Passage	$895	$41	$697	$238	1.3
Multipurpose RCC with Conventional Fishway	$895	$41	$726	$210	1.3
Multipurpose Rockfill with Experimental Fishway	$895	$41	$909	$27	1.0
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$895	$151	$601	$445	1.7
Multipurpose RCC with CHTR Fish Passage	$895	$127	$731	$291	1.4
Multipurpose RCC with Conventional Fishway	$895	$127	$759	$263	1.3
Multipurpose Rockfill with Experimental Fishway	$895	$127	$942	$80	1.1

Table O-21
Summary Results High Impact, Low Cost

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$234	$0	$108	$126	2.2
Low Enhancement Only	$0	$60	$61	-$1	1.0
High Enhancement Only	$0	$165	$82	$83	2.0
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$337	$60	$245	$152	1.6
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$337	$165	$265	$237	1.9
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$824	$44	$377	$491	2.3
Multipurpose RCC with CHTR Fish Passage	$824	$41	$486	$379	1.8
Multipurpose RCC with Conventional Fishway	$824	$41	$510	$355	1.7
Multipurpose Rockfill with Experimental Fishway	$824	$41	$669	$196	1.3
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$824	$151	$397	$578	2.5
Multipurpose RCC with CHTR Fish Passage	$824	$127	$507	$445	1.9
Multipurpose RCC with Conventional Fishway	$824	$127	$531	$421	1.8
Multipurpose Rockfill with Experimental Fishway	$824	$127	$690	$262	1.4
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$895	$44	$448	$491	2.1
Multipurpose RCC with CHTR Fish Passage	$895	$41	$557	$379	1.7
Multipurpose RCC with Conventional Fishway	$895	$41	$581	$355	1.6
Multipurpose Rockfill with Experimental Fishway	$895	$41	$740	$196	1.3
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$895	$151	$468	$578	2.2
Multipurpose RCC with CHTR Fish Passage	$895	$127	$578	$445	1.8
Multipurpose RCC with Conventional Fishway	$895	$127	$601	$421	1.7
Multipurpose Rockfill with Experimental Fishway	$895	$127	$761	$261	1.3

Table O-22
Summary Results High Impacts, High Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$234	$0	$108	$126	2.2
Low Enhancement Only	$0	$60	$134	-$74	0.4
High Enhancement Only	$0	$165	$182	-$18	0.9
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$337	$60	$339	$58	1.2
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$337	$165	$387	$115	1.3
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$824	$44	$588	$280	1.5
Multipurpose RCC with CHTR Fish Passage	$824	$41	$744	$121	1.2
Multipurpose RCC with Conventional Fishway	$824	$41	$788	$77	1.1
Multipurpose Rockfill with Experimental Fishway	$824	$41	$997	-$132	0.9
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$824	$151	$636	$339	1.5
Multipurpose RCC with CHTR Fish Passage	$824	$127	$792	$159	1.2
Multipurpose RCC with Conventional Fishway	$824	$127	$836	$115	1.1
Multipurpose Rockfill with Experimental Fishway	$824	$127	$1,045	-$94	0.9
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$895	$44	$679	$260	1.4
Multipurpose RCC with CHTR Fish Passage	$895	$41	$835	$101	1.1
Multipurpose RCC with Conventional Fishway	$895	$41	$879	$57	1.1
Multipurpose Rockfill with Experimental Fishway	$895	$41	$1,088	-$152	0.9
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$895	$151	$727	$319	1.4
Multipurpose RCC with CHTR Fish Passage	$895	$127	$883	$139	1.2
Multipurpose RCC with Conventional Fishway	$895	$127	$927	$95	1.1
Multipurpose Rockfill with Experimental Fishway	$895	$127	$1,136	-$114	0.9

Basin-wide Perspective: Uncertainty Analysis

Table O-23
Summary Results Expected Impact, Low Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$61	-$33	0.5
High Enhancement Only	$0	$78	$82	-$4	1.0
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$220	$28	$245	$3	1.0
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$220	$78	$265	$32	1.1
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$643	$20	$377	$286	1.8
Multipurpose RCC with CHTR Fish Passage	$643	$19	$486	$176	1.4
Multipurpose RCC with Conventional Fishway	$643	$19	$510	$152	1.3
Multipurpose Rockfill with Experimental Fishway	$643	$19	$669	-$7	1.0
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$643	$71	$397	$317	1.8
Multipurpose RCC with CHTR Fish Passage	$643	$59	$507	$196	1.4
Multipurpose RCC with Conventional Fishway	$643	$59	$531	$172	1.3
Multipurpose Rockfill with Experimental Fishway	$643	$59	$690	$13	1.0
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$698	$20	$448	$270	1.6
Multipurpose RCC with CHTR Fish Passage	$698	$19	$557	$160	1.3
Multipurpose RCC with Conventional Fishway	$698	$19	$581	$136	1.2
Multipurpose Rockfill with Experimental Fishway	$698	$19	$740	-$23	1.0
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$698	$71	$468	$301	1.6

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS		PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)			
Multipurpose RCC with CHTR Fish Passage	$698	$59	$578	$180	1.3
Multipurpose RCC with Conventional Fishway	$698	$59	$601	$156	1.3
Multipurpose Rockfill with Experimental Fishway	$698	$59	$761	-$3	1.0

Table O-24
Summary Results Expected Impact, High Cost

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$148	$0	$92	$56	1.6
Low Enhancement Only	$0	$28	$134	-$106	0.2
High Enhancement Only	$0	$78	$182	-$105	0.4
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$220	$28	$339	-$91	0.7
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$220	$78	$387	-$90	0.8
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$643	$20	$588	$75	1.1
Multipurpose RCC with CHTR Fish Passage	$643	$19	$744	-$82	0.9
Multipurpose RCC with Conventional Fishway	$643	$19	$788	-$126	0.8
Multipurpose Rockfill with Experimental Fishway	$643	$19	$997	-$335	0.7
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$643	$71	$636	$78	1.1
Multipurpose RCC with CHTR Fish Passage	$643	$59	$792	-$90	0.9
Multipurpose RCC with Conventional Fishway	$643	$59	$836	-$134	0.8
Multipurpose Rockfill with Experimental Fishway	$643	$59	$1,045	-$343	0.7
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$698	$20	$679	$39	1.1
Multipurpose RCC with CHTR Fish Passage	$698	$19	$835	-$118	0.9
Multipurpose RCC with Conventional Fishway	$698	$19	$879	-$162	0.8
Multipurpose Rockfill with Experimental Fishway	$698	$19	$1,088	-$371	0.7
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$698	$71	$727	$42	1.1
Multipurpose RCC with CHTR Fish Passage	$698	$59	$883	-$126	0.9
Multipurpose RCC with Conventional Fishway	$698	$59	$927	-$170	0.8
Multipurpose Rockfill with Experimental Fishway	$698	$59	$1,136	-$379	0.7

Table O-25
Summary Results Low Impact, Expected Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$86	$0	$82	$4	1.1
Low Enhancement Only	$0	$17	$95	-$78	0.2
High Enhancement Only	$0	$47	$128	-$81	0.4
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$148	$17	$289	-$124	0.6
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$148	$47	$322	-$127	0.6
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$475	$12	$477	$9	1.0
Multipurpose RCC with CHTR Fish Passage	$475	$11	$608	-$121	0.8
Multipurpose RCC with Conventional Fishway	$475	$11	$636	-$150	0.8
Multipurpose Rockfill with Experimental Fishway	$475	$11	$819	-$333	0.6
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$475	$43	$511	$7	1.0
Multipurpose RCC with CHTR Fish Passage	$475	$36	$641	-$130	0.8
Multipurpose RCC with Conventional Fishway	$475	$36	$669	-$158	0.8
Multipurpose Rockfill with Experimental Fishway	$475	$36	$852	-$342	0.6
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$499	$12	$553	-$42	0.9
Multipurpose RCC with CHTR Fish Passage	$499	$11	$683	-$173	0.7
Multipurpose RCC with Conventional Fishway	$499	$11	$712	-$201	0.7
Multipurpose Rockfill with Experimental Fishway	$499	$11	$895	-$384	0.6
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$499	$43	$587	-$44	0.9
Multipurpose RCC with CHTR Fish Passage	$499	$36	$717	-$182	0.7
Multipurpose RCC with Conventional Fishway	$499	$36	$745	-$210	0.7
Multipurpose Rockfill with Experimental Fishway	$499	$36	$928	-$393	0.6

Table O-26
Summary Results Low Impact, Low Cost

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$86	$0	$82	$4	1.1
Low Enhancement Only	$0	$17	$61	-$44	0.3
High Enhancement Only	$0	$47	$82	-$34	0.6
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$148	$17	$245	-$80	0.7
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$148	$47	$265	-$70	0.7
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$475	$12	$377	$110	1.3
Multipurpose RCC with CHTR Fish Passage	$475	$11	$486	$0	1.0
Multipurpose RCC with Conventional Fishway	$475	$11	$510	-$24	1.0
Multipurpose Rockfill with Experimental Fishway	$475	$11	$669	-$183	0.7
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$475	$43	$397	$121	1.3
Multipurpose RCC with CHTR Fish Passage	$475	$36	$507	$4	1.0
Multipurpose RCC with Conventional Fishway	$475	$36	$531	-$20	1.0
Multipurpose Rockfill with Experimental Fishway	$475	$36	$690	-$179	0.7
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$499	$12	$448	$63	1.1
Multipurpose RCC with CHTR Fish Passage	$499	$11	$557	-$46	0.9
Multipurpose RCC with Conventional Fishway	$499	$11	$581	-$70	0.9
Multipurpose Rockfill with Experimental Fishway	$499	$11	$740	-$229	0.7
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$499	$43	$468	$74	1.2
Multipurpose RCC with CHTR Fish Passage	$499	$36	$578	-$42	0.9
Multipurpose RCC with Conventional Fishway	$499	$36	$601	-$66	0.9
Multipurpose Rockfill with Experimental Fishway	$499	$36	$761	-$225	0.7

Table O-27
Summary Results Low Impacts, High Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$86	$0	$82	$4	1.1
Low Enhancement Only	$0	$17	$134	-$117	0.1
High Enhancement Only	$0	$47	$182	-$135	0.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$148	$17	$339	-$174	0.5
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$148	$47	$387	-$192	0.5
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$475	$12	$588	-$101	0.8
Multipurpose RCC with CHTR Fish Passage	$475	$11	$744	-$258	0.7
Multipurpose RCC with Conventional Fishway	$475	$11	$788	-$302	0.6
Multipurpose Rockfill with Experimental Fishway	$475	$11	$997	-$511	0.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$475	$43	$636	-$118	0.8
Multipurpose RCC with CHTR Fish Passage	$475	$36	$792	-$282	0.6
Multipurpose RCC with Conventional Fishway	$475	$36	$836	-$326	0.6
Multipurpose Rockfill with Experimental Fishway	$475	$36	$1,045	-$535	0.5
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$499	$12	$679	-$168	0.8
Multipurpose RCC with CHTR Fish Passage	$499	$11	$835	-$324	0.6
Multipurpose RCC with Conventional Fishway	$499	$11	$879	-$368	0.6
Multipurpose Rockfill with Experimental Fishway	$499	$11	$1,088	-$577	0.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$499	$43	$727	-$185	0.7
Multipurpose RCC with CHTR Fish Passage	$499	$36	$883	-$348	0.6
Multipurpose RCC with Conventional Fishway	$499	$36	$927	-$392	0.6
Multipurpose Rockfill with Experimental Fishway	$499	$36	$1,136	-$601	0.5

Table O-28
Summary Results High Impacts, Expected Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$234	$0	$108	$126	2.2
Low Enhancement Only	$0	$60	$95	-$35	0.6
High Enhancement Only	$0	$165	$128	$36	1.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$315	$60	$289	$86	1.3
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$315	$165	$322	$157	1.5
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$811	$44	$477	$378	1.8
Multipurpose RCC with CHTR Fish Passage	$811	$41	$608	$245	1.4
Multipurpose RCC with Conventional Fishway	$811	$41	$636	$216	1.3
Multipurpose Rockfill with Experimental Fishway	$811	$41	$819	$33	1.0
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$811	$151	$511	$452	1.9
Multipurpose RCC with CHTR Fish Passage	$811	$127	$641	$298	1.5
Multipurpose RCC with Conventional Fishway	$811	$127	$669	$269	1.4
Multipurpose Rockfill with Experimental Fishway	$811	$127	$852	$86	1.1
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$877	$44	$567	$354	1.6
Multipurpose RCC with CHTR Fish Passage	$877	$41	$697	$220	1.3
Multipurpose RCC with Conventional Fishway	$877	$41	$726	$192	1.3
Multipurpose Rockfill with Experimental Fishway	$877	$41	$909	$9	1.0
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$877	$151	$601	$428	1.7
Multipurpose RCC with CHTR Fish Passage	$877	$127	$731	$273	1.4
Multipurpose RCC with Conventional Fishway	$877	$127	$759	$245	1.3
Multipurpose Rockfill with Experimental Fishway	$877	$127	$942	$62	1.1

Table O-29

Summary Results High Impact, Low Cost

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$234	$0	$108	$126	2.2
Low Enhancement Only	$0	$60	$61	-$1	1.0
High Enhancement Only	$0	$165	$82	$83	2.0
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$315	$60	$245	$131	1.5
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$315	$165	$265	$215	1.8
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$811	$44	$377	$479	2.3
Multipurpose RCC with CHTR Fish Passage	$811	$41	$486	$366	1.8
Multipurpose RCC with Conventional Fishway	$811	$41	$510	$342	1.7
Multipurpose Rockfill with Experimental Fishway	$811	$41	$669	$183	1.3
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$811	$151	$397	$565	2.4
Multipurpose RCC with CHTR Fish Passage	$811	$127	$507	$432	1.9
Multipurpose RCC with Conventional Fishway	$811	$127	$531	$408	1.8
Multipurpose Rockfill with Experimental Fishway	$811	$127	$690	$249	1.4
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$877	$44	$448	$473	2.1
Multipurpose RCC with CHTR Fish Passage	$877	$41	$557	$361	1.6
Multipurpose RCC with Conventional Fishway	$877	$41	$581	$337	1.6
Multipurpose Rockfill with Experimental Fishway	$877	$41	$740	$178	1.2
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$877	$151	$468	$560	2.2
Multipurpose RCC with CHTR Fish Passage	$877	$127	$578	$427	1.7
Multipurpose RCC with Conventional Fishway	$877	$127	$601	$403	1.7
Multipurpose Rockfill with Experimental Fishway	$877	$127	$761	$244	1.3

Table O-30
Summary Results High Impacts, High Costs

100-YEAR NPV 1.63% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$234	$0	$108	$126	2.2
Low Enhancement Only	$0	$60	$134	-$74	0.4
High Enhancement Only	$0	$165	$182	-$18	0.9
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$315	$60	$339	$36	1.1
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$315	$165	$387	$93	1.2
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$811	$44	$588	$267	1.5
Multipurpose RCC with CHTR Fish Passage	$811	$41	$744	$108	1.1
Multipurpose RCC with Conventional Fishway	$811	$41	$788	$64	1.1
Multipurpose Rockfill with Experimental Fishway	$811	$41	$997	-$145	0.9
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$811	$151	$636	$326	1.5
Multipurpose RCC with CHTR Fish Passage	$811	$127	$792	$146	1.2
Multipurpose RCC with Conventional Fishway	$811	$127	$836	$102	1.1
Multipurpose Rockfill with Experimental Fishway	$811	$127	$1,045	-$107	0.9
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$877	$44	$679	$242	1.4
Multipurpose RCC with CHTR Fish Passage	$877	$41	$835	$83	1.1
Multipurpose RCC with Conventional Fishway	$877	$41	$879	$39	1.0
Multipurpose Rockfill with Experimental Fishway	$877	$41	$1,088	-$170	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$877	$151	$727	$301	1.4
Multipurpose RCC with CHTR Fish Passage	$877	$127	$883	$121	1.1
Multipurpose RCC with Conventional Fishway	$877	$127	$927	$77	1.1
Multipurpose Rockfill with Experimental Fishway	$877	$127	$1,136	-$132	0.9

Federal Perspective: Uncertainty Analysis

Table O-31
Summary Results Expected Impact, Low Costs

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$83	$0	$92	-$8	0.9
Low Enhancement Only	$0	$15	$61	-$46	0.2
High Enhancement Only	$0	$42	$81	-$39	0.5
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$109	$15	$246	-$122	0.5
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$109	$42	$266	-$116	0.6
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$11	$365	$47	1.1
Multipurpose RCC with CHTR Fish Passage	$401	$10	$462	-$50	0.9
Multipurpose RCC with Conventional Fishway	$401	$10	$489	-$78	0.8
Multipurpose Rockfill with Experimental Fishway	$401	$10	$646	-$235	0.6
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$39	$385	$54	1.1
Multipurpose RCC with CHTR Fish Passage	$401	$32	$482	-$49	0.9
Multipurpose RCC with Conventional Fishway	$401	$32	$509	-$76	0.9
Multipurpose Rockfill with Experimental Fishway	$401	$32	$667	-$234	0.6
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$11	$437	$4	1.0
Multipurpose RCC with CHTR Fish Passage	$430	$10	$534	-$93	0.8
Multipurpose RCC with Conventional Fishway	$430	$10	$561	-$121	0.8
Multipurpose Rockfill with Experimental Fishway	$430	$10	$719	-$278	0.6
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$39	$458	$11	1.0

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Multipurpose RCC with CHTR Fish Passage	$430	$32	$554	-$92	0.8
Multipurpose RCC with Conventional Fishway	$430	$32	$582	-$119	0.8
Multipurpose Rockfill with Experimental Fishway	$430	$32	$739	-$276	0.6

Table O-32
Summary Results Expected Impact, High Cost

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$83	$0	$92	-$8	0.9
Low Enhancement Only	$0	$15	$133	-$118	0.1
High Enhancement Only	$0	$42	$181	-$139	0.2
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$109	$15	$340	-$216	0.4
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$109	$42	$389	-$238	0.4
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$11	$575	-$163	0.7
Multipurpose RCC with CHTR Fish Passage	$401	$10	$715	-$304	0.6
Multipurpose RCC with Conventional Fishway	$401	$10	$763	-$352	0.5
Multipurpose Rockfill with Experimental Fishway	$401	$10	$971	-$559	0.4
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$401	$39	$623	-$183	0.7
Multipurpose RCC with CHTR Fish Passage	$401	$32	$763	-$330	0.6
Multipurpose RCC with Conventional Fishway	$401	$32	$811	-$378	0.5
Multipurpose Rockfill with Experimental Fishway	$401	$32	$1,018	-$585	0.4
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$11	$667	-$226	0.7
Multipurpose RCC with CHTR Fish Passage	$430	$10	$808	-$367	0.5
Multipurpose RCC with Conventional Fishway	$430	$10	$856	-$415	0.5
Multipurpose Rockfill with Experimental Fishway	$430	$10	$1,063	-$622	0.4
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$430	$39	$715	-$246	0.7
Multipurpose RCC with CHTR Fish Passage	$430	$32	$856	-$393	0.5
Multipurpose RCC with Conventional Fishway	$430	$32	$904	-$441	0.5
Multipurpose Rockfill with Experimental Fishway	$430	$32	$1,111	-$648	0.4

Table O-33
Summary Results Low Impact, Expected Costs

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$48	$0	$82	-$33	0.6
Low Enhancement Only	$0	$9	$95	-$86	0.1
High Enhancement Only	$0	$26	$128	-$102	0.2
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$72	$9	$290	-$209	0.3
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$72	$26	$324	-$226	0.3
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$304	$6	$465	-$155	0.7
Multipurpose RCC with CHTR Fish Passage	$304	$6	$581	-$271	0.5
Multipurpose RCC with Conventional Fishway	$304	$6	$613	-$303	0.5
Multipurpose Rockfill with Experimental Fishway	$304	$6	$794	-$484	0.4
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$304	$24	$498	-$171	0.7
Multipurpose RCC with CHTR Fish Passage	$304	$20	$614	-$291	0.5
Multipurpose RCC with Conventional Fishway	$304	$20	$646	-$323	0.5
Multipurpose Rockfill with Experimental Fishway	$304	$20	$827	-$504	0.4
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$315	$6	$542	-$221	0.6
Multipurpose RCC with CHTR Fish Passage	$315	$6	$658	-$337	0.5
Multipurpose RCC with Conventional Fishway	$315	$6	$690	-$369	0.5
Multipurpose Rockfill with Experimental Fishway	$315	$6	$872	-$550	0.4
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$315	$24	$576	-$237	0.6
Multipurpose RCC with CHTR Fish Passage	$315	$20	$691	-$357	0.5
Multipurpose RCC with Conventional Fishway	$315	$20	$724	-$389	0.5
Multipurpose Rockfill with Experimental Fishway	$315	$20	$905	-$570	0.4

Table O-34
Summary Results Low Impact, Low Cost

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$48	$0	$82	-$33	0.6
Low Enhancement Only	$0	$9	$61	-$52	0.2
High Enhancement Only	$0	$26	$81	-$55	0.3
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$72	$9	$246	-$165	0.3
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$72	$26	$266	-$169	0.4
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$304	$6	$365	-$55	0.8
Multipurpose RCC with CHTR Fish Passage	$304	$6	$462	-$152	0.7
Multipurpose RCC with Conventional Fishway	$304	$6	$489	-$179	0.6
Multipurpose Rockfill with Experimental Fishway	$304	$6	$646	-$336	0.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$304	$24	$385	-$58	0.8
Multipurpose RCC with CHTR Fish Passage	$304	$20	$482	-$159	0.7
Multipurpose RCC with Conventional Fishway	$304	$20	$509	-$186	0.6
Multipurpose Rockfill with Experimental Fishway	$304	$20	$667	-$343	0.5
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$315	$6	$437	-$116	0.7
Multipurpose RCC with CHTR Fish Passage	$315	$6	$534	-$212	0.6
Multipurpose RCC with Conventional Fishway	$315	$6	$561	-$240	0.6
Multipurpose Rockfill with Experimental Fishway	$315	$6	$719	-$397	0.4
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$315	$24	$458	-$119	0.7
Multipurpose RCC with CHTR Fish Passage	$315	$20	$554	-$219	0.6
Multipurpose RCC with Conventional Fishway	$315	$20	$582	-$247	0.6
Multipurpose Rockfill with Experimental Fishway	$315	$20	$739	-$404	0.5

Table O-35
Summary Results Low Impacts, High Costs

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$48	$0	$82	-$33	0.6
Low Enhancement Only	$0	$9	$133	-$124	0.1
High Enhancement Only	$0	$26	$181	-$155	0.1
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$72	$9	$340	-$259	0.2
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$72	$26	$389	-$291	0.3
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$304	$6	$575	-$264	0.5
Multipurpose RCC with CHTR Fish Passage	$304	$6	$715	-$405	0.4
Multipurpose RCC with Conventional Fishway	$304	$6	$763	-$453	0.4
Multipurpose Rockfill with Experimental Fishway	$304	$6	$971	-$660	0.3
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$304	$24	$623	-$295	0.5
Multipurpose RCC with CHTR Fish Passage	$304	$20	$763	-$440	0.4
Multipurpose RCC with Conventional Fishway	$304	$20	$811	-$488	0.4
Multipurpose Rockfill with Experimental Fishway	$304	$20	$1,018	-$695	0.3
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$315	$6	$667	-$345	0.5
Multipurpose RCC with CHTR Fish Passage	$315	$6	$808	-$486	0.4
Multipurpose RCC with Conventional Fishway	$315	$6	$856	-$535	0.4
Multipurpose Rockfill with Experimental Fishway	$315	$6	$1,063	-$742	0.3
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$315	$24	$715	-$376	0.5
Multipurpose RCC with CHTR Fish Passage	$315	$20	$856	-$521	0.4
Multipurpose RCC with Conventional Fishway	$315	$20	$904	-$569	0.4
Multipurpose Rockfill with Experimental Fishway	$315	$20	$1,111	-$776	0.3

Table O-36
Summary Results High Impacts, Expected Costs

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$131	$0	$108	$23	1.2
Low Enhancement Only	$0	$32	$95	-$62	0.3
High Enhancement Only	$0	$89	$128	-$39	0.7
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$162	$32	$290	-$96	0.7
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$162	$89	$324	-$73	0.8
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$498	$24	$465	$57	1.1
Multipurpose RCC with CHTR Fish Passage	$498	$22	$581	-$60	0.9
Multipurpose RCC with Conventional Fishway	$498	$22	$613	-$92	0.8
Multipurpose Rockfill with Experimental Fishway	$498	$22	$794	-$274	0.7
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$498	$82	$498	$82	1.2
Multipurpose RCC with CHTR Fish Passage	$498	$69	$614	-$47	0.9
Multipurpose RCC with Conventional Fishway	$498	$69	$646	-$79	0.9
Multipurpose Rockfill with Experimental Fishway	$498	$69	$827	-$260	0.7
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$534	$24	$556	$2	1.0
Multipurpose RCC with CHTR Fish Passage	$534	$22	$672	-$116	0.8
Multipurpose RCC with Conventional Fishway	$534	$22	$704	-$148	0.8
Multipurpose Rockfill with Experimental Fishway	$534	$22	$886	-$329	0.6
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$534	$82	$590	$27	1.0
Multipurpose RCC with CHTR Fish Passage	$534	$69	$705	-$102	0.9
Multipurpose RCC with Conventional Fishway	$534	$69	$738	-$134	0.8
Multipurpose Rockfill with Experimental Fishway	$534	$69	$919	-$315	0.7

Table O-37
Summary Results High Impact, Low Cost

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$131	$0	$108	$23	1.2
Low Enhancement Only	$0	$32	$61	-$29	0.5
High Enhancement Only	$0	$89	$81	$8	1.1
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$162	$32	$246	-$52	0.8
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$162	$89	$266	-$16	0.9
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$498	$24	$365	$157	1.4
Multipurpose RCC with CHTR Fish Passage	$498	$22	$462	$59	1.1
Multipurpose RCC with Conventional Fishway	$498	$22	$489	$31	1.1
Multipurpose Rockfill with Experimental Fishway	$498	$22	$646	-$126	0.8
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$498	$82	$385	$195	1.5
Multipurpose RCC with CHTR Fish Passage	$498	$69	$482	$85	1.2
Multipurpose RCC with Conventional Fishway	$498	$69	$509	$58	1.1
Multipurpose Rockfill with Experimental Fishway	$498	$69	$667	-$100	0.9
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$534	$24	$437	$121	1.3
Multipurpose RCC with CHTR Fish Passage	$534	$22	$534	$23	1.0
Multipurpose RCC with Conventional Fishway	$534	$22	$561	-$5	1.0
Multipurpose Rockfill with Experimental Fishway	$534	$22	$719	-$162	0.8
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$534	$82	$458	$159	1.3
Multipurpose RCC with CHTR Fish Passage	$534	$69	$554	$49	1.1
Multipurpose RCC with Conventional Fishway	$534	$69	$582	$22	1.0
Multipurpose Rockfill with Experimental Fishway	$534	$69	$739	-$136	0.8

Table O-38
Summary Results High Impacts, High Costs

100-YEAR NPV 3.5% DISCOUNT RATE ($2014), MILLIONS					
	IMPACTS				
	FLOOD DAMAGE REDUCTION	ENVIRONMENTAL (USE VALUES ONLY)	PROJECT IMPLEMENTATION COSTS	NET BENEFIT	BENEFIT /COST
Floodproofing Only	$131	$0	$108	$23	1.2
Low Enhancement Only	$0	$32	$133	-$101	0.2
High Enhancement Only	$0	$89	$181	-$92	0.5
I-5 Project Alternative Variations					
I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement	$162	$32	$340	-$146	0.6
I-5 Alternative + Airport Levee + Floodproofing + High Enhancement	$162	$89	$389	-$138	0.6
Upper Chehalis Storage Alternative Variations					
Storage + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$498	$24	$575	-$53	0.9
Multipurpose RCC with CHTR Fish Passage	$498	$22	$715	-$195	0.7
Multipurpose RCC with Conventional Fishway	$498	$22	$763	-$243	0.7
Multipurpose Rockfill with Experimental Fishway	$498	$22	$971	-$450	0.5
Storage + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$498	$82	$623	-$42	0.9
Multipurpose RCC with CHTR Fish Passage	$498	$69	$763	-$196	0.7
Multipurpose RCC with Conventional Fishway	$498	$69	$811	-$244	0.7
Multipurpose Rockfill with Experimental Fishway	$498	$69	$1,018	-$451	0.6
Storage + I-5 Project Alternative Variations					
Storage + I-5 Alternative + Airport Levee + Floodproofing + Low Enhancement					
Flood Retention RCC with CHTR Fish Passage	$534	$24	$667	-$109	0.8
Multipurpose RCC with CHTR Fish Passage	$534	$22	$808	-$251	0.7
Multipurpose RCC with Conventional Fishway	$534	$22	$856	-$300	0.7
Multipurpose Rockfill with Experimental Fishway	$534	$22	$1,063	-$507	0.5
Storage + I-5 Alternative + Airport Levee + Floodproofing + High Enhancement					
Flood Retention RCC with CHTR Fish Passage	$534	$82	$715	-$99	0.9
Multipurpose RCC with CHTR Fish Passage	$534	$69	$856	-$252	0.7
Multipurpose RCC with Conventional Fishway	$534	$69	$904	-$301	0.7
Multipurpose Rockfill with Experimental Fishway	$534	$69	$1,111	-$508	0.5