U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington

Final General Reevaluation Report

June 2003

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Chehalis River, Washington

General Reevaluation Study

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US Army Corps of Engineers
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EXECUTIVE SUMMARY

The Seattle District, U.S. Army Corps of Engineers (Corps, USACE) and Lewis County, Washington, have collaborated to re-evaluate a previously authorized flood damage reduction project in the Chehalis River Basin. This general reevaluation study was conducted in response to Resolution 2581 of the U.S. House of Representatives Committee on Transportation and Infrastructure, which directed a review of past Corps report recommendations in the study area and a reevaluation of flooding and environmental problems and solutions.

The purpose of this General Reevaluation Report (GRR) is to document the planning and formulation of the recommended plan. Similar to a traditional feasibility report, the GRR documents all aspects of acceptability, completeness, effectiveness, and efficiency of a broad range of alternatives. The report also identifies requirements and responsibilities associated with project implementation, operation, and maintenance. The main text of the report summarizes major technical studies conducted. Technical appendices provide detailed descriptions of study methodologies and findings. An Environmental Impact Statement, that has been published under separate cover, accompanies the report.

A setback levee alternative that includes levees along the Chehalis and Skookumchuck Rivers was combined with a new formulation of the previously authorized modification to Skookumchuck Dam, non-structural flood damage reduction features, and environmental mitigation features to form the National Economic Development (NED) Plan and the Locally Preferred Plan (LP Plan). The report recommends a plan for authorization. The LP Plan differs from the NED plan by providing more storage in Skookumchuck Dam and 100- year protection levees on the Skookumchuck River. All other features are the same. The local sponsor will incur all costs above those of the NED plan.

The recommended plan will provide 100-year flood protection for the cities of Centralia and Chehalis, Washington. The recommended plan provides estimated annual benefits of $8,949,000 including a reduction of $6.7 million in flood related damages to structures and their contents, $2.1 million in annual avoided costs associated with the need to elevate Interstate Highway 5 without the project, and an annual reduction of $131,000 in traffic delays related to flooding. There are no avoided agricultural damages, nor does the recommended plan induce agricultural damages. Annual economic costs of the recommended plan are estimated at $7,063,000, resulting in annual net benefits of $1,886,000 and a positive benefit-to-cost ratio of 1.27 to 1. In contrast, the NED Plan would provide annual benefits of $8,706,000 for an annual cost of $6,496,000, providing net benefits of $2,210,000 and a benefit-to-cost ratio of 1.34 to 1. The non-Federal sponsor, Lewis County, Washington, supports the recommended plan.

The recommended plan proposes a mitigation plan developed to avoid and minimize impacts, then mitigate. Mitigation selection was broken into three phases: 1. Mitigation sites were identified and evaluated for environmental and cost effectiveness; 2. Mitigation requirements for the NED and LP Plan were identified and the mitigation design was optimized; 3. The selected mitigation plan was assessed to ensure that it would meet the mitigation requirements. Levee designs were optimized to maximize setback and to minimize impacts to sensitive environments.

The setback levee alignment of the recommended plan would give the Chehalis River an opportunity to overbank during certain flood events and re-establish riparian zones along the river's banks, while protecting the main infrastructure of the cities of Centralia and Chehalis, and reducing flood damages to highways. Project features were formulated to address limiting factors for fish and wildlife in the basin and have been included in the recommended plan to mitigate for unavoidable impacts. The recommended plan will provide for future opportunities to establish restoration areas to enhance fish and wildlife habitat.

TABLE OF CONTENTS

EXECUTIVE SUMMARY iii
TECHNICAL APPENDICES x
LIST OF TABLES xi
LIST OF PLATES xiii
1. INTRODUCTION 1
1.1 Study Authority 1
1.2 Study Sponsorship 2
1.3 Study Area 2
1.4 Previously Authorized Project 2
1.5 Project History 3
1.6 Recent Local Activities 5
1.7.1 Skookumchuck Dam 7
1.7.2 Long Levee 7
1.7.3 Skookumchuck River Levee 8
1.7.4 Chehalis-Centralia Airport Levee 8
1.7.5 Salzer Creek Levee 8
1.8 Prior Reports 8
2. SCOPE OF GENERAL REEVALUATION STUDY 12
2.1 Survey and Mapping 13
2.2 Hydrology and Hydraulics 13
2.3 Economics 15
2.4 Engineering Design 15
2.5 Geotechnical Studies 16
2.5.1 Skookumchuck Dam Geotechnical Studies 16
2.5.2 Floodplain Investigations Geotechnical Studies 16
2.6 Institutional Studies 17
2.7 Real Estate Studies 17
2.8 Environmental Studies 18
2.8.1 EIS Preparation 18
2.8.2 Environmental Data Compilation 19
2.8.3 Riparian Survey 19
2.8.4 Wetland Survey 19
2.8.5 Fisheries Survey 19
2.8.6 Environmental Mitigation Measures 20
2.8.7 Endangered Species Act Coordination 20
2.8.8 Clean Water Act Section 404(b)(1) Evaluation 20
2.8.9 Fish and Wildlife Coordination Act Report 21
2.9 HTRW Studies 21
2.10 Cultural Resources Studies 22
2.11 Cost Estimating 23

2.12 Public Involvement 23
3. WITHOUT-PROJECT FLOODING AND FLOOD DAMAGE 26
3.1 Flooding 26
3.2 Recent Floods 27
3.2.1 January 1990 Flood 27
3.2.2 November 1990 Flood 28
3.2.3 February 1996 Flood 28
3.3 Flood Exceedance Frequency 29
3.4 Risk-Based Analysis for Flood Damage Reduction 30
3.4.1 Overview of RBA in Flood Damage Reduction Studies 31
3.4.2 Flood Damage Reduction Analysis Model 31
3.4.3 Uncertainties Specific to the Chehalis Study 31
3.4.3.1 Hydrologic Uncertainty 32
3.4.3.2 Hydraulic Uncertainty 33
3.4.3.3 Economic Uncertainty 34
3.4.4 Uncertainty of Existing Levee Performance 34
3.4.5 Expected Annual Damages 34
3.4.6 Expected Annual Exceedance Probability 35
3.4.7 Long Term Risk 35
3.4.8 Conditional Probability of Non-Exceedance 35
3.4.9 FEMA Certification 36
3.5 Without-Project Hydrology and Hydraulics 36
3.6 Expected Without-Project Flood Damages 46
3.6.1 Residential Structure and Content Damages 46
3.6.2 Residential Cleanup Cost 46
3.6.3 Emergency Costs 47
3.6.4 Commercial and Industrial Inundation Damage 49
3.6.5 Commercial and Industrial Cleanup Costs 50
3.6.6 Public Inundation Damage 50
3.6.7 Inundation Damage Summary 51
3.6.8 Residential, Nonresidential, and Public HEC-FDA Model Results 53
3.6.9 Agricultural Flood Damages 55
3.6.10 Summary of Agricultural Flood Damages 56
3.6.11 Transportation Related Damages 57
3.6.12 Avoided Cost of Interstate 5 Raising 59
3.6.13 Rail Freight Flood Impacts 59
3.7 Expected Annual Damage Summary 61
4. PLAN FORMULATION 62
4.1 Problems and Opportunities 62
4.2 Planning Objectives and Plan Formulation Overview 62
4.2.1 Planning Objectives 62
4.2.2 Plan Formulation Overview 63

4.3 Description of Preliminary Solutions....63
4.3.1 Alternative #1 – No Action Alternative....64
4.3.2 Alternative #2 – Skookumchuck Dam Modifications....64
4.3.2.1 Objective....64
4.3.2.2 Relation to Previously Authorized Project....64
4.3.2.3 Description....65
4.3.2.4 Dam Safety Considerations....65
4.3.2.5 Reservoir Regulation Considerations....66
4.3.2.6 Skookumchuck Dam Modifications, Sub-alternatives....66
4.3.2.7 Alternative 2B1 - Spillway Sluices with Gates and Rubber Crest Weir....67
4.3.2.8 Alternative 2B2 – Short Tunnel with Gates and Rubber Crest Weir....67
4.3.2.9 Alternative 2B3 – Tainter Gates in Rock Cut with Rubber Crest Weir....68
4.3.2.10 Alternative 2B4 – Tainter Gates in Rock Cut with Emergency Spillway....69
4.3.3 Alternative #3 – Overbank Excavation and Flowway Bypass....70
4.3.3.1 Objective....70
4.3.3.2 Relation to Previously Authorized Project....70
4.3.3.3 Description....70
4.3.3.4 Chehalis/SR-6 Area Floodplain Modifications....70
4.3.3.5 Alternative 3B – Skookumchuck Bypass....73
4.3.3.6 Alternative 3C – Centralia Hospital Bypass....73
4.3.3.7 Hump Excavation....73
4.3.4 Alternative #4 – Levee System....74
4.3.4.1 Objective....74
4.3.4.2 Relation to Authorized Project....74
4.3.4.3 Description....74
4.3.4.4 Design Objectives....75
4.3.4.5 Design Process....75
4.3.4.6 Levee Alignment....77
4.3.4.7 Planned Overtopping of Flood Control Levee....77
4.3.5 Alternative #5 – Upstream Flow Restriction Structures, and Upstream Storage....78
4.3.5.1 Flow Restrictors....78
4.3.5.2 Upstream Storage....79
4.3.6 Alternative #6 – Non-Structural Alternative....80
4.3.6.1 Objective....80
4.3.6.2 Relation to Authorized Project....81
4.3.6.3 Description....81
4.3.7 Alternative #7 – Interagency Committee Alternative....81
4.3.7.1 Objective....81
4.3.7.2 Relation to Authorized Project....82
4.3.7.3 Design Process Description....82
4.4 Hydrologic and Hydraulic Assessment of Preliminary Alternatives....86
4.4.1 Alternative 2 – Skookumchuck Dam Modifications....86
4.4.2 Alternative 3 – Excavation and Flowway Bypass....87

4.4.3 Alternative 4 – Levee System 88
4.4.4 Alternative 5 – Upstream Flow Restriction Structures....................90
4.4.5 Alternative 7 – Interagency Committee Alternative 90
4.5 Phase 1 - Screening of Preliminary Alternatives 92
4.5.1 Phase 1: Preliminary Alternatives Screening Criteria 92
4.5.2 Phase 1: Results of Preliminary Alternatives Screening 96
4.6 Phase 2 – Formulation and Screening of Final Alternatives....................101
4.7 Phase 2 – Description of Final Alternatives....................102
4.7.1 Phase 2: Alternative 2 – Skookumchuck Dam Modifications Alternative....................102
4.7.2 Phase 2: Alternative 3 – Overbank Excavation and Flowway Bypass Alternative 103
4.7.3 Phase 2: Alternative 4 – Levee Alternative....................104
4.7.4 Phase 2: Alternative 7 – Interagency Alternative....................106
4.8 Phase 2 - Summary of Final Alternatives 106
4.9 Phase 2 - Estimated Costs of Final Alternatives 107
4.10 Phase 2 - Risk-Based Assessment and Evaluation of Final Alternatives....................110
4.10.1 With-Project Hydrology and Hydraulics....................110
4.10.2 Residual Damages, Damages Reduced and Net Benefits....................110
4.10.3 Project Performance 113
4.11 Phase 2 - Screening Results, Preliminary NED Alternative 113
4.12 Phase 3 – Optimization and Identification of NED Plan 114
4.12.1 Optimization....................114
4.12.2 Identification of NED Plan....................121
4.13 Evaluation of Project Performance 123
4.14 Phase 3 – Locally Preferred Plan....................125
4.14.1 Elevation of Structures....................126
4.15 Formulation of Environmental Mitigation Plan (Phase 1) 127
4.15.1 Environmental Evaluation....................128
4.15.2 Potential Mitigation Features 129
4.15.3 Cost Effectiveness and Incremental Cost Analysis 129
4.16 Formulation of Environmental Mitigation Plan (Phase 2) 132
4.17 Formulation of Environmental Mitigation Plan (Phase 3) 134
4.17.1 Institutional Mitigation Requirements 135
4.17.2 Modification of Environmental Evaluation Methodology 135
4.17.3 Benefits and Costs of Phase 3 Mitigation Plan 135
5. RECOMMENDED PLAN 138
5.1 Description of Recommended Plan....................138
5.2 Cost of Recommended Plan....................138
5.3 Benefits of Recommended Plan....................140
5.4 Structural Flood Control Features of Recommended Plan....................141
5.5 Non-Structural Flood Control Features of Recommended Plan 142
5.5.1 New 100-Year FEMA Floodplain....................143
5.5.2 Flood Warning System....................143

5.5.3 Restriction of Development 144
5.5.4 Restriction of Fill in the Floodplain 145
5.5.5 Storm Water Management 146
5.5.6 Non-Structural Summary 146
5.6 Skookumchuck Dam Operational Modification Description 146
5.7 Environmental Impacts of NED and Locally Preferred Plans 147
5.8 Environmental Mitigation Features and Benefits of Recommended Plan 147
5.9 Real Estate Requirements of Recommended Plan 148
5.10 Operation and Maintenance Requirements of Recommended Plan 150
5.10.1 Chehalis/Skookumchuck River Levee System O&M 150
5.10.2 Skookumchuck Dam O&M 151
5.10.3 Environmental Mitigation O&M 153
5.10.4 Summary of O&M Costs 154
6. IMPLEMENTATION OF RECOMMENDED PLAN 155
6.1 Division of Responsibilities for Implementing the Recommended Plan 155
6.1.1 Federal Responsibilities 155
6.1.2 Non-Federal Responsibilities 155
6.2 Preconstruction Engineering and Design Phase 156
6.2.1 PED Procedural Overview 156
6.2.2 Issues Requiring Additional Study During PED 157
6.2.2.1 Interior Drainage Analyses 157
6.2.2.2 Skookumchuck Dam Stability Evaluation 161
6.3 Construction Phase 162
6.3.1 Project Cooperation Agreement 162
6.3.2 Project Construction 166
6.4 Operation and Maintenance 168
6.5 Cost Allocation 168
6.6 Cost Apportionment 168
6.7 Institutional Requirements 169
6.8 Environmental Requirements 170
6.9 Sponsorship Agreements 171
6.10 Sponsor's Financial Plan and Capability Assessment 171
6.10.1 Financial Analysis 171
6.10.2 Assessment of Financial Capability 172
7. LEGAL AND TECHNICAL REVIEW 173
8. DISTRICT COMMANDER'S RECOMMENDATION 175

TECHNICAL APPENDICES

APPENDIX A – HYDROLOGY AND HYDRAULICS
APPENDIX B – SKOOKUMCHUCK DAM DESIGN
APPENDIX C – LEVEE PLAN AND CIVIL DESIGN
APPENDIX D – ECONOMICS
APPENDIX E - REAL ESTATE PLAN
APPENDIX F – MCACES REPORT

LIST OF TABLES

TABLE 1-1 CHEHALIS RIVER AND TRIBUTARIES CHRONOLOGY OF FEDERAL STUDIES 4
TABLE 1-2 CORPS OF ENGINEERS FLOOD CONTROL REPORTS IN STUDY AREA 10
TABLE 3-1 ANNUAL FLOOD PEAKS AT 3 LOCATIONS SINCE 1971 27
TABLE 3-2 PEAK DISCHARGE FREQUENCY DATA FOR SELECTED LOCATIONS 29
TABLE 3-3 COMPARISONS OF FLOOD RECURRENCE INTERVALS AT GRAND MOUND 30
TABLE 3-4 FLOOD ANALYSIS DAMAGE REACHES 36
TABLE 3-5 STAGE DISCHARGE FUNCTIONS WITH UNCERTAINTY FOR CHEHALIS AND SKOOKUMCHUCK RIVERS 37
TABLE 3-6 UNET STORAGE AREAS AND LINKS TO INDEX CROSS-SECTIONS FOR THE HEC-FDA ANALYSIS 43
TABLE 3-7 NON-DAMAGING ELEVATIONS BY REACH 44
TABLE 3-8 WITHOUT-PROJECT DISCHARGE-PROBABILITY FUNCTION STATISTICS FOR HEC-FDA ..45
TABLE 3-9 CHEHALIS RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT ($) 46
TABLE 3-10 SKOOKUMCHUCK RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT ($) 46
TABLE 3-11 RESIDENTIAL CLEANUP COSTS CHEHALIS RIVER BY EVENT ($) 47
TABLE 3-12 RESIDENTIAL CLEANUP COSTS SKOOKUMCHUCK RIVER BY EVENT ($) 47
TABLE 3-13 EMERGENCY COSTS – CHEHALIS RIVER ($) 49
TABLE 3-14 EMERGENCY COSTS – SKOOKUMCHUCK RIVER ($) 49
TABLE 3-15 CHEHALIS COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE BY EVENT ($) 49
TABLE 3-16 SKOOKUMCHUCK COMMERCIAL/INDUSTRIAL INUNDATION DAMAGE BY EVENT ($) .49
TABLE 3-17 CHEHALIS NONRESIDENTIAL CLEANUP COSTS BY EVENT ($) 50
TABLE 3-18 SKOOKUMCHUCK NONRESIDENTIAL CLEANUP COSTS BY EVENT ($) 50
TABLE 3-19 CHEHALIS PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT ($) 50
TABLE 3-20 SKOOKUMCHUCK PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT ($) 51
TABLE 3-21 CHEHALIS PUBLIC STRUCTURE CLEANUP COSTS BY EVENT ($) 51
TABLE 3-22 SKOOKUMCHUCK PUBLIC STRUCTURE CLEANUP BY EVENT ($) 51
TABLE 3-23 STRUCTURAL DAMAGE SUMMARY ($) 52
TABLE 3-24 EXPECTED ANNUAL DAMAGE BY CATEGORY 53
TABLE 3-25 WITHOUT-PROJECT EXPECTED ANNUAL DAMAGES BY REACH 54
TABLE 3-26 LEWIS COUNTY CROP HARVESTS – 1996 55
TABLE 3-27 PER ACRE CROP DAMAGE 56
TABLE 3-28 PER ACRE FIELD CROPLAND RESTORATION COSTS 56
TABLE 3-29 AGRICULTURAL DAMAGES BY FLOOD EVENT ($) 57
TABLE 3-30 EXPECTED ANNUAL AGRICULTURAL DAMAGE ($) 57
TABLE 3-31 INTERSTATE 5 DAILY TRANSPORTATION DELAY COSTS WHEN FLOODED 58

TABLE 3-32 INTERSTATE 5 DAMAGES BY FLOOD EVENT....58
TABLE 3-33 RAILROAD DAMAGES BY FLOOD EVENT....60
TABLE 3-34 EXPECTED ANNUAL DAMAGE SUMMARY....61
TABLE 4-1 PRELIMINARY ALTERNATIVES....64
TABLE 4-2 ALTERNATIVES FOR PHASE 2 SCREENING....101
TABLE 4-3 FINAL ALTERNATIVES....107
TABLE 4-4 SUMMARY COST ESTIMATES FOR FINAL ARRAY OF ALTERNATIVES....108
TABLE 4-5 WITH-PROJECT ECONOMIC ANALYSIS....112
TABLE 4-6 PHASE 2 PERFORMANCE ANALYSIS....113
TABLE 4-7 PHASE 3 ALTERNATIVES....115
TABLE 4-8 PHASE 3 ALTERNATIVES NED BENEFITS....117
TABLE 4-9 COMPONENT COSTS....118
TABLE 4-10 TOTAL ANNUAL COSTS AND NED NET BENEFITS PHASE 3 ALTERNATIVES....119
TABLE 4-11 NED PLAN RESIDUAL DAMAGES....122
TABLE 4-12 ENGINEERING PERFORMANCE EVALUATION....124
TABLE 4-13 LP PLAN RESIDUAL DAMAGES....126
TABLE 4-14 COSTS OF ELEVATING STRUCTURES WITH INDUCED FLOODING....127
TABLE 4-15 POTENTIAL MITIGATION AREAS/COMPONENTS....129
TABLE 4-16 RESTORATION MEASURES, WITH COST AND OUTPUT*....130
TABLE 4-17 INCREMENTAL COST ANALYSIS....134
TABLE 5-1 MCACES COST ESTIMATE FOR NED PLAN....139
TABLE 5-2 MCACES COST ESTIMATE FOR RECOMMENDED PLAN(LOCALLY PREFERRED PLAN)...139
TABLE 5-3 COST COMPARISON OF NED AND LOCALLY PREFERRED PLAN....140
TABLE 5-4 SUMMARY BASELINE COST ESTIMATE FOR REAL ESTATE (BCERE)....149
TABLE 5-5 LER ACQUISITION SCHEDULE....149
TABLE 5-6 DETAILED ANNUALIZED COSTS FOR EQUIPMENT MAINTENANCE AT SKOOKUMCHUCK DAM....153
TABLE 5-7 OPERATION AND MAINTENANCE COSTS ($)....154
TABLE 6-1 CHINA CREEK PRE-FEASIBILITY FLOOD REDUCTION ALTERNATIVES EVALUATION...159
TABLE 6-2 CONSTRUCTION SEQUENCING....167
TABLE 6-3 CHEHALIS RIVER FLOOD DAMAGE REDUCTION COST APPORTIONMENT ($)....169
TABLE 6-4 STATUS OF COMPLIANCE WITH ENVIRONMENTAL LAWS/REGULATIONS/TREATIES ...170

LIST OF PLATES

(All plates at back of GRR)

PLATE 1 – VICINITY MAP
PLATE 2 – CHEHALIS RIVER BASIN MAP
PLATE 3 – 2/5 YEAR FLOODPLAINS
PLATE 4 – 100/500 YEAR FLOODPLAINS
PLATE 5 – ECONOMIC DAMAGE REACHES
PLATE 6 – SELECTED PLAN ALIGNMENT

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1. INTRODUCTION

The cities of Chehalis and Centralia and surrounding communities in Lewis and Thurston Counties, Washington, have a long history of flooding and flood damages. These problems have been acknowledged and studied for many years. More recently, heightened environmental awareness and the potential listing of area aquatic species as threatened and endangered have resulted in a need for increased focus on development of flood control alternatives that minimize environmental impacts and incorporate environmental features to mitigate any adverse impacts to fish and wildlife communities and habitats. This general reevaluation report documents the methods and findings of studies aimed to address these flooding and environmental problems.

The studies documented in this report are General Reevaluation Studies of the recommended project in the 1982 Feasibility Report titled *Centralia, Washington Flood Damage Reduction*. That report recommended modification of Skookumchuck Dam to provide for increased flood control storage. That recommendation was later found to be economically unjustified during the Preconstruction Engineering and Design (PED) phase and studies were terminated. The current General Reevaluation Study is in response to Congressional direction to reexamine previous recommendations for flood damage reduction in the vicinity of Centralia and Chehalis and to examine opportunities for ecosystem restoration.

1.1 Study Authority

Authority for the Centralia Flood Damage Reduction General Reevaluation Study is provided by the following Congressional actions:

Skookumchuck Dam Modification Project: Section 401(a) of 1986 Flood Control Act (PL 99-662) authorized construction of “works of improvement” substantially in accordance with the Report of the Chief of Engineers, dated 20 June 1984. The report was an interim report submitted (third in a series) under the Chehalis River and Tributaries Feasibility Study authority, originally authorized by a 19 April 1946 House of Representatives Flood Control Committee Resolution. A project to increase the dam to 28,500 acre-feet (ac-ft) of storage was recommended and was authorized in 1986.

Chehalis River & Tributaries General Reevaluation Study: On 9 October 1998, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted Resolution 2581, requesting a review of past Corps report recommendations with a view to determining if the recommendations should be modified "with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification." This resolution provided the authority and directive for the Corps to conduct this Flood Damage Reduction Study for the Chehalis River Basin.

1.2 Study Sponsorship

Although the City of Centralia was the local sponsor through the feasibility phase and initial PED work for the authorized Skookumchuck Dam Modification Project, it was Lewis County that requested the Corps resume PED work with a view to combining additional measures with the authorized dam modification element to form a more complete flood damage reduction plan for the Centralia-Chehalis urban area. Lewis County has agreed to serve as local sponsor for project construction and to provide the appropriate cost sharing for PED and construction costs when necessary. PED work was resumed in July 1998.

1.3 Study Area

The study area includes the mainstem Chehalis River, its floodplain and tributaries from the South Fork Chehalis River confluence to Grand Mound, and includes the cities of Centralia and Chehalis, in Lewis County, Washington. Tributaries entering the study area include the Skookumchuck and Newaukum rivers, Salzer, China, Coal, Bunker, and Lincoln creeks, among others. Studies along the Skookumchuck River extend upriver to Skookumchuck Dam and include the town of Bucoda in Thurston County.

1.4 Previously Authorized Project

The recommended project was authorized in 1986 with an estimated cost of $19.9 million ($30.2 million when converted to 2001 price level). It proposed adding a 12-foot-diameter, 1,200-foot-long, low-level, gated discharge tunnel through the dam's north abutment and a bascule gate, 15 feet high by 136 feet wide, on the existing spillway crest. That project would provide up to 28,500 ac-ft of flood storage and reduce the Skookumchuck River 200-year flood flow (1985 analysis) from 13,300 cfs to 6,700 cfs (a flood depth reduction of 2 to 5 feet along the

Skookumchuck River in Centralia). With average annual benefits estimated at $4.3 million (2001 price level), the project had a benefit-to-cost ratio of 1.4 to 1.0.

PED work on the Centralia project was previously underway from February 1988 through August 1990. Negotiations were undertaken with the dam operator, PacifiCorp, to identify the maximum amount of flood storage they would agree to provide at Skookumchuck Dam, which was about 12,000 ac-ft. Earlier hydrologic, hydraulic, and economic studies were updated from the Feasibility Report and preliminary spillway design layouts and cost estimates were refined. Design work was suspended after studies indicated that the recommended plan lacked economic justification. A Wrap-Up Report was provided to the local governments in May 1992 that contained the useful information that had been generated by the project's design work.

1.5 Project History

There is a long history of study activities related to potential flooding on the Chehalis River and its tributaries. The following is a brief chronology of Federal study activities in the area.

TABLE 1-1 CHEHALIS RIVER AND TRIBUTARIES CHRONOLOGY OF FEDERAL STUDIES

1931	Corps of Engineers reports on the Chehalis River and Tributaries were completed in 1931, 1935, and 1944 and all concluded that flood control improvements were not economically justified.
1944	In 1944 Congress authorized construction of a levee system to protect the communities of Hoquiam, Aberdeen, and Cosmopolis. The authorization expired in 1952 because local sponsors did not provide required items of local cooperation.
1965	Following serious flooding, study of the Chehalis River and Tributaries resumed in 1965 at the request of the city of Centralia and Lewis, Thurston, and Grays Harbor counties. Studies found that large multi-purpose storage projects in the Chehalis Basin were not economically justified and that levee and or channel modifications along with small headwater dams should be studied further (including in the vicinity of Centralia-Chehalis). Enlargement of Skookumchuck Dam to provide flood control storage was determined to be not economically feasible.
1972	The Chehalis Basin study was divided into separate geographically based studies. Interim reports were published for each area. One of the areas was Centralia-Chehalis.
1974	Findings of further studies of flood control alternatives in the Centralia area found that an urban levee system was the only alternative that appeared economically justified.
1980	Analysis of the Levee Alternative from 1975-1980 resulted in a tentative recommendation for a levee system providing a 200-year level of protection for 2,080 acres in Centralia. Levees to provide protection for other areas, including Chehalis, were not economically justified. Centralia requested that the Corps review the potential for modifying Skookumchuck Dam to provide flood control.
1982	Further feasibility studies during 1981-1982 of modifying Skookumchuck Dam indicated that the dam modification would be a better solution than the urban levee system. The feasibility report, produced in 1982, recommended dam modifications (provision of a low-level flood control outlet, and raising the reservoir elevation to provide flood control storage).
1986	The Water Resources Development Act of 1986 authorized construction of the Skookumchuck Dam modifications recommended in the 1982 Feasibility Report, *Centralia, Washington Flood Damage Reduction.*
1988-91	The Preconstruction Engineering and Design Phase followed the Feasibility Phase of study. In this phase, a limited reevaluation study was conducted to identify possible cost savings through design modifications and to update project economics to reflect revised mapping, revised water surface profiles, modified levee break assumptions, and revised stage-damage functions for frequent hydrologic events. Although project costs were significantly lowered through value engineering, the recalculation of economic benefits brought the benefit-to-cost ratio below unity. In 1991 the Corps' Northwest Division Engineer issued a public notice to terminate the study of the authorized modification to Skookumchuck Dam.
1990	The Salzer Creek Flood Damage Reduction Study, completed in September 1990, looked at flooding in the Salzer Creek basin, which occurs primarily from October through March. The primary plans considered were 6,000 feet of levee to protect the city of Centralia, and a small levee and pump plant to protect the cities of Centralia and Chehalis. The plan would protect portions of the cities of Centralia and Chehalis from the 100-year flood event on the Chehalis River and a larger event on Salzer Creek. The recommended plan consisted of a pump station, an approximately 1,000-foot-long levee that would cross Salzer Creek at I-5 and which would prevent Chehalis River backwater flooding, and still allow Salzer creek to flow through. Local funding issues precluded this project from proceeding to construction.
1998	In 1998, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted Resolution 2581, requesting a review of past Corps report recommendations with a view to determining if the recommendations should be modified "with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification."
1998	Seattle District and Lewis County initiated the Chehalis River and Tributaries General Reevaluation Study. The study explores structural and non-structural flood control solutions.

1.6 Recent Local Activities

Following disastrous 1990 and 1996 flood events, a group of interested citizens in the spring of 1996 formed the Flood Action Council (FAC) to work on options to reduce or eliminate severe flooding in the Centralia-Chehalis area. With the help of a consultant team, the FAC developed a preliminary plan that combined modifying Skookumchuck Dam with overbank excavation at Centralia and additional upstream flood storage. Their proposal to form a Chehalis Basin (Lewis County) Flood Control District to implement that plan was rejected by the Lewis County Commissioners, because it did not meet legal criteria for creation. However, the Commissioners decided that the county would take the lead in identifying flood reduction measures and set up by ordinance a countywide Flood Control Zone District (FCZD).

Subsequently, Lewis County, using local and state funding and the same consultant team, conducted studies that identified possible modifications to the recommended project in the Chief's report that could result in a potentially economically justified project. Originally, these studies were developed to provide a community-based alternative to the Washington State Department of Transportation's (WSDOT) plan to raise the Interstate Highway 5 (I-5) grade near Centralia and Chehalis by up to 12 feet. Local governments wanted a plan for a comprehensive flood hazard management project that would provide flood relief as well as avoid raising I-5.

In May 1998, Lewis County completed a "Pre-Feasibility Analysis of Alternatives" report (similar in scope to a Corps reconnaissance study) identifying a plan that appeared to be economically justified and warranting further consideration. This plan was further refined in their November 1998 "Draft Interim Report." The version of the plan identified in that report combined dam modifications (sluices through the spillway and a rubber, weir-type gate on top of the spillway) with overbank excavation near Centralia and flood bypass measures near Chehalis.

The Chehalis River Basin Partnership (CRBP) was also established in 1998 by an inter-local agreement among cities, towns, counties and tribes in the Chehalis River basin. The CRBP aims to implement state mandated watershed planning, particularly addressing water quality, water quantity, and fish habitat.

In April 1998, the Washington State Legislature provided through the Department of Transportation $600,000 to "establish alternatives for flood management and flood hazard reduction projects in the Chehalis basin." A provision in the legislation required that a Technical Committee be established composed of WSDOT, WDOE, USACE, FEMA (Federal Emergency

Management Agency), USGS (U.S. Geological Survey), and "affected counties and tribes, and other entities with critical knowledge related to flood hazard reduction projects." In accordance with those provisions, the then existing Chehalis Basin Coordinating Committee (which had been established in 1997) was reconstituted to form the Technical Committee. It established an Alternatives Subcommittee to identify and develop flood damage reduction measures and combine them into alternative plans for comparison with the alternative already developed by Lewis County. Most of the 1998 WSDOT funding was provided to Lewis County to continue work on developing a flood damage reduction alternative for the Centralia-Chehalis area. In the 1999-2001 state budget an additional $300,000 was included to continue this effort, concentrating on coordination with the Corps of Engineers, negotiation with PacifiCorp on dam ownership transfer, the NEPA/SEPA process, and general project coordination.

In addition, in May 1999, the Washington State Legislature provided the WSDOT $800,000 "for activities considered essential to understanding flood hazard reduction options for I-5, State Route (SR) 12 and other chronic flood hazards to transportation within the Chehalis watershed." The WSDOT and the local governments' Executive Committee were required by the legislation to develop a Memorandum of Agreement to identify the tasks to be performed. A Memorandum of Agreement to "support community protection and salmon recovery efforts where possible" was signed.

1.7 Existing Projects in Study Area

1.7.1 Skookumchuck Dam

Skookumchuck Dam was completed in 1970 by Pacific Power and Light Company as agent for the owners, a group of eight public and private utilities. The dam is on the Skookumchuck River, 22 miles upstream from the river's confluence with the Chehalis River. The dam provides an assured water supply for the coal-fired Centralia Steam Electric Plant. The dam stores water during the late fall and winter for release during the low flow period of summer and early fall. The storage releases are carried instream for about 14 miles to a pumping plant that diverts water through a 3-mile pipeline to the plant. In July 1982, the Federal Energy Regulatory Commission (FERC) approved an application for exemption from license from Pacific Power and Light Company for a 980-kilowatt (kW) generating facility at Skookumchuck Dam that uses existing excess discharges from the dam to generate power.

On 15 July 1998, Lewis County asked the dam owner, PacifiCorp, to begin formal discussions on transferring flood control operating authority and/or ownership rights for the dam and reservoir. They signed a Memorandum of Agreement (MOA) on 30 June 1999 that identifies the process and procedures to follow to investigate and ultimately, if favorable, transfer ownership of the dam and reservoir.

1.7.2 Long Levee

The Long Road Flood Damage Reduction project was constructed under authority of Section 205 of the 1948 Flood Control Act, as amended. The project is just south of the City of Centralia in Lewis County, Washington. The levee project ties into the embankment of Interstate 5 near milepost 81. The project is designed to protect approximately 100 acres of land, residential homes, a church, and a 100-bed convalescent center from floods up to about the 40-year event, which is a flood that has about a 2.5 percent chance of occurring or being exceeded on any year. The area protected is within the Long Road Diking District.

The project consists of a 2,200-foot earthfill levee stretching between the Tacoma Eastern Railroad (TERR) and I-5 embankments in a reversed L-shape. Excavated material from the interior of the reverse-L created a ponding area and provides storage for the project. To drain the interior storage area the project includes an outlet for the ponding area with two 30-inch culverts and flap gates, and a ditch and berm with two 30-inch culverts and flap gates.

1.7.3 Skookumchuck River Levee

Currently a levee exists along the Skookumchuck River, starting at Skookumchuck river mile[1] (RM) 2.2 for a length of .75 river miles. This small section of levee currently gets outflanked during flood events prior to being overtopped by floodwaters. This section of levee is not a Federal levee project.

1.7.4 Chehalis-Centralia Airport Levee

An existing levee protects the Chehalis-Centralia Airport, starting at Chehalis river mile 70.2 and extending for a length of 2.6 river miles. The levee is outflanked on the southern end of the airfield. This levee is not a Federal project.

1.7.5 Salzer Creek Levee

An existing levee runs along Salzer Creek starting at river mile .87 and extending upstream for .45 river miles for protection of the fairgrounds. This levee is not a Federal project.

1.8 Prior Reports

A series of Corps of Engineers reports related to flood control in the Chehalis River basin have been produced dating back to 1931. These reports are listed in Table 1-2 and are described in the following paragraphs.

Corps of Engineers reports on the Chehalis Basin completed in 1931, 1935, and 1944 all concluded that flood control improvements were not economically justified. However in 1944 Congress authorized a levee system to protect Aberdeen, Hoquiam, and Cosmopolis. The authorization expired in 1952. An interim report was transmitted to Congress in November 1978,

[1] All references to river miles (RM) on the Chehalis and Skookumchuck rivers (and other tributaries) start at the respective river's (in some cases, creek's) outlet. For example, Chehalis river mile 0.0 is at the outlet to Grays Harbor. Skookumchuck River mile 0.0 is at the river's outlet to the Chehalis River. All other river mile references refer to the miles upstream from the outlet.

recommending construction of a levee system to protect the south side of the Chehalis River at its mouth in the City of Aberdeen and town of Cosmopolis.

In the Chehalis-Centralia area, the lower 1,700 feet of Coffee Creek was modified in 1966 under the authority of Section 208 of the 1954 Flood Control Act. A floodplain information report was completed in June 1968 for the Chehalis River and Skookumchuck River in the Chehalis-Centralia area. A hydraulic floodway study for the same area was completed in August 1974. A second hydraulic floodway study was completed in March 1976 covering the Chehalis and Newaukum rivers in the vicinity of Chehalis. A comprehensive framework study of the water and related land needs of the Columbia River-North Pacific region was completed in 1972 under the direction of the Pacific Northwest Rivers Basin Commission, identifying the Chehalis-Centralia area as an area where levees should be constructed for urban flood damage reduction.

In 1982 the Corps released the Feasibility Report and Environmental Impact Statement for Centralia, Washington Flood Damage Reduction. The report recommended modifications to Skookumchuck Dam (provision of a low-level flood control outlet, and raising the reservoir elevation to provide flood control storage). This project was later found to be economically unjustified based upon updated economic studies during the PED phase. In February 1992 the Corps prepared the Skookumchuck Dam Modification Project, Centralia, Washington Wrap-Up Report, summarizing PED studies and data.

TABLE 1-2 CORPS OF ENGINEERS FLOOD CONTROL REPORTS IN STUDY AREA

Report	Date	Content
House Document 148 72nd Congress 1st Session	1931	Investigated improvements on the Chehalis River for navigation, flood control, hydropower development, and irrigation; concluded no improvements were justified
Preliminary Examination (not published as Congressional Document)	1935	Preliminary examination of flood control for the Chehalis River; concluded that flood control reservoir or channel improvements at Centralia-Galvin, Oakville, Malone, and Potter were not economically justified.
House Document 494 78th Congress 2nd Session	1944	Preliminary examination and survey for flood control on the Chehalis River and tributaries considering construction of a levee system to protect Aberdeen, Cosmopolis, and Hoquiam; concluded any additional flood control in the basin was not economically feasible. (Levee system was subsequently authorized by Congress in 1944. The authorization expired in 1952.)
Coffee Creek, Channel Excavation and Debris Removal under Section 208 of 1954 Flood Control Act	1965	Examined floodway problems along Lum Road in Centralia and recommended clearing and snagging on 1,660 feet of Coffee Creek (completed March 1966).
Floodplain Information, Chehalis and Skookumchuck River, Bucoda, Washington	1968	Delineated the floodplain along the Skookumchuck River from the Lewis/Thurston county line to about 1 mile upstream of Bucoda.
Floodplain Information, Chehalis and Skookumchuck Rivers, Centralia-Chehalis, Washington	1968	Delineated the floodplain along the Chehalis River from the Lewis/Thurston county line to Chehalis and along the Skookumchuck River from the mouth to the Lewis/Thurston county line.
Special Study, Suggested Hydraulic Floodway, Chehalis and Skookumchuck Rivers	1974	Delineated the suggested hydraulic floodway for the area covered by the June 1968 floodplain information report.
Special Study, Suggested Hydraulic Floodway Chehalis and Newaukum Rivers	1976	Delineated the floodplain and suggested hydraulic floodway for Chehalis River from Chehalis to Adna and the Newaukum River from its mouth to the I-5 bridge.
Centralia, Washington Flood Damage Reduction Feasibility Report and Environmental Impact Statement	1982	Documents investigation of the feasibility of reducing flood damages in the cities of Centralia and Chehalis and surrounding areas. Recommended modification of the existing Skookumchuck Dam to provide flood control storage. (Recommendation later found to be economically unfeasible during PED phase).

TABLE 1-2 CORPS OF ENGINEERS FLOOD CONTROL REPORTS IN STUDY AREA

Salzer Creek Flood Damage Reduction Report	1990	The Salzer Creek Flood Damage Reduction Study, completed in September 1990, looked at flooding in the Salzer Creek basin, which occurs primarily from October through March. The primary plans considered were 6,000 feet of levee to protect the City of Centralia, and a small levee and pump plant to protect the cities of Centralia and Chehalis. The plan would protect portions of the cities of Centralia and Chehalis from the 100-year event flood on the Chehalis River and a larger event on Salzer Creek. The recommended plan consisted of a pump station, an approximately 1,000 foot long levee that would cross Salzer Creek at I-5 and that would prevent Chehalis River backwater flooding, and still allow Salzer Creek to flow through.
Skookumchuck Dam Modification Project, Centralia, Washington	1992	Preconstruction Engineering and Design (PED) work on the Skookumchuck Dam Modification Project was suspended in August 1990 when the updates of the project's economic analysis found the project unjustified. The wrap up report was prepared to document the technical work that had been completed at the time the PED work stopped.
Post Flood Study, Chehalis River at Centralia, Lewis County, Washington	1999	Provides updated flood information on the discharge and stage for the 50-year and 100-year floods on the Chehalis River in the vicinity of Centralia. The update was necessary due to significant changes in the flood frequency relations caused by a series of record floods over the previous 20 to 25 years. The study also addresses the effects of raising the road surface elevation of I-5 in the Chehalis-Centralia corridor on flood levels in the area. Study found discharges and flood levels had significantly changed from those published in the 1980 FEMA report due to the change in the hydrologic record. The 100-year event at Grand Mound gauging station increased from 58,700 cfs to 74,300 cfs, or approximately .9 foot in stage.

2. SCOPE OF GENERAL REEVALUATION STUDY

The Chehalis River General Reevaluation Study is a Post Authorization Study being conducted by the U.S. Army Corps of Engineers, Seattle District, and Lewis County, Washington. A general reevaluation study is a reanalysis of a previously completed and authorized study, using current planning criteria and policies, which is required due to changed conditions and/or assumptions. The results may affirm the previous plan; reformulate and modify it, as appropriate; or find that no plan is currently justified. The results of the study are documented in this General Reevaluation Report (GRR).

As mentioned in Section 1 of this report, in 1998, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted Resolution 2581, requesting a review of past Corps report recommendations (including the project authorized for construction in WRDA 1986) with a view to determining whether the recommendations should be modified "with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification." Seattle District and Lewis County initiated the Chehalis River and Tributaries General Reevaluation Study to reevaluate previous and new configurations of structural and non-structural flood control solutions and ecosystem restoration features. The study involved analysis of many technical areas including:

- Survey and mapping
- Hydrology and hydraulics
- Engineering Design
- Geotechnical Studies
- Economic Analysis
- Institutional Studies
- Real Estate Studies
- Environmental Studies
- HTRW Studies
- Cultural Resources Studies
- Cost Estimating
- Public Involvement

The scopes of these technical studies are summarized in the following sections, followed by an overview of risk-based flood damage reduction analysis and its application in the General Reevaluation Study. Results of these studies are presented in detail in the respective technical appendices of this GRR and the associated Environmental Impact Statement (EIS) as appropriate. Those results that were key to the formulation and selection of the recommended plan are summarized throughout the following chapters in this report.

2.1 Survey and Mapping

To provide topographic input for the UNET1D computer models, an aerial photogrammetric survey was conducted for large portions of the Chehalis River basin including: Chehalis River floodplain from Cedarville (RM 42) through Pe Ell (RM 107). The existing Thurston County 2-foot contour interval (CI) topographic mapping was used for the study areas in Thurston County. New 2-foot CI mapping was prepared for the following river reaches in Lewis County: 46 miles on the Chehalis River, 6 miles on the Skookumchuck River, 9 miles on the Newaukum River, about 5 miles in the Lincoln Creek valley, 9 miles in the Hanaford valley, 4 miles in the Sterns Creek valley, and 8 miles in the South Fork Chehalis River valley. The maps incorporate 2-foot contour intervals, planimetric details and extensive spot elevations (at grade breaks, road and railroad alignments) with a vertical accuracy of ±0.5 foot. New topographic mapping of 1-foot contour interval was developed for the immediate vicinity of the existing Skookumchuck Dam, its intake and outlet structures. New river cross-sections were obtained by field measures.

2.2 Hydrology and Hydraulics

Hydrologic and hydraulic study tasks were completed to update, calibrate, and operate a hydraulic model of the Chehalis River valley and to support all hydrologic and hydraulic design work associated with layout and design of the potential project. Previous Corps of Engineers archived databases and models were activated and updated as appropriate. The deregulated natural and existing condition flows on mainstem Skookumchuck and Chehalis rivers and tributaries associated with winter and spring floods of record were updated for use in hypothetical flood and dam regulation analyses. Historic and expected future changes in land use and population in the basin were researched and evaluated to assess influences on basin hydrology.

The Chehalis basin frequency curves were reviewed and, particularly the low flow curves, revised, and hypothetical floods developed for the 2-, 10-, 25-, 50-, 100-, 200-, 500-year, and larger events. Work developed the magnitude of flow versus timing relationships and updated observed and hypothetical flood routings for use in hydraulic model. Information was developed on the expected interior runoff for any areas protected by the potential alternatives. Risk and uncertainty associated with hydrologic data were identified.

Reservoir release options at Skookumchuck Dam were investigated regarding fishery impacts, river sedimentation, and water supply. The former reservoir temperature analyses were updated. The former Probable Maximum Flood and Standard Project Flood analyses were reviewed and updated using the new HMR57 model and routed through the reservoir for site-specific dam safety analysis and spillway discharge adequacy. Reservoir storage rule curves and gate operating schedules were revised and updated. A preliminary data-collection plan and preliminary reservoir operating plan was developed.

The existing UNET1D hydraulic model was updated to reflect revised hydrologic and topographic data. The model covers the river floodplain from the mouth at Aberdeen through Pe Ell (RM 107) with particular emphasis in the upper basin above Grand Mound (RM 60). The model includes 10 miles on the Black River, 22 miles on the Skookumchuck River, 9 miles on the Newaukum River, about 5 river miles in the Lincoln Creek valley, 9 river miles in the Hanaford Valley, and 8 river miles in the South Fork Chehalis River valley. An assessment of sediment transport in the river was prepared. After the models were calibrated to replicate past flood conditions accurately, the existing without-project flooding conditions were determined for the selected range of floods. In addition, an analysis was conducted to update the flood insurance floodplain and floodway maps for FEMA to publish on an interim basis until such time as a project(s) was constructed. At that time a revised version of the maps would be prepared as one of the work items during the construction phase.

The model was used to develop the with-project conditions and to formulate and screen potential flood damage reduction measures and help select the recommended project by identifying impacts associated with three alternative with-project conditions reflecting flood damage reduction measures and/or alternatives. Limited sediment sampling and analysis was performed on the Chehalis River to evaluate the impact of alternative projects on the sediment regime and to develop potential project operation and maintenance costs. A probabilistic risk and uncertainty analysis was performed for the alternatives to help determine the recommended plan.

2.3 Economics

The economic analysis involved studies pertinent to an economic cost/benefit analysis of alternative flood damage reduction plans.[2] Expected annual flood damages were estimated under the existing (without-project) and the alternative with-project conditions. An economic report is included as Appendix E to this GRR, and its information is summarized in the main report.

The principal controlling guidance of the analysis comes from the Corps' "Planning Guidance Notebook", ER 1105-2-100, with specific guidance from the regulation's Appendix D – Economic and Social Considerations. Additional guidance on the risk-based analyses is from the Corps' EM 1110-2-1619, dated 1 August 1996, "Engineering and Design - Risk-based Analysis for Flood Damage Reduction Studies." Guidance on agricultural damages has been derived from the Corps of Engineers Water Resources Support Center's "National Economic Development Procedures Manual – Agricultural Flood Damage," IWR Report 87-R-10, dated October 1987.

The economic analysis was conducted in several phases. First project mapping was reviewed and all structures within the 500-year floodplain were provided a unique identifier number and entered into a database. This was followed by a field survey to obtain relevant data on the structures for entry into the database. A risk-based economic analysis was performed to develop the stage-damage function for each category of structures. The stage-damage functions and structures database were combined with water surface profiles from hydraulic analysis into the HEC-FDA model to calculate expected annual damages for each alternative. The damages reduced by each plan were then compared to the cost of each plan to identify the plan that maximizes net benefits. The results of these analyses are further described in the section on plan formulation.

2.4 Engineering Design

Engineering design studies of alternative flood damage reduction measures were conducted in three segments. In the first segment, engineering design studies were performed at the minimum level needed to establish conceptual designs for alternative project features and elements that can to be compared with each other. The second segment involved further development of selected measures and alternatives for comparison and evaluation and the formulation of a recommended plan. The detailed design of the recommended plan (including mitigation features) was developed in the third segment, along with refinements to construction and operation and maintenance cost estimates and project construction schedules. All work was performed with a view to forming an appropriate basis for further design efforts, such as physical model tests and Feature Design Memorandums (FDM). A Cost Engineering appendix (Appendix D) to this GRR provides all design data analyses, a written description of the design features of the recommended plan, plates, and cost estimates.

2.5 Geotechnical Studies

Geotechnical studies for this study include the investigation, exploration, and analysis of foundations and materials conditions related to the selection and design of the alternative flood damage reduction measures. Geotechnical effort was divided into two distinct elements: Skookumchuck Dam investigations and analyses and floodplain investigations and analyses.

2.5.1 Skookumchuck Dam Geotechnical Studies

The geotechnical effort for Skookumchuck Dam included a site-specific ground motion study due to increased estimations of the seismic risk in the Pacific Northwest. Past seismic studies were evaluated using present state-of-the-art practice and existing literature. A seismic analysis of the dam embankment stability based on dynamic loading methods followed the ground motion study. Work included a reservoir slope slide evaluation and investigation and analysis for a sluiceway(s) through the spillway. A soil exploration program was conducted beneath portions of the downstream dam embankment berm to determine liquefaction susceptibility of dam foundation silt and alluvium. An exploratory core drilling program was conducted to support rock cut slope stability and dewatering.

2.5.2 Floodplain Investigations Geotechnical Studies

The geotechnical effort for study area floodplains included a review of available geotechnical information from previous studies and intrusive field investigations to physically characterize materials to be excavated, stability of cut slopes, soil erosion potential, permeability of soils,

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[2] The economic analysis conducted for development of the without project and initial plan formulation for the general reevaluation study and presented in this report was based upon a 6.125 percent discount rate, 2002 price level, and 50-year period of analysis. The final costs and benefits for the NED and LP plans were revised to reflect the current 2003 price level and 5.875 percent discount rate.

seepage conditions, and potential borrow and materials sources. The exploration program involved auger drill borings, backhoe test pits, and the installation of piezometers. Appendix C, Levee Plan and Civil Design, and Appendix B, Skookumchuck Dam Design, to this GRR document the studies and their findings.

2.6 Institutional Studies

Institutional studies assess required institutional arrangements for funding project design, construction, operation, and maintenance; and identify, if any, necessary legislation requirements by the State of Washington to facilitate either project funding or construction. Institutional issues included:

- Coordination between the established governments was conducted to determine the legal entity that will serve as local sponsor for construction and operation
- Lewis County developed a legal analysis supporting their legal ability (or the legal ability of a new governmental entity) to provide the required items of local cooperation.
- Financial analysis in support of the construction recommendation was prepared by Lewis County to include a Statement of Financial Capability (SFC) and a Financing Plan (FP). The FP provides detail as to the anticipated funding authorities available to the sponsor and its specific plans for financing its share of project costs. The local sponsor prepared the SFC and FP, with review by the Corps and Corps preparation of a Financial Capability Assessment (FCA) for inclusion in this GRR.

Actions to be completed during PED include:

- negotiations between Lewis County and PacifiCorp regarding possible transfer of dam ownership; and
- coordination with FERC regarding a new license or exemption from license covering the changes in the spillway and/or project operations.

2.7 Real Estate Studies

Real estate studies involved the identification, assessment, and appraisal of all real property interests required to support the conduct of the feasibility study and the recommendations of the GRR. Specific real estate study tasks included:

- Rights-of-Entry (ROE) were acquired from landowners for survey and mapping, design, geotechnical, and hazardous, toxic and radioactive waste (HTRW) investigations, the cultural resources survey work, and site-specific environmental field studies.
- A gross appraisal of project land costs (including relocations as necessary) was prepared. Work included detailed determination of cost of lands, easements, and rights-of-way for the recommended plan.

A real estate plan is included as Appendix F to this GRR, describing the real estate requirements for the proposed project, the local sponsor's administrative acquisition costs, and Corps costs to review and advise the sponsor.

2.8 Environmental Studies

Environmental studies included environmental data collection and the determination of environmental impacts of alternative plans. Environmental study tasks included all activities required to comply with the National Environmental Policy Act (NEPA). Activities included literature searches and review of existing reports and field surveys to establish environmental baseline conditions; identification of future without-project conditions; determination of impacts of the alternatives; coordination with the U.S. Fish and Wildlife Service (USFWS), Environmental Protection Agency (EPA), Washington Department of Ecology (WDOE, Ecology), Washington Department of Fish and Wildlife (WDFW), Confederated Tribes of the Chehalis, and others; analysis of mitigation needs; development of potential habitat restoration opportunities; development and preparation of all appropriate NEPA documents; review of in-house reports; response to comments; and support to the project manager and others for the duration of the study.

2.8.1 EIS Preparation

The Corps prepared a draft and final EIS (published under separate cover) and public notice with assistance from the local sponsor. The EIS evaluated the environmental effects of the alternative plans and was coordinated with the tribal, Federal, state, and local governments and agencies, and interested groups and individuals. The Washington State Department of Transportation (WSDOT) was the cooperating agency for the EIS.

2.8.2 Environmental Data Compilation

A literature search and compilation of existing data was accomplished to collect all pertinent information for use in assessing project impacts. Some of the information is in the Geographical Information System (GIS) format and was entered on the Seattle District GIS for overlaying on study and/or report maps. The GIS information will be used as input to PED.

2.8.3 Riparian Survey

The study team reviewed existing information on riparian habitat, vegetation type and structure, and floodplains. A field survey was completed to evaluate the quality and extent of riparian areas along the Chehalis River and tributaries in the project area. The study team evaluated potential adverse impacts to riparian areas for each alternative.

2.8.4 Wetland Survey

Existing information on wetlands in the project area was reviewed and evaluated. Limited field surveys and hydric soil mappings were conducted to determine the extent of wetlands within the project area. Potential adverse impacts to wetlands were evaluated for each alternative.

2.8.5 Fisheries Survey

Existing information on fish distribution and use of the Chehalis River and tributaries was reviewed. Additional field investigations of instream habitats and fish distribution were conducted. Potential adverse impacts to fisheries were evaluated for each alternative. The study team conducted field surveys of instream habitats and fish use on the Skookumchuck River and fish use of portions of the Chehalis River during spawning, including the following:

- spawner surveys (Skookumchuck and mainstem Chehalis rivers);
- habitat survey (above Skookumchuck Dam);
- off-channel habitat surveys (Skookumchuck and mainstem Chehalis rivers) that assess functional connections with streams, access; temperature; and changes in off-channel habitat resulting from potential water level changes;
- fish passage at the dam;
- instream habitat effects of water level changes (proposed bypass reach); and
- investigation of potential habitat restoration opportunities.

2.8.6 Environmental Mitigation Measures

The Corps, in coordination with the local sponsor and resource agencies, preliminarily reviewed the scale of adverse environmental impacts associated with each alternative. The alternatives were evaluated to avoid, minimize and, if possible, rectify potential adverse environmental impacts associated with each. Mitigation measures were identified for all adverse environmental impacts of the recommended plan.

Preliminary alternative environmental mitigation designs were developed that focused on both offsetting project impacts and addressing limiting fish and wildlife habitat factors identified in the basin. These designs were developed in sufficient detail to develop cost estimates. The plans are documented in the EIS. An evaluation methodology was developed to evaluate the habitat outputs of alternative mitigation designs.

An incremental cost analysis was performed to assist with development of cost effective mitigation plans. The purposes of the incremental cost analysis were to determine and show variations in costs across alternative mitigation plans, and to assist in selecting the mitigation plan.

2.8.7 Endangered Species Act Coordination

The Corps prepared a biological assessment (BA) to identify possible impacts to species listed as threatened or endangered under the Endangered Species Act (ESA). The BA, prepared in coordination with the USFWS, focused on species likely to be found in the project area. Limiting factors for endangered species in the area were identified and evaluated as part of the study. A range of environmental features throughout the study area was identified that addressed these limiting factors and could potentially be implemented for mitigation of negative project impacts.

2.8.8 Clean Water Act Section 404(b)(1) Evaluation

A 404(b)(1) analysis was conducted during feasibility. Seattle District has determined that the proposed levee construction and dam modification includes practicable steps to minimize impacts to the aquatic environment, and that there is no practicable alternative to the proposed project that would have less impact on the aquatic environment. Therefore, Seattle District has determined that the proposed project complies with the Clean Water Act, Section 404 (b)(1) guidelines. The Corps will coordinate with the Washington Department of Ecology (Ecology) and the Chehalis Tribe to obtain Section 401 state water quality certification. Certification is usually done during PED (about 90 percent design level) when necessary information is developed. The 404(b)(1) report is available as Appendix G of the EIS.

2.8.9 Fish and Wildlife Coordination Act Report

The general reevaluation study includes coordination with, and studies conducted by, the USFWS, as required by the Fish and Wildlife Coordination Act (FWCA). The Corps developed a scope of work and transferred funds to the USFWS for interagency and tribal coordination, planning and evaluation of the impacts of alternative measures and plans on fish and wildlife resources, preparation of five planning aid letters (PAL), and a draft and final Fish and Wildlife Coordination Act Report for inclusion in the EIS. The USFWS effort includes environmental data collection and evaluation of the environmental resources of the study area. The USFWS reviewed alternative plans and assessed the effect on the environment within the study area. The USFWS provided recommendations concerning the formulation of the alternatives, and also prepared a FWCA Report documenting its findings. The Final FWCA Report is included in the EIS, and the Draft FWCA Report is included as an appendix to the EIS.

2.9 HTRW Studies

The Army Corps of Engineers Regulation 1165-2-132, Hazardous, Toxic and Radioactive Waste (HTRW) Guidance for Civil Works Projects, provides guidance for the consideration of issues associated with HTRW, which may be located within project boundaries or may affect or be affected by Corps civil works projects. This regulation outlines procedures to facilitate early identification and appropriate consideration of HTRW concerns in the reconnaissance; feasibility; preconstruction engineering and design; and operations, maintenance, repair, replacement, and rehabilitation phases of a project. Specific goals include (1) identification of level of detail for HTRW investigations and reporting for each phase of project; (2) promotion of early detection and response by the appropriate responsible parties; (3) determination of viable options to avoid HTRW problems; and (4) the establishment of a procedure for resolution of HTRW concerns, issues or problems.

For the general reevaluation study, HTRW studies were conducted to determine the presence and character of contamination, if any, on lands needed for the project. Lands potentially needed for the project were reviewed, and sites with possible contamination identified in an initial screening. Further review of available information concerning those sites was conducted to estimate the volume and level of any contamination.

A preliminary HTRW assessment was conducted via the Internet and through coordination with the Department of Ecology Toxics Cleanup Program, SW Regional Office, for occurrence of HTRW on lands, including structures and submerged land, in the study area. The assessment included a project review, review of site literature and project features, database search, review of available records and aerial photography, site inspections and interviews. The following potential indicators were looked for: landfills, sumps, disposal areas, aboveground and underground storage tanks, vats, containers of unidentified substances, spills, seepage, slicks, odors, dead or stressed vegetation, water treatment plants, wells, ditches, abandoned buildings, and transport areas (such as boat yards, harbors, rail yards, airports, truck terminals, and fueling stations).

The assessment included a review of historical documentation; a review of regulatory listings and, if necessary, review of site files; site visits; and interviews with regulators, site owners and tenants where available or necessary. Regulatory lists reviewed included:

- EPA Lists: CERCLIS and the NPL; and
- Washington Lists: Confirmed and Suspected Contaminated Sites, State Cleanup Sites (MTCA), Voluntary Cleanup Sites, Hazardous Waste Generator Sites, Underground Storage Tanks, Leaking Underground Storage Tanks

The assessment covered all study regions, within the general vicinity of the proposed project or existing features proposed for significant modifications. Several site visits were conducted over the past few years and a preliminary site investigation was conducted for the recommended project that resulted in no findings of contaminated materials. The results of the field investigations, preliminary assessment, and database search are included as an appendix to the EIS.

2.10 Cultural Resources Studies

Cultural resource studies were conducted to locate, identify, and evaluate historic and prehistoric cultural resources (CR) possibly impacted by alternative measures. Previous CR studies identified numerous CR sites within the larger project area. The general reevaluation study provided for completion of CR inventory (e.g., location and identification) and site evaluation in the study area. A preliminary evaluation of the effects of flood damage reduction alternatives upon historic properties was conducted.

These tasks were accomplished in consultation with the Washington State Historic Preservation Officer (SHPO). If required, site data recovery would occur during the project construction phase. The CR data recovery strategy will be developed in accordance with a Memorandum of Agreement between the Seattle District, the SHPO, the Advisory Council on Historic Preservation, and the Chehalis Tribe.

2.11 Cost Estimating

Preliminary alternative cost estimates were prepared to assist in the development and screening of alternative flood damage reduction measures and plans. The cost estimates included the preliminary construction costs for each alternative. Operation and maintenance costs were developed for each alternative as well. Mitigation and real estate costs were developed separately for the intermediate alternatives. Following initial screening and selection of an alternative, a detailed estimate of cost for the NED plan and recommended plan were prepared using MCACES software and are included in the Cost Engineering appendix (Appendix D).

2.12 Public Involvement

Public involvement activities were related to developing public information on the study and obtaining public comments during the study process. The public involvement/outreach strategy consisted of (1) a series of workshops and public meetings, (2) workshop and meeting notices, news releases, and public information brochures; and (3) speaking engagements at community service clubs and local organizations by Corps and Lewis County personnel. The study included extensive review throughout the process by agencies at the Federal, state, local and tribal governmental level, special interest groups, and the general public. Those entities most directly involved in review included Washington Department of Fish and Wildlife (WDFW), WSDOT, Department of Ecology, USFWS, NMFS, the Chehalis and Quinault tribes, local governments, and interest groups. The Corps and Lewis County jointly conducted workshops and public meetings and participated in the community outreach engagements.

Coordination with several groups was maintained to facilitate dialogue among basin residents and interest groups, including the following:

- Chehalis River Basin Partnership (CRBP). The CRBP was established in 1998 by local governments in the Chehalis River basin to implement state mandated watershed planning. CRBP's goals are to coordinate cooperative efforts on: 1) improvement of water quality, 2) management of water supplies for farms, fish, industry, and people, 3) reduction of effects of flooding, 4) increase in recreational opportunities, and 5) increase in public awareness through education. Their primary focus is on preparing a watershed management plan that will address water quality, water quantity, and fish habitat. Coordination will be maintained with the CRBP to identify any information that they collect or develop that would be beneficial in PED. As PED develops the flood reduction measures, these will be discussed with the CRBP to obtain their comments on the project features, their potential impacts, and questions and concerns that should be addressed as part of design.

- Technical Committee and Alternatives Subcommittee. The Technical Committee was established in 1998 to advise on the use of the money appropriated by the Washington State Legislature for flood hazard reduction projects in the Chehalis River basin. The Technical Committee in October 1998 formed an Alternatives Subcommittee to focus on identification of flood damage reduction measures and alternatives that could be discussed, screened, developed and compared with the one alternative previously developed by Lewis County.

A Notice of Intent (NOI) to prepare an EIS on structural and non-structural alternatives to address flood damage reduction in the Centralia/Chehalis area and an announcement of public scoping meetings appeared in Federal Register Volume 64, Number 174, on 9 September 1999. A meeting notice describing the project, requesting comments, and announcing the dates, times, and locations of the public scoping meetings was mailed to interested individuals, groups, agencies, and tribes. A press release announcing the public meetings was sent to local media.

The Corps held two public scoping meetings on 28 and 29 September 1999 at WF West High School in Chehalis and Rochester High School in Rochester respectively. The Corps presented alternatives being considered to address flood damage reduction in the Centralia/Chehalis/I-5 urbanized area and provided opportunities for interested parties to identify issues and concerns associated with the proposed alternatives or to propose additional alternatives. Over 50 members of the public attended the two meetings and they were invited to comment orally or in writing. Over 75 comments were received at the meetings and in comment sheets sent in afterward.

The Corps continued to involve the local communities, state and Federal agencies and the tribes in the alternative selection process. In addition, since 1999 the Corps has presented project updates to the Chehalis River Basin Partnership, in order to keep the public informed of the process of the project. The Corps has also held several public information meetings regarding the selection of a recommended alternative.

3. WITHOUT-PROJECT FLOODING AND FLOOD DAMAGE

This section describes historic, current, and expected flooding and flood damage in the study area without the implementation of a project.

3.1 Flooding

In addition to extensive property damage caused by flooding in the cities of Centralia and Chehalis, floods have caused periodic closure of critical transportation routes resulting in significant economic losses. In closing transportation routes, the flooding also significantly disrupts emergency response by local governments, hurting public safety. Without implementation of flood hazard reduction measures, actions, or projects, the area will continue to suffer from damaging floods, and the local economy will continue to experience depressing economic effects due to the damages and uncertainty associated with future floods.

Stream flow generated within the Chehalis River Basin originates primarily from rainfall, although snowmelt occasionally augments runoff in the highest elevation reaches of the basin. The average annual runoff of the Chehalis River at its mouth (drainage area 2,114 square miles) and at the USGS stream gage near Grand Mound (drainage area 895 square miles), are estimated to be 6.4 million ac-ft and 2.0 million ac-ft, respectively.

Flows in the rivers and creeks of the Chehalis River basin show seasonal variation characterized by sharp rises of relatively short duration from October to March, corresponding to the period of heaviest rainfall. After March, the flows tend to gradually decrease to a relatively stable base flow, which is maintained from July into October.

Major flooding occurs during the winter season, usually from November through February, as the result of heavy rainfall occasionally augmented by snowmelt. Flooding may be either widespread throughout the Chehalis River basin or localized in sub-basins. Some storms may cover the entire basin and cause widespread flooding. Other storms may center over the Willapa Hills and cause flooding of the upper Chehalis River or center over the Black Hills and Cascade foothills and result in flooding of the Skookumchuck River and Newaukum River.

Table 3-1 lists the discharges and stages at three principal stream gauges chronologically for the 10 greatest floods since 1971. This table shows that the record flood in January 1972 near Grand Mound was exceeded in November 1986, January 1990, and again in February 1996.

TABLE 3-1 ANNUAL FLOOD PEAKS AT 3 LOCATIONS SINCE 1971

Gage:	Chehalis near Grand Mound			Skookumchuck near Bucoda			Newaukum R. near Chehalis		
Year [1/]	Stage	Disch.	Rank	Stage	Disch.	Rank	Stage	Disch.	Rank
Jan. ' 71	17.29	40,800	7	15.82	6,630	6	11.99	8,390	8
Jan. ' 72	18.21	49,200	4	16.82	8,190	4	12.12	9,770	6
Jan. ' 74	16.88	37,400	8	15.30	5,950	8	11.17	8,440	7
Dec. ' 75	17.73	44,800	6	15.42	6,110	7	10.85	8,020	9
Dec. ' 77	16.79	36,500	9	16.18	7,170	5	12.49	10,300	5
Nov. ' 86	18.41	51,600	3	15.01	5,770	9	12.76	10,700	2
Jan. ' 90	19.34	68,700	2	17.33	8,540	2	12.75	10,400	3
Nov. ' 90	18.12	48,000	5	17.23	8,400	3	12.73	10,300	4
Dec. ' 94	16.97	35,900	10	14.02	4,100	13	10.62	6,040	28
Feb. ' 96	19.98	74,800	1	17.87	11,300	1	13.34	13,800	1

[1/] Flood dates are labeled by calendar year. The data is gathered by water years that begin in October and end in September. For instance, Jan. ' 90 is in water year 1990 and Nov. ' 90 is in water year 1991.
Source: Post Flood Study, USACE 1999.

3.2 Recent Floods

Brief descriptions of the three most recent, largest floods in the Centralia-Chehalis area (January 1990, November 1990, and February 1996 floods) are provided below.

3.2.1 January 1990 Flood

The January 1990 flood was primarily the result of a series of back-to-back storms accompanied by heavy rainfall over the 8-day period 3-10 January. The heaviest rainfall occurred on the seventh day of the storm, 9 January, causing extreme flooding because the rain fell on soils that were saturated from the preceding rainstorms.

The storm system was quite complex and included high winds and strong surges of precipitation. The Centralia climatological station recorded 8 inches of rain during the 8-day period. This 8-day total precipitation represents 19 percent of the total yearly precipitation recorded at the station on the average. The most intense precipitation in the basin occurred near the headwaters of the Skookumchuck and Newaukum rivers.

The surges in precipitation resulted in more than one flood peak in many of the rivers and creeks in the basin. The streams did not return to base flow between storm surges. The early precipitation saturated the soils in the basin and added greatly to the runoff potential when the heaviest rains arrived on 9 January.

3.2.2 November 1990 Flood

Above average precipitation in October and early November 1990 resulted in saturated soils that contributed to the flooding potential when the major storm arrived during the period of 21-25 November. During the period between a smaller storm in early November and the major storm, wet weather accompanied by cool temperatures continued and snow levels descended to about the 1,000-foot elevation. The Cascade foothills averaged 6 inches at elevations of 1,000 to 2,000 feet; 12 inches at 2,000 to 3,000 feet; and 12-18 inches at 3,000 to 4,000 feet. The water content of the snow was generally 10 percent or higher. As a warm front moved through western Washington on Wednesday, 21 November, snow changed to rain and temperatures rose. The warm front caused melting of snow up to elevations of 5,500 feet. Over the next 3 days, intense rain fell on drainages that were starting to swell from snowmelt runoff; disastrous flooding resulted. A cold front moved in from the north on 26 November 1990, lowered freezing levels and diminished precipitation, finally ending the severe flooding.

3.2.3 February 1996 Flood

The February 1996 flood is the flood of record, to date, on all the major drainages in the Chehalis River basin. Several of the main ingredients for a major storm flood were in place by 5 February. The ground throughout the basin was at or near saturation from above average precipitation, which had fallen in the preceding weeks. In addition, snow had recently fallen as low as 500 feet above sea level during a cold snap. Third, warm, moist subtropical air was being transported from the Pacific Ocean into the Pacific Northwest. The freezing level in this subtropical air mass was well above 8,000 feet, which meant warm rains on the snow pack in the foothills.

Next, there was a strong polar jet stream with maximum wind speeds in its core in excess of 150 knots. These strong winds extended out into the central and western Pacific. Storms fed upon the stream and this powerful jet sustained and strengthened the storms as they moved in off the eastern Pacific. Also, the atmosphere was set up in a blocking pattern, which meant the major troughs and ridges around the Northern Hemisphere were stationary. The Pacific Northwest was situated between a major trough to the west and a major ridge to the east, ideal conditions for weather systems to be at maximum strength when they reached the area. The atmosphere remained in this general pattern for at least 96 hours during which copious amounts of rain fell and large quantities of water in the existing snow pack were released to flow into the rivers.

3.3 Flood Exceedance Frequency

To reflect the series of record floods over the last 25 years, the Corps recently updated their flood frequency curves for the Chehalis River in the vicinity of Centralia (USACE 1997b). The Corps previously published flood frequency curves for the Chehalis River for a 1980 FEMA report (ENSR 1994), and made revisions to the curves in 1989 (USACE 1992). Since 1980, there have been three floods of record, and several other major floods on the Chehalis River. Seattle District incorporated the data since 1980 and recomputed the frequency curves. The recomputed frequency curves data, shown as years of recurrence interval, are shown below. The recomputed frequency curves are significantly higher than those published in 1980 or 1989. Table 3-2 shows the updated peak discharge frequency data for selected locations in the study area. Table 3-3 shows the changes in flood recurrence interval from FEMA 1980 to the Corps updates in 1989 and 1998.

TABLE 3-2 PEAK DISCHARGE FREQUENCY DATA FOR SELECTED LOCATIONS

Location	2-Year Flow (cfs)	10-Year Flow (cfs)	25-Year Flow (cfs)	50-Year Flow (cfs)	100-Year Flow (cfs)
Chehalis near Grand Mound	25,000	43,800	55,000	64,300	74,300
Skookumchuck at Mouth	5,200	9,000	10,600	11,900	13,000
Skookumchuck at Pearl St.	4,800	8,450	10,100	11,300	12,500
Skookumchuck near Bucoda	3,900	6,900	8,300	9,300	10,400
Chehalis at Mellen St.	18,400	32,700	41,400	49,000	57,200
Chehalis above Salzer Creek	17,900	31,900	40,400	47,600	55,700
Newaukum near Chehalis	5,800	9,300	11,200	12,400	13,800

TABLE 3-3 COMPARISONS OF FLOOD RECURRENCE INTERVALS AT GRAND MOUND

Year	Date	Maximum Flow (cfs) at Grand Mound Gage	Flood Recurrence Interval (years)		
			USACE (1998 update)	USACE (1989 update)	FEMA (1980-present)
1996	Feb. 6	73,900	100	400	600
1990	Nov. 25	48,000	15	30	35
1990	Jan. 10	68,700	70	250	400
1972	Jan. 21	49,200	15	30	35

3.4 Risk-Based Analysis for Flood Damage Reduction

Risk involves exposure to a chance of injury or loss. Corps policy has long been to acknowledge risk and uncertainty in predicting floods and their impacts and to plan accordingly. Historically, planning relied on analysis of the expected long-term performance of flood management measures, on application of safety factors and freeboard, on designing for worse-case scenarios, and on other indirect solutions to compensate for uncertainty.

These indirect approaches were necessary because of both the lack of technical knowledge of the complex interaction of uncertainties in estimating hydrologic, hydraulic and economic factors and because of the complexities in performing the mathematics if the interactions were understood. However, with advances in statistical hydrology and the availability of analysis tools, it is now possible to describe the uncertainty in the choice of hydrologic, hydraulic, and economic functions, to describe the uncertainty in the parameters of the functions, and to describe explicitly in results when the functions are used.

Through this risk-based analysis (RBA), and with careful communication of the results, the public can be better informed about what to expect from flood management projects and thus can make better informed decisions. The RBA is integral to the Corps plan formulation process, which systematically reviews the characteristics of the problem to identify and evaluate promising candidate flood management measures or combinations of measures. The policies, methods and procedures for the RBA conducted in this effort are as detailed in ER1105-2-101, “Risked-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies” and in EM 1110-2-1619, “Risk-Based Analysis for Flood Damage Reduction Studies”.

3.4.1 Overview of RBA in Flood Damage Reduction Studies

The determination of expected annual damage (EAD) in a flood damage reduction study must take into account complex hydrologic, hydraulic, geotechnical and economic information. Specifically, EAD is determined by combining the discharge-frequency, stage-discharge, and stage-damage functions, then integrating the resulting damage-frequency function. Uncertainties are present for each of these functions and are carried forth into the EAD computation. In addition, for the rivers being studied that have levees or alternatives that contain levee measures, geotechnical failure parameters become very critical to the analysis.

Once levees have failed and water enters the floodplain, then stages in the floodplain become more critical to the EAD computation than stages in the river channel. Additionally, economic efficiency of a plan or alternative is not the sole criterion for flood-damage reduction plan selection. Performance indices that assist in making informed decisions could include expected annual exceedance, long-term risk, and conditional probability of non-exceedance. These engineering performance indices allow for plan-to-plan comparison of risk of failure based on either the full range of floods or a specific flood. These indices are described below.

3.4.2 Flood Damage Reduction Analysis Model

The Corps primary model for performing flood damage reduction analysis is the Hydrologic Engineering Center's Flood Damage Reduction Analysis model (HEC-FDA, V1.2). The functions mentioned above are input into the model. HEC-FDA incorporates uncertainty for risk–based analysis using a Monte-Carlo simulation procedure. The two primary outputs from HEC-FDA include expected annual damage estimates and project performance statistics that are consistent with Corps guidance concerning the formulation of flood damage reduction plans.

3.4.3 Uncertainties Specific to the Chehalis Study

The Centralia Flood Reduction Project, as with any other flood damage reduction study, has critical uncertainties associated with the hydrologic, hydraulic, and economic data used to compute estimates of EAD and project performance statistics. The following discussion lists the important uncertainties for each of these disciplines and how they were (or were not) considered in this study.

3.4.3.1 Hydrologic Uncertainty

A number of factors contribute to hydrologic uncertainty. Such factors typically include limited or non-existent discharge data and uncertainty associated with existing discharge measurements. In situations where runoff modeling is used to estimate discharge, uncertainty exists in the rainfall-runoff relationship and is also associated with pertinent meteorological data (e.g., precipitation). In situations where stream flow is regulated by human activities, future regulation is subject to variability and uncertainty.

Hydrologic uncertainty is often expressed in terms of uncertainty in the discharge-probability relationship. Hydrologic uncertainty for this study was determined using one of two methods based on whether discharge at a given index location was significantly impacted by upstream regulation. Uncertainty in the discharge-probability relationship for unregulated flows was determined in the HEC-FDA program using Bulletin 17B procedures based on the mean, standard deviation, skew, and the equivalent record length. An equivalent record length of 70 years was used for index locations along the Chehalis River based on the period of record at the Grand Mound gaging station (USGS 12027500).

A similar procedure was used to characterize hydrologic uncertainty under existing conditions at index locations along the Skookumchuck River based on the observation that existing Skookumchuck reservoir operations have a generally limited impact on downstream peak annual discharge. An equivalent record length of 49 years was used for index locations along the Skookumchuck River based on an extension of existing Skookumchuck River discharge data using a two-gage comparison with Newaukum River discharge data. Hydrologic uncertainty at index locations along the Skookumchuck River under with-project conditions is based on the assumption that future flood control regulation at the dam will significantly change the discharge-probability relationship within downstream reaches of the Skookumchuck River. Uncertainty in the discharge-probability relationship in this case was determined using the graphical exceedance probability method in the HEC-FDA program. The graphical method uses a statistical method called ordered events, which determines standard errors of points along the curve from the relationship of each of the estimates to adjacent points and the slope of the function.

3.4.3.2 Hydraulic Uncertainty

Hydraulic uncertainty generally relates to uncertainty in the stage-discharge relationship (rating curve) at the location(s) of interest along a stream network. Hydraulic uncertainty is influenced by a variety of factors including the inherent uncertainty of using a numerical model to represent a natural stream network and uncertainty in hydraulic parameters (e.g., channel cross-section information, Manning's roughness coefficient, representation of off-channel storage). A sensitivity analysis of the UNET modeling to certain hydraulic parameters was performed for this study to identify the parameters that appear to have the most significant influence on the stage-discharge relationship. For instance, the sensitivity analysis suggested that the volume associated with off-channel storage areas could be altered significantly with little apparent impact to the simulated stage-discharge relationships. Conversely and not surprisingly, simulated rating curves were quite sensitive to variations in the Manning's roughness coefficient.

The roughness coefficient was varied during the sensitivity analysis to capture both the uncertainty and variability (i.e., spatial and seasonal variability) of this parameter. Changes to the roughness coefficient were made by varying this parameter as a percentage of the value determined through model calibration. It was ultimately determined that a 40 percent variation of the roughness coefficient (i.e., +/- 20 percent from the calibrated values) provided a reasonable representation of the variability and uncertainty of this parameter. Results of the UNET modeling based on a 20 percent reduction of the roughness coefficient from the calibrated values were used to estimate the approximate lower confidence limit of the simulated rating curves. Conversely, results of the UNET modeling based on a 20 percent increase of the roughness coefficient from the calibrated values were used to estimate the approximate upper confidence limit of the simulated rating curves. Hydraulic uncertainty at the index locations was characterized by assuming that the overall range between the upper and lower bounds of the rating curves based on the 40 percent variation in roughness coefficient represents a range of four times the standard deviation of the uncertainty function. (This assumes that roughly 95 percent of the uncertainty lies between the upper and lower confidence limits determined from the sensitivity analysis assuming a normal [Gaussian] distribution of the uncertainty function.) Hydraulic uncertainty at the index locations was characterized in the HEC-FDA program by assuming that the error (uncertainty) function is characterized by a normal distribution centered about the expected rating curve with a standard deviation as determined from the sensitivity analysis.

3.4.3.3 Economic Uncertainty

The @Risk program (described in Appendix E, Economic Report) was used in the Phase 2 economic analysis to develop stage-damage relationships with uncertainty. Damages were estimated by impact area and by damage category. Economic variables with uncertainty used in the @Risk model include structure value, content value, foundation height, and depth-damage percentage.

3.4.4 Uncertainty of Existing Levee Performance

The damage analyses for new or well-maintained Federal project levees have traditionally been based on the assumption that, until water stage exceeds the top-of-levee elevation, all damage is eliminated. The without-project impacts of four existing levees were evaluated as specified in Risk-Based Analysis for Flood Damage Reduction Studies, EM 1110-2-1619.

The existing 2,200-foot levee at Long Road is described in Section 1.7.2. The project is well-maintained and is assumed to provide flood protection for up to a 40-year event. The existing levee has a 2.5 percent chance of overtopping during any year. The without-project impact analysis assumed that damages did not occur until water stage exceeds the existing top-of-levee elevation.

The existing Skookumchuck River, Chehalis-Centralia, and Salzer Creek levees are described in Sections 1.7.3, 1.7.4, and 1.7.5, respectively. The levees are not Federal project levees and are of unknown construction. The levees are discontinuous and can be outflanked during flood events, causing performance uncertainties. The without-project damage impact assessment was based on the assumption that all three levees fail to provide flood protection.

3.4.5 Expected Annual Damages

The benefits and costs of a flood reduction study are expressed in average annual equivalents by performing appropriate discounting and annualizing. The expected value of annual damage is equivalent to integrating the annual damage-cumulative probability function. This function is developed by systematically combining the discharge-frequency, the stage-discharge and the stage-damage functions, including uncertainties. These functions are input into the HEC-FDA model. HEC-FDA incorporates uncertainty for risk-based analysis using a Monte-Carlo simulation procedure. Expected annual damages are computed for both without- and with-project conditions. Benefits are the difference between without- and with-project damages.

3.4.6 Expected Annual Exceedance Probability

The "expected annual exceedance probability" (AEP) is the probability of a project or alternative being exceeded in any one year. This performance parameter is derived by tracking the number of "failures" in the Monte Carlo sampling within HEC-FDA, divided by the number of samples. For example, if a levee has a 0.04 probability of being overtopped, it is said that in any given year it has a 1 in 25 chance of failing.

3.4.7 Long Term Risk

Long-term risk characterizes the probability of a plan or alternative being exceeded in a specified period of time. This duration could be the proposed design life of the project, say 50 years, or the duration of a home mortgage, 30 years. For example, within the 30-year life of a conventional home mortgage, the probability of overtopping is 0.27 (or 27 percent). Such information is useful to help the public understand the risk of a given alternative and how it may apply directly to them.

3.4.8 Conditional Probability of Non-Exceedance

Conditional probability of non-exceedance is an index of the likelihood that an alternative will not be exceeded, given the occurrence of a specific hydrometeorological event. This index is similar to the AEP except the Monte Carlo sampling is performed at specific frequencies rather than sampling the entire range of frequencies. An example of the use of this index is, for the Levee Alternative, the probability of containing the 0.01 or the 100-year event is 87 percent. This index is similar to the classic definition of "level of protection" (LOP). The LOP can be expressed as the average return period in years of the largest flood that can be contained by an alternative with a very high conditional non-exceedance probability, say 90 percent (see FEMA Certification below). Under this definition, the example levee alternative above does not meet the definition of a 100-year LOP.

3.4.9 FEMA Certification

The "Guidance on Levee Certification for the National Flood Insurance Program" dated 25 March 1997 was used to evaluate levee alternatives for FEMA certification. The guidance states that a levee is certifiable if the levee elevation meets FEMA criteria of 100-year flood elevation plus 3 feet of freeboard and achieves a conditional probability of non-exceedance of 90 percent. When the FEMA criteria results in a conditional probability of non-exceedance greater than 95 percent, the levee may be certified at the elevation corresponding to 95 percent.

3.5 Without-Project Hydrology and Hydraulics

The study area was divided into eleven damage reaches for evaluating expected flood damages. Hydrologic and hydraulic modeling produced stage-discharge functions with uncertainty for the each damage reach. These damage reaches are listed in Table 3-4.

The historic changes in land use and population in the basin, expected future change, and relative influence on basin hydrology were researched and evaluated. It was determined that much of the upper basins will remain in forestry for the foreseeable future. The largest cities in the basin are Centralia and Chehalis whose populations are expected to grow in the next 15 years from 13,379 and 7,299 to 15,533 and 8,600 respectively. For all of Lewis County, the population has increased from 46,000 to 70,000 from 1972-1998. Expected land use and population changes were determined to not dramatically affect the runoff characteristics for the 895 square mile basin above Grand Mound.

TABLE 3-4 FLOOD ANALYSIS DAMAGE REACHES

Chehalis River

Reach Number	Extent of reach in terms of river miles (RM)	Index Cross-Section for Reach (RM) [1]	Description
Chehalis 1	RM 75.2 to RM 73	RM 74.02	Confluence of Chehalis/Newaukum Rivers to south end of airport
Chehalis 2	RM 73 to RM 71.5	RM 72.80	South end of airport to north end of airport
Chehalis 3	RM 71.5 to RM 69.2	RM 70.30	North end of airport to confluence of Chehalis River/Salzer Creek
Chehalis 4	RM 69.2 to RM 67.45	RM 68.67	Confluence of Chehalis River/Salzer Creek to Mellen St. Bridge
Chehalis 5	RM 67.45 to RM 66.9	RM 67.29	Mellen St. Bridge to confluence of Chehalis/Skookumchuck Rivers
Chehalis 6	RM 66.9 to RM 66.0	RM 66.30	Confluence of Chehalis/Skookumchuck Rivers to downstream end of proposed floodway excavation
Chehalis 7	RM 66.0 to RM 61.8	RM 65.20	Downstream end of proposed floodway excavation to Chehalis/Lincoln Creek confluence

1 - Index cross-sections for Chehalis River reaches are referenced to Chehalis River river mile (RM)

Skookumchuck River

Reach Number	Description of reach	Index Cross-Section for Reach (RM) [2]	Description
Skookumchuck 1	Town of Bucoda	RM 10.56	Town of Bucoda
Skookumchuck 2	RM 5.08 to RM 3.85	RM 5.08	Skookumchuck river mile 5.08 to confluence of Skookumchuck River/Hanaford Creek
Skookumchuck 3	RM 3.84 to RM 1.57	RM 2.415	Confluence of Skookumchuck River/Hanaford Creek to confluence of Skookumchuck River/Coffee Creek
Skookumchuck 4	RM 1.57 to RM 0.22	RM 0.98	Confluence of Skookumchuck River/Coffee Creek to limit of backwater effect from Chehalis River on Skookumchuck River.

2 - Index cross-sections for Skookumchuck River reaches are referenced to Skookumchuck River river mile (RM)

The resultant stage discharge functions for each damage reach are provided in Table 3-5. The uncertainty (the standard deviation of error) was developed by varying Manning's n-value. An unsteady state hydraulic model that accounts for the variability of discharge over time and off-channel storage areas was used to determine the stage discharge functions. A trend in decreasing river mileage with decreasing stage and increasing discharge is typical of steady state models, not unsteady state models; therefore, variable stage and discharge by river mile is found in Table 3-5.

TABLE 3-5 STAGE DISCHARGE FUNCTIONS WITH UNCERTAINTY FOR CHEHALIS AND SKOOKUMCHUCK RIVERS

Reach Chehalis 1				
Index Cross-Section (RM) 74.02				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)*	Standard Deviation of Error (ft)
N/A	N/A	451	150.00	0.00
2	0.500	21,637	173.68	0.49
5	0.200	29,146	175.54	0.52
10	0.100	33,592	176.37	0.51
25	0.040	43,313	177.79	0.47
50	0.020	50,891	178.58	0.42
100	0.010	56,851	179.16	0.40
200	0.005	66,681	179.92	0.40
500	0.002	79,143	180.96	0.56
N/A	N/A	100,000	**183.00**	0.56

Reach Chehalis 2				
Index Cross-Section (RM) 72.80				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.95	0.00
2	0.500	20,231	172.34	0.57
5	0.200	28,237	174.47	0.54
10	0.100	32,582	175.32	0.51

25	0.040	42,186	176.77	0.47
50	0.020	48,736	177.53	0.50
100	0.010	52,747	178.12	0.54
200	0.005	60,574	178.89	0.73
500	0.002	67,166	180.06	1.02
N/A	N/A	90,000	**182.50**	1.02

** All of the elevations given in these tables are referenced to the NGVD 1929 vertical datum.*

Reach Chehalis 3				
Index Cross-Section (RM) 70.30				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.90	0.00
2	0.500	18,648	168.22	0.59
5	0.200	27,623	170.45	0.58
10	0.100	32,011	171.62	0.67
25	0.040	41,029	173.58	0.93
50	0.020	46,116	174.81	1.07
100	0.010	49,638	175.86	1.14
200	0.005	54,031	177.05	1.18
500	0.002	60,445	178.58	1.10
N/A	N/A	80,000	**182.00**	1.10

Reach Chehalis 4				
Index Cross-Section (RM) 68.67				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.90	0.00
2	0.500	18,743	166.90	0.75
5	0.200	27,075	169.82	0.75
10	0.100	31,511	171.14	0.76
25	0.040	40,364	173.22	0.78
50	0.020	47,113	174.50	0.81
100	0.010	52,678	175.59	0.84
200	0.005	59,865	176.81	0.87
500	0.002	69,541	178.36	0.90
N/A	N/A	90,000	**181.50**	0.90

Reach Chehalis 5				
Index Cross-Section (RM) 67.29				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	471	149.90	0.00
2	0.500	18,718	165.45	0.78
5	0.200	27,071	168.36	0.72
10	0.100	31,396	169.59	0.70
25	0.040	40,512	171.42	0.68
50	0.020	47,289	172.47	0.68
100	0.010	53,343	173.40	0.69
200	0.005	61,636	174.40	0.74
500	0.002	72,201	175.72	0.86
N/A	N/A	95,000	**178.50**	0.86

Reach Chehalis 6				
Index Cross-Section (RM) 66.30				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	599	149.80	0.00
2	0.500	24,251	161.89	0.60
5	0.200	34,728	164.10	0.68
10	0.100	41,029	165.28	0.71
25	0.040	52,740	167.03	0.72
50	0.020	61,363	167.96	0.71
100	0.010	70,006	168.81	0.70
200	0.005	80,817	169.81	0.70
500	0.002	96,788	171.06	0.77
N/A	N/A	120,000	**173.00**	0.77

Reach Chehalis 7				
Index Cross-Section (RM) 65.20				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	323	143.75	0.00
2	0.500	24,260	157.97	0.66
5	0.200	34,717	160.67	0.63
10	0.100	41,006	162.01	0.61
25	0.040	52,754	163.70	0.59
50	0.020	61,399	164.67	0.57
100	0.010	70,026	165.51	0.56
200	0.005	80,800	166.50	0.55
500	0.002	96,802	167.77	0.55
N/A	N/A	120,000	**169.50**	0.55

Reach Skookumchuck 1				
Index Cross-Section (RM) 10.56				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	1,263	234.59	0.39
3.1	0.323	4,129	238.59	0.39
6.1	0.164	5,750	239.82	0.40
12.7	0.079	7,147	240.68	0.40
34	0.029	9,238	241.74	0.41
50	0.020	10,258	242.17	0.42
88	0.011	11,428	242.60	0.43
143	0.007	12,500	242.97	0.44
320	0.0031	14,331	243.60	0.46
482	0.0021	15,750	244.04	0.49
N/A	N/A	25,000	**247.00**	0.49

Reach Skookumchuck 2				
Index Cross-Section (RM) 5.08				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	1,319	195.60	0.39
3.1	0.323	4,191	200.89	0.39
6.1	0.164	5,797	202.01	0.36
12.7	0.079	7,355	202.89	0.33
34	0.029	9,393	203.62	0.27
50	0.020	10,561	203.92	0.24
88	0.011	11,804	204.19	0.21
143	0.007	12,940	204.43	0.20
320	0.0031	14,867	204.81	0.20
482	0.0021	16,137	205.04	0.23
N/A	N/A	25,000	**206.70**	0.23

Reach Skookumchuck 3				
Index Cross-Section (RM) 2.415				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	2,039	180.55	0.40
3.1	0.323	5,369	184.00	0.40
6.1	0.164	7,423	185.19	0.37
12.7	0.079	9,322	185.89	0.35
34	0.029	12,147	186.65	0.32
50	0.020	13,792	187.06	0.30
88	0.011	16,183	187.56	0.28
143	0.007	17,885	187.79	0.26
320	0.0031	21,158	188.07	0.24
N/A	N/A	40,000	**189.50**	0.24

Reach Skookumchuck 4				
Index Cross-Section (RM) 0.98				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
3.1	0.323	5,508	171.31	0.68
6.1	0.164	7,623	173.77	0.48
12.7	0.079	9,553	174.36	0.37
34	0.029	12,381	175.21	0.32
50	0.020	14,091	175.84	0.33
88	0.011	16,554	176.39	0.39
143	0.007	18,124	176.90	0.44
320	0.0031	21,195	177.69	0.56
N/A	N/A	40,000	**181.00**	0.56

In addition to the 11 damage reaches incorporated into the UNET hydraulic model, 25 hydraulic storage areas were also modeled. Each storage area was linked in the flood damage assessment model to a single index cross section on either the Chehalis or Skookumchuck Rivers. Table 3-6 lists the modeled storage areas and their linkages.

TABLE 3-6 UNET STORAGE AREAS AND LINKS TO INDEX CROSS-SECTIONS FOR THE HEC-FDA ANALYSIS

Storage Area Number [1]	River cross-section that storage area is hydraulically linked to [2]	Associated Economics Reach [3]	Associated Index Cross-Section [3]
102	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
101	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
100	Chehalis RM 76.70	Chehalis Econ. Reach 1	Chehalis RM 74.02
301	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
302	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
303	Chehalis RM 74.57	Chehalis Econ. Reach 1	Chehalis RM 74.02
2	Chehalis RM 72.80	Chehalis Econ. Reach 2	Chehalis RM 72.80
3	Salzer RM 1.56	Chehalis Econ. Reach 4	Chehalis RM 68.67
4	Salzer RM 1.28	Chehalis Econ. Reach 4	Chehalis RM 68.67
5	Chehalis RM 68.05	Chehalis Econ. Reach 4	Chehalis RM 68.67
501	Chehalis RM 68.67	Chehalis Econ. Reach 4	Chehalis RM 68.67
601	Skookumchuck RM 2.99	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
602	Skookumchuck RM 2.415	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
603	China Creek - N/A [4]	Not included in stage-damage function	N/A
604	China Creek - N/A [4]	Not included in stage-damage function	N/A
605	China Creek - N/A [4]	Not included in stage-damage function	N/A
606	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
608	China Creek - N/A [4]	Not included in stage-damage function	N/A
609	Skookumchuck RM 0.49	Skookumchuck Econ. Reach 4	Skookumchuck RM 0.98
610	Chehalis RM 67.36	Chehalis Econ. Reach 5	Chehalis RM 67.29
701	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
702	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
703	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
704	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
705	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415

1 - Storage Area number as related to the Chehalis UNET model and as delineated on the 1"=400' scale maps.
2 - Stream and river mile most closely associated with overflow to storage area.
3 - Economics reach and associated index cross-section that should be used to link the storage area to hydrologic (discharge-probability) and hydraulic (stage-discharge) information.
4 - Storage area is mostly flooded from China Creek (China Creek is not modeled hydraulically in the UNET model).

Table 3-7 provides the non-damaging elevation (bank-height) used for calculating damages in each study reach. These values are used in the analysis to identify the point at which water leaves the channel and damages may start to accrue.

TABLE 3-7 NON-DAMAGING ELEVATIONS BY REACH

Chehalis River Index Cross-Sections

Reach	**Index Cross-Section** (RM)	**Estimated zero-damage elevation at Index Cross-Section** (feet - msl)
Chehalis 1	74.02	172.5
Chehalis 2	72.80	172.3
Chehalis 3	70.30	169.2
Chehalis 4	68.67	166.2
Chehalis 5	67.29	168.0
Chehalis 6	66.30	164.0
Chehalis 7	65.20	160.0

Bank elevations are in feet (msl) as defined in the UNET model
Estimated zero-damage stage at index cross-section (to be used for stage-damage evaluation)
All of the elevations given in these tables are referenced to the NGVD 1929 vertical datum

Skookumchuck River Index Cross-Sections

Reach	**Index Cross-Section**	**Estimated zero-damage elevation at Index Cross-Section**
	(RM)	(feet - msl)
Skookumchuck 1	10.56	240.6
Skookumchuck 2	5.08	201.5
Skookumchuck 3	2.415	184.5
Skookumchuck 4	0.98	173.0

Bank elevations are in feet (msl) as defined in the UNET model
Estimated zero-damage stage at index cross-section (to be used for stage-damage evaluation)
All of the elevations given in these tables are referenced to the NGVD 1929 vertical datum

Table 3-8 provides the frequency distribution for the annual peak flows for both the Chehalis River and the Skookumchuck River under the without-project condition. The uncertainty associated with these values is computed based on the equivalent length of record, which is 70 years on the Chehalis River and 49 years on the Skookumchuck River.

TABLE 3-8 WITHOUT-PROJECT DISCHARGE-PROBABILITY FUNCTION STATISTICS FOR HEC-FDA

Chehalis River Reaches

Reach	Chehalis 1	Chehalis 2	Chehalis 3	Chehalis 4	Chehalis 5	Chehalis 6	Chehalis 7
Index Cross-Section (RM)	**74.02**	**72.80**	**70.30**	**68.67**	**67.29**	**66.30**	**65.20**
Equivalent Record Length (years)	**70**	**70**	**70**	**70**	**70**	**70**	**70**
Exceedance Probability	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**
0.999	14,516	10,455	5,079	8,549	8,448	11,683	11,688
0.500	21,637	20,231	18,648	18,743	18,718	24,251	24,260
0.200	28,285	27,181	26,573	25,951	26,030	33,620	33,632
0.100	33,715	32,444	31,978	31,429	31,606	40,892	40,906
0.040	41,835	39,889	38,958	39,202	39,539	51,392	51,408
0.020	48,878	46,043	44,257	45,645	46,132	60,233	60,251
0.010	56,851	52,747	49,638	52,678	53,343	70,006	70,026
0.005	65,898	60,078	55,132	60,384	61,259	80,847	80,869
0.002	79,781	70,871	62,613	71,750	72,958	97,060	97,085
0.001	91,971	79,974	68,458	81,352	82,862	110,942	110,970

Skookumchuck River Reaches

Reach	Skookumchuck 1	Skookumchuck 2	Skookumchuck 3	Skookumchuck 4
Index Cross-Section (RM)	**10.56**	**5.08**	**2.42**	**0.98**
Equivalent Record Length (years)	**49**	**49**	**49**	**49**
Exceedance Probability	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**
0.999	573	549	976	1,029
0.500	3,200	3,200	4,050	4,200
0.200	5,109	5,170	6,508	6,713
0.100	6,525	6,645	8,471	8,712
0.040	8,470	8,683	11,358	11,642
0.020	10,025	10,321	13,819	14,133
0.010	11,666	12,057	16,562	16,903
0.005	13,402	13,900	19,620	19,987
0.002	15,856	16,515	24,212	24,606
0.001	17,841	18,638	28,152	28,561

3.6 Expected Without-Project Flood Damages

3.6.1 Residential Structure and Content Damages

In the study area there were approximately 4,000 residential units counted from base maps prepared by the Corps of Engineers, with a depreciated structural value of approximately $383,517,000[3], yielding an average residential unit cost of $97,700. Residential flood inundation damages to structures referenced to the Chehalis River by event are shown in Table 3-9.

TABLE 3-9 CHEHALIS RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT ($)

Flood Event	Structure	Content
25-year	8,487,000	4,949,000
50-year	14,072,000	8,117,000
100-year	19,552,000	11,187,000
500-year	50,953,000	28,297,000

Residential flood inundation damages to structures referenced to the Skookumchuck River by event are shown in Table 3-10.

TABLE 3-10 SKOOKUMCHUCK RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT ($)

Flood Event	Structure	Content
34-year	4,709,000	2,826,000
50-year	6,362,000	3,785,000
88-year	9,086,000	5,349,000
143-year	12,753,000	7,479,000
320-year	18,783,000	10,853,000

3.6.2 Residential Cleanup Cost

Flooding not only causes damage to structures and contents but floodwaters present significant cleanup costs in their aftermath. Floodwaters leave debris, sediment and the dangers of diseases and mycotoxins throughout flooded structures. The cleaning of these structures is a necessary post-flood activity. Cleanup costs for the extraction of floodwaters, dry-out, and decontamination

[3] All dollar values in this section are expressed at 2002 price level.

range from $1 to $4.75 per square foot, with a mean cost of $3.65 and standard deviation of $0.94 based on prior studies. Residential cleanup costs by location are shown in Table 3-11 and Table 3-12.

TABLE 3-11 RESIDENTIAL CLEANUP COSTS CHEHALIS RIVER BY EVENT ($)

Flood Event	Cleanup Costs
25-year	2,976,000
50-year	4,377,000
100-year	5,510,000
500-year	9,481,000

TABLE 3-12 RESIDENTIAL CLEANUP COSTS SKOOKUMCHUCK RIVER BY EVENT ($)

Flood Event	Cleanup Costs
34-year	2,139,000
50-year	2,672,000
88-year	3,454,000
143-year	4,657,000
320-year	5,853,000

3.6.3 Emergency Costs

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

FEMA provides grants to assist individuals and families to find suitable housing when they are displaced in cases of Federally declared disasters. This assistance being directly attributable to the disaster and being an expenditure that would not be undertaken except for the disaster falls clearly under the emergency costs guidance of ER 1105-2-100. Therefore, funds expended by FEMA for Temporary Rental Assistance in the event of flooding are NED flood damages.

Complying with ER 1105-2-100, an Internet database search of FEMA disaster reports for flood and storm damage was performed. In these studies, the average per claim expenditure by FEMA for TRA ranged from $583 to $2,034 with an overall average expenditure of $1,537 per claim. The standard deviation of the average per claim expenditures is $411. For risk-based modeling purposes it is assumed that TRA per claim expenditure is normally distributed with a mean of $1,537 and a standard deviation of $411.

FEMA will reimburse local and state governments and certain nonprofits up to 75 percent of eligible disaster response costs through the public assistance program. It includes all or parts of the following:

- debris removal;
- emergency protective measures;
- road systems and bridges;
- water control facilities;
- public buildings and contents;
- public utilities; and
- parks, recreational and other activities of a governmental nature.

These costs, as well as the 25 percent contribution by local and state governments and the nonprofits, are eligible NED emergency costs under ER 1105-2-100. Again, care must be taken to make sure double counting does not occur between public assistance expenditures and structural or other damage categories.

Total Public Assistance (PA) expenditures were found to be 3.01 times the expenditures on TRA. On an individual disaster basis, PA expenditures range from zero to an unknown factor based on the FEMA reports, with the highest reported factor of 9.45. Applying the four standard deviation rule, common to other HEC-FDA variance protocols, the risked-based function of PA is a mean damage of 3.01 times the individual TRA expenditure with a normal deviate of a multiple of 2.36 bounded by zero damage.

Emergency costs (temporary relocation and public assistance expenditures) by flood event and river are shown in Table 3-13 and Table 3-14.

TABLE 3-13 EMERGENCY COSTS – CHEHALIS RIVER ($)

Flood Event	Temporary Relocation Assistance	Public Assistance
25-year	419,000	1,456,000
50-year	675,000	2,345,000
100-year	924,000	3,212,000
500-year	2,109,000	7,327,000

TABLE 3-14 EMERGENCY COSTS – SKOOKUMCHUCK RIVER ($)

Flood Event	Temporary Relocation Assistance	Public Assistance
34-year	249,000	864,000
50-year	335,000	1,161,000
88-year	472,000	1,641,000
143-year	654,000	2,274,000
320-year	943,000	3,276,000

3.6.4 Commercial and Industrial Inundation Damage

Within the study area there are approximately 300 commercial and industrial properties with a total floor space of approximately 2,507,000 square feet. The total nominal depreciated structure value of these properties is $146,730,000 with a total content value of $189,575,000. The average square footage cost of these structures is $46. Overall content-to-structure value ratio for these structures is 129.2 percent. Flood inundation damages to these structures by river and event are shown in Table 3-15 and Table 3-16.

TABLE 3-15 CHEHALIS COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE BY EVENT ($)

Flood Event	Structure Damage	Content Damage
25-year	1,685,000	1,709,000
50-year	11,495,000	14,620,000
100-year	14,735,000	20,116,000
500-year	25,153,000	39,367,000

TABLE 3-16 SKOOKUMCHUCK COMMERCIAL/INDUSTRIAL INUNDATION DAMAGE BY EVENT ($)

Flood Event	Structure Damage	Content Damage
34-year	2,481,000	2,122,000
50-year	2,927,000	2,602,000
88-year	4,317,000	4,020,000
143-year	5,007,000	5,345,000
320-year	6,114,000	7,204,000

3.6.5 Commercial and Industrial Cleanup Costs

Nonresidential cleanup costs are limited to public, commercial, and retail structures normally expected to engage with the public, e.g., restaurants, retail stores, office structures and other such businesses. Cleanup costs are not anticipated to occur with light industrial or other non-public commercial enterprises. Cleanup costs for commercial and industrial structures are presented in Table 3-17 and Table 3-18.

TABLE 3-17 CHEHALIS NONRESIDENTIAL CLEANUP COSTS BY EVENT ($)

Flood Event	Cleanup Costs
25-year	310,000
50-year	2,905,000
100-year	3,768,000
500-year	5,609,000

TABLE 3-18 SKOOKUMCHUCK NONRESIDENTIAL CLEANUP COSTS BY EVENT ($)

Flood Event	Cleanup Costs
34-year	461,000
50-year	481,000
88-year	643,000
143-year	1,004,000
320-year	1,022,000

3.6.6 Public Inundation Damage

The floodplain survey identified 138 public structures whose locations are shown in Table 5 of the Economics appendix. These structures cover an area of approximately 1,109,500 square feet and have a depreciated structural value of $69,040,000 or approximately $68 per square foot. Each public structure's content value was determined individually based on its function in coordination with past Corps evaluations of similar functions. The total for all public structures equals $64,798,000, which yields an average content-to-structure ratio of 94 percent. Flood inundation damages to these structures by river and event are shown in Tables 3-19 and 3-20.

TABLE 3-19 CHEHALIS PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT ($)

Flood Event	Structure Damage	Content Damage
25-year	537,000	359,000
50-year	3,965,000	3,267,000
100-year	4,978,000	4,050,000
500-year	10,239,000	9,836,000

TABLE 3-20 SKOOKUMCHUCK PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT ($)

Flood Event	Structure Damage	Content Damage
34-year	1,188,000	1,364,000
50-year	1,621,000	1,684,000
88-year	1,767,000	1,975,000
143-year	2,989,000	2,837,000
320-year	3,453,000	3,788,000

Cleanup costs for public structures are presented in Table 3-21 and Table 3-22.

TABLE 3-21 CHEHALIS PUBLIC STRUCTURE CLEANUP COSTS BY EVENT ($)

Flood Event	Cleanup Costs
25-year	16,000
50-year	379,000
100-year	422,000
500-year	1,398,000

TABLE 3-22 SKOOKUMCHUCK PUBLIC STRUCTURE CLEANUP BY EVENT ($)

Flood Event	Cleanup Costs
34-year	132,000
50-year	242,000
88-year	258,000
143-year	397,000
320-year	543,000

3.6.7 Inundation Damage Summary

Table 3-23, following, presents a summary of the previously discussed damages.

TABLE 3-23 STRUCTURAL DAMAGE SUMMARY ($)

Chehalis River

Flood Event	Residential			Commercial			Public					
	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
25-year	8,487,000	4,949,000	2,976,000	1,685,000	1,709,000	310,000	537,000	359,000	16,000	419,000	1,456,000	22,903,000
50-year	14,072,000	8,117,000	4,377,000	11,495,000	14,620,000	2,905,000	3,965,000	3,267,000	379,000	675,000	2,345,000	66,217,000
100-year	19,552,000	11,187,000	5,510,000	14,735,000	20,116,000	3,768,000	4,978,000	4,050,000	422,000	924,000	3,212,000	88,454,000
500-year	50,953,000	28,297,000	9,481,000	25,153,000	39,367,000	5,609,000	10,239,000	9,836,000	1,398,000	2,109,000	7,327,000	189,769,000

Skookumchuck River

Flood Event	Residential			Commercial			Public					
	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	Total
34-year	4,709,000	2,826,000	2,139,000	2,481,000	2,122,000	461,000	1,188,000	1,364,000	132,000	249,000	864,000	18,535,000
50-year	6,362,000	3,785,000	2,672,000	2,927,000	2,602,000	481,000	1,621,000	1,684,000	242,000	335,000	1,161,000	23,872,000
88-year	9,086,000	5,349,000	3,454,000	4,317,000	4,020,000	643,000	1,767,000	1,975,000	258,000	472,000	1,641,000	32,982,000
143-year	12,753,000	7,479,000	4,657,000	5,007,000	5,345,000	1,004,000	2,989,000	2,837,000	397,000	654,000	2,274,000	45,396,000
320-year	18,783,000	10,853,000	5,853,000	6,114,000	7,204,000	1,022,000	3,453,000	3,788,000	543,000	943,000	3,276,000	61,832,000

3.6.8 Residential, Nonresidential, and Public HEC-FDA Model Results

Stage-damage functions were developed for each damage category and were combined with the hydrology and hydraulic information into the HEC-FDA model for computation of the expected annual damages with uncertainty. The results of the HEC-FDA model are shown in Table 3-25. Total expected annual damage on the Chehalis River is $6,590,730 and $2,254,190 for the Skookumchuck River. The relative damage by category is shown below in Table 3-24 for each river.

TABLE 3-24 EXPECTED ANNUAL DAMAGE BY CATEGORY

Category	Chehalis River		Skookumchuck River	
	$ Damage	Percentage	$ Damage	Percentage
Residential				
Structure	1,789,290	27.15	663,700	29.44
Content	1,036,310	15.72	394,210	17.49
Cleanup	588,290	8.93	278,600	12.36
Nonresidential				
Structure	1,002,610	15.21	352,340	15.63
Content	1,119,860	16.99	311,300	13.81
Cleanup	239,120	3.63	62,240	2.76
Public				
Structure	229,080	3.48	22,800	1.01
Content	189,360	2.87	15,290	0.68
Cleanup	24,490	0.37	4,270	0.19
TRA	83,250	1.26	33,380	1.48
PA	289,070	4.39	116,060	5.15
TOTAL*	6,590,730	100.00	2,254,190	100.00

**Total may not add due to rounding*

TABLE 3-25 WITHOUT-PROJECT EXPECTED ANNUAL DAMAGES BY REACH

Stream	Reach	Damage Categories (Damage in $1,000s)											
		Commercial Cleanup	Commercial Contents	Commercial Structures	Public Assistance	Residential Cleanup	Residential Contents	Residential Structures	Temporary Relocation Assistance	Public Cleanup	Public Contents	Public Structures	Total
TOTAL ALL STREAMS		**301.36**	**1431.16**	**1354.95**	**405.13**	**866.89**	**1430.52**	**2452.99**	**116.63**	**28.76**	**204.65**	**251.88**	**8844.92**

3.6.9 Agricultural Flood Damages

The Planning Guidance Notebook of the Corps (ER 1105-2-100) has specific rules on the treatment of agricultural crops. Agricultural crops are divided into two categories. The first is basic crops and the second is other crops. The guidance indicates that the loss in income is only applicable to basic crops and that damages to other crops are limited to the variable costs per the Corps' IWR Report 87-R-10. These conventions are the basis of the current agricultural analysis.

With no change in cropping patterns anticipated, benefits are restricted to damage reduction benefits. Damage reduction benefits are the increases in net income due to the plan, as measured by farm budget analysis. These income increases may result from increased crop yields and decreased production costs.

The study area contains approximately 2,200 acres of agricultural lands that are subject to flooding. Three crops are listed as the principal for the study area, as shown in Table 3-26.

TABLE 3-26 LEWIS COUNTY CROP HARVESTS – 1996

Crop	Acres	Percentage
Hay	1,320	60%
Green Peas – Process	550	15%
Sweet Corn – Process	330	25%
Total	2,200	100%

Source: Cooperative Extension Office – Lewis County

Agricultural acreage for the study is treated as having a composite crop based on the above three crops. The use of a composite crop was required because no formal survey of agricultural production by location was conducted. Agricultural production acreage and locations were ascertained through the use of an overlay of floodplain boundaries on aerial photography of agricultural production acreage. Farm budgets were obtained from the Cooperative Extension, Washington State University, and damages computed based on the monthly probability of flood occurrence. Through farm budget analysis the per-acre damage has been determined at the following values for the crops of the study area (Table 3-27).

TABLE 3-27 PER ACRE CROP DAMAGE

Crop Type	Per Acre Damage ($)	Weight (%)	Weighted Loss ($)
Hay	220.48	60	132
Corn	52.77	25	13
Peas	61.60	15	9
Total per acre loss			155

The requirement to restore agricultural land after flood inundation necessitates the reworking of fields at twice the level of normal land preparation and the application of additional cycles of fertilizer, weed control, and pest control, based upon consultation with the Lewis County Farm Advisor. The estimated net cost for agricultural land restoration on a per acre basis is presented in Table 3-28.

TABLE 3-28 PER ACRE FIELD CROPLAND RESTORATION COSTS

Operation	$ Cost/per Acre
Disc (4 times)	60.00
Subsoil	9.00
Chisel Field (2 times)	15.00
Landplane (2 times)	24.00
Fertilize	64.00
Weed Control	45.00
Pest Control	26.00
Total	$243.00

In addition to restoration costs, it is assumed that post-flood cleanup of debris and other matter will cost $20 per acre for all agricultural land.

3.6.10 Summary of Agricultural Flood Damages

Agricultural damages by flood event are shown in Table 3-29.

TABLE 3-29 AGRICULTURAL DAMAGES BY FLOOD EVENT ($)

Flood Event	Crop Damage	Land Restoration	Cleanup	Total
6-year	52,000	82,000	6,000	140,000
10-year	227,000	356,000	29,000	612,000
100-year	341,000	534,000	44,000	919,000
500-year	341,000	534,000	44,000	919,000

Expected annual agricultural damages were calculated using HEC-EAD. The results of the HEC-EAD model for agricultural damages are shown in Table 3-30.

TABLE 3-30 EXPECTED ANNUAL AGRICULTURAL DAMAGE ($)

Category	Expected Annual Damage
Crop Damage	42,930
Land Restoration Costs	67,420
Cleanup Costs	5,500
Total	115,850

3.6.11 Transportation Related Damages

Chehalis River flooding presents a serious threat to interstate commerce. Past floods have necessitated the closure of I-5 to vehicle traffic, as well as the closures of two major railroad lines (Burlington Northern Santa Fe and Union Pacific Railroads). The costs associated with travel delays, diversion costs, and cleanup costs are valid project concerns on a National Economic Development (NED) basis. The following paragraphs explore these transportation related damages.

Mapping of the floodplains indicates that I-5 will be subject to closure from floods, and will be closed between Centralia and Chehalis. This mapping also indicates that a diversion around the floodplain will be required. This diversion will be quite lengthy, approximately 101 miles. The diversion, going southbound, involves leaving I-5 at its junction with SR-507 traveling northeast to Yelm, transitioning to SR-702 east and proceeding to SR-7. Proceeding southward on SR-7 for approximately 35 miles to Morton where a connection to US-12 westbound is taken to return to I-5. Northbound traffic would reverse the route.

The estimate of the traffic count involved in the diversion is taken from the WSDOT's Trips System for 2000. Average total daily through traffic between state route milepost 81.21 (before ramp SR-507) and milepost 68.94 (after ramp SR-12) Bow Hill Road is estimated at 51,000. In the immediate vicinity of the cities of Chehalis and Centralia average daily volume reaches approximately 62,000, but this added traffic is assumed to not leave the area. The affected daily traffic for the analysis is a base flow traffic rate of 51,000. Further, the analysis employs the Trips System indication that 18 percent of the traffic is truck as measured by the Bow Hill Road indicator.

The analysis of transportation delays and costs was carried forward by employing the procedure in ER 1105-2-100, Appendix D, and as shown in Table D-4: Value of Time (VOT) Saved by Trip Length and Purpose of that appendix, with a measure of median household income for Lewis County of $32,557 (1997 U.S. Bureau of the Census). A per vehicle passenger rate of 1.15 is assumed for the analysis. The diversion is estimated to take 3.16 hours, assuming a 32 mph diversion speed. Mileage rates are further assumed to be 34.5 and 48 cents for cars and truck, respectively. The above factors yield the following transportation related damages (Table 3-31).

TABLE 3-31 INTERSTATE 5 DAILY TRANSPORTATION DELAY COSTS WHEN FLOODED

								Daily Costs		
	Value of Time $/hr	Occupancy Factor	Occ. Weighted VOT	Time Costs	Diversion Mileage Cost	Total Cost per Vehicle	Vehicle Units	Time	Mileage	Total
Cars	8.42	1.15	9.68	$30.57	$34.85	$65.41	44880	$1,371,783	$1,563,844	$2,935,627
Trucks	8.42	1	8.42	$26.58	$48.48	$75.06	6120	$162,662	$296,698	$459,360
							TOTAL	$1,534,445	$1,860,541	$3,394,986

Transportation delay costs due to flood impacts are shown in the table below based on estimated closure durations for flooding and cleanup for Chehalis-Centralia area.

TABLE 3-32 INTERSTATE 5 DAMAGES BY FLOOD EVENT

Flood Event	I-5 Closure in Days	Total Cost ($)
25	0	0
50	4	13,579,945
100	4.5	15,277,438
200	5	16,974,931
500	6	20,369,917

Applying these flood related values to the HEC-EAD model yields an estimate of equivalent annual damage of $476,300. Based upon a planned elevation of I-5 in the without-project condition, traffic delays were assumed to occur only through 2012 (estimated completion of elevation). Average annual traffic delay damages through 2012 amount to $129,100.

3.6.12 Avoided Cost of Interstate 5 Raising

I-5 has been particularly susceptible to inundation in the project area and has been shut down twice in the last 10-years with floodwater up to 8 feet in depth over the roadway (closed for 4-days in 1996, and 1 day in 1990). Because of safety issues and the tremendous economic impacts associated with I-5 closures, WSDOT has stated that I-5 will require raising to above the 100-year flood elevation at the same time as other Federally mandated widening and upgrading is accomplished. The incremental cost of raising the freeway under the without-project condition has been estimated at $44 million.

The plan for I-5 indicates that implementation would take place after the base year of any of the alternatives and would be finished in 2012. Discounting this future expenditure yields a current base year value of $32,686,200. Amortization of this avoided cost yields average annual savings of $2,110,000. Under with-project conditions and at least 100-year protection to this section of I-5, the incremental costs of raising the freeway would not need to be expended. Under this scenario, the avoided cost can be included as an NED benefit (though it is not included in the accounting of "damages").

3.6.13 Rail Freight Flood Impacts

The basis for the examination of NED costs from rail disruptions is the Pharos Corporation's "Chehalis River Flood Reduction Project" study of 2001 for Lewis County (Appendix D). The study reports that the Burlington Northern Santa Fe Railway (BNSF) owns and operates the rail line running north and south within the Chehalis floodplain. This double mainline track parallels I-5 within the floodplain and continues south to Eugene, Oregon, where it connects with the Union Pacific Railroad. BNSF traffic typically ranges from 30 to 40 trains per day, and trains are primarily composed of grain for export; forest products imported from Canada; and domestic shipments of metals and minerals, coal, chemicals, automobiles and consumer goods.

The second major rail service connected to the study area is the Union Pacific Railroad (UPRR). Although UPRR lines do not run directly within the floodplain, the UPRR operates its own trains over the BNSF's track in the Chehalis corridor to access and route shipments to many of their western Washington rail customers via trackage rights. The number of UPRR trains utilizing the Chehalis corridor amounts to 18 to 20 trains per day.

Based on annual reports published by BNSF and UPRR and assuming a per rail car carrying weight of 268,000 pounds, the estimated daily rail car transit rate is 1,230 in the Chehalis corridor. In the event of a prolonged rail outage, these rail lines may be forced to reroute traffic via routes in either Pasco or Spokane, Washington. The shortest alternate route bypassing the Chehalis floodplain would increase trip mileage by 350 miles. BNSF estimates that the average mileage payout for equipment rent/car ownership at approximately $0.40 per mile. Given the mileage increase of the shortest alternate route, the additional cost per railcar diverted equals $140.00 or $172,200 per day for all railcars being diverted.

Furthermore, depending on the alternate line's available capacity, the rerouted cars would likely be subject to a minimum of 48 hours of extended transit time for the additional 350-mile trip. Estimating from the 1999 primary carriers annual reports, the approximate average daily equipment expense per railcar is $23.30. On an estimated daily volume of 1,230 railcars the rail lines would incur additional daily equipment expenses totaling $28,659.

Potential flood related operation and equipment expenses to the rail lines by flood event are shown below in Table 3-33, Railroad Damages by Flood Event.

TABLE 3-33 RAILROAD DAMAGES BY FLOOD EVENT

Flood Event	Duration (days)	Railcars Affected	Reroute Expenses ($)	Equipment Expenses ($)	Total ($)
50-year	4	4920	688,800	229,272	918,072
100-year	4.5	5535	774,900	257,931	1,032,831
200-year	5	6150	861,000	286,590	1,147,590
500-year	6	7380	1,033,200	343,908	1,377,108

Railroad damages were modeled in HEC-EAD to estimate expected annual damages. Applying a 25-year non-damaging event to the HEC-EAD model yields expected annual damage for railroads of $32,200.

3.7 Expected Annual Damage Summary

Table 3-34 summarizes the expected annual damages from flooding along the Chehalis and Skookumchuck Rivers developed by the preceding analyses.

TABLE 3-34 EXPECTED ANNUAL DAMAGE SUMMARY

Damage Category	Expected Annual Damage ($)
Structures	4,059,810
Contents	3,066,330
Cleanup	1,197,010
Temporary Relocation Assistance	116,630
Public Assistance	405,130
Agriculture	115,850
Interstate 5 Delays	129,100
Fill Costs Associated with Elevating I-5	0
Railroad Delays	32,200
Total	**$9,122,060**

4. PLAN FORMULATION

4.1 Problems and Opportunities

Specific problems addressed by the study include:

- flood inundation damages to structures and contents;
- transportation delays as a result of flooding; and
- quantity and quality of aquatic and riparian fish and wildlife habitats.

Opportunities to address these problems include:

- implementation of flood damage reduction measures in study area to protect structures; and
- implementation of environmental measures to protect and restore sensitive fish and wildlife habitats in study area.

4.2 Planning Objectives and Plan Formulation Overview

4.2.1 Planning Objectives

The objectives of this project are to:

Engineering Objectives:

1. reduce flood hazards in the project area to the maximum extent practicable.
2. decrease the transportation closures during flooding on I-5 and other critical transportation corridors to the maximum extent practicable;
3. avoid increasing flood risks downstream from the project area; and
4. avoid decreasing any existing low flow benefits provided by Skookumchuck Dam.

Economic Objectives:

5. reduce flood damage costs in the project area to the maximum extent practicable;
6. reduce transportation delay costs in the study area to the maximum extent practicable; and

7. be cost-effective for both construction and maintenance.

Environmental Objectives:

8. avoid adverse impacts to the aquatic environment to the extent practicable and minimize and compensate for unavoidable adverse impacts to the aquatic environment;
9. incorporate appropriate fish and wildlife habitat creation, enhancement, and restoration measures to the extent practicable; and
10. comply with all Federal, state, and local regulations, including environmental regulations.

4.2.2 Plan Formulation Overview

To accomplish these objectives, a range of alternative plans were identified and evaluated. This formulation and evaluation process was conducted in three phases.

- *Phase 1:* For the study, seven preliminary alternatives were identified from previous studies, the local sponsor, interested agencies, and tribes. The preliminary alternatives were screened by their capacity to address planning objectives. Those alternatives that addressed objectives were carried forward for further modeling and evaluation.

- *Phase 2:* The final set of alternatives was more rigorously evaluated and screened based upon risk-based benefit-cost analysis utilizing the HEC-FDA program. All of the alternatives included in the Phase 2 analysis were designed to protect during the 100-year frequency flow. The final alternatives were evaluated both independently and in select combinations. This served to identify the first added elements as well as the performance and residual damages of combinations. This analysis identified the features for the NED plan and supported selection of the preliminary recommended plan.

- *Phase 3:* Finally, in the third phase, several different sizes of the NED plan features were evaluated for optimization of project size.

4.3 Description of Preliminary Solutions

Seven preliminary alternatives were identified for inclusion in the initial plan formulation and evaluation phase. These alternatives were based upon previous studies, new local studies, and interagency and tribal coordination. The preliminary alternatives are listed in Table 4-1 and are described in the paragraphs that follow.

TABLE 4-1 PRELIMINARY ALTERNATIVES

Alternative 1	No- Action Alternative
Alternative 2	Skookumchuck Dam Modifications Alternative
Alternative 3	Overbank Excavation and Flowway Bypass Alternative
Alternative 4	Levee System Alternative
Alternative 5	Flow Restrictors Alternative
Alternative 6	Non-Structural Alternative
Alternative 7	Interagency Alternative

4.3.1 Alternative #1 – No Action Alternative

Under the no action alternative, no project features are implemented. Technical studies conducted in the General Reevaluation Study indicate that this alternative would result in continued flooding in the study area. With no action, expected annual flood damages are estimated at $9,122,060. In addition, I-5 would have to be raised at an annual cost of $2,110,000.

4.3.2 Alternative #2 – Skookumchuck Dam Modifications

4.3.2.1 Objective

This alternative is intended to provide reductions in flooding along the Skookumchuck River. This is needed to address flooding problems in the area including in the town of Bucoda and the City of Centralia. This alternative may also provide some reduction in discharge in the Chehalis River downstream of the confluence with the Skookumchuck River.

4.3.2.2 Relation to Previously Authorized Project

Congress authorized a project modifying Skookumchuck Dam in 1986. The project recommended in the 1984 feasibility report envisioned modification of the existing, private, water supply dam on the Skookumchuck River to provide a maximum of 28,500 ac-ft of flood storage, reducing flood damages in the Skookumchuck valley, the town of Bucoda, and the City of Centralia. Most of the alternative configurations of dam modifications evaluated in this study (and described below) are improvements on the originally authorized project.

4.3.2.3 Description

Skookumchuck Dam is located on the Skookumchuck River at approximately RM 22. The dam was constructed in 1970 to supply water for the Centralia steam generating plant. The dam is an earthfill structure approximately 190 feet high with the top of the dam at elevation 497 feet. The dam has a 130-foot-wide uncontrolled spillway, on the left abutment, with a crest at elevation 477 feet. Outlet works consist of two 24-inch Howell-Bunger valves with a combined discharge capacity of 220 cubic feet per second (cfs).

This alternative consists of modifications to the existing Skookumchuck Dam for the purpose of providing flood control. The current dam has an uncontrolled spillway at elevation 477 feet and a limited capacity to release water from the reservoir when the pool is lower than elevation 477 feet. As a result, the current project configuration provides little flood control regulation since most incoming flow is passed through the reservoir with little attenuation. There is currently about 11,000 ac-ft of storage space available in the reservoir between elevation 455 feet (proposed lower elevation of flood control pool) and 477 feet.

Future modifications to the dam for flood control purposes could include modification of the outlet works to allow a maximum flood storage pool of elevation 492 feet (compared to the current maximum flood pool elevation of 477 feet). Modifications would also likely include additional low-level outlet works to allow the rapid evacuation of stored water above an elevation of about 455 feet. Storage of water to a maximum pool elevation of 492 feet would add an additional 9,000 ac-ft of flood control storage to the reservoir such that the total storage space between elevations 455 and 492 feet would be about 20,000 ac-ft.

4.3.2.4 Dam Safety Considerations

Any proposed modifications to Skookumchuck Dam must enable the project to safely pass the Probable Maximum Flood (PMF) outflow of 32,500 cfs at a maximum design pool elevation of 492 feet. The dam embankment elevation must be sufficient to prevent overtopping during the PMF, while accounting for contingencies such as surcharge, wind wave runup, and embankment settlement. The dam embankment currently has a top elevation of 497 feet. The maximum design pool level is at elevation 492 feet. Five feet between the top of the dam and the maximum pool level is considered adequate freeboard.

The Corps conducted additional studies during the General Reevaluation Study to assess the seismic stability of the dam. This was due to uncertainties about the nature of foundation materials and properties, foundation liquefaction, and stability. In the investigations conducted by the Corps in 2001, based on recent seismic information, the study concluded that the sandy gravel soils underlying the silts appear to be liquefiable under all design Maximum Credible Earthquake (MCE) ground motions. In 2001, a similar stability analysis was performed utilizing subsurface explorations, the liquefaction data, and seismic hazard analysis from recent studies. This included evaluation of the existing static and post-seismic stability of the downstream slopes of the dam and berm using a limit-equilibrium approach. The extent of liquefied soils is uncertain beyond the area of investigations with Becker and SPT borings, thus slope failures were calculated for five different ranges of liquefied soils. The calculations indicate a factor-of-safety below 1.0 for conditions where liquefied soils are present from the core to the toe of the downstream berm. This is an issue that will be addressed by FERC and the current owner of the dam prior to the local sponsor taking ownership.

4.3.2.5 Reservoir Regulation Considerations

The Corps developed a preliminary flood control operation rule curve as part of its flood control operations investigation (USACE 1992). The USACE rule curve provided flood control storage of 11,900 ac-ft between elevations 453 and 477 feet, from 1 November to 1 February. After 1 February, the reservoir would be allowed to refill. Drawdown of the reservoir would begin each year in early to mid-September and would continue until elevation 453 feet was reached, usually around the first of November.

The current proposed dam modifications would provide flood control storage of approximately 20,000 ac-ft between pool elevation 455 and 492 feet. A new reservoir operation rule curve similar to the current Corps rule curve will have to be developed for the flood control operation during the finalization of the dam water control plan.

4.3.2.6 Skookumchuck Dam Modifications, Sub-alternatives

Four basic alternatives for modifications at Skookumchuck Dam are being studied, as follows.

- Alternative 2B1 – Spillway Sluices with Gates and Rubber Crest Weir
- Alternative 2B2 – Short Tunnel with Gates and Rubber Crest Weir
- Alternative 2B3 – Tainter Gates in Rock Cut with Rubber Crest Weir
- Alternative 2B4 – Tainter Gates Rock Cut with Emergency Spillway

These alternatives were chosen based on analysis and findings from previous studies. The following sections describe each of the alternatives in greater detail.

4.3.2.7 Alternative 2B1 - Spillway Sluices with Gates and Rubber Crest Weir

In this alternative, a section of the existing ogee spillway would be removed and a new spillway section containing three gated sluices would be constructed. The three sluice gates would each be approximately 10 feet wide and 10 feet high. An emergency bulkhead would be installed to allow for dewatering of the gates.

Design Objectives and Description:

- Pass PMF discharge event of 32,500 cfs
- Provide and maintain dam safety under all conditions
- Provide flood control storage
- Maintain provision of existing water supply demands
- Modify spillway to enable the use of the 15 feet of reservoir storage between elevation 477 and 492 feet for flood control and provide the PMF discharge capability
- Add a 15-foot-high by 130-foot-wide inflatable rubber weir to the existing spillway crest
- Excavate and lower the spillway ogee crest to make room for the new spillway sluices

4.3.2.8 Alternative 2B2 – Short Tunnel with Gates and Rubber Crest Weir

This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a short tunnel constructed in the rock forming the left abutment of the embankment dam. The intake would have two 8-foot by 11-foot slide gates. The tunnel would vary in shape from a 16-foot-diameter horseshoe to a 10-foot-diameter conduit. Flow would discharge through the tunnel into the existing spillway chute.

Design Objectives and Description:

- Due to concerns that the left abutment rock may be highly weathered or fractured, and thus not very suitable for tunneling, it was assumed that the tunnel would be constructed as a cut and cover structure.
- Cut down trench in stages with rock anchors being placed prior to the next excavation cut

- Construct a cast-in-place concrete tunnel at the bottom of the trench.
- Excavate approximately 12,600 cubic yards of rock for tunnel construction.
- Construct concrete walls at both the upstream and downstream ends of the trench and backfill the space between
- Drill new grout curtain holes to prevent the flow of water through the dam embankment
- The intake structure would be a freestanding tower with an invert elevation of 438 feet, and a top deck at elevation 497 feet.
- The tower would be approximately 28 by 30 feet in plan, and would contain the two control gates, two guard gates, and all the necessary hydraulic control equipment.
- An inclined trashrack would be provided at the tunnel entrance, as would bulkhead slots.
- The existing uncontrolled overflow spillway would be modified, and a 15-foot high inflatable rubber weir would be constructed on top.
- The outlet tunnel would be designed to discharge up to 8000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway.

4.3.2.9 Alternative 2B3 – Tainter Gates in Rock Cut with Rubber Crest Weir

This alternative is similar to Alternative 2B2 described above. This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a channel constructed in the rock forming the left abutment of the dam. The intake would have a single 16-foot wide by 15-foot high tainter gate. Flow would discharge through the channel into the existing spillway chute.

Design Objectives and Description:

- A cast-in-place concrete lining would be constructed.
- Approximately 12,600 cubic yards of rock would have to be excavated for channel construction. A bridge structure would be incorporated to allow vehicles to pass over the outlet channel.
- New grout curtain holes would be drilled to prevent the flow of water through the dam embankment.
- The intake structure would be a freestanding tower with an invert elevation of 438 feet, and a top deck at elevation 497 feet.
- An inclined trashrack would be provided at the tunnel entrance, as would bulkhead slots.

- The existing uncontrolled overflow spillway would be modified, and a 15-foot high inflatable rubber weir would be constructed on top.
- The outlet channel would be designed to discharge up to 8000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway.

4.3.2.10 Alternative 2B4 – Tainter Gates in Rock Cut with Emergency Spillway

This alternative includes a rock cut and tainter gates similar to Alternative 2B3; however, the rock cut and gates would be sized to pass the entire PMF flow. The existing overflow spillway would be raised to the reservoir freeboard elevation, and would serve as an emergency spillway. Alternative 2B4 consists of four main features:

- Construction of a new reinforced concrete control structure directly in the existing spillway discharge chute (SDC).
- Reconstruction of the existing SDC.
- Excavation of a new intake channel upstream of the new control structure.
- Excavation and rock bolting of SDC rock walls.

Advantages of Skookumchuck Dam Modifications Alternative 2B4 include:

- 2B4 is the only alternative that would pass the revised PMF of 32,500 cfs at a pool elevation of 492 feet while also providing a means of emergency control.
- Although 2B4 would probably require replacement of the existing low flow intake access bridge pier, it provides excellent unrestricted maintenance access to the new control structure and eliminates need for maintenance activities in the vicinity of the existing skewed access bridge and spillway ‘bottleneck.’
- Relocating and lowering the crest of the spillway ogee 34 feet essentially eliminates the “fill and spill” method of operation that has been used since dam construction. 2B4 would allow the dam to store spring inflows for possible summer fish augmentation releases.
- 2B4 provides improved hydraulic discharge conditions by allowing releases directly into the SDC.
- 2B4 provides a new low flow fish passage pipe.

4.3.3 Alternative #3 – Overbank Excavation and Flowway Bypass

4.3.3.1 Objective

The flowway bypass and overbank excavation features were developed in an effort to 1) reduce flooding in the City of Chehalis and to prevent SR-6 from overtopping in large floods through floodplain modification; and 2) to reduce flooding of I-5 and the City of Centralia by overbank excavation to increase channel capacity in the vicinity of Centralia. It was anticipated that the combination of these two features would provide significant flood damage reduction in these areas.

4.3.3.2 Relation to Previously Authorized Project

In order to provide flood damage reduction along the Skookumchuck River, these features were proposed for implementation in combination with modifications to Skookumchuck Dam.

4.3.3.3 Description

This floodplain modification alternative would consist of three primary components. The first component, common to all alternative variations of this feature, is modifications to Skookumchuck Dam to provide flood control storage. The second component is floodway modifications in the vicinity of Mellen Street bridge between RM 65.90 and RM 68.25. One of the alternatives would also include modifications to the existing Mellen Street bridge abutment. The third component is floodplain modifications in the vicinity of Chehalis/SR-6 to provide flood flow bypass and storage.

4.3.3.4 Chehalis/SR-6 Area Floodplain Modifications

Design Objectives and Description:

- Reduce flooding in the City of Chehalis between the 13th Street interchange and the Main Street (SR-6) interchange, along I-5
- Eliminate floodwaters from the Newaukum River from spilling through Stan Hedwall Park and into nearby Dillenbaugh Creek and then through the railroad openings to the east side of I-5.

Alternative Features:

- SR-6 Bridge Modification
- SR-6 Flood Bypass
- Chehalis Flowway Bypass Berm

4.3.3.4.1 SR-6 Bridge Area Modifications

- Floodway excavation on the Chehalis River from shortly downstream of the SR-6 bridge (RM 74.55) to the mouth of the Newaukum River (Chehalis RM 75.08)
- Excavate approximately 800,000 cubic yards of material from the floodway in this reach of the Chehalis River (would result in approximately 1.5 feet of peak flood stage reduction on the lower 1.5-mile reach of the Newaukum River and Dillenbaugh Creek east of I-5, for a flood event such as the February 1996 event; floodway excavation in this area would need to be substantially extended and increased downstream if further flood stage reduction is required.)
- Reconstruct the right bank approach of the existing SR-6 bridge
- Excavate floodway in the SR-6 bridge area (would also likely require extension of the abandoned Riverside Road bridge 0.25 mile upstream).
- Due to the large volume of excavation required, and the high cost related to the structural work, and the potential magnitude of environmental impact, this alternative was not considered further.
- The SR-6 flood bypass option discussed below provides a similar or better flood reduction benefit in the Chehalis area for less cost and with less environmental impact.

4.3.3.4.2 SR-6 Flood Bypass Works

- Modify a 1,500-foot section of the SR-6 roadway adjacent to an existing oxbow lake at RM 77 to prevent overtopping of SR-6 during floods up to the 100-year event, and to provide a flood flow bypass to the floodplain east of Scheuber Road,
- Excavate approximately 250,000 cubic yards of material and elevate the SR-6 roadway to provide a 5-foot vertical clearance for bypassing overbank flows to the floodplain.

- Excavate approximately 60,000 cubic yards (up to a 4-foot excavation depth) of a 500-foot by 1000-foot overbank area west of the oxbow lake between the Chehalis River and the roadway to provide more frequent overbank flow through this area.

4.3.3.4.3 Chehalis Flowway Bypass Berm

- Construct a north-south oriented 1.5-mile long curving berm on the floodplain north of SR-6. This floodplain fill is intended to form a drainage divide for creating two separate hydraulic regimes between the floodplain bypass/storage area and a 3-mile reach of the main stem Chehalis River downstream of the SR-6 Bridge (RM 74.6 to RM 71.6).
- Flood flows bypassing through the modified SR-6 overflow site to the floodplain would not return to the river until the flows reach the north end of the floodplain bypass/storage area. Returning flows would discharge first through the existing Scheuber drainage ditch and then over the low-lying overbank area between RM 71.6 and RM 72.4 of the Chehalis River.

4.3.3.4.5 Alternative 3A – Centralia Overbank Excavation

Among the variations modeled, floodway excavation between RM 65.90 and RM 68.05 appears to be the most efficient and cost-effective design.

Design Objectives and Description:

- Excavate approximately 2.4 million cubic yards of material.
- The floodway bench elevation was set to an elevation above the summer normal flow stage so that construction activities would be above the water level.
- At the upper end of the excavation around RM 68.05, the bench elevation would be approximately at elevation 158 feet. At the lower end of the excavation reach (RM 65.90), the bench elevation would be approximately at elevation 148 feet.
- Side slopes of the excavation were assumed to be two horizontal to one vertical (2:1). Channel velocities in the excavation reach would be reduced from a high of almost 8 feet per second to less than 4 feet per second.
- The Mellen Street bridge section of the Chehalis River is one of the most restrictive for flood flows. In order to alleviate this bottleneck, modifications to the bridge area would be necessary. The right bank (east bank) would be excavated. In conjunction

with the excavation, the bridge would be extended on piers to remain elevated above the excavated floodway.

4.3.3.5 Alternative 3B – Skookumchuck Bypass

This alternative would involve diverting a portion of the flow in the Skookumchuck River during flood events. This secondary overflow channel would start at approximately RM 1.5 of the Skookumchuck River.

Design Objectives and Description:

- Route channel under I-5 at Blakeslee Junction and connect with some existing small lakes, and then a remnant channel of the Chehalis River.
- The channel would empty back into the Chehalis River at approximately RM 60.5, 6.5 miles downstream of the Skookumchuck's confluence with the Chehalis River.
- It was assumed that the channel would be designed to divert up to 5,000 cfs.

4.3.3.6 Alternative 3C – Centralia Hospital Bypass

The bypass channel would start at about RM 68.0 and would end at the mouth of Scammon Creek at RM 65.9. The alignment would run roughly northwest following localized low ground and would pass immediately south of the hospital.

Design Objectives and Description:

- This channel alignment would require the construction of three bridges and would require excavating out lower Scammon Creek.
- The entrance to the bypass channel would be set at approximately elevation 165 feet. This is approximately the water surface elevation for the annual flood event.
- The channel would likely be grass lined and have a rock-armored entrance to prevent scour.

4.3.3.7 Hump Excavation

The “hump” area is located in the Chehalis River at approximately RM 67.1 to RM 65.9. The channel bottom at this location is approximately at elevation 148 feet. This is approximately 10 feet higher than much of the riverbed further upstream. This high bottom elevation appears to restrict flow during the 100-year flood. There have been numerous suggestions that excavation of this "hump" would significantly increase hydraulic capacity of the channel during flood flows, and thus reduce upstream flooding.

To evaluate the effects of the hump on hydraulic capacity during flood flows, two excavation alternatives were analyzed. The maximum velocity reductions resulting from either alternative are insignificant in the excavation reach because during a flood, a significant portion of the flow is in the overbank area. Thus, the slight increase in channel area has only a marginal impact on the total flow area. This feature was not examined further.

4.3.4 Alternative #4 – Levee System

4.3.4.1 Objective

This project was designed to reduce flood damages associated with the Chehalis and Skookumchuck Rivers. It also addresses flooding along Salzer Creek, Dillenbaugh Creek, and the Newaukum River. This alternative reduces damages to structures and allows for I-5 to stay open for transportation.

4.3.4.2 Relation to Authorized Project

Various levee alignments in the study area were studied previously by the Corps in the 1970s. The Levee Alternative can be combined with Skookumchuck Dam modifications (Alternative 2) to provide more comprehensive flood damage reduction throughout the study area.

The basic levee alignment was originally developed through a pervious study (circa 1970s). Local sponsors helped the study team develop the Levee Alternative. The plan was presented at public meetings for their review and comment. Draft reports were completed in 1976 and 1978.

4.3.4.3 Description

This alternative consists of constructing a system of levees to protect flood-prone areas in the vicinity of Chehalis and Centralia. Levees would be constructed at selected locations along the Chehalis and Skookumchuck rivers as well as along several tributaries (i.e., Salzer Creek, Coffee Creek). This alternative was considered both with and without the benefit of flood control operations at Skookumchuck Dam. A total of 20,000 ac-ft of flood control storage was assumed available in the Skookumchuck reservoir for the levee plus Dam Modifications Alternative.

4.3.4.4 Design Objectives

In reviewing the work of previous studies, considering the increased importance placed on environmental concerns, and conducting site visits with shareholders, it became apparent that much coordination was necessary. This made it important to incorporate as many concerns as possible early in the design effort to avoid impacts later in the study. To facilitate the expedited study some guiding design objectives were considered throughout the project. These objectives also correlate to the project criteria. The following are the guiding design objectives:

- avoid environmental impacts to the maximum extent possible;
- minimize the environmental impact as much as possible;
- minimize the initial construction and long term maintenance;
- provide a minimum of a 50-year project life;
- minimize project-induced damages, both within the project area and downstream;
- avoid inundating or excavating of hazardous materials;
- maximize the transportation corridor benefits;
- maximize local infrastructure benefits; and
- incorporate restoration opportunities into project.

In addition, a general assumption in the initial levee system design was that it would provide 100-year protection from flooding of the Chehalis River. This includes protection from Chehalis River backwater on the tributaries, including on Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek and the Skookumchuck River.

4.3.4.5 Design Process

The study team took the levee alignment developed in 1976, made refinements based on flood observations in 1990 and 1996. The team investigated the project area, identified areas needing flood protection, aligned the levee to tie into existing levees, and adjusted the alignment to protect existing infrastructure while providing a floodplain. The team also adjusted the original alignment to have the least impact to community (residential) infrastructure, to the environment, and to WSDOT roadways.

Following initial hydraulic modeling, the team re-evaluated the levee segments. Some segments were deleted because 1) protection was not required, and 2) improved alignments were identified. Additional modifications and refinements to the levee plan were based upon coordination with WSDOT and their widening project of I-5, incorporating I-5 into the levee alignment where practical to reduce costs and minimize environmental impacts.

The standard Corps levee design consists of a 12-foot top width and 2:1 side slopes (2 horizontal to 1 vertical). The fill material must meet the gradation specification and be compacted to Corps standards for levees (see Appendix C, Levee Plan and Civil Design). A 6-inch layer of gravel is placed on the top surface to provide access during flood events and maintenance. Both sides of the levee are hydro-seeded with grass with 4 inches of topsoil over compacted embankment material. Most levees are set back levees, which do not require rock bank protection. For those few areas that do require bank protection, the protection includes 30-inch minus riprap about 3 feet thick, with a 1-foot layer of quarry spalls between the riprap and compacted embankment material.

Environmental impacts were identified and then avoided to the maximum extent possible. Unavoidable impacts were minimized with design modifications; for example, a levee was changed to a floodwall in certain areas of concern to minimize the footprint of the structure.

In the design process, designers also:

- Used 1976 levee alignment from previous study that had gone through public review process as a starting point.
- Standard Corps levee 12 feet wide and 2 horizontal to 1 vertical slopes were assumed as the primary levee design. Variations including vertical wall in tight area may be required in setback areas only.
- Toured the basin with plans in hand, with a Corps study manager who had been on-site during the 1996 flood event. This event was approximately the 100-year event. High water marks from that event were noted and incorporated into design with minor revisions.
- The plan was drawn onto CADD drawing and distributed to the study team for comments.

- Plan was revised by internal study team, and the drawings were sent out externally to local sponsors (county and cities), and agencies
    - Site visit/tour with local sponsors.
    - Site visit/tour with state agencies (environmental).
    - Meetings with WSDOT
    - WSDOT requested levee elevation for I-5 corridor be set at 2.5 feet above 100-year flood elevation. WSDOT is also doing environmental assessment of raising or protecting road.
    - Addressed concerns of culverts/underpasses.
    - Meetings and tours of area with Chehalis Tribe.
    - Meetings with Department of Ecology to obtain list of known HTRW sites and share proposed levee alignment.
    - Utilized wetland inventory to minimize and avoid wetland area impacts.
- The design team coordination with agencies included conducting multiple meetings showing plan and requesting comments, submittal of written requests for comments, and provision of study area tours upon request.

4.3.4.6 Levee Alignment

The proposed levee alignment protects residential and commercial structures, highway and other transportation infrastructure from flooding. Protection would extend along the Chehalis River from approximately RM 75 to RM 64, along the Skookumchuck River from approximately RM 5 to near the mouth, as well as along most of the lower 2 miles of both Dillenbaugh Creek and Salzer Creek. The proposed levee alignment is shown on Plate 6.

4.3.4.7 Planned Overtopping of Flood Control Levee

Levee designs using superiority can force initial overtopping in the least hazardous location in an attempt to minimize sudden levee failure and safety concerns. The planned overtopping analyses adhered to the Overtopping of Flood Control Levees and Floodwalls guidance (ETL 1110-2-299).

The selected area of planned overtopping is near the Chehalis-Centralia Airport, from RM 73.0 to RM 71.5. This reach is also described as economic damage Reach 2 (Section 3.5), and levee design Reach 7A (Appendix C). The levee ties into the west embankment of the I-5 freeway at Salzer Creek and proceeds south along the river side of Airport Road to the I-5/SR-6 junction south of the airport. Highest and best use of lands within this levee footprint include commercial/transportation on airport lands as well as two agricultural and one residential parcel. The levees will protect the airport and commercial-retail establishments located on the west side of the airport as well as the I-5 freeway from Salzer Creek south to the SR-6/I-5 junction. Access to the levee is available from public rights-of-way at Mellen Street and Airport Road.

The top-of-levee height will be lowered in this reach no more than 1.0 foot to allow planned overtopping. The length of the overtopping will be located within the design Reach 7 (economic Reach 2) from station 00+00 to 10+280. This will yield a levee that protects against the base 100-year flood level with 95 percent reliability performance (conditional non-exceedance for the 0.01 event). The final levee profile will be established during the final design phase. The buildings in this area are already flood proofed and the aircraft can either be evacuated during flood warnings or may be submerged in the aircraft hangars up to wheel height. There are three private owners and one public owner (Chehalis-Centralia Airport) affected by the proposed levees. The perpetual levee easement covers about 7.3 acres of land in public ownership and 3.6 acres privately owned.

4.3.5 Alternative #5 – Upstream Flow Restriction Structures, and Upstream Storage

4.3.5.1 Flow Restrictors

Objective:
Flow restrictors are intended to increase water surface elevation upstream of the flow restrictor at low flows providing potential benefits to wetlands and fisheries. Currently there is a lack of off-channel habitat for salmon along the mainstem of the Chehalis River. If spring and summer flows could be backed up into adjoining low areas or disconnected oxbows, without also resulting in a stage increase during the 100-year flood event, then additional off-channel habitat could be created. The increased upstream inundation could also have a potential benefit in regards to increasing groundwater recharge.

Description:
Flow restrictors are any kind of structure that intentionally restricts and holds back flow in order to help reduce downstream flooding, or to increase upstream inundation. Increased upstream inundation can be beneficial for wetlands and fisheries in some cases. It was envisioned that these structures would be much simpler and of smaller scale than flood control dams, as well as less costly and more environmentally friendly.

For all structures, it was assumed that upstream inundation levels would not be allowed to exceed the current 100-year flood level. Known high water marks from the February 1996 flood were used as the criteria during modeling. For the first site studied, three different structure types were analyzed: a slot structure, a fixed weir structure, and a control type structure.
The control type was found to be the most effective of the three. For the remaining sites, only a control type structure was considered. Sites included:

- Mainstem Chehalis River at RM 87.56
- Mainstem Chehalis River at RM 89.61
- Mainstem Chehalis River at RM 104.09
- South Fork Chehalis River at RM 0.3
- Lincoln Creek
- Stearns Creek
- Salzer Creek

Two options were modeled. Option 1 had a single flow restrictor, and option 2 had four separate flow restrictors in combination, using the controlled structure sites. The modeling demonstrated no significant water surface reductions to the 100-year flood. Due to the fact the flow restrictor structures would have no significant water surface reduction for the 100-year flood in the Centralia-Chehalis area (because of the rather limited volume of flood control storage they would provide), other larger structures were considered in this alternative.

4.3.5.2 Upstream Storage

In order to create the volume of flood control storage necessary to effect significant water surface level reductions downstream, three basic alternatives were examined: individual flood control dams, multiple smaller headwater dams, and flood storage dikes on the floodplain. It was anticipated that all three options would have significantly greater environmental impact than the initially proposed flow restrictor structures. It was found that none of these larger structures were economically feasible, and these were not carried forward for further study.

4.3.5.2.1 Upstream Flood Control Dams

The Corps investigated five potential locations for large multi-purpose storage dams in the upper Chehalis River basin in the course of its flood control studies (USACE 1982). The five locations consisted of two sites on the Newaukum River, one site on the South Fork Chehalis River and two sites on the mainstem of the Chehalis River, upstream of the Newaukum River. All five features were determined to be economically infeasible.

4.3.5.2.2 Small Headwater Dams

In its studies, the Corps also investigated the feasibility of building several small headwater dams (USACE 1982). The Corps evaluated 12 sites in the drainage above Centralia-Chehalis. The combined flood storage capacity of all 12 dams would be only 14,500 ac-ft, with an estimated reduction in flow at Grand Mound of 3,000 cfs for a 100-year flood event. The 3,000 cfs flow reduction would result in flood stage reduction of approximately 3 inches. In 2001 dollars, the Corps-estimated cost to construct the twelve dams would be approximately $118 million, which would equate to approximately $472 million dollars per foot of flood stage reduction. Because of the poor benefit-to-cost ratio, this feature was not investigated further.

4.3.5.2.3 Flood Storage Dikes on the Floodplain

The Corps also investigated the feasibility of flood storage areas in the floodplain. This would be accomplished by enclosing a large area with a dike. During floods, the floodwaters would overflow into the dike enclosed storage area. Stored floodwaters would then be released slowly through a downstream outlet. This type of flood storage operation would not be as efficient and effective as that provided by a flood control dam. Placing flood control storage in the floodplain is also not as effective as utilizing storage in the headwaters. In the floodplain, the flows are already rather attenuated and a much larger storage volume is required for an equivalent stage reduction.

4.3.6 Alternative #6 – Non-Structural Alternative

4.3.6.1 Objective

The intent of the non-structural alternative was to formulate a viable non-structural solution to reduce flood damages throughout the study area.

4.3.6.2 Relation to Authorized Project

This alternative does not include incorporation of the authorized project at Skookumchuck Dam.

4.3.6.3 Description

Non-structural measures include watershed management, flood proofing structures, evacuation plans, and removal of structures from the floodplain. Watershed management includes such actions as reforestation, timber harvest control, and restrictions on floodplain development. These measures do not directly address flood elevations, but reduce economic damages and safety hazards. Flood proofing structures would require elevation of residential buildings to the 100-year flood level, and making commercial first floor buildings watertight. Also, no new construction would be allowed in the floodplain. Evacuation plans assist floodplain dwellers in avoiding flooding impacts. Relocation of a selected number of structures in the floodplain, or even all the structures in the floodplain, has been proposed. Because there are no flood control structures proposed for construction, no footprint value is calculated. However, overall impact area would extend throughout the upper Chehalis Basin. For this reason, the entire project area, plus 10 percent, is included as the overall impact area (41,360 acres).

Impacts are negligible for this alternative. No structures are proposed for construction and several of the components of this alternative may actually improve floodplain and river conditions. Removal of structures and control of development would reduce the impervious surface area in the floodplain, improving groundwater recharge and base flows. Reforestation would increase the amount of riparian vegetation and increase large wood debris recruitment.

Any combination of restoration measures could be selected to provide restoration above the requirements for mitigation, since mitigation is not required for this alternative.

4.3.7 Alternative #7 – Interagency Committee Alternative

4.3.7.1 Objective

In the fall of 1996, the Washington Department of Ecology set up the Chehalis Basin Local Action Team, an internal team, to work with local governments and build partnerships to solve water problems in the basin. In 1998, a Technical Committee was formed, comprised of representatives of local, state and Federal agencies and tribes. During 1998, the Technical

Committee formed an Alternatives Subcommittee to identify and evaluate potential flood hazard reduction measures and to develop alternatives for meeting specific flood hazard reduction goals.

The purpose of this alternative is to provide short- and long-term actions that will reduce flooding hazards to the Centralia and Chehalis area residents, while at the same time, restore and enhance river hydrology and floodplain functions to support the basin's salmonid habitat base. This alternative seeks to reduce flood hazards and increase floodwater storage by focusing first on regulatory and voluntary measures. The connectivity of the Chehalis River to its floodplain is maintained and enhanced using land use and development regulations before implementation of any costly structural solutions. In addition, this alternative seeks to maintain vital I-5 and State Route access by constructing a traffic bypass and by reducing flood frequency and duration. Also advocated are the uses of floodplain easements, acquisition of frequently flooded areas and structures, relocation or elevation of structures, and improved upland water storage. Finally, the alternative is presented as a sequence of actions that require analysis before additional actions are proposed.

4.3.7.2 Relation to Authorized Project

This alternative was evaluated in combination with the modifications to Skookumchuck Dam.

4.3.7.3 Design Process Description

The Alternatives Subcommittee reviewed a variety of different flood hazard reduction measures and used a format of facilitated workshops to sift through potential combinations of measures. The approach that was agreed to begins by describing the major elements (these could be individual measures or measures in combination) that make up the combination alternative. These measures include:

- *Measure 1 – Moratorium on Floodplain Development.* In the interim, a moratorium on floodplain development is recommended until the new flood insurance rate maps are adopted. Lewis County, and possibly Grays Harbor and Thurston counties, and area cities should enact interim regulations that restrict new fills until the new FEMA floodplain and floodway maps are prepared and adopted.

- *Measure 2 - Adopt New FEMA Floodplain and Floodway Maps.* Define a new floodway based on a 0.2-foot rise in the water surface profile. Use the new topographic information for this analysis. These data are required for the accurate evaluation and implementation of this alternative. The 0.2-foot rise and the new 100-year floodplain will be used to develop or update floodplain management plan and regulations governing future floodplain development.

- *Measure 3 – Develop Flood Warning System.* Develop and implement a basin-wide flood warning system. Ensure that the system is well coordinated and interconnected among the various jurisdictions and agencies that provide emergency services.

- *Measure 4 - Restrict Floodway Development.* Restrict development (residential, commercial, industrial) in the newly defined floodway; and have outstanding approved filling/floodplain development activities provide a hydraulic analysis to show a 0.2-foot rise or less in the floodwater surface elevation. Jurisdictions would review pending permits to ensure that the proposed development does not increase flood damage risk to adjacent, upstream, and downstream properties. Jurisdictions should also consider establishing a time limit on development permits.

- *Measure 5 – Restrict Development in Flow Path.* In addition to defining the 0.2-foot floodway as described in Measure 2 above, development should also be restricted within additional critical portions of the floodplain, specifically in areas considered to be significant flow paths. Flow paths are naturally occurring swales, which are normally dry, but which have historically conveyed significant amounts of flowing water during flood stage. These flow paths could be established by identifying split flow conditions as part of the HEC-RAS analysis, or by simply identifying flow paths from photos and observations. Generally these flow paths have floodwaters greater than 3 feet deep, and velocities greater than 3 feet per second, during the 100-year event. If blockage of a flow path produces more than 0.2-foot backwater, then it is a flow path and will be protected from future development and/or fill under this alternative.

- *Measure 6 – Restrict Floodplain Filling.* Restrict new filling by requiring that fill be mitigated by removal of equal volume of fill elsewhere in the floodplain or floodway. Cut and fill balances should be retained within the project site whenever possible.

- *Measure 7 – Preserve/Enhance Floodplain Flood Storage.* Conduct an analysis to quantify the potential amount of floodplain storage provided by existing, expanded and enhanced floodwater storage areas. Potential areas are south of SR-6 in the Newaukum basin, South Fork of the Chehalis River, and the area bordered by Ceres Hill and White Road, proposed

WSDOT wetlands mitigation site near Stan Hedwall Park, existing wetlands, connections to oxbows and historic flow paths, SR-6 floodplain storage, and upland storage. The analysis will provide an assessment of the storage capacity that could be gained by removing barriers that are no longer used or can be redesigned, such as railroad grades, roadways and bridges. The analysis will generate hydrographs demonstrating the role of storage, and may be used to implement measures such as voluntary buyouts, purchase of flow easements, etc.

- *Measure 8 – Restrict Upland Land Uses.* Utilize other land use measures that lower and slow the hydrologic response of the basin. For example, consider upland vegetation coverage, reduced development densities, and reductions in the amount of impervious surfaces. Avoid impacts to wetlands, preserve and maintain wetlands, critical areas, and farmlands that supply floodplain storage capacity.

- *Measure 9 – Flood Audits.* Conduct a flood audit for the cities of Chehalis and Centralia and surrounding communities in order to determine which structures would benefit from raising, flood proofing, or acquisition.

- *Measure 10 – Upgrade Stormwater Management Systems.* Perform analyses to determine the detention effects of a 25-year design storm versus a 100-year design storm throughout the basin. Stormwater management is an integral element of the National Flood Insurance Program (NFIP). It regulates new development throughout the watershed to ensure that post-development runoff is no worse than pre-development runoff; and it regulates new construction to minimize soil erosion, and protect water quality. Stormwater management is also mitigation for development. This alternative is based on judicious planned development to reduce flood reduction risks. However, mitigation for development is inadequate when communities do not have a local stormwater management program or use less than the 100-year design storm for their local programs. With this in mind, it is imperative that stormwater management programs are implemented consistently throughout the basin to mitigate for development. It is also equally vital that the design criteria used for these programs are high enough to be effective. Detention for design storms will be based on the 100-year event. Use of a 100-year, 24-hour design storm is a standard national and state design criteria for stormwater management. This design storm should not be confused with a 100-year flood event, which is based on physical characteristics, geology, climatologic, antecedent conditions, land use, river morphology, size, and development density of the watershed.

- *Measure 11 – Improve Alternative Transportation and Emergency Access Routes.* Identify alternative transportation and emergency access routes. The proposed priority would be to lower flood levels so that I-5 and the State Routes are not closed during a 50-year storm event and to maintain emergency access routes on local roads up to a 25-year event. The local medical facility is on Cooks Hill in Centralia, and the two routes via Scheuber Road and Mellen Street are linked to SR-6 and I-5. Improvements will be needed on portions of Scheuber Road along with modifications on the SR-6 bridge, Mellen Street bridge, and I-5. This local access road could be used as an I-5 alternate route. Depending on the severity of the flood, the local route may be closed during severe flooding conditions. Depending on the need to keep local roads open, there may be additional modifications to SR-6.

- *Measure 12 – Expand Capacity of Chehalis-Centralia Airport Dike Culverts.* This measure proposes modifications to culverts and levees affecting the duration of flooding on northbound lanes of I-5 (modifications would reduce duration only -- not the incidence or frequency of flooding). Recommended measures are to install flap gates and expand culverts to direct water to drain northerly. Flap gated culverts will be needed on the west side of the highway to drain the airport and the southbound lanes of I-5. An additional flap gate will be needed on the east side in order to drain the northbound lanes of I-5. Presently it is necessary to excavate an opening in the levee to release the trapped water on the west side, and the east side must flow through a small diameter culvert, which takes about 40 additional hours to drain down. This alternative would reduce the highway closure time from 72 hours to about 30 hours. This would cut economic losses associated with the closure of I-5 by more than half.

- *Measure 13 – Off Channel Storage and Upstream Flow Restriction Structures.* Investigate the flood reduction achieved by installing flow restrictors (such as artificial log jams or agricultural storm water ponds) at strategic locations that would allow for significant amounts of water to be temporarily stored during normal and large flood events. In all areas above flow restrictors and where buyouts or flood easements take place, the following restoration activities are recommended: 1) restore floodplain and riparian areas via revegetation and livestock exclusion, 2) maximize stormwater mitigation opportunities from urban areas, 3) mitigate agricultural ditch runoff (agricultural stormwater ponds), 4) restore wetland complexes (enhancement of summertime flows), and 5) re-establish oxbow/side channel habitat functions as they relate to over winter/summer habitat for salmon.

- *Measure 14 – Chehalis Flowway Bypass.* Begin by adding the floodwater bypass measure at SR-6 (measure is defined in Technical Memorandum No. 3) in combination with voluntary buyouts and flood easements required to attain enhanced floodwater storage capacities in areas identified in measure 7. Then, reassess and if still needed to reach goals go to measure 15.

- *Measure 15 – Excavate Overbank Downstream of "Hump".* Add a carefully designed overbank excavation downstream of the hump. Any excavation should be strategically designed to align with old side channels, and to remove invasive species such as reed canary grass and restore native vegetation. Excavation should not be located where the banks are functioning well and mature riparian forest is established.

- *Measure 16 – Elevate Segments of Interstate Highway 5.* Add elevation to specific segments of I-5.

- *Measure 17 – Modify Skookumchuck Dam.* Finally, add modifications of Skookumchuck Dam to improve flow control, but do not increase the storage.

- *Other Measures If Required.* Following a detailed analysis of the flood hazard reduction achieved by the above listed measures, this alternative will consider a sequence of structural measures.

4.4 Hydrologic and Hydraulic Assessment of Preliminary Alternatives

The following paragraphs provide a brief summary of the hydrologic and hydraulic performance aspects of preliminary alternatives 2, 3, 4, 5, and 7. Alternatives 1 (No Action), and 6 (Non-Structural) did not involve hydraulic modifications to evaluate in the assessment.

4.4.1 Alternative 2 – Skookumchuck Dam Modifications

Summary of Hydraulic Aspects of Alternative 2:

1. Modifications to the Skookumchuck Dam as currently proposed for the purposes of flood control operation would have a significant impact on the areal extent of flooding along the Skookumchuck River and a significant reduction in the peak stage of the

Skookumchuck River. Reductions in peak stage would generally be greatest within the reach closest to the dam and would generally lessen in a downstream direction.

2. Flood control operations using the current maximum pool of elevation 477 feet (11,000 ac-ft of storage above elevation 455 feet) would be sufficient to provide significant flood reduction benefits along the Skookumchuck River below the dam during most moderate flood events (i.e., 2-year to 25-year flood events).
3. Flood control operations using an increased maximum pool of elevation 492 feet (20,000 ac-ft of storage above elevation 455 feet) would be sufficient to provide significant flood reduction benefits along the Skookumchuck River below the dam during most moderate to large flood events (considerable flood damage reduction would likely be realized during a 50-year event and possibly during a 100-year event).
4. Flood damage reduction benefits from this alternative are expected to be limited along the Chehalis River. No flood reduction benefits would be provided to the City of Chehalis. Very small reductions in the peak stage (up to 0.2 foot during a 100-year event) may occur in the Chehalis River between RM 70 and RM 67 (Chehalis/Skookumchuck confluence). Slightly larger reductions in peak stage (possibly up to 0.5 foot during a 100-year event) could occur in the Chehalis River downstream of RM 67. Flood reduction benefits to the Chehalis River from this alternative are limited given the large size of the Chehalis River basin (895 square miles at Grand Mound) relative to the small basin area draining to the Skookumchuck reservoir (on the order of 60 square miles).

4.4.2 Alternative 3 – Excavation and Flowway Bypass

Summary of Hydraulic Aspects of Alternative 3:

1. The bypass-only alternative would cause a relatively significant reduction in the areal extent of flooding and a significant reduction in the peak stage of the Chehalis River in the vicinity of the two bypass channels. Peak stage would be reduced by up to 3 feet in the vicinity of the bypass channels (RM 77 to 74 and RM 73 to 66) during the 10-year event and by up to 4 feet during the 100-year event.
2. The bypass-only alternative would cause a slight increase in the peak stage of the Chehalis River downstream of RM 66. Peak stage downstream of RM 66 would increase by about 0.2 to 0.7 foot during a 10-year event and increase by about 0.1 to 0.4 foot during a 100-year peak. Downstream increases in peak stage are attributed to a more

efficient routing of flood flows through the Chehalis-Centralia reach due to the bypass features.

3. With the exception of a very short reach of the Skookumchuck River near the Chehalis River confluence (RM 0 to 1), the bypass-only alternative would have no impact on stage and attendant flooding in the Skookumchuck River.
4. The bypass plus Skookumchuck Dam Modifications Alternative would cause a relatively significant reduction in the areal extent of flooding and a significant reduction in the peak stage of the Chehalis River in the vicinity of the two bypass channels (primarily attributed to the bypass features). Peak stage would be reduced by up to 3 feet in the vicinity of the bypass channels (RM 77 to 74 and RM 73 to 66) during the 10-year event and by up to 4 feet during the 100-year event.
5. The bypass plus Dam Modifications Alternative would have little to no impact to the peak stage of the Chehalis River downstream of RM 66. Peak stage downstream of RM 66 would be essentially equal to peak stage in this reach under existing conditions. Flood control operations at the modified Skookumchuck Dam would essentially offset any stage increases in this reach attributed to the bypass channels.
6. The bypass plus Dam Modifications Alternative would cause a relatively significant reduction in the areal extent of flooding and a significant reduction in the peak stage of the Skookumchuck River downstream of the dam. Reductions in peak stage would generally be greatest within the reach closest to the dam (peak stage reductions of 2 to 6 feet during the 100-year event) and would generally lessen in a downstream direction (peak stage reductions of 1 to 3 feet in the vicinity of Centralia during the 100-year event). With the exception of a very short reach of the Skookumchuck River near the Chehalis River confluence (RM 0 to 1), flood reductions along the Skookumchuck River under this option are attributed solely to modified flood control operations at the dam.

4.4.3 Alternative 4 – Levee System

Summary of Hydraulic Aspects of Alternative 4:

1. The levee-only alternative would cause a relatively significant reduction in the areal extent of flooding in the Chehalis River valley in the Chehalis-Centralia reach. Although the levees would cause relatively small (less than 1 foot up to a 100-year event) increases in peak stage within the Chehalis River channel, water levels would be reduced in targeted areas of the floodplain where damages are most likely to occur. Slight increases

in the peak stage within the Chehalis River channel would occur as a result of the levees keeping a higher proportion of the flow confined to the channel (resulting in less flow leaving the channel and entering overbank and floodplain areas).

2. The levee-only alternative would cause a slight increase in the peak stage of the Chehalis River downstream of RM 66. Peak stage downstream of RM 66 could increase by about 0.1 during a 10-year event and could increase by up to 0.15 feet during a 100-year peak. Slight downstream increases in peak stage are attributed to a more efficient routing of flood flows through the Chehalis-Centralia reach due to the levee system.
3. The levee-only alternative would cause a relatively significant reduction in the areal extent of flooding in the lower Skookumchuck River valley in the Centralia area. This is based on the assumption that a system of continuous levees would be placed along both banks of the Skookumchuck River along the lower 4 miles of the river. Although the levees would cause moderate (up to 1 foot during a 10-year event, up to 3 feet during a 100-year event) increases in peak stage within the Skookumchuck River channel, water levels would be reduced in targeted areas of the floodplain where damages are most likely to occur. Increases in the peak stage within the Skookumchuck River channel would occur as a result of the levees keeping a higher proportion of the flow confined to the channel (resulting in less flow leaving the channel and entering overbank and floodplain areas).
4. The levee plus Skookumchuck Dam Modifications Alternative would have a similar reduction in the areal extent and depth of flooding along the Chehalis River as the levee only option. Additional flood damage reduction benefits to the Chehalis River from the modification of Skookumchuck Dam would be limited and would be primarily limited to reaches downstream of the Chehalis/Skookumchuck confluence. Possibly the biggest benefit of adding flood control regulation at Skookumchuck Dam to this alternative is that the slight increase in stage in the Chehalis River downstream of Centralia attributed to the levee system would be mitigated. As a result, the peak Chehalis River stages downstream of Centralia under the levee plus Dam Modifications option would likely be lower relative to the peak stages under existing conditions.
5. The levee plus Skookumchuck Dam Modifications Alternative would cause a significant reduction in the areal extent and depth of flooding along the Skookumchuck River. The assumed system of levees along the lower 4 miles of the river would protect most of Centralia from Skookumchuck River related flooding, and flood control operations at the dam would cause a significant reduction in stage within the channel.

4.4.4 Alternative 5 – Upstream Flow Restriction Structures

Summary of Hydraulic Aspects of Alternative 5

1. Both options of the flow restrictors would lower stage along the mainstem Chehalis River within the Chehalis-Centralia area, but would have essentially no impact to stage in the Skookumchuck River (i.e., the flow restrictors have no beneficial impact on flooding attributable to the Skookumchuck River).
2. Option 1 (a single flow restrictor) would lower peak stage in the Centralia/Chehalis area (damage area) on the order of 0.1 to 0.3 foot during a 10-year flood event. Option 1 would lower peak stage in the damage area on the order of 0.1 to 0.3 foot during a 100-year flood event.
3. Option 2 (four separate flow restrictors) would lower peak stage in the damage area on the order of 0.1 to 0.45 foot during a 10-year flood event. Option 2 would lower peak stage in the damage area on the order of 0.1 to 0.5 foot during a 100-year flood event.
4. Both options would have little impact on the areal extent of flooding in the damage area.
5. Based on the assumption of a 20-foot-high structure, each flow restrictor could cause a relatively significant increase in the areal extent and depth of flooding upstream of the structure. For instance, a single flow restrictor located at RM 87.54 on the Chehalis River would apparently worsen flooding across sections of SR-6 and would likely worsen flooding at homes and property upstream of the structure. The increased stage associated with a single flow restrictor at RM 87.54 could reach as far as 4 miles upstream of the structure. There may also be short-term impacts to fish passage and sediment transport associated with the flow restrictors.

4.4.5 Alternative 7 – Interagency Committee Alternative

This alternative seeks to reduce the impacts of flooding by focusing first on regulatory and voluntary measures. This alternative is presented as a sequence of measures that require analysis before additional measures are proposed. The sequence of measures is listed below:

1. Moratorium on floodplain development.
2. Adopt new FEMA flood maps.
3. Improve flood-warning system.
4. Restrict floodway development.
5. Restrict development in flow paths.

6. Restrict floodplain filling.
7. Preserve/enhance floodplain storage.
8. Restrict upland land uses.
9. Conduct flood audits.
10. Upgrade stormwater management systems.
11. Improve alternative transportation and emergency access routes.
12. Expand capacity of Chehalis-Centralia Airport dike culverts.
13. Use of upstream flow restrictor structures.
14. Construction of Chehalis (SR-6) flowway bypass channel.
15. Excavation of the "hump" in the Chehalis River channel near Galvin.
16. Elevate segments of I-5.
17. Modify Skookumchuck Dam to provide flood control.

Items 1 through 11 are primarily non-structural items and, as such, the effects of these items cannot be modeled using the UNET hydraulic model. Items 12 through 17 are mostly structural in nature and therefore can be simulated using the UNET model. Three options were evaluated for the current analysis. Option 1 simulates the effects of Items 12 through 15; Item 13 is assumed to consist of four flow restrictors as discussed under Alternative 5, Item 14 is considered as discussed under Alternative 3. Option 2 simulates the effects of Items 12 through 16 (Items 13 and 14 are simulated as described under Option 1). Option 3 simulates the effects of Items 12 through 17 (Items 13 and 14 are simulated as described under Option 1, Item 17 (Skookumchuck Dam modification) assumes a maximum of 11,000 ac-ft of flood control storage (maximum pool elevation of 477 feet).

Summary of Hydraulic Aspects of Alternative 7:

(1) Option 1 would reduce peak flood stages in the Chehalis River significantly in the vicinity of the SR-6 bypass (up to a maximum peak stage reduction of approximately 3.5 feet for the 10-year and 100-year flood events) but would result in little to no stage reductions downstream of the bypass (i.e., peak stage reductions in the Chehalis River downstream of RM 72 would be on the order of 0 to 0.5 foot during the 100-year event, no apparent reductions in peak stage would occur in the Chehalis River downstream of RM 72 during small to moderate [i.e., up to a 25-year event] flood events).
(2) Option 1 would have no impact (i.e., no stage reduction) in the Skookumchuck River.
(3) Option 2 would reduce peak flood stages in the Chehalis River significantly in the vicinity of the SR-6 bypass (up to a maximum peak stage reduction of approximately 3.5

feet for the 10-year and 100-year flood events) but would result in little to no stage reductions downstream of the bypass (i.e., peak stage reductions in the Chehalis River downstream of RM 72 would be on the order of 0 to 0.5 foot during the 100-year event, no apparent reductions in peak stage would occur in the Chehalis River downstream of RM 72 during small to moderate [i.e., up to a 25-year event] flood events).

(4) Option 2 would have no impact (i.e., no stage reduction) in the Skookumchuck River.

(5) Option 3 would reduce peak flood stages in the Chehalis River significantly in the vicinity of the SR-6 bypass (up to a maximum peak stage reduction of approximately 3.5 feet for the 10-year and 100-year flood events). Option 3 would reduce peak flood stages in the Chehalis River downstream of the bypass as a result of flood control operations at Skookumchuck Dam. Reductions in the peak stage in the Chehalis River downstream of RM 72 would be modest (on the order of 0.1 to 0.5 foot during a 10-year event, slightly greater during a 100-year event).

(6) Option 3 would significantly reduce the peak stage in the Skookumchuck River as a result of flood control operations at Skookumchuck Dam. Reductions in peak stage would generally be greatest within the reach closest to the dam (peak stage reductions of 1.5 to 3.5 feet during the 100-year event) and would generally lessen in a downstream direction (peak stage reductions of 1 to 2 feet in the vicinity of Centralia during the 100-year event).

(7) All three options were simulated based on the assumption of the installation of four upstream flow restrictors (see Alternative 5). Based on the assumption of a 20-foot-high structure, each flow restrictor could cause a relatively significant increase in the areal extent and depth of flooding upstream of the structure. For instance, a single flow restrictor located at RM 87.54 on the Chehalis River would apparently worsen flooding across sections of S-6 and would likely worsen flooding at homes and property upstream of the structure. The increased stage associated with a single flow restrictor at RM 87.54 could reach as far as 4 miles upstream of the structure. There may also be short-term impacts to fish passage and sediment transport associated with the flow restrictors.

4.5 Phase 1 - Screening of Preliminary Alternatives

4.5.1 Phase 1: Preliminary Alternatives Screening Criteria

Section 4.2.1 listed the planning objectives for this project. In plan formulation, alternatives were screened by their capacity to meet objectives. In the initial screening phase, the plan formulation team reviewed results of preliminary modeling of initial alternatives to assess their ability to address the following criteria.

Engineering Criteria:

1. Reduce flood hazards in the project area to the maximum extent practicable.
2. Decrease the transportation closures during flooding on I-5 and other critical transportation corridors to the maximum extent practicable.
3. Avoid increasing flood risks downstream from the project area.
4. Avoid decreasing any existing low flow benefits provided by Skookumchuck Dam.

Economic Criteria:

5. Reduce flood damage costs in the project area to the maximum extent practicable.
6. Reduce transportation delay costs in the study area to the maximum extent practicable.
7. Be cost-effective for both construction and maintenance.

Environmental Criteria:

8. Avoid adverse impacts to the aquatic environment to the extent practicable. Minimize and compensate for unavoidable adverse impacts to the aquatic environment.
9. Incorporate appropriate fish and wildlife habitat measures to the extent practicable.
10. Comply with all Federal, state, and local regulations, including environmental regulations

The first phase in the plan formulation process was to utilize the project criteria to screen each alternative. The formulation team used most current design, cost and modeling information that had been developed to determine if an alternative could possibly meet the criteria. If it was determined that an alternative could potentially meet all project criteria, or that it could be combined with other alternatives to help them meet all project criteria, then that alternative was carried forward for further evaluation in Phase 2. Several of the alternatives did not meet multiple criteria and were screened from further modeling and evaluation.

In addition to the design, cost and modeling information used to evaluate the preliminary alternatives, a limited environmental analysis of the impacts of the various alternatives was conducted. This included identification of the known HTRW sites in the project area. It also included working with the state and Federal agencies and the local tribes on a panel to identify the possible impacts of each alternative. It was this information that was utilized to identify the impacts and potential mitigation and associated costs of mitigation. Finally a limited investigation of the effect on the geomorphology of the Chehalis River by several of the structural alternatives was conducted. The conclusions from this investigation were utilized in Phase 2 to confirm that the tentatively selected preferred plan did not have any significant impacts.

Several of the preliminary alternatives had various configurations or designs that had either been carried through from the previous feasibility studies or had been developed by the local sponsor previous to this study. Some of these designs were weighed against each other and eliminated from further study. Other configurations were judged to be more cost effective or more effective from an engineering standpoint.

The following flowchart documents the procedure for this phase of the formulation. It identifies the alternatives, the screening against the project criteria and whether an alternative was carried forward to Phase 2.

EVALUATION/SCREENING CRITERIA

ENGINEERING CRITERIA:

1) Reduce flood hazards in the project area to the maximum extent practicable
2) Decrease the transportation closures during flooding on Interstate Highway 5 and other critical transportation corridors to the maximum extent practicable.
3) Avoid increasing flood risks downstream from the project area.
4) Avoid decreasing any existing low flow benefits provided by Skookumchuck Dam.

ECONOMIC CRITERIA:

5) Reduce flood damage costs in the project area to the maximum extent practicable
6) Reduce transportation delay costs in the study area to the maximum extent practicable.
7) Be cost-effective for both construction and maintenance.

ENVIRONMENTAL CRITERIA:

8) Avoid adverse impacts to the aquatic environment to the extent practicable. Minimize and compensate for unavoidable adverse impacts to the aquatic environment.
9) Incorporate appropriate fish and wildlife habitat creation, enhancement, and restoration measures to the extent practicable.
10) Comply with all Federal, State, and local regulations, including environmental regulations

ALTERNATIVES	SCREENING RESULTS	CARRY FORWARD?
Alternative 1 No Action	Alternative 1 – Does not address 1, 2, 5, 6, 9	YES (NOACTION)
Alternative 2 Skookumchuck Dam	Alternative 2 – Alone it does not address 2, 6	YES
Alternative 3 Flowway/ Excavation	Alternative 3 – Meets all criteria	YES
Alternative 4 Levee Alternative	Alternative 4 – Meets all criteria	YES
Alternative 5 Flow Restrictor Alternative	Alternative 5 – Does not address 1, 2, 5, 6	NO
Alternative 6 Non-Structural Alternative	Alternative 6 – Does not address 1, 2, 5, 6	NO
Alternative 7 Interagency Alternative	Alternative 7 – Meets all criteria	YES

4.5.2 Phase 1: Results of Preliminary Alternatives Screening

Alternative 1 - No Action: The No Action Alternative would not reduce flood hazards in the project area, and would not meet Criterion 1; it would also do nothing to reduce flood-related transportation closures (Criterion 2). It would not reduce flood damage costs (Criterion 5), or transportation delay costs (Criterion 6). Under the No Action Alternative, flood damage would continue to cost the local economy an estimated $9.1 million annually, and flood damage costs would increase as the cost of living increases. The No Action Alternative clearly could not reasonably meet the project criteria; however, it was carried forward for comparative purposes.

Alternative 2 – Skookumchuck Dam Modifications: This alternative was subjected to detailed economic and feasibility review, although it was evident early in the study process that it could not reasonably meet the project criteria as a stand-alone alternative. Modifications to Skookumchuck Dam would provide some flood damage reduction to Bucoda and parts of Centralia, but not to other parts of the study area (specifically, the City of Chehalis) and therefore could not fully meet Criteria 1 and 5 (maximum reduction of damage and damage costs). This alternative would have no effect on flooding of I-5 and other transportation routes and therefore could not meet Criteria 2 and 6 (maximum reduction of transportation delay and delay costs).

However, the Skookumchuck Dam modifications could provide flood damage reduction for portions of the study area. This alternative could also provide protection from some potential downstream flooding impacts by delaying flood flows on the Skookumchuck River until Chehalis River peak flows have passed. Alternative 2 was carried forward to evaluate the benefit of incorporating it into Alternatives 4 and 7. Skookumchuck Dam modifications are also a feature of Alternative 3. As part of this process, the four dam design variations were evaluated. The short tunnel with slide gates was the only design that proved to be feasible from an engineering standpoint.

Alternative 3 – Overbank Excavation and Flowway Bypass: As a result of the initial analysis, the Skookumchuck bypass, the Centralia Hospital bypass, and hump excavation components were dropped from this alternative. The Centralia overbank excavation and the SR-6 bypass were retained as components of Alternative 3. As noted earlier, modifications to Skookumchuck Dam (described in Alternative 2 above) would be included to provide flood damage reduction along the Skookumchuck River and reduce downstream effects.

Alternative 3 was then further evaluated based on the project criteria. The first stages of analysis indicated that this alternative met all of the project criteria. Hydraulic modeling demonstrated that Alternative 3 would reduce flood stages significantly within the study area; therefore, it met Criterion 1. Alternative 3 would provide 100-year flood protection for I-5 and significantly decrease the flooding of other transportation corridors (Criterion 2). With the inclusion of Skookumchuck Dam modifications, Alternative 3 would not result in any additional downstream flood risks (Criterion 3). Low flow benefits at Skookumchuck Dam would be maintained (Criterion 4). The screening indicated that the flood stage reductions would significantly reduce the flood damage costs (Criterion 5). Because flooding would be decreased on transportation corridors, transportation delay costs would be reduced (Criterion 6). Construction, operation, and maintenance appeared to be cost effective (Criterion 7).

With regard to Criterion 8, a number of environmental concerns and issues were raised about Alternative 3. For example, concerns raised by resource agencies included potential changes in sediment transport on the Chehalis River, changes in river geomorphology, effects on groundwater recharge, potential reduction in summer low flows, impacts on water quality, and loss of wetlands and riparian areas. This alternative appeared to have the potential for more than minimal environmental impacts. Additional studies would be needed to evaluate the alternative’s impact on environmental resources. The SR-6 bypass would reconnect a portion of the historic floodplain to the Chehalis River and could be designed to maximize the environmental benefits of this reconnection (Criterion 9). Additional review would be necessary to determine compliance with all applicable rules and regulations (Criterion 10).

The screening indicated that this alternative was consistent with the project criteria, although there were issues that needed further investigation. Specifically, the economic benefits and environmental impacts warranted further review. This alternative was carried forward for further evaluation.

Alternative 4 – Setback Levees: The initial screening indicated that Alternative 4 would reduce flooding from the Chehalis River, Salzer Creek, Skookumchuck River and Dillenbaugh Creek and would significantly reduce the flood hazards in Chehalis and Centralia (Criterion 1). Alternative 4 would meet Criterion 2 by protecting I-5 from flooding and providing protection to other critical transportation corridors in and around Chehalis and Centralia. This alternative would slightly increase flood stages downstream of the project area, potentially not meeting Criterion 3. However, further evaluation determined that these downstream risks would not be significant. By incorporating modifications to Skookumchuck Dam into the alternative, the risk would be alleviated and no increase in downstream flood impacts would be experienced. Low-flow benefits of the Skookumchuck Dam would be maintained (Criterion 4). Alternative 4 would protect a significant portion of the existing residential and commercial infrastructure in Centralia and Chehalis area from flooding and protect I-5, thereby reducing flood damage costs and transportation delay costs (Criteria 5 and 6, respectively). The initial analysis indicated that Alternative 4 was cost-effective (Criterion 7).

With regard to Criterion 8, Alternative 4 could result in impacts to wetlands and riparian areas. The Skookumchuck Dam modifications could also result in adverse impacts to fish habitat and riparian areas along the Skookumchuck River, mainly between the dam and the first tributary downstream of the dam. Those impacts will be based on the dam re-operation process. Potential adverse impacts will be minimized by strict adherence to the proposed operation rule: not allowing additional water to be held behind the dam for a period longer than 5 consecutive days and release control based on fishery guidelines. The resource agencies raised questions about reductions in groundwater recharge, changes in sediment transport, channel self-maintenance, and channel stability. Additional evaluation of the alternative's impact on environmental resources would be needed. Although the levee alignment incorporated avoidance of environmental impacts within the design, additional adjustments to the levee alignment may further reduce adverse impacts to wetlands and riparian areas. Setting the alignment away from the river's edge may also allow opportunities for environmental restoration (Criterion 9). Finally, additional review would be necessary to determine compliance with all applicable rules and regulations (Criterion 10).

This alternative appeared to be consistent with the criteria, although there were issues that needed further investigation. Specifically, the economic benefits and environmental impacts warranted further review. This alternative was carried forward for further evaluation.

Alternative 5 – Flow Restrictors: Preliminary hydraulic modeling of flow restrictors showed that they would not significantly reduce flooding in the project area and that they could cause a relatively significant increase in the areal extent and depth of flooding upstream of the structures. Therefore, Alternative 5 could not reasonably meet Criterion 1. Because flow restrictors would not decrease the flooding to I-5 or other critical transportation corridors in or around Chehalis or Centralia, the alternative would not meet Criterion 2. Any of the design options of Alternative 5 would avoid increased flooding downstream as the purpose would be to store water during a flood (Criterion 3). Alternative 5 does not include any modifications to Skookumchuck Dam, so low flow benefits would not be affected (Criterion 4). The flow restrictors would not reduce flood stages and flood damages in the study area and would not meet Criterion 5. Alternative 5 would not decrease flooding to I-5 and the costs of transportation delay and would not meet Criterion 6. All design options of Alternative 5 had very high operational and maintenance costs because of the multiple structures and extensive area of coverage, and Criterion 7 would not be met. Although there may be short-term changes in sediment transport associated with installation of flow restrictors, this alternative would likely not have significant environmental impacts (Criterion 8). The flow restrictors have potential to create or enhance wetlands and create off-channel fish habitat, and would meet Criterion 9. Further investigation would be necessary to determine if this alternative would comply with all Federal, state, and local regulations (Criterion 10).

Although Alternative 5 met some of the project criteria, none of the design options could reasonably meet all of the criteria. Alternative 5 was therefore dropped from further evaluation.

Alternative 6 – Non-Structural Alternative: Alternative 6 would reduce some of the flood hazards in the study area by removing structures from the floodplain (Criterion 1) although it would not have any effect on closures of the existing transportation corridors (Criterion 2). Alternative 6 would not result in flooding impacts downstream of the study area (Criterion 3) or affect the low flow benefits of Skookumchuck Dam (Criterion 4). Alternative 6 would reduce flood damages (Criterion 5) but would not have any effect on reducing the costs of transportation delays (Criterion 6). The cost effectiveness of Alternative 6 was not fully evaluated because the initial screening showed that large-scale and relocation of residents and businesses would be cost prohibitive. For example, based on information provided by the City of Centralia (City of Centralia 1998) it has been estimated that as many as 3,000 structures could need to be removed from Centralia alone. Therefore, this alternative would not meet Criterion 7. With regard to Criterion 8, there would be at least temporary air quality, soil disturbance, hazardous waste, and water quality issues associated with the demolition and removal of structures, and substantial adverse impacts on the social fabric and economy of the area if large numbers of residents and businesses were required to relocate. These impacts would need further evaluation if the alternative were carried forward. Alternative 6 would have high potential for environmental restoration, including reforestation and reestablishment of wildlife corridor connectivity, and would meet Criterion 9. Further investigation would be necessary to determine if this alternative would comply with all Federal, state, and local regulations (Criterion 10).

Because Alternative 6 could not reasonably meet Criteria 2, 6, and 7, it was dropped from further investigation. However, many of the non-structural measures contained in this alternative could be incorporated into any recommended plan.

Alternative 7 – Interagency Committee Alternative: Alternative 7 combines several aspects of Alternatives 2 through 6 and therefore is a multiple-action alternative. Through discussion with the alternatives subcommittee, the subcommittee concurred with the Corps' findings regarding the use of flow restrictors (see discussion of Alternative 5) and excavation of the hump (see discussion of Alternative 3) and therefore dropped those measures from Alternative 7. However, the other actions remained as part of Alternative 7.

When structural measures are included, Alternative 7 would reduce flood hazards (Criterion 1) and decrease transportation closures (Criterion 2). Again, when structural measures are included, Alternative 7 would not result in downstream impacts (Criterion 3) or changes in the low-flow operation of Skookumchuck Dam (Criterion 4). Because flood hazards would be reduced, costs of flood damages would also be reduced (Criterion 5) as would the costs of transportation delay (Criterion 6). Costs of operation and maintenance would need to be further evaluated to determine if Criterion 7 could be met. With regard to Criterion 8, adverse environmental impacts such as loss of existing wetlands and riparian areas, corridor connectivity, and impacts to potential fish habitat would likely be similar to Alternatives 4 and 6 if all measures were implemented. Additional analysis would need to be done to evaluate the socioeconomic effects of development restrictions. Restoration opportunities would be similar to Alternatives 4 and 6 and inclusion of the SR-6 bypass would provide restoration opportunities described earlier for that component of Alternative 3 (Criterion 9). Further investigation would be necessary to determine if this alternative would comply with all Federal, state, and local regulations (Criterion 10).

This alternative appeared to be consistent with the criteria, although there were issues that needed further investigation. Specifically, the operation and maintenance costs and environmental impacts warranted further review. This alternative was carried forward for further evaluation.

Preliminary Alternatives Screening Summary: The conclusion of this process identified three alternatives that tentatively met all the project criteria; it also identified one alternative that could actually be a project feature for the other three alternatives. Consistent with NEPA requirements, the No Action Alternative (Alternative 1) was also carried forward for further evaluation. The three alternatives that were carried through to Phase 2 are provided in Table 4-2.

TABLE 4-2 ALTERNATIVES FOR PHASE 2 SCREENING

• Alternative 1 – No Action Alternative
• Alternative 3A – Centralia overbank excavation and Chehalis SR-6 flow-way bypass (could be combined with the Dam Modifications, Alt 2)
• Alternative 4 – Levee System (could be combined with the Dam Modifications, Alt 2)
• Alternative 7 – Interagency Committee Alternative (combination of non-structural and structural features including the Dam Modifications, Alt 2)
• Alternative 2 – While Skookumchuck Dam Modifications did not meet multiple criteria, it was found to provide significant hydraulic reductions in flood stages along the Skookumchuck River and in parts of the City of Centralia. For this reason it was carried forward for further modeling and evaluation as a component to be considered for implementation in combination with other alternatives.

4.6 Phase 2 – Formulation and Screening of Final Alternatives

A risk-based analysis as described in Section 2.2.6, was performed for each alternative to determine residual damages, net benefits and project performance. The intermediate array of alternatives, as described in Section 4.5.2, is generally comprised of measures on both the Chehalis and Skookumchuck rivers. The formulation and screening strategy was developed to determine economic viability of each measure that comprises an alternative. The strategy first determines the measure that maximizes net benefits, then incrementally adds measures that (1) are incrementally justified; and (2) do not render the entire alternative unjustified. Each river, and the associated measures, were evaluated initially as hydraulically separable elements. The measure that yielded the highest net benefit became the first added measure. The evaluation separated the Chehalis and the Skookumchuck elements, however the influence (damages reduced) of one on the other was captured jointly as well as incrementally. The Chehalis River measures were evaluated as the first element, because those measures had the potential for the largest damage reduction. The Skookumchuck Dam element was the first added element, with other measures evaluated beyond the first added to determine if those measures were incrementally justified. The following paragraphs describe the risk based analysis (RBA) results for both damages reduced and project performance for each alternative.

4.7 Phase 2 – Description of Final Alternatives

In Phase 2, the initial alternatives carried forward from Phase 1 were further modified into multiple variations of each alternative. The Phase 2 modified alternatives were configured based on a common water surface profile from the hydraulic model. All alternatives analyzed in this phase used the 100-year frequency flow and the associated profile to define levee heights, bypass size, etc.; alternatives that did not reliably contain the 100-year flood event were not included. The 100-year frequency was selected as the common event for Phase 2 economic screening and also to allow comparison of engineering performance to the FEMA certification criteria.

4.7.1 Phase 2: Alternative 2 – Skookumchuck Dam Modifications Alternative

In Phase 2, a HEC-FDA analysis was conducted for the Skookumchuck River floodplain that evaluated benefits of the modifications at Skookumchuck Dam. The results showed the dam reduced damages and provided a positive benefit-to-cost ratio. To optimize the configuration, the team configured and modeled a "lower" pool (elevation 477 feet) to evaluate its costs and benefits.

The lower pool option does not raise the pool by inflatable rubber weir as with other alternatives, but focuses on the addition of an improved outlet structure. The variations on Alternative 2 that were evaluated in Phase 2 are listed below by the name of each variation. The configuration of each variation is described.

- ***ExSkDam:*** This configuration describes the existing Skookumchuck Dam that is not a flood control reservoir.

- ***SKDam1:*** This is the "lower dam" configuration that does not raise the pool (remains at elevation 477 feet) but improves the outlet structure (2B2, without pool raise); it has 11,000 ac-ft of flood control storage.

- ***SKDam2:*** This is the configuration described as Skookumchuck Dam Modifications 2B2. This alternative has 20,000 ac-ft of flood control storage by raising the storage elevation to 492.

In this phase a new configuration of 2B2 was utilized. It incorporated a design for both 11,000 ac-ft storage and 20,000 ac-ft storage. The reconfigured Alternative 2B2, Short Tunnel with

Slide Gates, would consist of constructing a short outlet works tunnel in the left abutment of the dam between the existing spillway and dam crest. An outlet works tower with slide gates would be built at the entrance to the new tunnel. The tunnel would discharge into the existing spillway chute, which would be modified to handle the full PMF flow. For the high flood storage pool option, 20,000 ac-ft, three steel tainter gates would be added to the top of the existing ogee spillway.

For the 11,000 ac-ft option, the existing overflow spillway would remain as it is with no control gates. For this case, the overflow spillway would have a total capacity of approximately 28,000 cfs. In order for the spillway to pass the full PMF flow of 32,500 cfs, the spillway chute entrance would have to be modified as was assumed in Alternative 2B1. Reference the Skookumchuck Dam Design appendix (Appendix B) for additional details.

4.7.2 Phase 2: Alternative 3 – Overbank Excavation and Flowway Bypass Alternative

The study team modeled this alternative as a separable first element measure and also in combination with the Skookumchuck Dam Modifications feature. This evaluation determined that the alternative, including the Chehalis bypass measures alone, did not provide sufficient damage reduction and subsequent net benefits to remain a viable stand-alone alternative. Therefore, a levee component was added around the Chehalis-Centralia Airport. The names used for the sub-alternatives of Alternative 3 in documentation of the Phase 2 screening are:

- ***Bypass/APLev:*** This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A with the addition of levee modification at Chehalis-Centralia Airport and Skookumchuck Dam Modifications 2B2 with 20,000 ac-ft of storage.

- ***Bypass/SkDam1:*** This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modifications 2B2 with 11,000 ac-ft of flood storage.

- ***Bypass/SkDam2:*** This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modifications 2B2 with 20,000 ac-ft of flood storage.

Another iteration of this alternative was added to the analysis process. This included adding the remainder of the Chehalis levee system to this alternative and modifying the configuration of the bypasses. This alternative combined elements of alternatives 3A, 2 and 4.

- ***Hybrid Plan - SkookDam1:*** This configuration included a modification to the bypass at Mellen Street and the SR-6 bypass. Both overbank excavations were reduced in size from the original Alternative 3A configuration, and the berm in the floodplain was removed. In addition the Chehalis levee system was added to this alternative. The levee heights were adjusted for the difference in hydraulic stages due to the influence of the overbank excavation areas. This also included the 11,000 ac-ft Skookumchuck Dam Modifications.

- ***Hybrid Plan -SkookDam2:*** This included the Hybrid Plan with the 20,000-ac-ft dam.

4.7.3 Phase 2: Alternative 4 – Levee Alternative

The Chehalis and Skookumchuck levees were evaluated separately to determine if the flood reductions measures for each segment were individually justified. Modeling runs indicated that the levees reduced damages significantly and were economically justified.

Seven sub-alternatives of Alternative 4 were developed and evaluated in this phase. These alternative configurations are as follows:

- ***CheLev1:*** This configuration includes levees on the Chehalis River at the original design height including levees along the Chehalis River, Salzer Creek and Dillenbaugh Creek.

- ***CheLev2:*** This configuration includes the levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height.

- ***CheLev1-SkDam1:*** This configuration includes levees on the Chehalis River at the original design height combined with 11,000 ac-ft Skookumchuck Dam Modifications Alternative.

- ***CheLev2-SkDam1:*** This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with 11,000 ac-ft Skookumchuck Dam Modifications Alternative.

- ***CheLev2-SkDam2:*** This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with the 20,000 ac-ft Skookumchuck Dam Modifications Alternative.

- ***Skook Levee:*** This configuration includes the Skookumchuck River levees alone.

- ***CheLev1-SkLev:*** This configuration includes levees on the Chehalis River at the original design height combined with Skookumchuck River levees.

- ***CheLev2-SkLev:*** This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with Skookumchuck River levees.

Another set of iterations of this alternative was added to the analysis process. This included addition of SR-6 bypass to the levee combination and reduction of the length of the Skookumchuck River levees (from approximately 4 miles to approximately 2 miles), in combination with the original Chehalis levees and the Skookumchuck Dam. The following describes these additional alternatives:

- ***CheLev2- SR-6-SkDam1:*** This configuration includes levees on the Chehalis River at a 100-year protection, and the 11,000 ac-ft Skookumchuck Dam Modifications Alternative.

- ***CheLev2 -SR-6-SkDam2:*** This configuration includes the 100-year levees on the Chehalis River, a 20,000 ac-ft Skookumchuck Dam Modifications Alternative and the modified SR-6 bypass.

- ***CheLev2-SkDam1/SkLevee:*** This configuration includes the 100-year Chehalis levees, an 11,000 ac-ft Skookumchuck Dam and the addition of the Skookumchuck levees as a second added feature.

- ***CheLev2-SkDam2/SkLevee:*** This configuration includes the 100-year Chehalis levees, a 20,000 ac-ft Skookumchuck Dam and the addition of the Skookumchuck levees as a second added feature.

4.7.4 Phase 2: Alternative 7 – Interagency Alternative

Earlier hydraulic model runs showed that all the structural measures of Alternative 7 would need to be implemented in order to meet project criteria related to engineering effectiveness. This resulted in excessive costs that were not economically justified. In order to determine if this alternative could still be viable the team modified it to include levees and eliminated features such as flow restrictors and raising I-5 because they were too costly and did not provide substantial hydraulic benefits. Alternative 7 was reconfigured to included levees along I-5.

The resultant alternative configurations of Alternative 7 that were evaluated during Phase 2 are as follows:

- ***Alternative 7:*** This alternative included all the structural features listed in the description of Alternative 7 (measures 12 through 17). The non-structural measures could not be modeled or costed out for the study. This alternative did not reduce damages to the highway or the buildings; therefore it was not further evaluated.

- ***Alternative 7A Combo- SkookDam1:*** This configuration is the same as Alternative 7 above, but elevation of I-5 is not included and is replaced by implementation of levees along I-5. This alternative included a dam with 11,000 ac-ft flood storage.

- ***Alternative 7A Combo- SkookDam2:*** This configuration is the same as Alternative 7 above, but elevation of I-5 is not included and is replaced by implementation of levees along I-5. This alternative included a dam with 20,000-ac-ft of flood storage.

4.8 Phase 2 - Summary of Final Alternatives

Table 4-3 provides a summary list of the final alternatives to undergo Phase 2 screening.

TABLE 4-3 FINAL ALTERNATIVES

ALTERNATIVE	CONFIGURATION	DESCRIPTION
Alternative 1		**No Action Alternative**
Alternative 2		**Skookumchuck Dam Modifications Alternative**
	SKDam1	Dam Modifications Alternative 2B2 without pool raise
	SKDam2	Dam Modifications Alternative 2B2
	SKDam	Existing dam
Alternative 3		**Overbank Excavation and Flowway Bypass Alternative**
	Bypass – SkDam2	Bypass 3A with Dam Modifications Alternative 2B2
	Bypass –SkDam1	Bypass 3A with Dam Modifications Alternative 2B2 without pool raise
	Hybrid –SkDam1	Modified bypass with Levee Alternative with Dam Modifications Alternative 2B2 without pool raise
	Hybrid –SkDam2	Modified bypass with Levee Alternative with Dam Modifications Alternative 2B2 with pool raise
Alternative 4		**Levee System Alternative**
	CheLev2 - SkDam	Chehalis River, Salzer Creek, Dillenbaugh Creek modified levee design to 100-year performance level with existing dam
	CheLev2 – SKDam1	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-year performance level with SKDam1
	CheLev2 – SKDam2	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-year performance level with SKDam2
	CheLev2-ExSkDam/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-year performance level with existing dam and Skookumchuck levees
	CheLev2-SkDam1/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-year performance level with SKDam1 and Skookumchuck Levees
	CheLev2-SkDam2/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-year performance level with SKDam2 and Skookumchuck Levees
Alternative 7		**Interagency Alternative**
	Alternative 7- existing dam	All structural features without I-5 raise and with levees with existing dam
	Alternative 7- SkDam1	All structural features without I-5 raise and with levees with low pool dam
	Alternative 7- SkDam2	All structural features without I-5 raise and with levees with high pool dam

4.9 Phase 2 - Estimated Costs of Final Alternatives

Preliminary cost estimates developed during Phase 1 were refined for all final Phase 2 alternatives, as follows in Table 4-4:

TABLE 4-4 SUMMARY COST ESTIMATES FOR FINAL ARRAY OF ALTERNATIVES

	ALTERNATIVES	First Cost of Alternative	O & M Costs (per year)	Real Estate Appraised Cost	Mitigation Costs	Interest During Construction	Total Costs w/o O&M	Total Annualized Costs
#2	**Skookumchuck Dam Modifications**							
	SkDam 1: This is the "lower dam" configuration that does not raise the pool (remains at 477 elevation) but improves the outlet structure (2.b.2 without pool raise); it has 11,000 acre-feet of flood control storage.	$6,034,053	$448,297	$0	$3,270,000	$569,873	**$9,873,926**	**$1,085,698**
	SkDam 2: This is the configuration described as Skookumchuck Dam Modification 2.b.2. This alternative has 20,000 acre-feet of flood control storage by raising the storage elevation to 492.	$8,237,016	$514,512	$0	$3,270,000	$704,805	**$12,211,821**	**$1,302,834**
#3	**Bypass**							
	Bypass w/o Dam: This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A.	$64,553,252	$37,100	$14,794,758	$8,713,900	$5,393,792	**$93,455,702**	**$6,070,038**
	Bypass - SkDam 1: This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modification 2.b.2 with 11,000 acre feet of flood storage.	$70,587,305	$448,297	$14,794,758	$11,983,900	$6,024,915	**$104,390,878**	**$7,187,144**
	Bypass - SkDam 2: This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modification 2.b.2 with 20,000 acre of flood storage.	$72,790,268	$551,612	$14,794,758	$11,983,900	$6,159,847	**$106,728,773**	**$7,441,379**
	Bypass - AP Levee- Skdam2 This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A with the addition of levee modification at Centralia-Chehalis Airport and Skookumchuck Dam Modification 2.b.2 with 20,000 acre feet of storage.)	$74,481,054	$551,612	$14,794,758	$8,713,900	$6,001,870	**$103,991,582**	**$7,264,683**
	Hybrid - SkDam1: This configuration included a modification to the bypass at Mellen Street and the SR6 bypass. Both overbank excavations were reduced in size from the original Alternative 3A configuration. And the berm in the floodplain was removed. In addition the Chehalis levee system was added to this alternative. The levee heights were adjusted for the difference in hydraulic stages due to the influence of the overbank excavation areas. This also included the 11,000 acre-foot Skookumchuck Dam.	$61,135,412	$547,789	$14,794,758	$8,713,900	$5,184,449	**$89,828,519**	**$6,346,578**
	Hybrid - SkDam2 (This included the Hybrid plan with the 20,000-acre foot dam)	$63,338,375	$1,099,401	$14,794,758	$8,713,900	$5,319,381	**$92,166,414**	**$7,049,110**

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	ALTERNATIVES	First Cost of Alternative	O & M Costs (per year)	Real Estate Appraised Cost	Mitigation Costs	Interest During Construction	Total Costs w/o O&M	Total Annualized Costs
#4	**Levee**							
	CheLev2: This configuration includes the levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height.	$39,790,000	$99,492	$7,493,624	$8,713,900	$3,429,848	**$59,427,372**	**$3,935,766**
	CheLev2 - SkDam1: This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with Skookumchuck Dam Alternative.	$45,824,053	$547,789	$7,493,624	$11,983,900	$3,999,722	**$69,301,299**	**$5,021,464**
	CheLev2 - SkDam2: This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with the 20,000 acre-foot Skookumchuck Dam Alternative.	$48,027,016	$514,512	$7,493,624	$11,983,900	$4,134,653	**$71,639,193**	**$5,139,107**
	SR 6	$2,907,935	$10,000	$2,000,000	$0	$300,611	**$5,208,546**	**$346,232**
	CheLev2-SkDam1-SR6: (This configuration includes levees on the Chehalis River at a 100 year protection, the 11,000 acre foot Skookumchuck dam alternative and a modified 400 foot wide SR6 bypass)	$48,731,988	$557,789	$9,493,624	$11,983,900	$4,300,333	**$74,509,845**	**$5,367,696**
	CheLev2-SkDam2-SR6: (This configuration includes the 100-year levees on the Chehalis River, a 20,000-acre foot Skookumchuck dam alternative and the modified SR6 bypass)	$50,934,951	$624,004	$9,493,624	$11,983,900	$4,435,264	**$76,847,739**	**$5,584,832**
	Skooklevee - 100 year: This configuration includes the Skookumchuck River levees alone.	$10,360,000	$19,025	$2,802,000	$0	$806,173	**$13,968,173**	**$920,726**
	Skooklevee - Chehalis Backwater: This shows the cost of the Skookumchuck River Levees that are attributable to the Chehalis levees to mitigate against all backwater stage increases.	$5,560,000	$19,025	$2,802,000	$0	$512,173	**$8,874,173**	**$591,888**
	CheLev2-SkDam1-Skooklevee: This configuration includes the 100-year Chehalis levees, an 11,000 acre-foot Skookumchuck Dam and the addition of the Skookumchuck levees as a second added feature.	$56,184,053	$566,814	$10,295,624	$11,983,900	$4,805,894	**$83,269,471**	**$5,942,190**
	CheLev2-SkDam1-Skooklevee-SR6: This configuration includes levees on the Chehalis River at a 100 year protection, the 11,000 acre foot Skookumchuck dam alternative and a modified 400 foot wide SR6 bypass.	$59,091,988	$576,814	$12,295,624	$11,983,900	$5,106,505	**$88,478,017**	**$6,288,422**
#7	**Interagency Committee Alternative - Modified**						**$0**	
	Alternative 7A Combo- SkookDam1: This configuration is the same as Alternative 7 above, but elevation of I-5 is not included and is replaced by implementation of levees along I-5. This alternative included a dam with 11,000-acre foot flood storage.	$55,336,224	$251,080	$12,493,624	$11,983,900	$4,888,592	**$84,702,340**	**$5,718,953**

4.10 Phase 2 - Risk-Based Assessment and Evaluation of Final Alternatives

The following paragraphs describe the RBA results for damages reduced for each measure and combination of alternatives. The analysis results and screening logic are described below.

4.10.1 With-Project Hydrology and Hydraulics

The with-project conditions for each measure were modeled by modifying the existing condition input data according to the results of the UNET modeling results. For example, if a particular discharge-frequency or stage-discharge function was altered as a result of a particular measure (levee, bypass, or reservoir), the appropriate without-project data set was modified and HEC-FDA recalculated residual damages and performance parameters. Total residual damages for each alternative were determined by coupling measures for each of the Chehalis River and the Skookumchuck River. For example, one alternative is comprised of levees on the Chehalis and levees on the Skookumchuck. The full array of intermediate alternatives is described in Section 4.7.

4.10.2 Residual Damages, Damages Reduced and Net Benefits

The Chehalis River Levee measures, as the first alternative element, were evaluated using the existing Skookumchuck Dam operation. The HEC-FDA results for residual damages are presented in Table 4-5. Table 4-5's Other Damages Reduced includes transportation delays, agricultural damages, and the avoided cost savings from eliminating raising I-5 during its scheduled modification as described in Section 6.3. Table 4-5 indicates that only three of the five general alternative plans presented in the table have a likelihood of meeting NED criteria. These three general plans are: (1) CheLev2, (2) Hybrid Plan, and (3) CheLev2 – SKLev. Each of these general plans may or may not contain a Skookumchuck Dam modification. The two general plan types that can be ruled out as potentially producing a NED candidate are Bypass and Alternative 7. These two general plan types are ruled out for further analyses by their negative net NED benefits showing at this level of plan formulation. The Hybrid general plan type is also eliminated from further analyses at this time given the disparity in net NED benefits in comparison to the other two general plan types. Although the Hybrid Plan type shows positive net NED benefits, it is unlikely that this plan type could close the annual benefit difference of $324,000, given the level of feature overlap between the general plan types.

The general plan type with the highest net benefit is CheLev2 with a net annual benefit range $1,677,000 to $2,699,000. With the difference between the two remaining general plan types being only levees on the Skookumchuck River and that the general plan type with these levees (CheLev2 – SKLev) showing incremental justification of the Skookumchuck levees, the remaining analyses will focus on this general plan type.

Skookumchuck Dam was included in the evaluation as a first added element to determine the flood reduction effectiveness. There were two storage alternatives evaluated an 11,000 ac-ft dam and a 20,000 ac-ft dam. Each storage component was evaluated for each of the Chehalis plans. The incremental benefit for the CheLev2 plan with the 11,000 ac-ft dam is $2,107 with an incremental benefit-to-cost of 1.94. The combined plan yields a net benefit of $2,698.64 with a benefit-to-cost of 1.48. This includes the impacts of the dam on the Chehalis since the effects are captured in the resultant hydraulic analysis. The incremental benefit for raising the CheLev2 plan from 11,000 ac-ft to the 20,000 ac-ft dam is $122 with an incremental cost of $217, and an incremental benefit-to-cost of 0.56. Increasing the dam size from 11,000 ac-ft to 20,000 ac-ft is not justified, and for this reason the analysis assumes that the 11,000 ac-ft dam is incrementally justified as the first added element.

In an attempt to further reduce flooding on the Skookumchuck River, specifically in Reach 4, levees along the Skookumchuck River were analyzed. The incremental net benefit change from CheLev2 plan with the 11,000 ac-ft dam to the CheLev2 plan with the 11,000 ac-ft dam and Skookumchuck levees is -$6,000; and given that the CheLev2 with 11,000 ac-ft dam alternative does not consider backwater effects on the Skookumchuck River at this stage, it is reasonable to assume that the CheLev2 – SKDam and SKLev plan type would most likely generate the NED recommended plan.

TABLE 4-5 WITH-PROJECT ECONOMIC ANALYSIS

Alternative	Expected Annual Damages ($1,000s)*					Flood Damages Reduced	Other Damages**	Other Damages Reduced	Total Damages Reduced	Cost	Net Benefit	B/C
	Chehalis		Skookumchuck		Total							
	Res/Comm	Public	Res/Comm	Public								
No Action	6147.81	442.93	2211.84	42.36	8844.94	0.00	2239.10	0.00	0.00	0.00	0.00	0.00
CheLev2 - Existing SkDam	2347.19	82.95	2392.52	46.94	4869.60	3975.34	2239.10	2239.10	6214.44	4537.06	1677.38	1.37
CheLev2 - SkDam 1	2081.67	70.05	595.59	15.34	2762.65	6082.29	2239.10	2239.10	8321.39	5622.75	2698.64	1.48
CheLev2 - SkDam 2	2057.19	68.37	504.68	10.57	2640.81	6204.13	2239.10	2239.10	8443.23	5839.89	2603.34	1.45
CheLev2SR-6 - Ex SkDam	2186.09	58.63	2290.11	42.72	4577.55	4267.39	2239.10	2239.10	6506.49	4863.89	1642.60	1.34
CheLev2SR-6 - SkDam 1	1893.35	45.85	694.59	14.09	2647.88	6197.06	2239.10	2239.10	8436.16	5949.58	2486.58	1.42
CheLev2SR-6 - SkDam 2	1876.98	43.86	498.56	10.30	2429.70	6415.24	2239.10	2239.10	8654.34	6166.72	2487.62	1.40
Hybrid Plan - Existing Dam	2231.15	61.06	1363.55	38.16	3693.92	5151.02	2239.10	2239.10	7390.12	5098.44	2291.68	1.45
Hybrid Plan - SkDam 1	1901.64	47.66	562.03	14.14	2525.47	6319.47	2239.10	2239.10	8558.57	6184.14	2374.43	1.38
Hybrid Plan - SkDam 2	1900.60	45.02	464.71	8.85	2419.18	6425.76	2239.10	2239.10	8664.86	6401.28	2263.58	1.35
CheLev2 - Ex SkDam/SKLev	2217.91	60.56	1677.61	42.06	3998.14	4846.80	2239.10	2239.10	7085.90	4865.90	2220.00	1.46
CheLev2 - SkDam 1/SkLev	1932.99	50.86	453.78	11.19	2448.82	6396.12	2239.10	2239.10	8635.22	5951.60	2683.62	1.45
CheLev2 - SkDam 2/SkLev	1924.27	48.05	337.42	9.32	2319.06	6525.88	2239.10	2239.10	8764.98	6168.73	2596.25	1.42
Bypass - Existing Dam	3404.44	30.56	2225.90	38.25	5699.15	3145.79	2239.10	0.00	3145.79	6070.04	-2924.25	0.52
Bypass - SkDam 1	2996.60	98.17	542.00	9.28	3646.05	5198.89	2239.10	0.00	5198.89	6882.46	-1683.57	0.76
Bypass - SkDam 2	2977.01	94.28	458.70	6.60	3536.59	5308.35	2239.10	0.00	5308.35	7526.87	-2218.52	0.71
Alternative 7 - Existing Dam	3382.07	97.10	2288.89	41.94	5810.00	3034.94	2239.10	0.00	3034.94	5081.55	-2046.61	0.60
Alternative 7 - SkDam 1	2899.76	74.89	601.44	18.63	3594.72	5250.22	2239.10	0.00	5250.22	5718.95	-468.73	0.92
Alternative 7 - SkDam 2	2869.41	70.80	526.26	7.69	3474.16	5370.78	2239.10	0.00	5370.78	5869.87	-499.09	0.91

** Numbers may not add due to rounding* ***Other Damages includes 1-5 avoided cost savings and traffic delay reductions through 2012.*

4.10.3 Project Performance

In addition to the economic basis for screening alternatives, the engineering performance is also considered. The two performance indices targeted for this analysis were the Expected Annual Exceedance and the Conditional Probability of Non-Exceedance for the .01 event. A goal of the recommended alternative would be to provide certification to FEMA for providing protection against a 100-year flood event. The reporting of the performance is based on the controlling value at any of the index locations for each river. Table 4-6 below details the expected exceedance, the conditional probability of non-exceedance and the equivalent long-term risk.

TABLE 4-6 PHASE 2 PERFORMANCE ANALYSIS

Alternative	Expected Annual Exceedance %		Equivalent Long-Term Risk						Conditional Probability of Design Containing Indicated Event							
			10 Yrs		25 Yrs		50 Yrs		10%		4%		2%		1%	
	Chehalis	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook
New Existing	59.6	21.1	100.0	90.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CheLev2 - Exsting SkDam	0.3	21.1	2.7	90.4	6.7	99.7	12.9	100.0	100.0	6.3	100.0	0.2	99.7	0.1	95.7	0.0
CheLev2 - SkDam 1	0.3	5.5	2.5	43.3	6.1	75.8	11.2	94.1	100.0	87.6	100.0	48.6	99.7	4.2	95.9	0.1
CheLev2 - SkDam 2	0.2	5.5	2.4	43.3	6.0	75.3	11.6	94.1	100.0	87.5	100.0	48.2	99.7	4.1	96.3	0.6
CheLev2SR6 - Ex SkDam	0.2	21.1	2.0	90.6	4.9	99.7	9.5	100.0	100.0	6.4	100.0	0.2	99.7	0.0	97.3	0.0
CheLev2SR6 - SkDam 1	0.2	5.4	1.7	42.7	4.3	75.2	8.3	93.8	100.0	87.8	100.0	51.8	99.8	3.3	98.1	0.1
CheLev2SR6 - SkDam 2	0.2	5.4	1.7	42.4	4.1	74.8	8.1	93.7	100.0	87.7	100.0	52.4	99.8	4.3	98.2	0.5
Hybrid Plan - Existing Dam	0.3	20.5	2.7	89.9	6.7	99.7	12.9	100.0	100.0	7.5	100.0	0.2	99.7	0.1	96.0	0.0
Hybrid Plan - SkDam 1	0.2	2.4	2.4	50.4	6.0	82.6	11.6	97.0	100.0	79.1	100.0	37.6	99.8	3.7	97.5	0.1
Hybrid Plan - SkDam 2	0.2	6.8	2.4	50.4	5.8	82.7	11.3	97.0	100.0	79.1	100.0	37.6	99.7	3.8	97.4	0.6
CheLev2 - Ex SkDam/SKLev	0.2	21.0	2.2	90.5	5.4	99.7	10.6	100.0	100.0	6.4	100.0	0.2	99.6	0.0	96.9	0.0
CheLev2 - SkDam 1/SkLev	0.2	6.7	2.1	50.1	5.1	82.4	9.9	96.9	100.0	80.6	100.0	35.7	99.6	3.7	96.9	0.1
CheLev2 - SkDam 2/SkLev	0.2	6.7	1.7	50.1	4.6	82.4	9.0	96.9	100.0	80.6	100.0	35.7	99.8	3.6	97.8	0.7
Bypass - Existing Dam	49.2	21.0	99.9	90.5	100.0	99.7	100.0	100.0	0.0	6.4	0.0	0.2	0.0	0.0	0.0	0.0
Bypass - SkDam 1	49.2	6.7	99.9	49.8	100.0	82.2	100.0	96.8	0.0	80.2	0.0	38.1	0.0	3.4	0.0	0.2
Bypass - SkDam 2	49.3	6.6	99.9	49.5	100.0	81.9	100.0	96.7	0.0	80.2	0.0	38.5	0.0	4.1	0.0	0.6
Alternative 7 - Existing Dam	53.0	21.1	100.0	90.6	100.0	99.7	100.0	100.0	0.0	6.3	0.0	0.2	0.0	0.0	0.0	0.0
Alternative 7 - SkDam 1	52.0	6.8	99.9	50.5	100.0	82.7	100.0	97.0	0.0	80.1	0.0	34.0	0.0	3.6	0.0	0.1
Alternative 7 - SkDam 2	52.0	6.8	99.9	50.4	100.0	82.7	100.0	97.0	0.0	80.1	0.0	34.0	0.0	3.7	0.0	0.7

4.11 Phase 2 - Screening Results, Preliminary NED Alternative

Based on economic performance and engineering performance evaluated in screening Phase 2, the most effective alternative for reducing flood damages was identified as a combination of the flood control features Chehalis Levee 2 and Skookumchuck Dam 1. This alternative produced the highest net benefits. The alternative producing the next highest level of net benefits was Chehalis Levee 2, Skookumchuck Dam 1, and Skookumchuck Levees. Because the net benefits of the two alternatives were very close, all three features were carried forward to the next iteration of plan formulation, Phase 3 - Optimization

At this time, no plan satisfies FEMA's Conditional Non-Exceedance Probability criteria for both rivers. However, the Chehalis Levee 2 Plan alternative meets the 0.01 Conditional Non-Exceedance Probability for the Chehalis River along the protected areas. To achieve the same performance along the Skookumchuck River, it appears that additional levees will need to be included along with a dam measure.

4.12 Phase 3 – Optimization and Identification of NED Plan

In the final phase of plan formulation, several different sizes of the plan features carried over from Phase 2 were further evaluated for optimization of project size. This optimization resulted in identification of the NED plan.

4.12.1 Optimization

The array of alternatives analyzed in this optimization phase consists of three basic features that are as follows.

- Skookumchuck Dam Modification;
- Chehalis River Levee Improvements; and
- Skookumchuck River Levee Improvements.

Each of these basic features has an array of its own. For Skookumchuck Dam, two storage capacity level increases were considered with these capacity increases, as follows:

- an 11,000 ac-ft increase; and
- a 20,000 ac-ft increase.

For the Chehalis and Skookumchuck Rivers, five levee improvement levels were considered for each with these levels, as follows[4]:

- a levee height 2 feet below the 100-year water surface elevation (WSE)[5];

[4] Additionally, levee heights at 2 and 3 feet below the 100-year WSE were evaluated on the Skookumchuck River.
[5] As the study is conducted under a risk-based approach, the "100-year" flood consists of a distribution of floods defined by risk-based parameters as presented in hydraulics and hydrology appendices. For the 100-year WSE, the mean values of the risk parameters associated with the 1 percent chance flood were utilized to develop the water

- a levee height at the 100-year WSE;
- a levee height that has a 75-year level of flood protection;
- a levee height that has a 100-year level of flood protection;
- a levee height of approximately 200-year level of protection; and
- a backwater levee only option on the Skookumchuck River.

These basic modes were combined to form 54 potential alternatives, as shown in Table 4-7, below.

TABLE 4-7 PHASE 3 ALTERNATIVES

Existing	100	Backwater
11,000	100	Backwater
11,000	WSE -1	WSE -1
11,000	WSE -1	WSE
11,000	WSE -1	200
11,000	WSE -1	100
11,000	WSE -1	75
11,000	WSE	WSE -1
11,000	WSE	WSE
11,000	WSE	200
11,000	WSE	100
11,000	WSE	75
11,000	75	WSE -1
11,000	75	WSE
11,000	75	200
11,000	75	100
11,000	75	75
11,000	100	WSE-3
11,000	100	WSE-2
11,000	100	WSE -1
11,000	100	WSE
11,000	100	200
11,000	100	100
11,000	100	75
11,000	200	WSE -1
11,000	200	WSE
11,000	200	200
11,000	200	100
11,000	200	75
20,000	WSE -1	WSE -1
20,000	WSE -1	WSE
20,000	WSE -1	200
20,000	WSE -1	100
20,000	WSE -1	75

surface elevation. To provide protection of a given frequency, and as a flood of a given frequency consists of many differing levels, the height of the levee must contain 90 percent of that level's distribution of floods (100-year WSE + 3 feet).

20,000	WSE	WSE
20,000	WSE	200
20,000	WSE	100
20,000	WSE	75
20,000	75	WSE -1
20,000	75	WSE
20,000	75	200
20,000	75	100
20,000	75	75
20,000	100	WSE -1
20,000	100	WSE
20,000	100	200
20,000	100	100
20,000	100	75
20,000	200	WSE -1
20,000	200	WSE
20,000	200	200
20,000	200	100
20,000	200	75

The HEC-FDA model was employed to determine residual damages for all damages except for those damages related to agriculture and transportation. In the case of agricultural damages, the designs of the alternatives would not afford protection to the Chehalis River's west side in the area of agricultural production and agricultural damage reductions would be minimal, if at all. Therefore, no agricultural damage reductions are claimed for any alternative. In the case of rail freight transportation damages, the proposed alternatives would not fully protect the rail lines and transportation delays would continue during flooding events since the railroads would be inundated prior to entering the project area. Therefore, no damage reductions are claimed.

In the without-project condition, traffic on Interstate-5 experiences delays during flood events. I-5 is scheduled to have major modifications made by 2012 to increase its capacity and to eliminate flood-related delays. The without-project analysis indicates that the annual damages associated with traffic delays on I-5 are $476,300. Full implementation of flood control operations for all alternatives is 2007. Applying a net present value approach to the expected annual traffic delay costs during the 2007 to 2012 timeframe yields an annual damage reduction of $129,079, if a project that provides at least 100-year protection is implemented.

Currently there are plans to upgrade and modernize I-5 to increase its capacity and remove it from the threat of flooding. The current cost of this future modernization for elevating the roadway above the 100-year event is estimated at $44,000,000. The plan for I-5 indicates that implementation would take place after the base year of any of the alternatives and would be finished in 2012. If an alternative with at least a 100-year level of protection is implemented, modernization of I-5 would avoid the elevation expenditure of $44,000,000. As this expenditure would occur in the future after the construction of an alternative, discounting this future cost yields a current base year value of $32,686,200. Amortization of this avoided expenditure yields an annual savings of $2,110,000.

NED benefits for the alternatives are shown in Table 4-8, below.

TABLE 4-8 PHASE 3 ALTERNATIVES NED BENEFITS

($1,000s, 2002 price level)

Skookumchuck Dam	Chehalis Levee	Skookumchuck Levee	Residual Damages*	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits
No Action	100	Backwater	4577.55	4267.37	2110.00	129.10	6,506.47
11,000	100	Backwater	2647.88	6197.04	2110.00	129.10	8,436.14
11,000	WSE -1	WSE -1	4340.59	4504.33	0.00	0.00	4504.33
11,000	WSE -1	WSE	4320.37	4524.55	0.00	0.00	4524.55
11,000	WSE -1	75	4305.28	4539.64	0.00	0.00	4539.64
11,000	WSE -1	100	4256.03	4588.89	0.00	0.00	4588.89
11,000	WSE -1	200	4213.24	4631.68	0.00	0.00	4631.68
20,000	WSE -1	WSE -1	4179.64	4665.28	0.00	0.00	4665.28
20,000	WSE -1	WSE	4157.31	4687.61	0.00	0.00	4687.61
20,000	WSE -1	75	4142.48	4702.44	0.00	0.00	4702.44
20,000	WSE -1	100	4087.72	4757.2	0.00	0.00	4757.20
20,000	WSE -1	200	4060.17	4784.75	0.00	0.00	4784.75
11,000	WSE	WSE -1	3695.48	5149.44	0.00	0.00	5149.44
11,000	WSE	WSE	3675.26	5169.66	0.00	0.00	5169.66
11,000	WSE	75	3660.17	5184.75	0.00	0.00	5184.75
11,000	WSE	100	3610.93	5233.99	0.00	0.00	5233.99
11,000	WSE	200	3568.13	5276.79	0.00	0.00	5276.79
20,000	WSE	WSE -1	3540.11	5304.81	0.00	0.00	5304.81
20,000	WSE	WSE	3517.77	5327.15	0.00	0.00	5327.15
20,000	WSE	75	3502.94	5341.98	0.00	0.00	5341.98
20,000	WSE	100	3448.18	5396.74	0.00	0.00	5396.74
20,000	WSE	200	3420.63	5424.29	0.00	0.00	5424.29
11,000	75	WSE -1	2983.3	5861.62	0.00	0.00	5861.62
11,000	75	WSE	2963.1	5881.82	0.00	0.00	5881.82
11,000	75	75	2948	5896.92	0.00	0.00	5896.92
11,000	75	100	2898.76	5946.16	0.00	0.00	5946.16
11,000	75	200	2855.97	5988.95	0.00	0.00	5988.95
20,000	75	WSE -1	2846.42	5998.5	0.00	0.00	5998.50
20,000	75	WSE	2824.1	6020.82	0.00	0.00	6020.82
20,000	75	75	2809.27	6035.65	0.00	0.00	6035.65
20,000	75	100	2754.5	6090.42	0.00	0.00	6090.42
20,000	75	200	2726.94	6117.98	0.00	0.00	6117.98
11,000	100	WSE-3	2591.48	6253.44	2110.00	129.10	8492.54
11,000	100	WSE-2	2556.29	6288.63	2110.00	129.10	8527.73
11,000	100	WSE -1	2533.37	6311.55	2110.00	129.10	8,550.65
11,000	100	WSE	2513.16	6331.76	2110.00	129.10	8,570.86
11,000	100	75	2498.06	6346.86	2110.00	129.10	8,585.96
11,000	100	100	2448.83	6396.09	2110.00	129.10	8,635.19
20,000	100	WSE -1	2409.98	6434.94	2110.00	129.10	8,674.04
11,000	100	200	2406.04	6438.88	2110.00	129.10	8,677.98
20,000	100	WSE	2388.65	6456.27	2110.00	129.10	8,695.37
20,000	100	75	2373.82	6471.1	2110.00	129.10	8,710.20
11,000	200	WSE -1	2337.05	6507.87	2110.00	129.10	8,746.97
20,000	100	100	2319.05	6525.87	2110.00	129.10	8,764.97

Skookumchuck Dam	Chehalis Levee	Skookumchuck Levee	Residual Damages*	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits
11,000	200	WSE	2316.83	6528.09	2110.00	129.10	8,767.19
11,000	200	75	2301.74	6543.18	2110.00	129.10	8,782.28
20,000	100	200	2291.5	6553.42	2110.00	129.10	8,792.52
11,000	200	100	2252.5	6592.42	2110.00	129.10	8,831.52
20,000	200	WSE -1	2223	6621.92	2110.00	129.10	8,861.02
11,000	200	200	2209.71	6635.21	2110.00	129.10	8,874.31
20,000	200	WSE	2200.67	6644.25	2110.00	129.10	8,883.35
20,000	200	75	2185.85	6659.07	2110.00	129.10	8,898.17
20,000	200	100	2131.07	6713.85	2110.00	129.10	8,952.95
20,000	200	200	2103.52	6741.4	2110.00	129.10	8,980.50

***Residual damages in this table do not include agriculture damages and rail damages – both these categories are not affected by proposed alternatives. Residual annual damages in these categories are $115,850 for agriculture and $32,200 for rail.*

Construction and annual costs for the various components are shown below in Table 4-9.

TABLE 4-9 COMPONENT COSTS

($1,000s, 2002 price level)

ALTERNATIVE	Total Construction Cost*	IDC	Total Economic Cost	Annualized Cost	O&M	TOTAL ANNUAL COST
Skookumchuck Dam						
Skookumchuck Dam 11,000 ac-ft	9,304.05	569.87	9,873.93	637.40	448.30	1,085.70
Skookumchuck Dam 20,000 ac-ft	11,507.02	704.80	12,211.82	788.32	514.51	1,302.83
Skookumchuck Levee						
Backwater	8,122.00	497.47	8,619.47	556.00	19.03	575.03
100yr WSE -3	9,006.00	551.62	9,557.62	617.00	19.03	636.03
100yr WSE -2	9,602.00	588.12	10,190.12	623.00	19.03	642.03
100yr WSE -1	9,774.00	598.66	10,372.66	669.00	19.03	688.03
100yr WSE	10,410.00	637.61	11,047.61	713.00	19.03	732.03
75yr Protection	10,952.00	670.81	11,622.81	750.30	19.03	769.32
100yr Protection	13,162.00	806.17	13,968.17	901.70	19.03	920.73
200yr Protection	14,482.00	887.02	15,369.02	992.13	19.03	1,011.16
Chehalis Levee						
100yr WSE -1	48,155.46	2,949.52	51,104.98	3,299.03	99.49	3,398.52
100yr WSE	50,705.46	3,105.71	53,811.17	3,473.73	99.49	3,573.22
75yr Protection	53,675.46	3,287.62	56,963.08	3,677.19	99.49	3,776.69
100yr Protection	60,905.46	3,730.46	64,635.92	4,172.51	99.49	4,272.00
200yr Protection	64,975.46	3,979.75	68,955.21	4,451.33	99.49	4,550.83

**includes Real Estate*

These components in combination form the alternatives and have total costs and net benefits as shown in Table 4-10, below.

TABLE 4-10 TOTAL ANNUAL COSTS AND NED NET BENEFITS PHASE 3 ALTERNATIVES

($1,000s, 2002 price level)

Dam Size	Chehalis Levee*	Skookumchuck Levee*	Residual Damages**	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits	Skook. Dam Cost	Chehalis Levee Cost	Skook. Levee Cost	Total Cost	Net Benefits
11	100	-2	2,556.28	6,288.65	2,110.00	129.10	8,527.75	1,085.70	4,272.00	642.03	5,999.73	2,528.00
11	100	-1	2,533.37	6,311.55	2,110.00	129.10	8,550.65	1,085.70	4,272.00	688.03	6,045.73	2,504.92
11	100	BW	2,647.88	6,197.04	2,110.00	129.10	8,436.14	1,085.70	4,272.00	575.03	5,932.73	2,503.41
11	100	-3	2,591.48	6,253.44	2,110.00	129.10	8,492.54	1,085.70	4,272.00	636.03	5,993.73	2,498.81
11	100	0	2,513.16	6,331.76	2,110.00	129.10	8,570.86	1,085.70	4,272.00	732.03	6,089.73	2,481.13
11	100	75	2,498.06	6,346.86	2,110.00	129.10	8,585.96	1,085.70	4,272.00	769.32	6,127.02	2,458.94
11	200	-1	2,337.05	6,507.87	2,110.00	129.10	8,746.97	1,085.70	4,550.83	663.14	6,299.66	2,447.31
20	100	-1	2,409.98	6,434.94	2,110.00	129.10	8,674.04	1,302.83	4,272.00	663.14	6,237.97	2,436.07
11	200	0	2,316.83	6,528.09	2,110.00	129.10	8,767.19	1,085.70	4,550.83	711.09	6,347.62	2,419.57
20	100	0	2,388.65	6,456.27	2,110.00	129.10	8,695.37	1,302.83	4,272.00	711.09	6,285.92	2,409.45
11	200	75	2,301.74	6,543.18	2,110.00	129.10	8,782.28	1,085.70	4,550.83	769.32	6,405.85	2,376.43
20	100	75	2,373.82	6,471.10	2,110.00	129.10	8,710.20	1,302.83	4,272.00	769.32	6,344.16	2,366.04
11	100	100	2,448.83	6,396.09	2,110.00	129.10	8,635.19	1,085.70	4,272.00	920.73	6,278.42	2,356.77
20	200	-1	2,223.00	6,621.92	2,110.00	129.10	8,861.02	1,302.83	4,550.83	663.14	6,516.80	2,344.22
20	200	0	2,200.67	6,644.25	2,110.00	129.10	8,883.35	1,302.83	4,550.83	711.09	6,564.75	2,318.60
11	100	200	2,406.04	6,438.88	2,110.00	129.10	8,677.98	1,085.70	4,272.00	1,011.16	6,368.85	2,309.13
20	200	75	2,185.85	6,659.07	2,110.00	129.10	8,898.17	1,302.83	4,550.83	769.32	6,622.98	2,275.19
11	200	100	2,252.50	6,592.42	2,110.00	129.10	8,831.52	1,085.70	4,550.83	920.73	6,557.25	2,274.27
20	100	100	2,319.05	6,525.87	2,110.00	129.10	8,764.97	1,302.83	4,272.00	920.73	6,495.56	2,269.41
11	200	200	2,209.71	6,635.21	2,110.00	129.10	8,874.31	1,085.70	4,550.83	1,011.16	6,647.68	2,226.63
20	100	200	2,291.50	6,553.42	2,110.00	129.10	8,792.52	1,302.83	4,272.00	1,011.16	6,585.99	2,206.53
20	200	100	2,131.07	6,713.85	2,110.00	129.10	8,952.95	1,302.83	4,550.83	920.73	6,774.38	2,178.57
20	200	200	2,103.52	6,741.40	2,110.00	129.10	8,980.50	1,302.83	4,550.83	1,011.16	6,864.82	2,115.68
Ext	100	BW	4,577.55	4,267.37	2,110.00	129.10	6,506.47	0.00	4,272.00	591.89	4,863.89	1,642.58
11	75	-1	2,983.30	5,861.62	0.00	0.00	5,861.62	1,085.70	3,776.69	663.14	5,525.52	336.10
11	75	0	2,963.10	5,881.82	0.00	0.00	5,881.82	1,085.70	3,776.69	711.09	5,573.48	308.34
11	75	75	2,948.00	5,896.92	0.00	0.00	5,896.92	1,085.70	3,776.69	769.32	5,631.71	265.21
20	75	-1	2,846.42	5,998.50	0.00	0.00	5,998.50	1,302.83	3,776.69	663.14	5,742.66	255.84
20	75	0	2,824.10	6,020.82	0.00	0.00	6,020.82	1,302.83	3,776.69	711.09	5,790.61	230.21

Dam Size	Chehalis Levee*	Skookumchuck Levee*	Residual Damages**	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits	Skook. Dam Cost	Chehalis Levee Cost	Skook. Levee Cost	Total Cost	Net Benefits
20	75	75	2,809.27	6,035.65	0.00	0.00	6,035.65	1,302.83	3,776.69	769.32	5,848.84	186.81
11	75	100	2,898.76	5,946.16	0.00	0.00	5,946.16	1,085.70	3,776.69	920.73	5,783.11	163.05
11	75	200	2,855.97	5,988.95	0.00	0.00	5,988.95	1,085.70	3,776.69	1,011.16	5,873.54	115.41
20	75	100	2,754.50	6,090.42	0.00	0.00	6,090.42	1,302.83	3,776.69	920.73	6,000.25	90.17
20	75	200	2,726.94	6,117.98	0.00	0.00	6,117.98	1,302.83	3,776.69	1,011.16	6,090.68	27.30
11	0	-1	3,695.48	5,149.44	0.00	0.00	5,149.44	1,085.70	3,573.22	663.14	5,322.05	-172.61
11	0	0	3,675.26	5,169.66	0.00	0.00	5,169.66	1,085.70	3,573.22	711.09	5,370.01	-200.35
20	0	-1	3,540.11	5,304.81	0.00	0.00	5,304.81	1,302.83	3,573.22	663.14	5,539.19	-234.38
11	0	75	3,660.17	5,184.75	0.00	0.00	5,184.75	1,085.70	3,573.22	769.32	5,428.24	-243.49
20	0	0	3,517.77	5,327.15	0.00	0.00	5,327.15	1,302.83	3,573.22	711.09	5,587.14	-259.99
20	0	75	3,502.94	5,341.98	0.00	0.00	5,341.98	1,302.83	3,573.22	769.32	5,645.37	-303.39
11	0	100	3,610.93	5,233.99	0.00	0.00	5,233.99	1,085.70	3,573.22	920.73	5,579.64	-345.65
11	0	200	3,568.13	5,276.79	0.00	0.00	5,276.79	1,085.70	3,573.22	1,011.16	5,670.07	-393.28
20	0	100	3,448.18	5,396.74	0.00	0.00	5,396.74	1,302.83	3,573.22	920.73	5,796.78	-400.04
20	0	200	3,420.63	5,424.29	0.00	0.00	5,424.29	1,302.83	3,573.22	1,011.16	5,887.21	-462.92
11	-1	-1	4,340.59	4,504.33	0.00	0.00	4,504.33	1,085.70	3,398.52	663.14	5,147.36	-643.03
11	-1	0	4,320.37	4,524.55	0.00	0.00	4,524.55	1,085.70	3,398.52	711.09	5,195.31	-670.76
20	-1	-1	4,179.64	4,665.28	0.00	0.00	4,665.28	1,302.83	3,398.52	663.14	5,364.49	-699.21
11	-1	75	4,305.28	4,539.64	0.00	0.00	4,539.64	1,085.70	3,398.52	769.32	5,253.54	-713.90
20	-1	0	4,157.31	4,687.61	0.00	0.00	4,687.61	1,302.83	3,398.52	711.09	5,412.45	-724.84
20	-1	75	4,142.48	4,702.44	0.00	0.00	4,702.44	1,302.83	3,398.52	769.32	5,470.68	-768.24
11	-1	100	4,256.03	4,588.89	0.00	0.00	4,588.89	1,085.70	3,398.52	920.73	5,404.95	-816.06
11	-1	200	4,213.24	4,631.68	0.00	0.00	4,631.68	1,085.70	3,398.52	1,011.16	5,495.38	-863.70
20	-1	100	4,087.72	4,757.20	0.00	0.00	4,757.20	1,302.83	3,398.52	920.73	5,622.08	-864.88
20	-1	200	4,060.17	4,784.75	0.00	0.00	4,784.75	1,302.83	3,398.52	1,011.16	5,712.51	-927.76

* For the Chehalis and Skookumchuck rivers, seven levee improvement levels are considered for each, with these levels being: “-1” = A levee height 1 foot below the 100-year WSE, “-2” = 2 feet below the 100-year WSE; “-3” = A levee height 3 feet below the 100-year WSE; “0” = A levee height at the 100-year WSE; “75”= A levee height that has a 75-year level of flood protection; “100” = A levee height that has a 100-year level of flood protection; “200” = A levee height of approximately 200-year level of protection, and “BW” = A backwater levee only option on the Skookumchuck River. As the study is conducted under a risk-based approach, the “100-year” flood consists of a distribution of floods defined by risk-based parameters, as presented in Appendix A, Hydraulics and Hydrology. For the 100-year WSE, the mean values of the risk parameters associated with the 1 percent chance flood were utilized to develop the water surface elevation. To provide protection of a given frequency, and as a flood of a given frequency consists of many differing levels, the height of the levee must contain 95 percent of that level’s distribution of floods.

**Residual damages in this table do not include agriculture damages and rail damages – Neither of these categories are affected by recommended alternatives. Residual annual damages in these categories are $115,850 for agriculture and $32,200 for rail. Additional project benefits categories of avoided cost of fill for elevating I-5 and reduced traffic delays are presented in other columns in the table.

Table 4-10 indicates that a levee scaled to 1-foot below the 100-year WSE provides greater net NED benefits than no levee construction on the Skookumchuck River other than the backwater levees required to mitigate the influences of the Chehalis River levee on the Skookumchuck River caused by the Chehalis River levees. This analysis showed that the –2 foot levee was the optimum elevation for Skookumchuck River levees.

4.12.2 Identification of NED Plan

Based on the above analyses, the structural plan that most reasonably maximizes net NED benefits consistent with protecting the environment, the NED Plan, consists of the following.

- an 11,000 ac-ft modification plan for the Skookumchuck Dam;
- levee construction of 100-year level protection on the Chehalis; and
- construction of a levee at 2 feet below the 100-year WSE on the Skookumchuck River.

For the identified NED Plan, the following tables reflect revisions in price levels and interest rates. All values are in October 2003 prices and are based on the current federal discount rate of 5.875 percent. Residual damages for the NED Plan are shown in Table 4-11, below.

TABLE 4-11 NED PLAN RESIDUAL DAMAGES

Expected Annual Flood Damage for the NED Plan*

11,000 ac-ft Skookumchuck Dam modification, 100-year Protection Levee Chehalis River, & 100-year WSE -2 Skookumchuck Levee

(Damage in $1,000s, October 2003 Prices, 5.875 %, 50 year analysis period)

Alternative	Damage Categories											
	Com - Cleanup	Com -Cnt	Com - Str	PA	Res - Cleanup	Res - Cnt	Res - Str	TRA	Pub - Cleanup	Pub – Cnt	Pub - Str	Total
Without-project Damages	312	1463	1385	424	896	1466	2514	122	30	209	257	9078
NED Plan	28	206	180	168	325	588	1018	48	5	25	34	2625
Damage Reduction	**284**	**1257**	**1205**	**256**	**571**	**878**	**1496**	**74**	**25**	**184**	**223**	**6453**

**Damages in this table do not include agriculture damages and rail damages – both these categories are not affected by recommended project. Residual annual damages in these categories are $119k for agriculture and $34k for rail. Additional project benefits categories of NED plan include $2,122k in avoided cost of fill for elevating I-5 and $131k in reduced traffic delays. Incorporating these values results in the following:*
Without-project damages including agricultural damages, rail damages, and traffic delays and cost of elevating I-5: ***$11,484***
NED Plan residual damages including agricultural damages and rail damages: ***$2,778***
NED Plan damage reduction including avoided cost of fill for elevating I-5 and reduced traffic delays: ***$8,706***

4.13 Evaluation of Project Performance

In addition to the economic basis for selecting an alternative to optimize, engineering performance as described in Section 3.4.5, is also considered. The three performance indices targeted for this analysis were the Expected Annual Exceedance and the Conditional Probability of Non-Exceedance for a series of events and the Long-Term Risks of Exceedance. Table 4-12 reports indices of engineering performance of the various alternative sizes. For reference, the median annual exceedance probability that corresponds to the top-of-levee stage is determined by direct reference to the stage-discharge and discharge-frequency relationships. The reporting of performance is based on the controlling value (lowest performing location) at any of the index locations for each river.

The Expected Annual Exceedance probability, with uncertainty analysis values, equals the annual exceedance probability with uncertainty included. These represent the protection provided, incorporating explicitly the uncertainty in predicting discharge associated with a specified probability and in predicting stage associated with discharge. In each case, the value is the probability with which the stage, with error included, exceeds the specified top-of-levee (or target elevation) in the simulation for economic evaluation. For example, with the Chehalis levee, the simulated water-surface elevation with errors included exceeded the top-of-levee elevation 61,000 times in 5,000,000 iterations. Therefore, the annual exceedance probability is 61/5,000 = 0.0122. The Expected Annual Exceedance for the existing condition is 39.4 percent on the Chehalis and 17.2 percent on the Skookumchuck (Reach 4 only). The Expected Annual Exceedance for the Chehalis Levee 2, 11,000 ac-ft dam and 100Skook Lev Plan is 0.2 percent on the Chehalis and 0.3 percent on the Skookumchuck (Reach 4 only). The Expected Annual Exceedance for the Chehalis Levee 2, 20,000 ac-ft dam and 100Skook Lev Plan is 0.2 percent on the Chehalis and 0.2 percent on the Skookumchuck (Reach 4 only).

The Conditional Probability of Non-Exceedance of the various plans for four benchmark events is also presented in Table 4-12. The values shown are frequencies of not exceeding the levee capacity, given occurrence of the events shown. For example, for the Chehalis Levee 2, the conditional non-exceedance probability for the 0.01 exceedance probability event is 0.957. That means that should a 0.01 exceedance probability event occur, the probability is 0.957 that it would not exceed the capacity of the levee.

A local goal of a preferred alternative would be to provide certification to FEMA for providing protection against a 100-year flood. This requires the Conditional Non-Exceedance Probability to be a minimum of 90 percent (if freeboard is at least 3 feet) or 95 percent if freeboard is less than 3 feet (per Corps “Guidance on Levee Certification for the NFIP”). The Conditional Non-Exceedance Probability (0.01 event) for the existing condition is 0 percent on the Chehalis and 0 percent on the Skookumchuck (Reach 4 only). The Conditional Non-Exceedance Probability for the Chehalis Levee 2, 11,000 ac-ft dam and 100Skook Lev Plan is 97.7 percent on the Chehalis and 98.2 percent on the Skookumchuck (Reach 4 only). The Conditional Non-Exceedance Probability for the Chehalis Levee 2, 20,000 ac-ft dam and 100Skook Lev Plan is 97.8 percent on the Chehalis and 99.8 percent on the Skookumchuck (Reach 4 only). Therefore, the Chehalis Levee 2 and 100Skook Lev Plan can be certified to meeting the requirements of the FEMA and Corps guidance for 100-year protection.

The Long-Term Risks of Exceedance presents the probability that each alternative could be overtopped in a given period of time. For Levee 2, 11,000 ac-ft dam and 100Skook Lev Plan, for example, there is a 4.7 percent chance that the Chehalis levee would be exceeded in a 25-year period and an 8.7 percent chance for the Skookumchuck Levee (Reach 4 only) for the same term. Levee 2, 20,000 ac-ft dam and 100Skook Lev Plan, there is a 4.6 percent chance that the Chehalis levee would be exceeded in a 25-year period and a 4.7 percent chance for the Skookumchuck Levee (Reach 4 only) for the same term. For the same period, the existing condition long-term risk is 100 percent on the Chehalis and 99 percent chance on the Skookumchuck River.

TABLE 4-12 ENGINEERING PERFORMANCE EVALUATION

Alternative	Expected Annual Exceedance %		Equivalent Long-Term Risk						Conditional Probability of Design Containing Indicated Event							
			10 Yrs		25 Yrs		50 Yrs		10%		4%		2%		1%	
	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook
Existing	39.4	71.2	99.3	84.9	100.0	99.1	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11k-100-200sk	0.2	0.2	1.9	1.9	4.7	4.6	9.1	8.9	100.0	99.9	99.9	99.9	99.8	99.9	97.7	99.9
11k-100-100sk	0.2	0.3	1.9	3.6	4.7	8.7	9.1	16.7	100.0	99.9	99.9	99.9	99.8	99.9	99.7	98.2
11k-100-75sk	0.2	0.8	1.9	7.6	4.7	18.0	9.1	32.7	100.0	99.9	99.9	99.9	99.8	99.3	97.7	73.3
11k-100-WSEsk	0.2	1.0	1.9	9.9	4.7	23.0	9.1	40.7	100.0	99.9	99.9	99.9	99.8	96.3	97.7	50.8
11k-100-WSE-1sk	0.2	1.5	1.9	14.1	4.7	31.6	9.1	53.2	100.0	99.9	99.9	99.7	99.8	79.1	97.7	20.6
11k-100-WSE-2sk	0.2	2.3	1.9	20.6	4.7	43.8	9.1	68.4	100.0	99.9	99.9	94.3	99.8	40.8	97.7	4.3
11k-100-WSE-3sk	0.2	3.9	1.9	33.0	4.7	63.2	9.1	86.5	100.0	96.6	99.9	67.3	99.8	10.9	97.7	0.5
20k-100-200sk	0.2	0.1	1.9	0.5	4.6	1.3	9.0	2.6	100.0	99.9	99.9	99.9	99.8	99.9	97.8	99.9
20k-100-100sk	0.2	0.2	1.9	1.9	4.6	4.7	9.0	9.1	100.0	99.9	99.9	99.9	99.8	99.9	97.8	99.8
20k-100-75sk	0.2	0.7	1.9	6.4	4.6	15.2	9.0	28.0	100.0	99.9	99.9	99.9	99.8	99.1	97.8	86.3
20k-100-WSEsk	0.2	0.9	1.9	8.6	4.6	20.2	9.0	36.3	100.0	99.9	99.9	99.9	99.8	95.5	97.8	68.3
20k-100-WSE-1sk	0.2	1.4	1.9	13.2	4.6	29.7	9.0	50.6	100.0	99.9	99.9	99.7	99.8	76.7	97.8	34.4

4.14 Phase 3 – Locally Preferred Plan

Following review of the optimization analysis results, the local sponsor (Lewis County) indicated preference for implementation of a Locally Preferred (LP) Plan that exceeds the performance, protection, and costs of the NED Plan. The county's preferred plan includes the same three features as identified in the NED Plan; that is, Chehalis River levees, Skookumchuck Dam modifications, and Skookumchuck River levees, however in a slightly different configuration as the NED Plan. The Locally Preferred Plan includes:

- the 20,000 ac-ft modification plan for the Skookumchuck Dam (as opposed to the 11,000 ac-ft modification in the NED Plan);
- levee construction of 100-year level protection on the Chehalis (the same as the NED Plan); and
- construction of a levee providing 100-year protection on the Skookumchuck River (as opposed to the levee at 2 feet below the 100-year WSE, as identified in the NED Plan).

No significant differences in adverse environmental impacts were identified in the EIS process between the NED Plan and the Locally Preferred Plan. For this reason, the same mitigation features and cost were applied to both plans.

Residual damages for the Locally Preferred Plan are shown in Table 4-13, below. All values are in October 2003 prices and are based on the current Federal discount rate of 5.875 percent.

TABLE 4-13 LP PLAN RESIDUAL DAMAGES

Expected Annual Flood Damage for the Locally Preferred Plan* 20,000 ac/ft Skookumchuck Dam modification, 100-yr Protection Levee Chehalis River, & 100-yr Skookumchuck Levee (Damage in $1,000's, October 2003 Prices, 5.875%, 50 -year analysis period)												
Alternative	Damage Categories											
	Com - Cleanup	Com-Cnt	Com-Str	PA	Res-Cleanup	Res-Cnt	Res-Str	TRA	Pub-Cleanup	Pub-Cnt	Pub-Str	Total
Without-project Damages	312	1463	1385	424	896	1466	2514	122	30	209	257	9078
NED Plan	20	169	137	156	303	547	947	45	5	22	31	2382
Damage Reduction	**292**	**1294**	**1248**	**268**	**593**	**919**	**1567**	**77**	**25**	**187**	**226**	**6696**

**Damages in this table do not include agriculture damages and rail damages – both these categories are not affected by the selected project. Residual annual damages in these categories are $119k for agriculture and $34k for rail. Additional project benefits categories of LP plan include $2,122k in avoided cost of fill for elevating I-5 and $131k in reduced traffic delays. Incorporating these values results in the following:*
Without-project damages including agricultural damages, rail damages, and traffic delays and cost of elevating I-5: ***$11,484***
LP Plan residual damages including agricultural damages and rail damages: ***$2,535***
*LP Plan damage reduction including avoided cost of fill for elevating I-5 and reduced traffic delays: $**8,949***

4.14.1 Elevation of Structures

Both the NED and the Locally Preferred Plan structural alternative will result in slightly increased flood elevations over existing conditions (average of 4 inches for the 100-year event) for eight residential structures in the study area 100-year floodplain. The identified structures included six to the south of the Chehalis-Centralia Airport and two to the north of SR-6. To address this issue, a non-structural analysis was conducted of raising affected structures so that first floor elevations would be 1 foot above the with-project 100-year water surface elevation (WSE). The estimated implementation cost is based on cost data obtained for previous Corps studies, which indicate an average of $25,000 per residence. Most of the costs of raising a structure are incurred in separating the structure from its foundations and installing a raised foundation. The height of this raised foundation is not generally a significant factor in the total cost and was not used in this estimate. However, the average number of feet these structures are below the 100-year WSE is included for information.

There are two study area sub-areas in which the affected structures are located. The eight structures would be raised an average of 1.85 feet for a total cost of $200,000 (or an average annual cost of $12,470). The flood damage reduction benefits of raising these structures were based on data taken from the HEC-FDA model results. This data indicated average annual flood damage reductions of $1,730 per structure, or $13,840 for all eight structures. Comparing average annual benefits of $13,840 to average annual costs of $12,468 results in a benefit-to-cost ratio of 1.1 to 1.0 for this non-structural project component.

Table 4-14 presents the two sub-areas with the number of affected residences, their average elevations below the 100-year without- and with-project WSE, and the first cost and average annual cost to elevate to 1 foot above the 100-year with-project WSE.

TABLE 4-14 COSTS OF ELEVATING STRUCTURES WITH INDUCED FLOODING

Sub-Area	Number of Affected Residences	Ave Elevation Below 100-yr WSE Without Project	Ave Elevation Below 100-yr WSE With Project	Average Change in 100-yr WSE due to project	First Cost Estimate	Average Annual Costs @ 5.875% over 50 Years
Below Airport	6	0.66	1.2	0.51	$150,000	$9,351
North of SR-6	2	0.29	0.5	0.18	$50,000	$3,117
Totals/Averages	8	0.475	0.85	0.345	$200,000	$12,468

4.15 Formulation of Environmental Mitigation Plan (Phase 1)

In the initial formulation of the proposed mitigation plan (referred to as Mitigation Phase 1 in this report), a variety of different environmental mitigation sites and features were evaluated to identify a cost effective mitigation plan. Identification of mitigation features was based upon findings of environmental studies conducted as part of the General Reevaluation Study that:

- identified basin-wide limiting factors to fish and wildlife production;
- assessed, quantified, and documented existing habitat conditions by sub-basins in the study area;
- identified geomorphic constraints and opportunities for restoring site-specific degraded habitats;
- identified watershed-scale opportunities to address limiting factors;
- formulated a range of potential environmental projects;
- developed an evaluation framework for quantifying environmental conditions;
- quantified environmental benefits of environmental projects;
- quantified environmental impacts of flood control alternatives; and
- identified cost effective mitigation strategies.

After reviewing the above listed parameters, mitigation features were identified and evaluated throughout the study area. These features were formulated to provide mitigation within the project area to address project impacts to significant sensitive resources.

4.15.1 Environmental Evaluation

An environmental evaluation methodology was designed for the study to provide a numerical estimate of the benefits provided by alternative mitigation plans. It also assisted in gathering information needed to assess mitigation needs and options during the formulation process. The framework was intended to differentiate benefits across alternatives and to provide information required for cost effectiveness and incremental cost analysis. An evaluation panel was utilized, composed of representatives from the tribes, Corps, U.S. Fish and Wildlife Service, EPA, Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington Department of Transportation, Grays Harbor County, Thurston County, and Pacific International Engineering, Inc., representing the local sponsor, Lewis County, and facilitation by Tetra Tech, Inc. The evaluation panel met to determine habitat unit scores for both the existing and with-project conditions associated with each alternative mitigation feature. Generally, the score is a reflection of consensus among the panel members. The environmental evaluation methodology provided estimates, in terms of habitat units, of the impact of flood control alternatives as well as the impact of implementing various mitigation alternatives. The analysis is documented in detail in chapter 5 of the EIS.

The Corps will continue to evaluate measures during the design process to avoid direct impacts to vegetation, wetlands, and riparian areas. These measures may include:

- additional adjustments to the levee alignment, where possible, to avoid direct impacts; and
- evaluation of the changes to the flood regimes of the Skookumchuck River.

Measures that would avoid and or reduce potential indirect impacts include:

- strict controls on construction stormwater to avoid direct discharges to wetlands and other aquatic habitats;
- siting of construction areas away from wetland and riparian habitats; and
- siting of construction access roads outside of wetland and riparian areas.

The EIS, Chapter 4, Environmental Effects, discusses specific effects on various reaches of the Chehalis and Skookumchuck rivers.

4.15.2 Potential Mitigation Features

A range of potential environmental projects were identified that addressed findings of the limiting factors analysis and would provide key habitats throughout the study area. The potential mitigation areas/components evaluated are presented in Table 4-15.

TABLE 4-15 POTENTIAL MITIGATION AREAS/COMPONENTS

Alternative
Scheuber Ditch Reconnection & Wetland Creation
SR-6 Oxbow Reconnection
Chehalis River Mainstem Oxbows Reconnections
Chehalis River Mainstem Riparian Revegetation, RM 66-80
Skookumchuck, Chehalis Confluence Revegetation
Skookumchuck Revegetation, RM 12
SF Chehalis Revegetation, RM 0-5
SF Chehalis, Chehalis Confluence Wetland Creation
Newaukum, Chehalis Confluence Revegetation and Wetland Creation
Newaukum, Stan Hedwall Park Side Channel and Wetlands
Newaukum Revegetation, RM 0-10
NF/SF Newaukum Confluence Wetland Creation
MF Newaukum Revegetation, Tauscher Road
NF Newaukum Revegetation, Tauscher Road
Salzer Creek, Chehalis Confluence Wetland Creation
Salzer Creek Wetland Creation, Frozen Foods Site
Salzer Creek, RM 3.1
Salzer Creek, RM 4.5

4.15.3 Cost Effectiveness and Incremental Cost Analysis

A cost effectiveness and incremental cost analysis was conducted to evaluate the relative effectiveness and efficiency of alternative mitigation measures at providing environmental benefits. The analyses provide a framework for comparing the differences in environmental output across alternative measures and the associated changes in cost. Cost and output estimates were developed for the components from Table 4-15. These estimates were used in the analyses to evaluate the cost effectiveness of the various mitigation options. The output estimates were derived by the evaluation framework process described in the paragraph above and are measured in habitat units. Cost estimates were developed that included design costs, construction costs, real estate costs, and operation and maintenance costs. This analysis is presented in chapter 5 of the EIS.

Eighteen potential mitigation sites were evaluated in the cost effectiveness and incremental cost analyses. The 18 sites are shown in Table 4-16 with cost and output estimates.

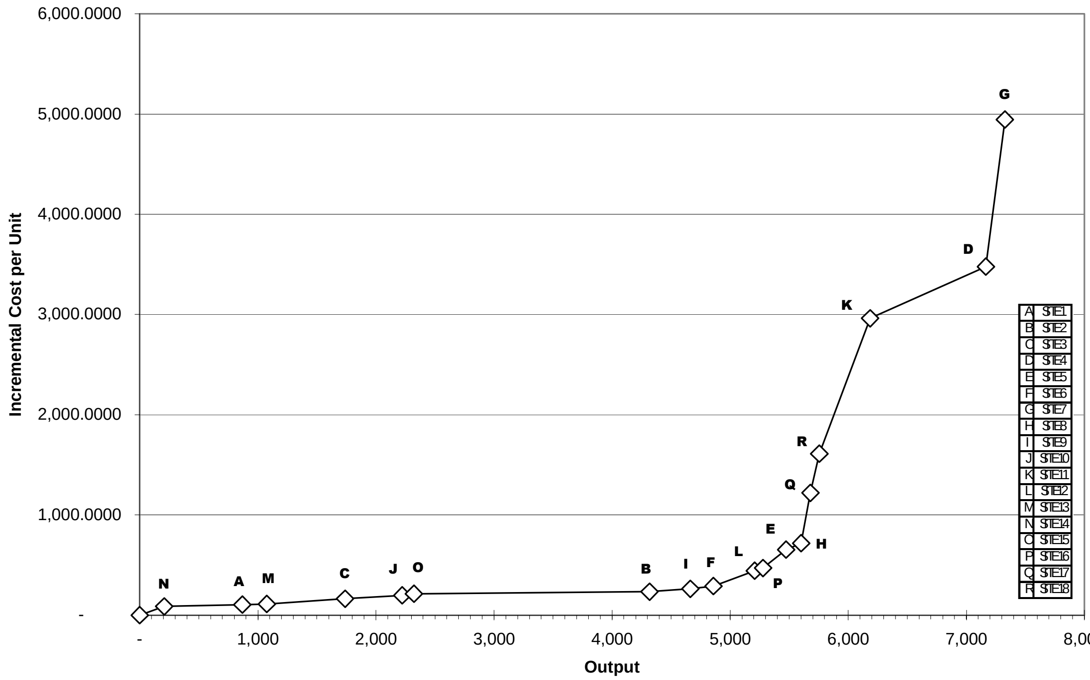
TABLE 4-16 RESTORATION MEASURES, WITH COST AND OUTPUT*

Code	Description	Average Annual Cost	Output
A	Site #1, SR6 Oxbow Reconnection	$69,500	661.97
B	Site #2, Scheuber Reconnection & Wetland Creation	$464,900	1994.79
C	Site #3, Mainstem Oxbows Reconnections	$108,000	662.81
D	Site #4, Mainstem Chehalis Riparian Revegetation, RM 66-80	$3,409,300	980.35
E	Site #5, Skookumchuck Confluence Revegetation	$127,100	194.61
F	Site #6, Skookumchuck Revegetation, RM 12	$56,600	194.57
G	Site #7, SF Chehalis Revegetation, RM 0-5	$795,600	160.87
H	Site #8, SF Chehalis Confluence Wetland Creation	$91,100	126.77
I	Site #9, Newaukum Confluence Revegetation and Wetland Creation	$90,400	345.76
J	Site #10, Newaukum Side Channel and Wetlands, Stan Hedwell Park	$95,500	483.35
K	Site #11, Newaukum Revegetation, RM 0-10	$1,276,900	431.23
L	Site #12, NF/SF Newaukum Confluence Wetland Creation	$155,000	349.38
M	Site #13, MF Newaukum Revegetation, Tauscher Road	$23,100	207.23
N	Site #14, NF Newaukum Revegetation, Tauscher Road	$17,800	206.77
O	Site #15, Salzer Creek Confluence Wetland Creation	$21,600	100.78
P	Site #16, Salzer Creek Wetland Creation, Frozen Foods Site	$33,400	71.14
Q	Site #17, Salzer Creek, RM 3.1	$96,500	79.14
R	Site #18, Salzer Creek, RM 4.5	$121,600	75.53
	TOTALS:	$7,053,900	7,327.05

**Data in Table 4-17 presented in 2002 price levels.*

In the analyses, all combinations of the measures were evaluated to identify the most efficient combinations for producing environmental output. The results of the analyses show the order in which the potential mitigation sites would be implemented in combination if their output levels were determined to be worth their cost. Figure 4-1 shows the results of the analysis.

Figure 4-1. Incremental Cost Analysis (Sites 1-18)



The analysis also compared the output of combinations of mitigation sites with the preliminary estimated impacts of flood control alternatives. As indicated in Figure 4-1, output increases at a relatively greater rate than does incremental cost through addition of Plan H (Site 8). Plan H includes the following measures:

- N - NF Newaukum Revegetation, Tauscher Road
- A - Scheuber Ditch Reconnection & Wetland Creation
- M - MF Newaukum Revegetation, Tauscher Road
- C - Chehalis River Mainstem Oxbows Reconnections
- J - Newaukum, Stan Hedwall Park Side Channel and Wetlands
- O - Salzer Creek, Chehalis Confluence Wetland Creation
- B – SR-6 Oxbow Reconnection
- I - Newaukum, Chehalis Confluence Revegetation and Wetland Creation
- F - Skookumchuck Revegetation, RM 12
- L - NF/SF Newaukum Confluence Wetland Creation

- P - Salzer Creek Wetland Creation, Frozen Foods Site
- E - Skookumchuck, Chehalis Confluence Revegetation
- H - SF Chehalis, Chehalis Confluence Wetland Creation

After adding measure H, addition of any more measures is associated with greater increases in cost relative to increases in output and require more rigorous scrutiny. The first 13 projects appear cost effective, while the remaining five projects would require more evaluation and more rigorous justification if desired for inclusion in the mitigation plan.

4.16 Formulation of Environmental Mitigation Plan (Phase 2)

In Phase 2 of formulating the mitigation plan, the restoration work group reviewed the results of the Phase 1 evaluation and incremental cost analysis. Based upon this information and further analysis of potential impacts of the flood control project, the Scheuber Ditch/SR-6 area was identified by the resource agencies as a priority zone to focus further development of mitigation features. In the Phase 1 analysis, features in the Scheuber Ditch/SR-6 area ("A", Scheuber Ditch Reconnection and Wetland Creation, and "B", SR-6 Oxbow Reconnection) were found to be cost effective and incrementally justified through the preliminary cost effectiveness and incremental cost evaluations.

Evaluation of the impacts of the NED and LP plans provided an initial assessment of the loss of wetlands and riparian areas within the footprint of the proposed levees. The only wetland type within the project footprint is emergent wetlands. As such, the wetland impact acreage is based on extent of mapped hydric soils.

Total wetland loss is estimated to be 34 acres of wetlands over approximately 15 miles of levees and floodwalls. Approximately 14 miles of the recommended alternative consists of levees and 1 mile of floodwall. Mitigation will be required to offset this loss of wetlands/riparian areas.

There will be loss of vegetation, with the NED or LP Plan, though these impacts are being minimized with design refinements. The expected impacts to vegetation were not found to be significant enough to require mitigation.

While this loss of low to moderate quality wetlands and some riparian habitat appears to be moderate, it is estimated to result in a significant loss of groundwater recharge and other biogeochemical functions (such as sediment retention, pollutant retention and uptake, etc.). The loss of these types of functions is extremely important to the regulatory agencies involved in the study's Restoration Working Group. A major issue in the Chehalis River basin is the loss of floodplain storage, groundwater recharge, and chemical and sediment retention. The cumulative loss of these functions has significantly contributed to the poor water quality and quantity conditions in the river and its tributaries and has significantly reduced accessibility and habitat for resident and anadromous salmonids and other native fish species. A more complete description of wetland functions is available in the EIS and the Mitigation appendix.

Throughout the development of the NED and LP Plans, minimization of impacts to sensitive areas was followed as a basis of design. Care was taken to stay close to developed areas, keeping the alignment setback as far as possible from the Chehalis River and its tributary streams, wetlands, and riparian areas. The design also incorporated areas of existing levees or tied into an existing levee system wherever practicable. Lastly, floodwalls were incorporated into the design where levees would have encroached upon the river.

Multiple combinations of environmental features in this area were developed and evaluated as a result. The same environmental evaluation methodology applied in Mitigation Phase 1 was applied in Mitigation Phase 2. Costs and outputs of the new features were compared with Phase 1 results to ensure that the new features were relatively cost effective mitigation components.

Cost effectiveness and incremental cost analyses were conducted to evaluate the relative cost effectiveness of the various alternative mitigation plans listed in Table 4-17. Only the most effective plans were retained. The cost effective plans were then added in different combinations to determine which combination of plans was the most cost effective.

The results of the incremental cost analysis are presented in Table 4-17 and graphically in Figure 4-2.

Mitigation Plan 2, described below, is the most cost effective combination of plans, and is therefore the proposed mitigation plan.

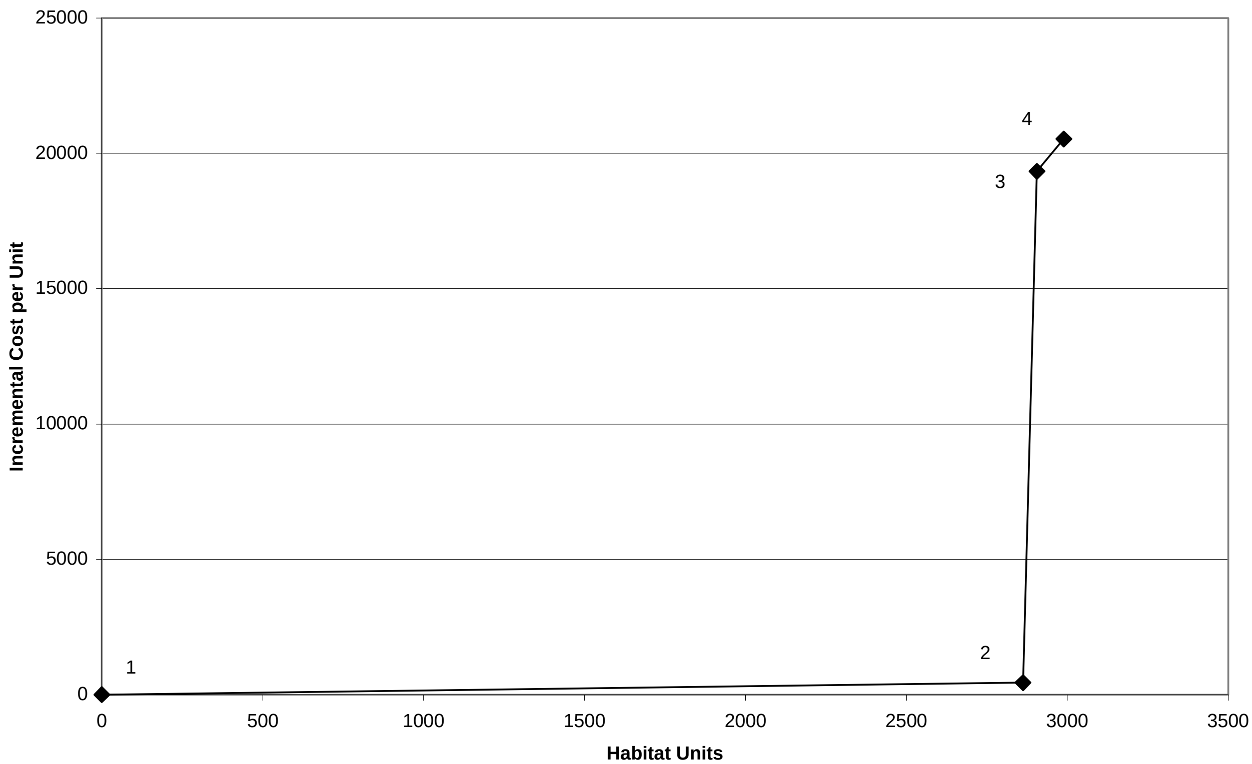
Features of Mitigation Plan 2 include:

- reconnection of oxbow (north of SR-6) to the Chehalis River in overbank events;
- conveyance of flows from reconnected oxbow under SR-6 to Scheuber Ditch Restoration Area; and
- development of wetland complex to the north of the Scheuber Ditch Restoration Area.

TABLE 4-17 INCREMENTAL COST ANALYSIS

Mitigation Alternative	Annual Cost	Output	Incremental Cost	Incremental Output	Inc Cost per Unit
1 No Action	0	0			0
2 Oxbow + Schueber Ditch + N Wetland	$1,270,700	2,862.86	$1,270,700	2,862.86	$444
3 Oxbow + Schueber Ditch + S Wetland + N Wetland	$2,104,300	2,905.96	$833,600	43.10	$19,341
4 Oxbow + Schueber Ditch + S Wetland + N Wetland + M Wetland	$3,812,600	2,989.15	$1,708,300	83.19	$20,535

Figure 4-2 Incremental Cost Analysis of Mitigation Plans



4.17 Formulation of Environmental Mitigation Plan (Phase 3)

This is the final formulation of actual mitigation required based on the recommended flood damage reduction plan. The mitigation plan is described in Chapter 5 of the EIS. Following review of the information developed in Mitigation Phase 2 of the mitigation plan formulation, the study team refined the analysis of impacts of the proposed flood control project to ensure that the mitigation plan would provide adequate and appropriate environmental benefits commensurate with the level of institutional mitigation requirements and projected functional impacts as identified by the modified environmental evaluation model. This evaluation is referred to as “Mitigation Phase 3” in this report.

4.17.1 Institutional Mitigation Requirements

As previously stated, the total loss of wetlands is estimated to be 34 acres, based on the current level of delineation that has been completed. As a starting point for developing the mitigation plan, we utilized a 2:1 replacement mitigation ratio for the 34 acres of wetland habitat that would be eliminated, which would involve the creation or enhancement of 68 acres of wetland. The Washington Department of Ecology frequently requires such a replacement ratio. Also, the additional acreage of wetland would compensate for the loss of hydrologic function to the other 108 acres of floodplain wetland. The loss of riparian habitat is very small, only estimated at about 1 acre. However, in order to create properly functioning wetlands the plan will require a 100-foot riparian buffer and the construction of an appropriate inlet to allow high flows into the site from the river, which will adequately compensate for the loss of riparian habitat and compensate for the loss of floodplain connections to the 108 acres of wetland.

4.17.2 Modification of Environmental Evaluation Methodology

The previously documented environmental evaluation methodology was developed for evaluation of the potential mitigation projects in the basin during the feasibility phase. This method was developed and used with extensive input from an interagency Restoration Working Group. This original method was also utilized to evaluate preliminary flood control alternatives and the proposed mitigation plan to ensure that it would provide an appropriate level of mitigation. However, following selection of the preferred flood control alternative, it was determined that the original method needed modifications that focused on the types of habitats that would be specifically affected by the flood control project in order to provide a suitable evaluation of the mitigation plan. The original method is documented in full in the EIS.

A modified method was developed that retained many of the parameters developed by the Restoration Working Group. However, there are two primary differences in the modified method: (1) where the original methodology characterized separate parameters for watershed and localized scales, the modified methodology characterizes parameters for the entire project footprint (at a sub-basin scale), and (2) the definitions for parameters have been modified to focus on wetland habitats as this was a primary impact of the proposed project.

Existing conditions (without-project) and future with-project (with levee) conditions were then scored using the modified method definitions. Ultimately, the purpose of the modified method is to translate the loss of wetland habitats into a HU output score. Then it is possible to also convert future with-project mitigation actions into a score of wetland HUs gained that can be compared to the expected loss to meet the goal of ensuring appropriate levels of mitigation that address institutional requirements and offset functional losses as identified by the modified evaluation methodology.

Upon applying the modified method to determine suitability of the mitigation plan developed in Mitigation Phase 2, it was found that the Scheuber Ditch/SR-6 mitigation plan overcompensated for impacts of the selected flood damage reduction alternative. It was also found that the re-meandering of the nearly 10,000-foot-long Scheuber Ditch and associated riparian revegetation provided significant habitat benefits but at significant cost and not necessarily in-kind mitigation value. As a result, alternative mitigation designs in the area were evaluated to determine which configuration would provide sufficient and effective mitigation, without incurring unnecessary expenses from out-of-kind mitigation measures.

Creation of wetlands at the south (upstream) end of the floodplain in the Scheuber Ditch/SR-6 area, with a connection to the Chehalis River beneath SR-6, was identified as an option to provide increased floodplain interactions. There would then be more frequent flood connections to the undeveloped floodplain along Scheuber Ditch. This revised plan would provide in-kind mitigation (wetlands and floodplain interactions) without providing the out-of-kind mitigation included in the previous plan.

The significant loss of floodplain in the area has resulted in a great need for increased groundwater recharge in the basin to maintain base flows in the river. The configuration of the selected Oxbow/SR-6 mitigation plan will allow greater floodplain connectivity with the Chehalis River and increased groundwater recharge on a frequent basis.

The proposed wetland mitigation will create and enhance 68 acres of wetland immediately north of SR-6 in the undeveloped floodplain. This will require the excavation of a new channel between the Chehalis River and the oxbow immediately south of SR-6. The channel will continue westward across the undeveloped floodplain and will connect to a tributary that passes beneath South Scheuber Road. The tributary will be diverted into the new channel to provide another source of hydrology for the wetlands and channel and be designed to have positive drainage back to the Chehalis River to prevent fish stranding.

Wetlands will be connected to the newly excavated channel and will also have positive drainage to the Chehalis River. The channel and wetlands will be designed to have a frequent surface water connection with the Chehalis River during winter flows. A berm will be constructed between the new channel and Scheuber Ditch to prevent flows below the 2-year flood elevation from connecting to the ditch. (This is to prevent fish stranding and also prevent fish from entering the very poor quality habitat in Scheuber Ditch, except during flood flows when the entire floodplain is connected.) A portion of SR-6 will be replaced with a bridge to accommodate the new channel and allow the floodplain interactions. A 100-foot riparian buffer will be planted along the new channels and around wetlands. Large woody debris (LWD) will be placed to enhance fish and wildlife habitat. The revised (Phase 3) formulation, evaluation, and design of the mitigation plan are presented in detail in chapter 5 of the EIS to this report.

4.17.3 Benefits and Costs of Phase 3 Mitigation Plan

The total wetland HUs lost with the construction of the levee is 102.1. The implementation of the selected mitigation plan provides a recovery of 115.4 HUs of wetland, which adequately compensates for the original wetland loss. This surplus will adequately address the risk and uncertainty associated with creation of wetlands in agricultural lands, as well as providing increased floodplain connections that were not quantified as impacts. Since the 68-acre design provides an appropriate amount of contingency, it was selected as the preferred plan.
The construction cost estimate for the Phase 3 mitigation plan is approximately $9,780,800 in 2003 prices, with an average annual equivalent value of approximately $610,000. The cost elements are described in detail in the chapter 5 of the EIS.

5. RECOMMENDED PLAN

5.1 Description of Recommended Plan

The plan selected for recommendation is the Locally Preferred (LP) Plan. This plan was selected because the local sponsor desired the added protection from the 20,000-ac-ft dam and FEMA certification for the 100-year flood for additional areas in Centralia.

The Locally Preferred Plan includes:

- the 20,000 ac-ft modification plan for the Skookumchuck Dam;
- levee construction of 100-year level protection on the Chehalis River;
- construction of a levee providing 100-year protection on the Skookumchuck River; and
- elevation of structures that would incur increased inundation as a result of the project to mitigate for induced damages.

5.2 Cost of Recommended Plan

A detailed cost estimate was developed for the recommended plan. The life-cycle project cost estimate, as shown in Table 5-3, is $113,288,000 and includes design and construction costs, mitigation costs, operation and maintenance costs, real estate acquisition costs, contingency, and interest during construction.[6] This is a difference of $9,089,000 over the NED Plan, which has a life cycle project cost estimate of $104,199,000. Both estimates include the addition of costs for elevating structures that would incur increased inundation with the project to mitigate for induced damages as described in Section 4.12.2. Complete estimates are presented in Appendix D, Economics.

The implementation cost estimate for the NED Plan and the recommended plan were developed using the Corps' Micro Computer Aided Cost Estimating Software (MCACES). Table 5-1 presents the NED cost estimate. Table 5-2 presents the recommended plan cost estimate. The differences in cost between the two plans are shown in Table 5-3. No significant differences in adverse environmental impacts between the NED Plan and the Locally Preferred Plan were

[6]These NED costs differ from those presented in Chapter 4, Plan Formulation, to reflect the most recent refinements in the cost estimate at the time of report publication. The differences were found to not have any significant effect on plan formulation and selection.

identified in the EIS process. For this reason, the same mitigation features and cost were applied to both plans.

TABLE 5-1 MCACES COST ESTIMATE FOR NED PLAN

CURRENT ESTIMATE PREPARED:		Jun-03				AUTHORIZ./BUDGET YEAR: 2004				FULLY FUNDED ESTIMATE				
EFFECTIVE PRICING LEVEL:		Oct-02				EFFECT. PRICING LEVEL: Oct-03								
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
04	Dams													
	1. Lower Dam Alternative (11,000 acre feet)	4,827.2	1,690	35%	6,517	4.3%	5,304	1,690	6,517	Apr-06	6.9%	5,382	1,884	7,265
06	FISH AND WILDLIFE													
	1. Mitigation[1]	7,247.2	2,537	35%	9,784	0.0%	7,247	2,537	9,784	Apr-06	6.9%	7,748	2,712	10,460
11	LEVEES AND FLOODWALLS													
	1. Chehalis Levee Alternative	29,421.5	7,355	25%	36,777	3.8%	30,534	7,634	38,168	Apr-06	6.9%	32,645	8,161	40,806
	2. Skookumchuck Region (-1' of 100 year WSE)	4,206.5	1,052	25%	5,258	3.8%	4,366	1,091	5,457	Apr-06	6.9%	4,667	1,167	5,834
	TOTAL CONSTRUCTION COSTS	**45,702**	**12,663**	**28%**	**58,336**	**3.2%**	**47,181**	**13,023**	**60,204**		**6.9%**	**50,442**	**13,923**	**64,365**
01	LANDS AND DAMAGES													
	1. Real Estate	11,892.0	2,378	20%	14,270	3.8%	12,342	2,468	14,810	Jul-06	6.9%	13,195	2,639	15,833
30	PLANNING, ENGINEERING AND DESIGN	4,570.2	1,143	25%	5,713	3.8%	4,743	1,186	5,929	Apr-06	6.9%	5,071	1,268	6,339
31	CONSTRUCTION MANAGEMENT	4,570.2	1,143	25%	5,713	3.8%	4,743	1,186	5,929	Apr-06	6.9%	5,071	1,268	6,339
	TOTAL PROJECT COSTS	**66,735**	**17,296**	**26%**	**84,031**	**3.4%**	**69,009**	**17,863**	**86,872**		**6.9%**	**73,778**	**19,097**	**92,876**

1 Mitigation costs listed in account number 06 were estimated at Oct 2003 price levels. No pricing adjustment was applied to this feature.

TABLE 5-2 MCACES COST ESTIMATE FOR RECOMMENDED PLAN(LOCALLY PREFERRED PLAN)

CURRENT ESTIMATE PREPARED:		Jun-03				AUTHORIZ./BUDGET YEAR: 2004				FULLY FUNDED ESTIMATE				
EFFECTIVE PRICING LEVEL:		Oct-02				EFFECT. PRICING LEVEL: Oct-03								
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
04	Dams													
	1. High Dam Alternative (20,000 acre feet)	6,589.6	2,306	35%	8,896	4.3%	6,872	2,405	9,277	Apr-06	6.9%	7,347	2,571	9,918
06	FISH AND WILDLIFE													
	1. Mitigation[1]	7,247.2	2,537	35%	9,784	0.0%	7,247	2,537	9,784	Apr-06	6.9%	7,748	2,712	10,460
11	LEVEES AND FLOODWALLS													
	1. Levee Alternative	29,421.5	7,355	25%	36,777	3.8%	30,534	7,634	38,168	Apr-06	6.9%	32,645	8,161	40,806
	2. Skookumchuck Region (100 - year protection)	7,126.1	1,782	25%	8,908	3.8%	7,396	1,849	9,245	Apr-06	6.9%	7,907	1,977	9,883
	TOTAL CONSTRUCTION COSTS	**50,384**	**13,980**	**28%**	**64,364**	**3.3%**	**52,049**	**14,424**	**66,473**		**6.9%**	**55,646**	**15,421**	**71,067**
01	LANDS AND DAMAGES													
	1. Real Estate	11,892.0	2,378	20%	14,270	3.9%	12,342	2,468	14,810	Jul-06	6.9%	13,195	2,639	15,833
30	PLANNING, ENGINEERING AND DESIGN	5,038.4	1,260	25%	6,298	3.9%	5,229	1,307	6,536	Apr-06	6.9%	5,590	1,398	6,988
31	CONSTRUCTION MANAGEMENT	5,038.4	1,260	25%	6,298	3.9%	5,229	1,307	6,536	Apr-06	6.9%	5,590	1,398	6,988
	TOTAL PROJECT COSTS	**72,353**	**18,877**	**26%**	**91,231**	**3.4%**	**74,849**	**19,507**	**94,355**		**6.9%**	**80,022**	**20,855**	**100,876**

TABLE 5-3 COST COMPARISON OF NED AND LOCALLY PREFERRED PLAN

	Locally Preferred Plan	NED Plan	Cost Difference
Construction Cost*	$56,689	$50,420	$6,269
Real Estate	$14,810	$14,810	$0
Mitigation Cost	$9,784	$9,784	$0
PED/Const. Mgmt.	$13,072	$11,858	$1,214
Total First Costs	$94,355	$86,872	$7,483
Interest During Construction	$8,463	$7,917	$546
O&M Cost	$10,470	$9,410	$1,060
Total Life Cycle Project Cost	$113,288	$104,199	$9,089
Average Annual Equivalent Cost	$7,063	$6,496	$567
Feasibility (sunk) costs	$6,051	$6,051	$0

All costs are in present value (October 2003 price level; dollars in $1000) (Numbers may not add due to rounding)
**Construction Cost does not include mitigation cost which is broken out separately.*

5.3 Benefits of Recommended Plan

The recommended plan provides estimated annual benefits of $8,949,000, including $6.7 million in reduction of flood related damages to structures and their contents, $2.1 million in annual avoided costs associated with the need to elevate I-5 without the project, and an annual reduction of $131,000 in traffic delays related to flooding. Residual annual damages in the study area amount to $2.5 million (including flood damages associated with structures and contents as well as residual agricultural damages and rail delay damages; neither of these latter two damage categories are affected by the NED or the selected Locally Preferred Plan).

Annual economic costs of the Locally Preferred Plan are estimated at $7,063,000, resulting in annual net benefits of $1,886,000 and a positive benefit-to-cost ratio of 1.27 to 1. The recommended project is supported by the local sponsor, Lewis County, Washington. The NED Plan will provide annual benefits of $8,706,000 for an annual cost of $6,496,000, providing net benefits of $2,210,000 and a benefit-to-cost ratio of 1.34 to 1.

5.4 Structural Flood Control Features of Recommended Plan

The recommended plan includes a combination of structural flood damage reduction features. These include:

- Chehalis River Levee System
  - Chehalis River Mainstem Levees
  - Salzer Creek Levees
  - Dillenbaugh Creek Levees

- Skookumchuck River Levee System

- Modified Outlet Works and New Gates on the Spillway at Skookumchuck Dam for the addition of 20,000 ac-ft of flood control storage

Design of the levee system took advantage of opportunities to maximize levee setbacks, allowing floodplain and channel connectivity for environmental purposes. The setback levee alignment will protect existing residential and commercial structures, highway and other transportation infrastructure from flooding while not encouraging new floodplain development. Proposed protection would extend along the Chehalis River from approximately RM 75 to RM 64, as well as along most of the lower 2 miles of both Dillenbaugh Creek and Salzer Creek. In addition, levee protection will be provided on the Skookumchuck River for backwater effects of the Chehalis River and flooding from the Skookumchuck River. The affected reach (Skookumchuck River Reach 4) is approximately 2 miles upstream on the Skookumchuck to the confluence with Coffee Creek.

The levee system is intended to provide 100-year protection from the Chehalis River flooding. This protection also extends to the tributaries of the Chehalis River. The Chehalis backwater flooding is prevented from going upstream on the following tributaries: Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek and the Skookumchuck River.

A proposed modification to Skookumchuck Dam will provide flood control storage of approximately 20,000 ac-ft between pool elevation 455 and 492 feet. The current elevation of the existing spillway crest is 477 feet, with an uncontrolled spillway. With this flood storage pool elevation the reservoir would provide approximately 20,000 ac-ft of flood control storage.

The proposed design includes modification to the spillway chute and installation of a short tunnel outlet with slide gates; this is Alternative 2B2. Modification of the dam will reduce the flood stages along the lower Skookumchuck River up to 1 foot during a 100-year flood. There is more significant reduction in 10- to 50-year flood events, up to 2.4 feet reduction in stage. This will provide significant flood damage reduction to the communities along the river. In addition the dam will provide incidental hydraulic mitigation downstream in the Chehalis River. The modification will also allow for not only flood control but also for control on releasing summer low flows.

5.5 Non-Structural Flood Control Features of Recommended Plan

The Corps considered non-structural components during the evaluation process. As part of the recommended plan, several structures will be elevated in the floodplain. In addition, other non-structural features were also considered. Many of these features are already being implemented at the county and city level. They include ordinances on construction in the floodways, emergency warning systems and other non-structural solutions, such as raising of homes and businesses and property buyouts. Land use management options are also in the process of being revised by the local sponsor to have more restrictive requirements.

Several non-structural components that will be a locally provided element of the recommended plan, include new FEMA floodplain mapping, flood warning system, restriction of development, restriction of fill in the floodplain, and stormwater management. The following describes these features, how they are currently implemented and what additional measures are under consideration for the new floodplain management plan. These features are the responsibility of the local communities and are not required for the recommended structural features of the plan to function. Further effort on non-structural options will be evaluated during the development of a new floodplain management plan for the project area to be compliant with Executive Order 11988, concurrent with the design process for the recommended project.

The following are non-structural components that are being considered for implementation in the project area:

Non Structural Feature	**Lead Implementing Parties**
Elevation of Structures	Corps and local sponsor (component of cost-shared plan)
Define New 100-year FEMA floodplain	Local communities
Flood Warning System	Local communities
Restriction of Development	Local communities
Restriction of Fill in Floodplain	Local communities
Stormwater Management	Local communities

5.5.1 New 100-Year FEMA Floodplain

A new 100-year FEMA floodplain map will be generated after the recommended plan has been approved and FEMA has accepted that the project will be completed. This map will be adopted by the communities.

5.5.2 Flood Warning System

Currently the cities and the county utilize the Emergency Broadcast System (EBS) and other means, such as radio and television, to transmit emergency and warning transmissions for the area. Also, three local emergency/information phone numbers have been established to answer the public's questions or receive important flood information from residents. There are also neighborhood notification networks. Lewis County Emergency Management division is responsible for carrying out the emergency response program. The City of Chehalis has warning sirens to notify the community, as well as a telephone network through the Chamber of Commerce. They also utilize a website to show where flooding is occurring. The community is also working with the National Weather Service to post bulletins of flood hazards. The flood warning system will be further addressed in the flood management plan.

Additional initiatives that are being considered by the County include:

1) Installing additional river gauging stations to help in flood warning and emergency response activities. Potential additional gauges may include the following:

a. Updating Newaukum gauge near Chehalis with telephone-linked capabilities.
b. Add telephone linked gauge at South Fork Chehalis

c. Install gages on other major tributaries within the Centralia/Chehalis area.

2) Personnel of the cities of Chehalis and Centralia and the County Engineer will coordinate the flood forecasting efforts.

3) Formalize and update road closure database creating a predictive tool by coordinating related flood stages to road closures.

4) Increase distribution of flood information materials to being not only available at the Emergency Management Office but also at libraries throughout the county.

5) Update Federal Insurance Rate Maps based on historical flood records to provide more accurate flood hazard information.

6) Provide a public disclosure ordinance of property's floodplain status at the time of purchase.

7) Document flood warning and emergency response activities for submittal to Community Rating System. These will count as credits to reduce flood insurance premiums.

5.5.3 Restriction of Development

The Corps will determine in the design phase the new floodway and flow paths within the project area after implementation of the structural features. The local community will utilize this information to ensure that their ordinances are being followed. This would include utilizing the newly developed 100-year floodplain and hydraulic modeling. The local jurisdictions can either adopt their own Flood Hazard and SEPA ordinances and their own Shoreline Master Programs, as directed under the state Shoreline Management Act, or utilize the state's guidelines. In addition to defining the 0.2-foot floodway, development is also discouraged within additional critical portions of the floodplain, specifically in areas considered to be significant flow paths. Flow paths are naturally occurring swales, which are normally dry, but which historically conveyed significant amounts of flowing water during flood stage. The following is a brief description of the current ordinances for floodway construction for Lewis County, City of Chehalis and the City of Centralia. These ordinances generally support having an approved filling/floodplain development plan, and allow a hydraulic analysis to show a 0.2-foot rise or less in the floodwater surface elevation.

- Lewis County - Development within the FEMA floodway is seriously discouraged. New residential structures are entirely prohibited. Commercial development is allowed, but only if accompanied by an engineer's certification that the proposed development would not raise flood levels at all during the 100-year flood. Variances are possible for development within the floodway from Lewis County.
- City of Centralia - Development is not allowed in the FEMA floodway. Request for variances are few and are seldom granted. The applicants whose properties lie in both the Floodplain Ordinance and the Shoreline Master Program areas are required to apply for, and obtain, both permits. In addition, any development within the FEMA flood fringe must be elevated to at least 1 foot above the elevation of the 100-year flood.
- City of Chehalis - Development within the FEMA floodway is seriously discouraged. New residential structures are entirely prohibited in special flood hazard areas. Commercial development is allowed, but only if accompanied by an engineer's certification that the proposed development would not raise flood levels at all during the 100-year flood. In addition, all new development and substantial improvements will comply with all applicable flood hazard reduction provisions of the city, state and Federal regulations.

5.5.4 Restriction of Fill in the Floodplain

This initiative is to ensure that there are restrictions to new filling of the floodplain by requiring that fill be mitigated by removal of an equal volume of fill at the site or elsewhere in the floodplain or floodway. Cut and fill balances should be retained within the project site whenever possible. The current Comprehensive Flood Hazard Management Plan for Lewis County is a method for reducing the effects of filling in the flood fringe. The plan includes adding the requirement for compensatory storage to the Flood Damage Prevention Ordinance. Whenever fill material is added to the flood fringe, the area that the fill occupies is removed from the potential flood storage area. Under compensatory storage requirements, any individual placing fill in the flood fringe must excavate an area of equivalent volume to eliminate the effects of the fill material on the flood storage.

- City of Centralia - Filling in the flood fringe landward of the floodway is allowed. All construction must be consistent with the model National Flood Insurance Regulations.
- Lewis County – The county’s standard is that fill materials must be obtained from the site to the extent practicable. If the fill cannot be so obtained from the same site, it must be

obtained as practicable from the flood hazard area. In addition, the fill must have a beneficial use and be deemed necessary.

- City of Chehalis: As a part of the Shoreline Management plan there is a restriction of a one-to-one fill and cut within the floodplain area.

5.5.5 Storm Water Management

This initiative relates to increasing the detention from a 25-year design storm to meet the Washington State Department of Ecology storm water management criteria. The communities are evaluating these new criteria and determining whether they can meet the new Ecology regulation. A better management of stormwater will assist in reduction of flooding in the project area. The Corps will continue to evaluate the timing of stormwater versus the watershed runoff, to determine an optimum management of stormwater release during a flood event. Stormwater is only a small portion of the basin hydrology.

5.5.6 Non-Structural Summary

The elevation of homes is a cost-shared feature of the recommended plan. The local sponsor to the maximum extent practicable will implement the other non-structural features at 100 percent non-Federal cost. These actions will be represented in the revised floodplain management plan for the project as required by Executive Order 11988. This plan will be completed prior to the signing of the cooperative agreement. The Corps will provide technical support to assist in development of sound actions within the project area to assure the integrity of any project structural components.

5.6 Skookumchuck Dam Operational Modification Description

The hydraulic design of the flood control outlet works, and the flood control regulation rule curves for Skookumchuck Dam will need to be refined and finalized in the next phase of studies. Approval and implementation of the re-operation plan is the responsibility of the Corps' Water Management office. In addition to hydraulic and engineering considerations, downstream environmental requirements related to reservoir operation and flood control regulation will continue to be a part of the operation plan.

The dam modifications currently being proposed could provide, approximately, an additional 9,000 ac-ft of storage between pool elevation 477 and 492 feet, bringing the total storage at Skookumchuck Dam to 20,000 ac-ft. This additional storage could potentially be available to augment summer low flows downstream if it were determined that this would be environmentally beneficial. This would, however, require a change in the current reservoir conservation pool level and is not being proposed at this time for the flood reduction project. If this action were to be pursued in the future, any potential environmental impacts and dam safety issues associated with a higher conservation pool would need to be addressed.

5.7 Environmental Impacts of NED and Locally Preferred Plans

It is expected that the recommended flood control alternatives would not likely adversely affect federally listed fish and wildlife species. Impacts were identified however for riparian and wetland communities and for losses of floodplain connectivity. No significant differences in adverse environmental impacts were identified in the EIS process between the NED Plan and the Locally Preferred (LP) Plan. For this reason, the same impact estimate was derived for each plan.

The NED and LP Plans include the setback levees to protect developed areas, plus Skookumchuck Dam modifications. The recommended levee alignment runs from Ford Prairie south and east to I-5, south along the west side of I-5, around the Chehalis-Centralia Airport, and ends at the southern end of the airport adjacent to I-5. Additional levees are recommended on both banks of the Skookumchuck River between the Coffee Creek and Chehalis River confluences, on the north side of Salzer Creek from Salzer Valley Road to the connection with the I-5 levee, and along Dillenbaugh Creek from Chehalis Junction to Fern Hill Cemetery. The levee designs have been optimized to minimize the footprint (and impacts) of the levee system.

5.8 Environmental Mitigation Features and Benefits of Recommended Plan

Environmental mitigation features of the recommended plan are sited in the vicinity of SR-6 and the Scheuber drainage ditch. Mitigation features include:

- connection of the mainstem Chehalis River to an oxbow near the intersection of SR-6 and South Scheuber Road;
- connection of an unnamed tributary that flows beneath South Scheuber Road to the oxbow;
- modification of SR-6 to a bridge where the new channel passes beneath the road;
- creation of 68 acres of wetlands along the length of the new channel, west of SR-6; and

- creation of 20 acres of riparian buffer around the wetland.

The cost estimate for these features is $9,784,000. As documented in the EIS, these features were determined adequate to offset adverse environmental impacts of the recommended plan's flood control features, including the 34 acres of impacted wetlands and 0.8 impacted acre of riparian habitats. These features are described in detail in chapter 5 of the EIS.

5.9 Real Estate Requirements of Recommended Plan

The recommended flood damage reduction project would require approximately 107 acres of land to implement the recommended levee and floodwall elements, 95 acres to implement the project mitigation elements and 871 acres at the Skookumchuck Dam site, which includes the current water impoundment area behind the dam, for a total project footprint of 1,365 acres. The project sites are proposed on lands that are currently in both public and private ownership: about 11 public owners and 185 private owners. Commercial borrow and disposal sites would be utilized. Standard estates to be acquired include fee simple, flood control levee easement, temporary work area easement, and a restrictive easement. In addition, non-standard estates developed for this project are being submitted with the project Real Estate Plan (REP) for higher authority review and approval with this report. The proposed non-standard estates include an estate to be used where an existing road is utilized as a flood protection levee, and an estate that will provide perpetual access to floodwalls and levees where access from a public right-of-way is not available.

Project implementation is planned to occur in three separate construction phases. After the Project Cooperation Agreement (PCA) is executed, the Non-Federal Sponsor (NFS, a.k.a. local sponsor) will have approximately 12 months to complete Phase 1 real estate acquisitions, 24 months to complete Phase 2 acquisitions, and 36 months to complete acquisitions for Phase 3. Table 5-5 below provides a summary of the proposed phased acquisition schedule. The NFS will have 180 days after certifying lands available for each construction phase to provide the Corps' Real Estate Division, Seattle District, with all supporting lands, easements and rights-of-way (LER) crediting documentation.

Appendix F, Real Estate Plan, provides additional real estate information, including real estate maps in Exhibit A. Exhibit B includes an assessment of NFS acquisition capability, while Exhibit C contains the Certification of Lands and Attorney's Certificate. Table 5-4 below provides a summary of the real estate baseline cost estimate (BCERE) for land values, NFS administrative costs and Federal review and assistance costs for implementing the proposed project. A 20 percent contingency is utilized to cover possible land value variations over time. A 35 percent contingency is utilized for NFS administrative costs and Federal review and assistance due to various issues that must be addressed in the next project phase when the proposed project design is refined.

TABLE 5-4 SUMMARY BASELINE COST ESTIMATE FOR REAL ESTATE (BCERE)

Site Names	Acres	Land Values	NFS Admin Costs	NFS LERRD	FED S&A
Chehalis Levees	91	$4,932,000	$740,000	$5,672,000	$300,000
Dillenbaugh Levees	1	$40,000	$38,000	$79,000	$34,000
Skookumchuck Levees	15	$2,459,000	$463,000	$2,921,000	$250,000
Mitigation Sites	95	$3,387,000	$390,000	$3,778,000	$155,000
Skookumchuck Dam	871	$1,515,000	$66,000	$1,582,000	$46,000
TOTALS:	1265	$12,333,000	$1,697,000	$14,032,000	$785,000

land values include a 20% contingency, and NFS admin. costs, and Federal review and assistance costs both include a 35% contingency.

Project construction is expected to occur in three consecutive phases pursuant to the award of eight separate construction contracts (see Table 6-2, Construction Sequencing).

TABLE 5-5 LER ACQUISITION SCHEDULE

Phase 1 construction is anticipated to begin in early 2006. The NFS will require approximately 12 months from the date the PCA is executed to acquire and certify lands available before the respective Phase 1 contracts are advertised (Dec 05 – Feb 06). Phase 1 construction currently includes the following proposed project elements:

- Contract 1—I-5 levees from Mellon St. to Salzer Creek (WSDOT)
- Contract 2—Airport levee from Salzer Creek to SR-6

Phase 2 construction is planned to commence in the summer of 2005. The NFS will have approximately 24 months to acquire and certify lands available before Phase 2 construction contracts are advertised (Dec 05 – Mar 07). Phase 2 construction currently includes the following proposed project elements:

- Contract 2—Skookumchuck Dam
- Contracts 4, 5 & 6—Salzer Creek levees east of I-5
- Contract 7—Dillenbaugh Creek levees (WSDOT)

Phase 3 construction is expected to begin in the summer of 2006. The NFS will have approximately 36 months to acquire and certify lands available before Phase 3 construction contracts are advertised (Dec 05 – Mar 08) for the following project elements:

- Contract 8—Ford's Prairie levees
- Contract 9—Skookumchuck River levees
- Contracts 10 & 11—Project Mitigation Elements including SR-6 Bypass

5.10 Operation and Maintenance Requirements of Recommended Plan

The local sponsor, who is responsible for maintenance of the entire project, will be provided with an Operation, Maintenance, Repair, and Rehabilitation Manual (OMR&R) at the time that the project is accepted and turned over to the local sponsor. It will specify the maintenance and estimated rehabilitation required to meet Federal standards. A cost estimate and time schedule will be included for budgeting and planning purposes. It also specifies the consequences of not doing the prescribed maintenance. If the Federal government feels the project is in jeopardy of not functioning due to lack of maintenance, the government will do the work and bill the local sponsor for the effort.

5.10.1 Chehalis/Skookumchuck River Levee System O&M

For the levee system, a minimum of one inspection annually, and preferably an inspection after each major flood event, by the local sponsor will be submitted to the Corps, documenting levee conditions and any repairs or maintenance required or completed. For cost estimating purposes, the OMRR&R costs for levees is approximately $8,000 per mile of levee. Approximately 15 miles of levees and floodwall are proposed in the recommended plan. In addition it is assumed that 50 percent of the rock will be replaced at year 25. Periodic government inspections will also be done to check that basic Federal standards are being maintained, including:

- no trees over 4-inch diameter;
- grassed side slopes;
- annual mowing for ease of inspection;
- maintained level gravel access road on top of the levee; and
- riprap rock sections monitored to assure bank protection, erosion control.

The government will identify any deficiencies in the maintenance or condition of the levee. A specific checklist of work items will be given to the local sponsor spelling out what is required to bring the project back into compliance, thus making the flood control structure eligible for Federal assistance when major rehabilitation is needed or in the event flood damage occurs. This includes eligibility for Federal funds through FEMA after a catastrophic disaster.

The OMRR&R will also include a Flood Fight Plan. Since flood fight efforts are an integral part of the levee system, it becomes critical that the necessary equipment, materials and personnel are available. In addition the plan must specify where and when flood fight actions need to take place, and who will be responsible for flood fighting.

This flood fight plan will need to be updated annually with points of contact, material and equipment inventory changes. Problem areas need to be identified and monitored, and then incorporated into the next year's maintenance plan.

5.10.2 Skookumchuck Dam O&M

Annual operation and maintenance (O&M) requirements for the flood control operation of Skookumchuck Dam were estimated based on the existing O&M requirements for a similar project, Wynoochee Dam. Wynoochee Dam is a multi-purpose project that is operated for hydropower, recreation, water supply, and flood control. The purposes of Skookumchuck Dam include flood control, water supply and currently limited hydropower (this last is to be decommissioned by the local sponsor). As with Wynoochee and several other flood control facilities in the region, during storm events, the Corps will take over flood control regulation of the dam.

The two projects are similar in size and have fairly similarly sized drainage basins with Wynoochee having 41 square miles and Skookumchuck having about 62 square miles. While the Wynoochee basin is smaller, the basin above Wynoochee Dam is of higher elevation and more mountainous than the basin above Skookumchuck Dam. Flood events at Skookumchuck Dam are not nearly as frequent or intense as events at Wynoochee Dam.

Skookumchuck Dam has no public access, and thus no costs are associated with the operation and maintenance of public facilities. At Skookumchuck Dam there is a small fish trap located at the base of the spillway stilling basin and a small operation is conducted to truck fish around the dam. Since only the flood control portion of the O&M costs are of interest here, these additional O&M costs have been excluded from consideration.

The recommended plan includes a gated structure on the spillway (unlike the low pool option without this requirement). Thus there will be added maintenance and operational expense for the gated structure. The additional maintenance is realized in the form of additional operation requirements (time) due to the nature of the watershed. Due diligence must be exercised to ensure appropriate manipulation of the spillway gates during moderate to large events.

The O&M requirements for the flood control portion of Skookumchuck Dam include the annual maintenance, flood control operation, and fish migration due to flood control operations[7]. A 50-year project life was used with a discount rate of 5.875 percent. Labor rates, including all overhead costs, were assumed to be $75 per hour, which is $108,000 a year for the recommended plan. The maintenance costs were estimated at approximately $13,500 per year for the recommended plan. The annual costs for Corps regulation is $75,000 per year, and for the USGS gaging operations and hydromet operations the cost is $45,000 per year. The costs also include administrative overhead and support. A detailed O&M cost summary is available in Table 5-6.

For flood control operation, it was assumed that there would be one fulltime person on site during the flood season, and an additional person would be assigned to the dam site during any storm events. It was also assumed that there would be a person onsite part-time for the remainder of the year. Offsite support and overhead costs, as well as miscellaneous costs and a contingency, were accounted for in both cases. Project costs for Corps flood regulation, USGS gaging and hydromet were kept the same as for the Wynoochee Project.

During flood control season, the dam will be operated in accordance with an O&M manual prepared by the Corps' Seattle District office. The project and flood control features would be inspected annually by the Corps to insure that any developing conditions that could adversely affect the flood control works are recognized and corrected in a timely manner.

[7] O&M costs and requirements for Skookumchuck Dam address only the increment of O&M that is attributable to the recommended flood control project. Actual O&M costs to the sponsor will be higher due to O&M costs attributable to other elements of the dam.

TABLE 5-6 DETAILED ANNUALIZED COSTS FOR EQUIPMENT MAINTENANCE AT SKOOKUMCHUCK DAM

ITEM	11,000 AC-FT COSTS ($)	20,000 AC-FT COSTS ($)
Sluice Gates		
Seals	2,663	2,263
Hydraulics	1,770	1,770
Paint	885	885
Control House		
General	1,000	1,000
Tainter Gates		
Seals	N/a	3,319
Hoists	N/a	830
Paint	N/a	1,946
Electrical	1,500	1,500
Total Maintenance	7,818	13,513
Operation		
Flood season	72,000	108,000
Fish Migration	18,000	18,000
Other - Debris, etc	54,000	54,000
COE Regulation	75,000	75,000
USGS Gaging Operations	40,000	40,000
Hydromet Operations	5,000	5,000
Total Operation	264,000	300,000
Administrative Overhead and Support (67%)	176,880	201,000
Total Operation and Maintenance	448,300	514,513

5.10.3 Environmental Mitigation O&M

Operation and maintenance (O&M) costs of the mitigation plan are associated with maintaining the mitigation project after it is built or repairing the project after a flood event or other natural disaster. It is estimated that some amount of vegetation will have to be replaced during the establishment period (annually for the first 5 years). Sediment that settles into the wetlands or channel, compromising the habitat quality, will need to be excavated periodically. Areas that erode significantly may require repair. Costs for maintaining the SR-6 bridge are estimated to be 1 percent of the total bridge construction cost. This translates into an annual cost of $5,800 for the life of the project. Total mitigation O&M costs over a 50-year period of analysis were estimated to have a present value of $317,000, or an average annual value of $19,800.

5.10.4 Summary of O&M Costs

The recommended plan includes annual O&M costs for its components. The annual O&M cost for each component is presented in Table 5-7. The table also provides a total present value of O&M requirements over the 50-year period of analysis. The total annual cost is $652,800 per year.

TABLE 5-7 OPERATION AND MAINTENANCE COSTS ($)

NED PLAN:	
Annual Chehalis River Levee O&M	99,500
Annual Skookumchuck River Levee O&M	19,000
Annual Skookumchuck Dam O&M*	448,300
Environmental Mitigation O&M	19,800
Total Annual O&M	586,000
Present Value O&M Stream	9,409,700
LOCALLY PREFERRED PLAN:	
Annual Chehalis River Levee O&M	99,500
Annual Skookumchuck River Levee O&M	19,000
Annual Skookumchuck Dam O&M*	514,500
Environmental Mitigation O&M	19,800
Total Annual O&M	652,800
Present Value O&M Stream	10,471,600

**Skookumchuck Dam O&M cost estimate includes only O&M requirements associated with flood control features.*

6. IMPLEMENTATION OF RECOMMENDED PLAN

This chapter summarizes cost-sharing requirements and procedures necessary to implement the features of the recommended plan.

6.1 Division of Responsibilities for Implementing the Recommended Plan

The WRDA of 1986 (PL 99-662) and various administrative policies have established the basis for the division of Federal and non-Federal responsibilities in the construction, operation and maintenance of Federal water resources projects accomplished under the authority of the Corps. This is discussed in detail below. Sections 6.2 and 6.3 specify Federal and non-Federal responsibilities during the preconstruction engineering and design phase (PED) and construction phase.

6.1.1 Federal Responsibilities

The Federal government is responsible for conducting and completing the PED (detailed plans and specifications), advertising and administering the construction contracts after authorization and receipt of Federal and non-Federal funds, and managing the construction phase. The Federal government is responsible for supervisory and administrative support for the non-Federal (local) sponsor’s LERRD activities. The Federal government is responsible for project inspections, and will provide 65 percent of the cost sharing for these project costs. The local sponsor is responsible for funding 35 percent of the costs of these project costs.

6.1.2 Non-Federal Responsibilities

The local sponsor is responsible for acquiring all real estate interests required to implement the recommended plan. The local sponsor is not required to provide this real estate until after the PCA is executed. The local sponsor will provide 35 percent of the cost sharing for further design, construction, construction management, Federal supervisory and administrative costs, and project monitoring for the NED plan. Additional work, or “betterments” to the NED plan will be 100 percent non-Federal cost responsibility. The local sponsor will receive credit for in-kind work per Chehalis River and Tributaries, House Report 106-1033 for Public Law 106-554, Section 118, which states: *“The project for flood control, Chehalis River and Tributaries,* *Washington, authorized by section 401(a) of the Water Resources Development Act of 1986 (100 Stat. 4126), is modified to authorize the Secretary of the Army to provide the non-Federal interest credit toward the non-Federal share of the cost of planning, design, and construction work carried out by the non-Federal interest before the date of execution of a cooperation agreement for the project if the Secretary determines that the work is integral to the project.* The local sponsor is responsible for obtaining all non-Federal permits and authorizations for the construction work. The local sponsor is also responsible for all future operation and maintenance.

6.2 Preconstruction Engineering and Design Phase

6.2.1 PED Procedural Overview

This phase of project development encompasses all planning and engineering necessary for project construction, and may commence after release of the Corps Division Engineer's Public Notice on a favorable study. These studies are required to review the earlier study data, obtain current data, evaluate any changed conditions, establish the most suitable plan for accomplishment of the improvement and establish the basic design of the project features in final detail. Preconstruction planning and engineering studies for projects authorized for construction will be programmed as "continuing" activities.

The results of preconstruction planning and engineering studies are presented in reports identified as "design memorandums." Preparation of design memorandums, and plans and specifications will be cost shared in accordance with the cost sharing required for project construction. Current engineering guidance respecting document preparation and approvals will be consulted (ER 1110-2-1150 9-2).

Since PED originally had been initiated prior to the policy change that requires upfront cost sharing of PED, all PED work will be performed at 100 percent Federal expense. PED will ultimately be cost shared at the rate for the project to be constructed with any adjustments necessary to bring the non-Federal contribution in line with the proper project cost sharing to be accomplished in the first year of construction.

After receiving Division approval of the project and an allocation of funds for future design studies, the Corps’ Seattle District office will commence further design. The cost allocation will include the flood control components that will be cost shared at 65 percent Federal, 35 percent non-Federal, and the additional components which will be 100 percent non-Federal.

6.2.2 Issues Requiring Additional Study During PED

6.2.2.1 Interior Drainage Analyses

The mainline project levee will include "minimum facilities" to relieve local runoff and potential ponding behind the levees for a low Chehalis River condition (i.e., gravity), as specified in EM 1110-2-1413. The minimum facilities will pass the local system design event without increasing interior flooding, therefore, no formal ponding areas are required.

6.2.2.1.1 China Creek Initiative

The local community will continue to look at what improvements can be constructed to solve all the flooding issues related to China Creek, which was not included in the Chehalis River Flood Reduction Study. The following describes the reconnaissance level study conducted by the local community to identify several alternatives to alleviate flooding in the China Creek Basin. The Corps will work with the community to see if China Creek qualifies for Federal interest under other Corps authorities.

A reconnaissance level evaluation was conducted to identify potential flood reduction alternatives for the China Creek drainage basin. The following structural flood control and reduction measures were reviewed and evaluated: pumping station, levee, gravity flood flow diversion, dry retention facilities for more storage capacity, channel modifications to increase channel hydraulic capacity, and creek relocation. Non-structural measures were reviewed but not evaluated. A preliminary evaluation of each of these flood reduction measures was conducted to identify potential flood reduction alternatives. The flood reduction measures were then evaluated independently, and in combination, to develop flood reduction alternatives capable of meeting the 100-year flood reduction design criteria. The size, location, flood reduction capability, cost, environmental impacts and benefits, and performance were factors in screening flood reduction measures to develop alternatives for the reconnaissance level evaluations. The construction cost for the 50-year and 25-year flood reduction design criteria was then determined for each alternative. The summary of this analysis is shown below.

The evaluation indicated that gravity flow diversion and creek relocation from China Creek, near STA 111+01, to the Skookumchuck River is feasible. Construction of a pumping station provides little additional benefit for significant additional cost. The Embankment Dam No. 2 requires substantial real estate acquisition and impacts existing residential neighborhoods. The Gold Street Ring Levee, Lower China Creek Excavation, and China Creek Floodwall do not provide sufficient capacity to be independent alternatives. They could provide economical flood reduction as a supplement to a larger flood reduction measure.

The conclusions of the reconnaissance identified the following as potential options: Flood Flow Diversion, Creek Relocation/Restoration, Gold Street Ring Levee, China Creek Excavation, and China Creek Urban Floodwall flood reduction measures. In addition, it is recommended that the China Creek channel excavation and floodwall components be further evaluated by the community for use with Alternative No. 8 (gravity flow bypass and ring levee) once additional data has been collected.

TABLE 6-1 CHINA CREEK PRE-FEASIBILITY FLOOD REDUCTION ALTERNATIVES EVALUATION

Flood Control Alternative	Preliminary Cost Estimate**	Flood Reduction (STA 55+20)	Pros	Cons
1. Pumping Station No. 1	$10.7 million *($10.7 million)	400 cfs	• Failsafe operation at any flood event • Maximum operational flexibility to provide bypass regardless of Skookumchuck River/China Creek flood stage timing. • Minimal real estate acquisition	• High cost • Maintenance of pumping station • Large pumps required to pump long distance • RR crossing • Coordination & timing of RR crossing construction with BNSF (3rd party)
2. Pumping Station No. 2 with Gold Street Ring Levee	$11.4 million *($11.5 million)	380 cfs	• Failsafe operation at any flood event • Maximum operational flexibility to provide bypass regardless of Skookumchuck River/China Creek flood stage timing. • Minimal real estate acquisition	• High cost • Maintenance of pumping station • Coordination & timing of RR crossing construction with BNSF (3rd party)
3. Embankment Dam No. 1	$7.6 million *($12.1 million)	420 cfs	• Flood reduction for larger length of creek	• Impact to local residential neighborhood/environment • Large real estate acquisition • Environmental impact issues • Impact to Hanaford Road
4. Embankment Dam No. 2 with Pumping Station No. 3	$12.4 million *($13.5 million)	420 cfs	• Pumping Station provides additional capability for controlling peak flows	• High cost • Maintenance of pumping station • Impact to local residential neighborhood/environment • Large real estate acquisition • Impact to Hanaford Road
5. Embankment Dam No. 2 with Gold Street Ring Levee	$7.4 million *($8.6 million)	400 cfs	• Levee provides supplemental flow reduction with minimal impacts to environment and adjacent property owners.	• Impact to local residential neighborhood/environment • Large real estate acquisition • High project cost
6. Embankment Dam No. 2 with Urban Flood Wall	N/A	400 cfs	• Floodwall provides supplemental flow reduction	• Impact to local residential neighborhood/environment • Bridge/culvert rehabilitation cost • Large real estate acquisition cost
7. Embankment Dam No. 2 with Creek Excavation	N/A	400 cfs	• Excavation provides supplemental flow reduction	• Bridge/culvert rehabilitation cost • Sediment deposition would reduce channel capacity
8. Flood Flow Diversion with Gold Street Ring Levee	$7.3 million *($7.8 million)	395 cfs	• Low Cost • Minimal maintenance • Minimal land acquisition	• More detailed data collection and hydrologic analysis required to verify Skookumchuck River/China Creek flood stage timing • Coordination & timing of RR crossing construction with BNSF (3rd party)

TABLE 6-1 CHINA CREEK PRE-FEASIBILITY FLOOD REDUCTION ALTERNATIVES EVALUATION

Flood Control Alternative	Preliminary Cost Estimate**	Flood Reduction (STA 55+20)	Pros	Cons
9. Creek Relocation/ Restoration with Gold Street Ring Levee	$9.6 million *(11.9 million)	590 cfs (diversion of entire flow)	• Stream/habitat restoration • Reduced China Creek bridge/culvert rehabilitation construction costs • Increased public shoreline access • Low maintenance	• Coordination & timing of RR bridge reconstruction at new location with BNSF (3rd party) • Impact to residential neighborhood • More detailed data collection and hydrologic analysis

*Cost includes assumed $18,000/acre real estate acquisition and $100,000/structure acquisition costs.

**Costs are based on 100-year flow or 1996 flood event.

6.2.2.2 Skookumchuck Dam Stability Evaluation

The Corps conducted Skookumchuck Dam geotechnical investigations in 2001. The results of these studies identified potential dam stability issues resulting from a seismic event, which will require further analysis.

During original construction of the dam, while stripping the foundation, a deposit of silt north of the original river channel was discovered. The initial exploration programs for the dam did not reveal the silt layer. An exploration program was undertaken to define the extent and thickness of this silt deposit. It was decided during construction of the dam to leave the silt layer alone. After 20 to 25 feet of embankment material was placed on the silt layer, there were indications that embankments would become unstable in their original design. It was judged that the silt body could be contained and stabilized by adding massive toe berms where the embankment shells are founded on the silty clay material; these were constructed.

In the investigations conducted by the Corps in 2001, based on recent seismic information, the study concluded that the sandy gravel soils underlying the silts appear to be liquefiable under all design Maximum Credible Earthquake (MCE) ground motions. In 2001, a similar stability analysis was performed utilizing subsurface explorations, the liquefaction data, and seismic hazard analysis from recent studies. This included evaluation of the existing static and post-seismic stability of the downstream slopes of the dam and berm using a limit-equilibrium approach. The extent of liquefied soils is uncertain beyond the area of investigations with Becker and SPT borings; thus slope failures were calculated for five different ranges of liquefied soils. The calculations indicate a factor-of-safety below 1.0 for conditions where liquefied soils are present from the core to the toe of the downstream berm.

The District has assembled a “dam safety team” regarding the potential seismic issues. This was established early in the study. This team will continue to coordinate until the issues are resolved. Currently, FERC is reviewing the information provided by PacifiCorp (the current owner) as required by the regulatory permit for operating a hydroelectric facility and the results of the Corps investigation described in the above paragraph. FERC will be issuing a letter to the owner recommending that they conduct further investigations to determine the extent of the liquefiable material. Based on this investigation the owner will be required to conduct remediation to the downstream berm to ensure that the dam meets dam safety requirements in a post-seismic flood event. The current owner, prior to the local sponsor taking ownership of the facility, will conduct this effort. This remediation effort will be a 100 percent cost to the current owner and the costs are not included in the cost estimate for the recommended plan. The flood district will inherit all the liabilities of ownership. They will also inherit all the requirements of the FERC permit if the permit is transferred and not terminated.

6.3 Construction Phase

6.3.1 Project Cooperation Agreement

The PCA will define the local sponsor's responsibility to provide all lands, easements, rights-of-way, and suitable borrow and dredged or excavated material disposal areas required for the project (collectively referred to as LERRD requirements; Section 101(a) and (e), Section 103(a) and (j) of P.L. 99-662). The value of the required LERRD provided by the local sponsor will be credited up to a maximum share of 50 percent of the costs of construction. The Government will reimburse the sponsor for LERRD expenses that exceed the maximum share.

The PCA will discuss the authorization's "grandfathering" of non-Federal cost sharing. Since the original authorization occurred before the policy change that requires upfront cost sharing of PED, work performed during PED has been and will continue to be funded at 100% Federal expense. The local sponsor will also receive credit for services performed prior to signing of a PCA, as authorized by House Report 106-1033 for Public Law 106-554, Section 118.

The PCA will reflect that any required seismic remediation will be completed prior to the construction of flood control modifications. The costs of the remediation will be born by the current owner. The remediation will not affect the fair market value of the dam. The transfer costs will remain unchanged with the decommissioning of the hydropower at the dam. The flood control district will be the owners and accept any liability. In addition, they are planning to decommission the power at the dam and thus not be regulated by FERC, but by Washington dam safety office. The local sponsor understands the legal responsibilities and liabilities for dam safety. These dam safety requirements will be included in the PCA.

The PCA for the project will be negotiated between representatives of the district and the local sponsor. Once the project is authorized for construction, the budget/appropriations process drives the PCA process. Current policy dictates that PCAs will not be executed until: (1) the project document has been approved by HQUSACE; (2) the project is budgeted as a new construction start or construction funds are added by Congress, apportioned by OMB, and their allocation approved by ASA(CW); (3) documentation of compliance with the National Environmental Policy Act (NEPA) and other associated environmental laws and statutes in the PCA checklist has been furnished; and (4) the draft PCA has been reviewed and approved by the Assistant Secretary of the Army (Civil Works).

All Civil Works projects are managed, planned, and executed under the Life Cycle Project Management System (LCPM), per ER 5-1-11. Consistent with ER 5-1-11, the forecast final cost estimate to be entered into PCAs for all specifically authorized new starts is based on the most current cost estimate prepared in accordance with the Micro-Computer Aided Cost Estimating System (MCACES) in the Code of Accounts format.

Under the terms of the PCA, when the Government determines that the entire project, or functional portion thereof, is complete, the Government will provide written notice to the local sponsor of such determination and furnish an Operations, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) Manual to the local sponsor. The local sponsor is then responsible for the OMRR&R of the project, or functional portion. After completion and notice to the local sponsor, authority is considered to expire for expenditure of Federal funds for construction of additional improvements on the project or for maintenance thereof.

The following provisions will be included in the PCA:

(1) Provide a minimum of 35 percent, but not to exceed 50 percent, of total project costs allocated to flood control, as further specified below:

(a) Enter into an agreement with relation to design costs;

(b) Provide, during construction, any additional funds needed to cover the non-federal share of design costs;

(c) Provide, during construction, a cash contribution equal to 5 percent of total project costs allocated to flood control;

(d) Provide all lands, easements, and rights-of-way, including suitable borrow and dredged or excavated material disposal areas, and perform or assure the performance of all relocations determined by the Government to be necessary for the construction, operation, and maintenance of the project;

(e) Provide or pay to the Government the cost of providing all retaining dikes, waste weirs, bulkheads, and embankments, including all monitoring features and stilling basins that may be required at any dredged or excavated material disposal areas required for the construction, operation, and maintenance of the project; and

(f) Provide, during construction, any additional costs as necessary to make its total contribution equal to at least 35 percent of total project costs allocated to flood control.

(2) Give the Government a right to enter, at reasonable times and in a reasonable manner, upon land which the local sponsor owns or controls for access to the project for the purpose of inspection, and, if necessary, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project.

(3) Assume responsibility for operating, maintaining, replacing, repairing, and rehabilitating (OMRR&R) the project or completed functional portions of the project, including mitigation features without cost to the Government, in a manner compatible with the project's authorized purpose and in accordance with applicable Federal and State laws and specific directions prescribed by the Government in the OMRR&R manual and any subsequent amendments thereto.

(4) Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended, and Section 103 of the Water Resources Development Act of 1986, Public Law 99-662, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element.

(5) Hold and save the Government free from all damages arising from the construction, operation, maintenance, repair, replacement, and rehabilitation of the project and any project-related betterments, except for damages due to the fault or negligence of the Government or the Government's contractors.

(6) Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project to the extent and in such detail as will properly

reflect total project costs.

(7) Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements or rights-of-way necessary for the construction, operation, and maintenance of the project; except that the non-Federal sponsor shall not perform such investigations on lands, easements, or rights-of-way that the Government determines to be subject to the navigation servitude without prior specific written direction by the Government.

(8) Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights-of-way that the Government determines necessary for the construction, operation, or maintenance of the project.

(9) Agree that, as between the Federal Government and the non-Federal sponsor, the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and, to the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.

(10) Prevent obstructions of or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) which might, reduce the level of protection the project affords, hinder its operation and maintenance, or interfere with its proper function, such as any new development on project lands or the addition of facilities which would degrade the benefits of the project.

(11) Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public law 91-646, as amended by title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR part 24, in acquiring lands, easements, and rights-of-way, and performing relocations for construction, operation, and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said act.

(12) Comply with all applicable Federal and State laws and regulations, including Section

601 of the Civil Rights Act of 1964, Public Law 88-352, and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army" and Section 402 of the Water Resources Development Act of 1986, as amended (33 USC 701b-12), requiring non-Federal participation and implementation of flood plain management plans.

(13) Provide the non-Federal share of that portion of the costs of mitigation and data recovery activities associated with historic preservation, that are in excess of 1 percent of the total amount authorized to be appropriated for the project, in accordance with the cost sharing provisions of the agreement;

(14) Participate in and comply with applicable Federal floodplain management and flood insurance programs;

(15) Do not use Federal funds to meet the non-Federal sponsor’s share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized.

(16) Inform affected interests, at least annually, regarding the limitations of the protection afforded by the project.

(17) Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

6.3.2 Project Construction

Construction is expected to occur over a period of 3 years (2006 to 2009). The local sponsor must provide all of their cost-sharing funds and real estate at the beginning of construction (prior to award of construction contracts) unless they specifically request a change to the PCA to allow provision of funds in a phased manner similar to the construction schedule.

Table 6-2 provides an estimated timeline from the release of a positive Chief of Engineers Report to project completion.

TABLE 6-2 CONSTRUCTION SEQUENCING

Description	**Dates**
Chief's Report	April 04
WRDA Authorization	Spring 04
Design Complete	Feb 06
All Permits Received	Jan 06
Project Cooperation Agreement Signed With Sponsor	Jan 06
Corps Receives Construction Funding	Feb 06
Sponsor Completes Real Estate Acquisition (Phase 1 will be completed in Jan 06)	May 08
Corps Advertises Construction Contract (First Contract)	April 06
Construction Contract Award (First Contract)	June 06
Contract Notice To Proceed: *Phase1.* I-5 levees from Mellon St. to Salzer Creek Airport levee from Salzer Creek to SR-6 *Phase 2.* Skookumchuck Dam Salzer Creek levees east of I-5 Dillenbaugh Creek levees *Phase 3.* Ford's Prairie levees Skookumchuck River levees Project Mitigation Elements including SR-6 Bypass	 July 06 July 06 July 06 July 07 July 07 July 08 July 08 July 08
Approve Contractors Plans (Safety, Health and Environmental Protection) for *Phase1*. I-5 levees from Mellon St. to Salzer Creek Airport levee from Salzer Creek to SR-6 *Phase 2.* Skookumchuck Dam Salzer Creek levees east of I-5 Dillenbaugh Creek levees *Phase 3.* Ford's Prairie levees Skookumchuck River levees Project Mitigation Elements including SR-6 Bypass	 Aug 06 Aug 06 Aug 06 Aug 07 Aug 07 Aug 08 Aug 08 Aug 08
Construction Contract Complete *Phase1.* I-5 levees from Mellon St. to Salzer Creek Airport levee from Salzer Creek to SR-6 *Phase 2.* Skookumchuck Dam Salzer Creek levees east of I-5 Dillenbaugh Creek levees (WA-DOT) *Phase 3.* Ford's Prairie levees Skookumchuck River levees Project Mitigation Elements including SR-6 Bypass	 Oct 07 Oct 07 July 08 Oct 08 Oct 08 Oct 09 Oct 09 Oct 09
Project Construction Physically Complete	Jan 2010
Project Fiscally Complete	Apr 2010
Final Acceptance & Transfer to Local Sponsor	April 2010

6.4 Operation and Maintenance

The local sponsor is responsible for all future operation and maintenance activities. An Operation and Maintenance Manual will be developed during construction and provided to the county for implementation. The estimated total cost of O&M is $10,471,600 with an average annual equivalent value of $652,800. See Section 5.9 for further discussion of operation and maintenance.

6.5 Cost Allocation

Cost allocation is the practice of allocating the separable costs of a project to the various project purposes they serve. Because all features of the recommended plan were formulated to address flood damage reduction objectives (or to mitigate for adverse environmental impacts) all costs are allocated to the authorized project purpose of Flood Damage Reduction. NED costs (economic costs that include opportunity costs) are used for cost allocation.

6.6 Cost Apportionment

Cost apportionment is the practice of dividing the responsibility for paying the costs of a project between the Federal government and the local sponsor (or appropriate non-Federal interests). Project financial costs are the costs that are shared by the planning partners. Cost sharing for construction of this project will be in keeping with current Corps of Engineers policy whereby, for flood damage reduction projects, the non-Federal share will be 35 percent of the project implementation costs (PED, construction, construction management, Federal supervision and administration, and monitoring). The local sponsor will provide 100 percent of the necessary lands, easements, rights-of-way, relocations and disposal areas (LERRDs), and conduct all future operation, maintenance, repair, rehabilitation and replacement (OMRR&R) activities. If the LERRD value exceeds the maximum share, the sponsor will be reimbursed for the value of the LERRD that exceeds the 50 percent. If the LERRD value is less than the required 35 percent non-Federal share, the sponsor will pay the difference in cash. In addition, the sponsor is also required to pay a minimum of 5 percent in cash. If this situation is estimated prior to executing the PCA, no additional credit will be given to the sponsor for in-kind services.

PED originally began prior to the policy change that required sponsors to provide 25% of PED costs; therefore the work performed during PED has been and will continue to be funded at ~~a~~ 100% Federal expense. The non-Federal cost share will include the cost allocation of the flood control cost shared elements and the betterments which will be 100% non-Federal.

Table 6-3 provides a summary of the estimated cost apportionment between the Federal and non-Federal interests for the recommended plan. The table shows the total first cost of the recommended project as $94,355,000 of which $56,466,800 is Federal cost and $37,888,200 is non-Federal cost. The non-Federal cost includes the sponsor's cash contribution of $23,078,200 and the LERRD value of $14,810,000.

TABLE 6-3 CHEHALIS RIVER FLOOD DAMAGE REDUCTION COST APPORTIONMENT ($)

	Federal Cost*	**Non-Federal Cost***	**Total***
NED Flood Damage Reduction and Mitigation	56,466,800	30,405,200	86,872,000
Plus Increment Flood damage Reduction and Buy-up to Locally Preferred Plan		7,483,000	7,483,000
Less LERRD Value		14,810,000	14,810,000
LP Plan Cash Contribution	56,466,800	23,078,200	79,545,000
Recommended Project (Locally Preferred Plan)	56,466,800	37,888,200	94,355,000

Apportionment of financial costs
**October FY03 price level (rounded)-Cost is project costs less OMRR&R*

6.7 Institutional Requirements

Before the PCA can be executed, the local sponsor will prepare the following financial analysis:

- the local sponsor's project-related yearly cash flows (both expenditures and receipts where cost recovery is proposed), including provisions for anticipated operation and maintenance requirements and contingencies for uncertain damages from natural events;
- the local sponsor's current and projected ability to finance its share of the project cost and to carry out project implementation and OMRR&R responsibilities;
- the means and certainty for raising additional non-Federal financial resources including but not limited to special assessment districts and state grants; and
- the steps that the local sponsor would take to ensure it would be prepared to execute its project-related responsibilities at the time of project implementation.

In addition, as part of any PCA, the local sponsor would be required to undertake to save and hold harmless the Federal government against all claims related to other activities associated with this project.

6.8 Environmental Requirements

There are many Federal, state, tribal and local laws, regulations and treaties applicable to the recommended plan. The EIS, including a Fish and Wildlife Coordination Act Report, programmatically satisfies NEPA requirements when a Record of Decision (ROD) is signed. In addition, a 404(b)(1) is also included in the EIS. As the design is finalized, the 404(b)(1) will be updated as needed on a site-specific basis prior to construction. The Corps will continue to coordinate with the state Department of Ecology and the Chehalis Tribe to obtain Section 401 state water quality certification prior to construction. Certification is usually done during PED (about 90 percent design level) when all necessary information is completed. Table 6-4 below shows the status and responsibility for compliance with the applicable laws, regulations and treaties.

TABLE 6-4 STATUS OF COMPLIANCE WITH ENVIRONMENTAL LAWS/REGULATIONS/TREATIES

Law/Regulation/Treaty	Status of Compliance
National Environmental Policy Act (NEPA)	In compliance for Final EIS/ROD
Endangered Species Act	In compliance.
National Historic Preservation Act	In compliance for this phase, ongoing coordination in next phase.
Clean Water Act	In compliance for this phase.
Clean Air Act	In compliance
Fish and Wildlife Coordination Act	In compliance
Natural Resource Conservation Service	In compliance
Migratory Bird Treaty Act	In compliance
Executive Order 12898, Environmental Justice	In compliance
Executive Order 11990, Protection of Wetlands	In compliance
Executive Order 11988, Floodplain Management	In compliance for this phase, floodplain management plan to be completed prior to PCA
Indian Treaty Rights	In compliance through public review process.
State Environmental Policy Act	In compliance for this phase. Lewis County will adopt Final EIS
Washington Hydraulic Code	In compliance for this phase, Lewis County will obtain permits before construction.
Water Quality Certification	In compliance for this phase.

Law/Regulation/Treaty	Status of Compliance
Growth Management Act	In compliance for this phase.
Model Toxics Control Act	In compliance for this phase. Lewis County will obtain any necessary approvals
State Aquatic Lands Management Laws	In compliance for this phase.
Thurston County Regulations	In compliance for this phase. Lewis County will obtain all required permits
Lewis County Regulations	In compliance for this phase. Lewis County will obtain all required permits
City Regulations and Ordinances	In compliance for this phase. Lewis County will obtain all required permits

6.9 Sponsorship Agreements

The local sponsor (Lewis County) has provided a letter of intent acknowledging sponsorship requirements of the project. Prior to the award of construction contracts, the sponsor will be required to execute the Project Cooperation Agreement and provide required funds.

6.10 Sponsor's Financial Plan and Capability Assessment

In accordance with ER 1005-2-100, paragraph 6-184.b, a preliminary financing plan and statement of financial capability was prepared by the local sponsor. The Corps' Seattle District office has reviewed the plan and assessed the sponsor's understanding of the budgetary issues related to financing the proposed project. The Corps has determined that the local sponsor has the capability to fund their portion of implementation responsibilities.

6.10.1 Financial Analysis

Local sponsor Lewis County is willing and able to share the costs of project implementation. As shown in Table 6-3, the cost estimate for the NED Plan is $86,872,000. The sponsor is responsible for 35 percent of the implementation cost, an estimated $30,405,200. Assuming that the real estate value for which the sponsor will get credit is $14,810,000, and the sponsor will get credit for the $3,000,000 already contributed in in-kind services, Lewis County would be responsible to provide the Corps of Engineers an additional $12,595,200 in cash over the construction period for the NED Project. The sponsor, however, has expressed an interest to upgrade portions of the NED Plan to provide additional levels of flood protection. These upgrades (buy-ups) are a 100 percent local responsibility, and are estimated to add $7,483,000 in costs to the NED Plan. Therefore, the total cash responsibility of the sponsor, if they continue to support the betterments and after crediting of LERRD and already contributed funds, may be as much as $20,078,200. Cost estimates change over time, and the final cost sharing numbers would be determined at the end of construction.

Despite the fact that Lewis County is the official sponsor and will be signing the Project Cooperation Agreement (PCA) with the Corps of Engineers, the county is expecting to receive the majority of its required project funds from the Washington State Department of Transportation (WSDOT). This source of funding, as well as other sources of non-Federal project matching funds are discussed in the county’s Financing Plan and Statement of Financial Capability, provided by letter to Seattle District, dated 13 August 2002.

6.10.2 Assessment of Financial Capability

The Corps' assessment of the local sponsor's financial capability is required to verify that sufficient funds will be available to the sponsor to satisfy the financial obligations for the project. The financing plan submitted by Lewis County is satisfactory and sufficient.

The county intends to fund its land acquisition expenses, cash contribution requirements, and annual operation and maintenance costs from the following sources:

1. Washington State Department of Transportation funding.
2. creation of a flood control district (or similar local service district with taxing authority), or in the event sufficient funds are not available through these sources;
3. enter into an inter-local agreement with the cities of Centralia and Chehalis to assist in funding;
4. issue general obligation bonds.

An allocation of funds table will be included prior to the signing of the PCA.

7. LEGAL AND TECHNICAL REVIEW

The study's Quality Control (QC) Plan defined the process by which to assure quality products for the General Reevaluation Study. This QC Plan defined the responsibilities and roles of each member of the study team, along with a legal sufficiency and policy compliance review

The project team is comprised of qualified staff from within the Corps' Seattle District, Northwestern Division, the local sponsor, Lewis County, USFWS, and their consultants and contractors.

An Independent Technical Review (ITR) team was established whose members were selected on the basis of their lack of direct affiliation with the development of the GRR/EIS. ITR is currently a Corps district function. The objective of ITR was to ensure and confirm that:

- the documents are consistent with established criteria, procedures and policy;
- assumptions that are clearly justified have been utilized in accordance with established guidance and policy, with any deviations clearly identified and properly approved;
- the concepts, features, analytical methods, analyses, and details are appropriate, fully coordinated, and correct;
- the problems/issues are properly defined and scoped; and
- the conclusions and recommendations are reasonable.

ITR was conducted for all decision documents and was independent of the technical production of the product/project. The ITR included periodic technical review team meetings to discuss critical plan formulation or other project decisions, and coordinate the review of the written GRR, EIS, appendices, report documentation and files.

The ITR was divided into two major segments. The first part of the ITR took place in July 2001 and covered the basic hydrology, hydraulics, and economic analysis involved in developing the existing condition analyses and determining the appropriate "without-project" analysis. In addition, an ITR of Skookumchuck Dam liquefaction and stability analysis was also conducted to ensure that Corps dam stability criteria would be met. The second part of the ITR concentrated on review of the draft technical reports and covered all other aspects of project planning and design.

A Certification of Technical and Legal Review memorandum is included with the submittal of this report. This memorandum includes:

- a Statement of Technical and Legal Review that discusses the general scope of the review and lists the ITR team members;
- a Certification of ITR that identifies the significant technical concerns raised during the review and the resolution of those concerns, and is signed by the District Chiefs of Planning, Engineering, Operations, and Real Estate;
- a Certification of Legal Review of all documents and their legal sufficiency, signed by a District Office of Counsel attorney.

8. DISTRICT COMMANDER'S RECOMMENDATION

The cities of Chehalis, Centralia, and surrounding communities in Lewis and Thurston Counties, Washington, have a long history of flooding and flood damages. These problems have been acknowledged and studied for many years. More recently, heightened environmental awareness and the potential listing of area aquatic species as threatened and endangered have resulted in a need for increased focus on the development of flood control alternatives that minimize environmental impacts and that incorporate environmental features to mitigate any adverse impacts to fish and wildlife habitats.

The recommended project is the Locally Preferred Plan as described in this report. It would provide 100-year flood protection for the cities of Centralia and Chehalis, Washington. The project would provide estimated annual benefits of $8,949,000, including $6.7 million in flood related damages to structures and their contents, $2.1 million in annual avoided costs associated with the need to elevate Interstate Highway 5 without the project, and an annual reduction of $131,000 in traffic delays related to flooding. Annual economic costs are estimated at $7,063,000, resulting in annual net benefits of $1,886,000 and a positive benefit-to-cost ratio of 1.27 to 1. The NED Plan would have annual costs of $6,496,000, providing net benefits of $2,210,000 at a benefit-to-cost ratio of 1.34 to 1. The recommended project is supported by the local sponsor, Lewis County, Washington, who will assume all costs over those of the NED Plan as identified in this report.

I recommend that the selected plan described herein for flood damage reduction purposes be authorized for implementation as a Federal project. The implementation cost of the project is currently estimated at $94,355,000. The Federal share is currently estimated at $56,466,800 and the non-Federal share is $37,888,200.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However, prior to transmittal to the Congress, the sponsor, the states, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Colonel Ralph H. Graves
U.S. Army Corps of Engineers
District Engineer

U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington
General Reevaluation Report

Appendix A:
Hydrology and Hydraulics

June 2003

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TABLE OF CONTENTS

Section/Paragraph | **Page No. A-**

1. INTRODUCTION 1
2. CHEHALIS RIVER BASIN 2
2.1 Watershed Physiography 2
2.1.1 Drainage Basin 2
2.1.2 Upper Chehalis River Basin 3
2.2 Geology and Soils 8
2.2.1 Geology 8
2.2.2 Soils and Vegetation 8
2.3 Climate 9
2.4 Stream Flow Characteristics 11
2.4.1 Streamgage Stations 11
2.4.2 Runoff 11
2.4.3 Historical Floods 12
2.4.4 Flood Exceedance Frequency 15
2.5 Hydrology Output Requirements for Analysis of Projects 16
2.6 Hypothetical Hydrograph Development Method 18
2.6.1 Flood Frequency Analysis 18
2.6.2 Correlation to Chehalis River at Grand Mound Gaging Station 19
2.6.3 Shaping of the Hypothetical Hydrographs 19
2.6.4 Development of Hydrographs for Minimally Gaged and Ungaged Sites 24
2.6.5 Flood Timing 26
2.6.6 Regulation of Skookumchuck Flows 26
3. BASELINE FLOOD MODELING 28
3.1 Introduction 28
3.2 Methodology 28
3.3 Subbasin Rainfall-Runoff Modeling 32
3.3.1 General 32
3.3.2 Subbasin Definition 33
3.3.3 Meteorological Input 33
3.3.4 Optimization of Hydrological Parameters for Gaged Subbasins 34
3.3.5 Derivation of Hydrological Parameters for Ungaged Subbasins 36
3.4 Flood Routing Modeling 36
3.4.1 General 36
3.4.2 Development of the UNET Model 36
3.4.3 Geometric Data 38
3.4.4 UNET Model Calibration 39
3.4.5 UNET Model Verification 40
3.4.6 UNET Model Sensitivity Analyses 42
4. HYDRAULIC DESIGN 68
4.1 Design Considerations and Criteria 68
4.1.1 General 68
4.1.2 Water Surface Profiles 68
4.1.3 Levee Height Analysis 68
4.2 The Levee Plan 68
4.2.1 Levee / Floodwall System 68
4.2.2 Levee Design Criteria 69
4.3 Skookumchuck Dam Description 69
4.3.1 General 69
4.3.2 Proposed Dam Modifications 70

4.4 Reservoir Regulation Considerations 71
4.4.1 Existing Operations *71*
4.4.2 Flood Control Operations *72*
4.4.3 Routine Operations (Post Construction) *72*
4.4.4 Reservoir Operations *73*
4.4.5 Downstream Flows *73*
4.5 Recommendations for an Operations Plan 73
4.5.1 Flood Control Rule Curve and Discharges *73*
4.5.2 Maximum flows *75*
4.5.3 Bedload Movement and Channel Processes *75*
4.5.4 Minimum Flows *76*
4.5.5 Ramping Rates *76*
4.5.6 Upstream Fish Passage Operations *77*
4.5.7 Downstream Fish Passage Operations. *77*
4.6 UNET Hydraulic Model 78
4.7 Modification of UNET Model 78
4.7.1 Skookumchuck Dam Modification *78*
4.7.2 Levee Segments *79*
4.7.3 Flood control boxes *79*
4.8 Hydraulic Modeling Results 79
4.8.1 Alternative 4 only *79*
4.8.2 Alternative 4 and Skookumchuck Dam Modifications *80*
5. REFERENCES 82

FIGURES

Figure 2-1: Chehalis River Basin Watershed Boundary 3
Figure 2-2: Upper Chehalis River Basin Boundary 4
Figure 3-1: Upper Chehalis River Basin UNET Model – Schematic Diagram 30
Figure 3-2: Upper Chehalis River Subbasin Division Map 34
Figure 3-3: Accumulated Rainfall Curves 45
Figure 3-4: Comparison of Computed and Observed Hydrographs for the February 1996 Flood 47
Figure 3-5: Comparison of Computed and Observed Hydrographs for the November 1990 Flood 48
Figure 3-6: Comparison of Computed and Observed Hydrographs for the January 1990 Flood 49
Figure 3-7: Comparison of Computed and Observed Hydrographs for the January 1972 Flood 50
Figure 3-8: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street - February 1996 Flood 51
Figure 3-9: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street - February 1996 Flood 52
Figure 3-10: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda - February 1996 Flood 53
Figure 3-11: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound - February 1996 Flood 54
Figure 3-12: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street – November 1990 Flood 55
Figure 3-13: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda – November 1990 Flood 56
Figure 3-14: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street – November 1990 Flood 57
Figure 3-15: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound – November 1990 Flood 58
Figure 3-16: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street – January 1990 Flood 59

Figure 3-17: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda – January 1990 Flood 60
Figure 3-18: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street – January 1990 Flood 61
Figure 3-19: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound – January 1990 Flood 62
Figure 3-20: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street – January 1972 Flood 63
Figure 3-21: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda – January 1972 Flood 64
Figure 3-22: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street – January 1972 Flood 65
Figure 3-23: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound – January 1972 Flood 66
Figure 3-24: Comparison of Computed and Existing USGS Discharge Rating Curve for the Chehalis River at Grand Mound – USACE Statistical Flood Hydrographs 67
Figure 3-25: Comparison of Distance Step Value - Chehalis River 67
Figure 4-1: Provisional Rule Curve for Skookumchuck Dam 74
Figure 4-2: Pebble Count Data at Reach 37 (left) 75
Figure 4-3: Pebble count data at Reach 1 (right) 75

TABLES

Table 2-1: Climatological Stations and Data Summary 10
Table 2-2: USGS Streamgage Information 12
Table 2-3: Precipitation Totals Ranked for 10 Largest Storms at Centralia 1W 13
Table 2-4: Ten Largest Floods on the Chehalis, Skookumchuck, and Newaukum Rivers (Since 1971) 13
Table 2-5: Peak Discharge Frequency Data for Selected Locations 15
Table 2-6: Comparison of Flood Recurrence Intervals at Grand Mound 15
Table 2-7: Expected Flood Frequency Discharges for Peak, 1-day, 3-day, 7-day, and 15-day Events for Fully Gaged Sites 20
Table 2-8: Two Gage Comparisons of Partial Gage Records to Full Gage Records 21
Table 2-9: Expected Flood Frequency Discharges for Peak, 1-day, 3-day, 7-day, and 15-day Events for Partially Gaged Sites 22
Table 2-10: Correlated Flows to Grand Mound 23
Table 2-11: Recurrence Intervals in Years of Flow Volumes for Chehalis near Grand Mound Gage 24
Table 2-12: Ratios of 1-day Discharge per Square Mile from Lower Basins to Upper Basins 25
Table 2-13: Flow Determination for Tributaries in Close Proximity to the Mainstem Chehalis River 25
Table 2-14: Observed Flood Timing 26
Table 2-15: Chehalis River Subbasin Timing for Different Recurrence Intervals 27
Table 3-1: Upper Chehalis River Subbasin Division Summary 31
Table 3-2: HEC-1 Optimization Results 35
Table 3-3: Characteristics of UNET Routing Reaches 37
Table 3-4: Comparison of Computed and Observed Maximal Water Surface Elevations (February 1996 Flood) 39
Table 3-5: Comparison of Computed and Observed Maximal Water Surface Elevations (January 1990 Flood) 41
Table 4-1: Recommended Ramping Rates for the Skookumchuck River 77

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1. INTRODUCTION

This appendix presents information and analyses performed for the re-evaluation study. It presents the conceptual basis for the hydraulic design of the proposed action. The information in this appendix will serve as the basis for subsequent hydraulic modeling in support of the final design, construction plans and specifications to complete the project. The basic flood control objectives of the project are to prevent flooding in the Centralia-Chehalis area from a 1 percent or 100-year flood event and to preserve, as much as possible, existing wetlands and riparian and aquatic habitat along the Chehalis, Newaukum and Skookumchuck Rivers.

2. CHEHALIS RIVER BASIN

2.1 WATERSHED PHYSIOGRAPHY

2.1.1 Drainage Basin

The Chehalis River drainage basin covers approximately 2,114 square miles (Figure 2-1). Above the stream gage at Porter, river mile (RM) 33.3, the drainage area is 1,294 square miles, and above the stream gage at Grand Mound (RM 59.89) the drainage area is 895 square miles. The Chehalis River is about 125 miles long, originating in the Willapa and Doty Hills southeast of the City of Aberdeen and flowing northeast and then northwest before emptying into Grays Harbor at Aberdeen. The basin uplands include the Willapa Hills, the western flank of the Cascade Mountains, and the southern Olympic Mountains.

The Chehalis River originates in the extreme southwestern corner of the basin, and flows east for about 25 miles to its confluence with the Newaukum River at the City of Chehalis. From Chehalis, the river flows north for 8 miles, where it meets the Skookumchuck River at the City of Centralia. The river then turns and flows generally north and west for about 50 miles to its mouth at Grays Harbor on the Washington coast.

The Chehalis River Valley, located in the southern end of the Puget Trough, is characterized by a broad, well-developed floodplain and low terraces surrounded by highly dissected uplands of low to moderate relief that have broad, rounded ridges. There are numerous perennial streams in the valley. The valley bottom in the Centralia-Chehalis area is at an elevation of about 150 feet, and upland elevations average about 300 to 600 feet. Higher elevations in the basin range from about 1,000 feet in the lowland hills, to 2,658 feet at Capital Peak in the south Olympic Range, to 3,800 feet in the foothills of the Cascade Range east of Centralia-Chehalis, and 3,110 feet in the Boistfort Hills along the south basin.

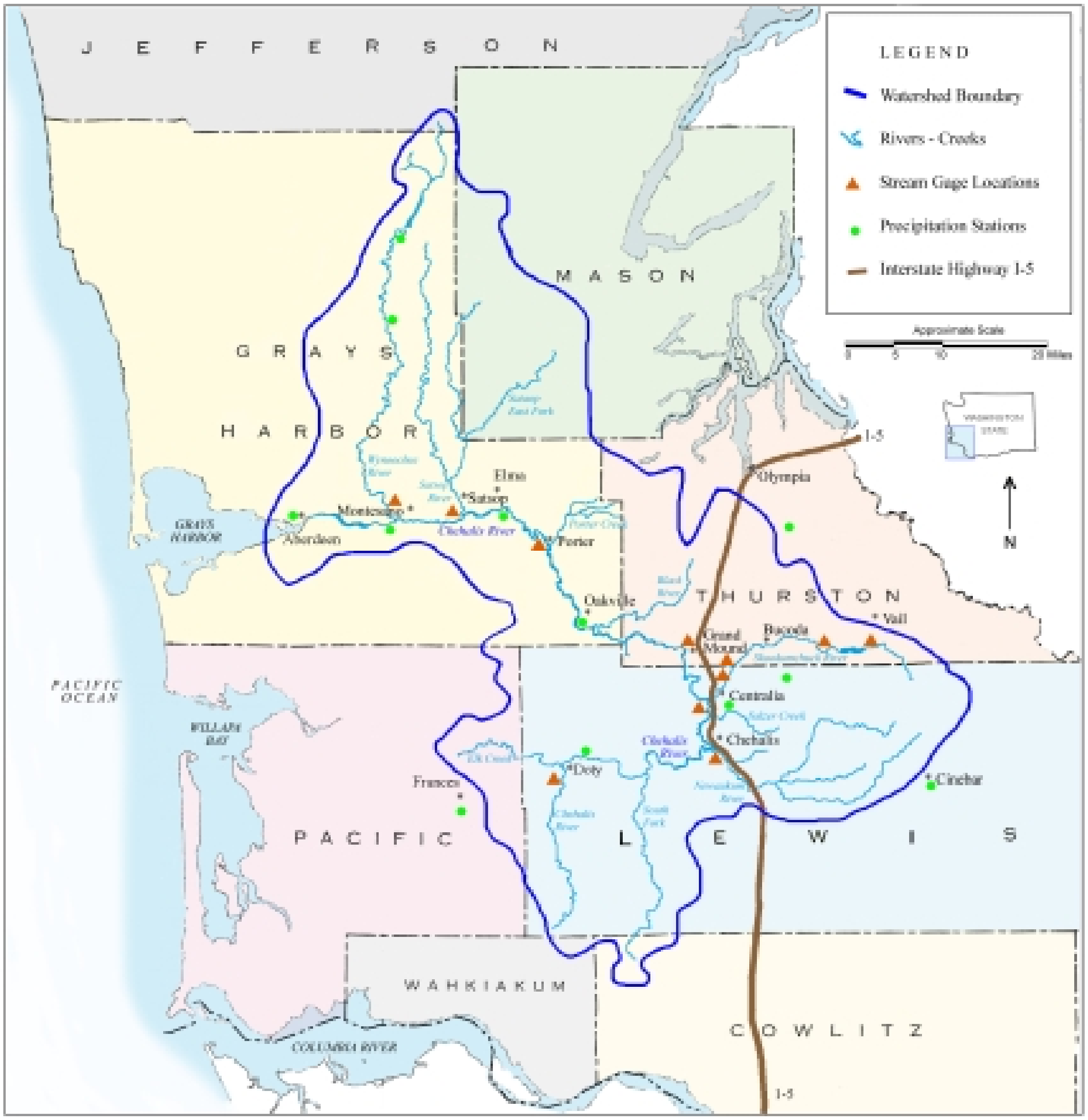


Figure 2-1: Chehalis River Basin Watershed Boundary

2.1.2 Upper Chehalis River Basin

The slope of the upper Chehalis River from its source to the City of Chehalis is steep, falling an average of 16 feet per mile. The slope flattens to about 3 feet per mile in the valley surrounding the cities of Centralia and Chehalis, where the Chehalis River has a meandering channel that occupies a fairly uniform floodplain averaging over 1 mile wide. Most of the valley is inundated during a severe flood such as the January 1990 and the February 1996 floods.

The Upper Chehalis River Basin above Centralia includes four main drainages: the Skookumchuck River, the Newaukum River, the South Fork Chehalis River, and the Chehalis River above Doty. In addition, there are several smaller subdrainages in the Centralia-Chehalis area, including Coffee Creek, China Creek, Salzer Creek, and Dillenbaugh Creek (Figure 2-2). The main drainages between Centralia and the town of Porter include: Lincoln Creek, Scatter Creek, Independence Creek, Black River, Garrad Creek, Rock Creek, Shelton Creek, Cedar Creek, and Porter Creek.

Figure 2-2: Upper Chehalis River Basin Boundary

Skookumchuck River

The Skookumchuck River, one of the major Chehalis River tributaries, joins the Chehalis River at RM 67, and is approximately 41 miles in length. It originates in the Mt. Baker-Snoqualmie National Forest northeast of the City of Centralia, and empties into the Chehalis River at Centralia. The total drainage area for the Skookumchuck River is 181 square miles. Elevations within the basin range from 150 feet at the mouth to 3,800 feet at the headwaters, with approximately two-thirds of the basin located below an elevation of 1,000 feet. The slope of the Skookumchuck River from its source to the town of Bucoda is steep, falling an average of 19 feet per mile. Below Bucoda, the slope flattens to about 5 feet per mile near Centralia. Except for the uppermost portion, the Skookumchuck River flows as a meandering channel in a floodplain, varying in width from a few hundred feet to 0.5 mile.

The Skookumchuck River Basin has three distinctly different hydrologic regions of approximately the same size. The region above Bloody Run Creek has a drainage area of 66 square miles and is a steep, well-forested, mountainous area with elevations generally above 1,000 feet. The river in this region flows through a steeply sided, narrow floodplain that drains into the Skookumchuck Reservoir. The region from Bloody Run Creek to the mouth (excluding the Hanaford Creek drainage) has a drainage area of 56 square miles and contains a relatively broad (.5 to 1 mile wide) floodplain bordered by steeply sided ridges. Hanaford Creek drains into the Skookumchuck at RM 3.8 and has a drainage area of 59 square miles. Hanaford Creek is broad and is at relatively low elevations with a substantial amount of natural overbank storage compared to the mainstem.

Three developments are notable within the Skookumchuck River system. The first is the City of Centralia, which occupies several square miles at the lower end of the basin. The second development is Skookumchuck Dam, located about 20 miles upstream from Centralia and operated by PacifiCorp. Skookumchuck Dam was completed in 1971 and has been considered several times for flood control use. The third development of note in the Skookumchuck Basin is the Centralia Steam Generating Plant on Hanaford Creek. Authority has been granted for this coal-fired facility to divert up to 54 cubic feet per second (cfs) of water from the Skookumchuck River.

The Skookumchuck River is regulated by the Skookumchuck Dam, which is owned by Scottish Power (PacifiCorp). Skookumchuck Dam is located at RM 21.9, just upstream from Bloody Run Creek. The dam is an earthfill structure approximately 190 feet high with a crest elevation of 497 feet. Construction of the dam was completed in January 1971. The primary purpose of the project is water supply for the Centralia coal-fired power generator plant. Outflow from the reservoir is either over the spillway crest at elevation 477 feet or through the outlet works with intake gates at elevations 449, 420, and 378 feet. The discharge capacity of the outlet works is approximately 220 cfs when the pool elevation is at the spillway invert. Because of this limited outlet capacity, the reservoir typically fills early in the flood control season and passes subsequent floods over the 28,000 cfs capacity spillway. The normal active storage capacity of the reservoir is 38,700 acre-feet (ac-ft) between elevations 400 feet (normal minimum operating pool) and 492 feet (maximum operating pool). Additional usable storage of 3,170 ac-ft is available between elevations 378 feet (invert of the lowest intake) and 400 feet. Dead storage is approximately 1,420 ac-ft between elevations 378 and 340 feet.

The land use in the Skookumchuck River floodplain is generally agricultural in the upper reaches with increasing urbanization towards the mouth. The most developed portion of the floodplain is from the mouth to RM 4.5 with the city of Centralia’s central residential/business district being within the floodplain on the left bank near RM 2.0. The small town of Bucoda is within the floodplain on the right bank near RM 12.

Newaukum River

The Newaukum River joins the Chehalis River at RM 75 at the City of Chehalis. The Newaukum drains 175 square miles of lowland and foothills southeast of the City of Chehalis. Elevations in the basin range from approximately 180 feet at the confluence with the Chehalis River, to just over 3,000 feet in the upper basin. The Newaukum River is the second major tributary to the Chehalis River in Lewis County.

The Newaukum River is made up of three forks: the north, middle, and south forks. Upstream sections on both the north and middle forks have slopes of 83 feet per mile; the south fork has a slope of 188 feet per mile above the town of Onalaska. The average channel slope for the entire drainage is 35 feet per mile. The lower two miles of the stream and floodplain are within the flood backwater area of the Chehalis River.

South Fork Chehalis River

The South Fork Chehalis River joins the mainstem Chehalis River at RM 86 and drains 130 square miles. The lower basin (up to RM 9) consists of a broad, flat valley with small creeks draining the hills on either side. From RM 9 to RM 15, the valley narrows from 1.5 miles wide to 0.75 miles wide.

Upper Chehalis River above Doty

The upper Chehalis River is at comparatively lower elevations with most areas ranging in elevation from 200 feet to 1000 feet above sea level. The stream slope averages 16 feet per mile.

Coffee Creek

Coffee Creek is a tributary of the Skookumchuck River. With headwaters in Thurston County, Coffee Creek flows south through the Zenkner Valley to the Skookumchuck River north of Centralia. The watershed encompasses 6.2 square miles of moderately sloping hills. Watershed elevations range from 186 feet at the confluence with the Skookumchuck River to 645 feet at the northern tip of the watershed. The stream gradient is low in the lower four miles of the watershed. Coffee Creek has been moved from its natural location to a periphery channel bordering the edge of adjacent hills and the valley floor.

China Creek

China Creek is a relatively small, short stream that flows through the City of Centralia to the Chehalis River. The watershed extends about five miles east of the Chehalis River at Centralia. It encompasses approximately 4.4 square miles, ranging in elevation from 180 feet to 570 feet. Much of the land is moderately steep. Most of the channel consists of pipes and culverts through Centralia.

Salzer Creek

Salzer Creek flows into the Chehalis River from the east, just south of the Centralia city limits, and drains 24.3 square miles. Salzer Creek originates in the low-lying hills east of Centralia-Chehalis, and has a maximum elevation of about 800 feet. The stream gradient of Salzer Creek is relatively flat. The lower two miles of the stream are within the flood backwater area of the Chehalis River. Coal Creek, a major tributary of Salzer Creek, has a drainage area of 5.4 square mile, and a steeper slope.

Dillenbaugh Creek

Dillenbaugh Creek flows into the Chehalis River from the east, at the City of Chehalis. It originates in the steep foothills southeast of Chehalis, and has a drainage area of approximately 11.7 square miles. The gradient of Dillenbaugh Creek in the upper reaches is approximately 70 feet per mile. After it flows out onto the Newaukum River floodplain, the gradient drops as Dillenbaugh Creek parallels the Newaukum and Chehalis Rivers for nearly three miles before finally flowing into the Chehalis River. Dillenbaugh Creek collects much of the storm drainage from the City of Chehalis in this lower reach. Substantial flood flows overtopping the Newaukum River also enter into lower Dillenbaugh Creek.

Upper Chehalis River

The upper Chehalis River, above the Newaukum River, drains an area of 445 square miles, and can be divided into two main drainages and several smaller subdrainages. The two main drainages are the South Fork Chehalis River and the mainstem of the Chehalis River. The South Fork Chehalis River joins the mainstem of the Chehalis River at RM 88 and drains 130 square miles. The mainstem of the Chehalis River above Doty drains 113 square miles at RM 101.8 (USGS Gage). The major subdrainages include Bunker Creek, Stearns Creek, and Elk Creek, which drain 34.1, 34.8, and 46.7 square miles, respectively.

Centralia-Chehalis Reach

This reach of the river stretches from the Skookumchuck River at RM 66.89 to the Newaukum River at RM 75.20. This reach is comprised primarily of the Centralia-Chehalis floodplain, with both cities located within the reach. Dillenbaugh Creek, Salzer Creek, and China Creek all enter the Chehalis River along this reach. The river is characterized by a very shallow gradient and a meandering stream course in this area.

Grand Mound Reach

This reach of the river stretches from the upstream end of the Chehalis Indian reservation at RM 53, to the mouth of the Skookumchuck River at RM 66.89. The major subdrainages are Lincoln Creek and Scatter Creek, which drain 42.84 and 41.3 square miles, respectively. The Chehalis River drains 895 square miles at the Grand Mound gage.

Independence Creek

Independence Creek flows northeast out of the Doty Hills to enter the Chehalis River at about RM 51.07, immediately due south of the Chehalis Indian Reservation. Independence Creek extends over 8 miles into the watershed and drains approximately 26 square miles. The watershed ranges in elevation from 630 feet to 105 feet at the confluence with the Chehalis River. Much of the land is steep hillside with a small half-mile wide valley along the bottom.

Black River

The Black River is located in the west central portion of the Chehalis River Basin and is characterized by relatively flat topography. The Black River originates in Black Lake, about three miles west of Tumwater, and is about 25 miles in length. The river flows generally southwest and begins to meander in the downstream portion where it flows just north of the Chehalis Indian Reservation. The Black River drains approximately 136 square miles at its mouth. Significant amounts of flood flow overtopping the Chehalis River right bank and crossing the floodplain and State Route (SR) 12 within and east of the Reservation enter into the Black River between RM 5 and RM 9.

Porter Reach

The floodplain in this reach is approximately 1.5 to 2 miles wide and is confined between the Black Hills to the north and the Doty Hills to the south. The principal communities within the reach include the cities of Porter and Oakville, and the Chehalis Indian Reservation. Porter, Oakville, and other small rural communities are generally situated on the floodplain margins. The Chehalis Indian Reservation lies directly within the floodplain with development generally occupying the limited areas of high ground. Major subdrainages include Garrad Creek, Rock Creek, Shelton Creek, and Porter Creek, which drain 26, 24.8, 35.9, and 35.3 square miles, respectively. The Chehalis River drains 1,294 square miles at the Porter gage.

2.2 Geology and Soils

2.2.1 Geology

The bedrock geology of the Chehalis River Basin is composed primarily of igneous and sedimentary bedrocks of the Tertiary Period. Surficial deposits include the unconsolidated glacial sediments of the Pleistocene Epoch. Following formation of the bedrock 7 to 55 million years ago, the area underwent geologic uplift, raising the volcanic and sedimentary rocks above sea level. Deformation, in the form of faulting and folding, accompanied the uplift. Landslides, erosion, glaciation, and glaciofluvial deposition, as well as recent volcanic activity, followed. The most recent 10,000 years have been a period of relatively stable climatic and geologic conditions with erosion being the dominant geologic process (ENSR 1994).

From the City of Chehalis to the City of Montesano, the average width of the floodplain is about 1.5 to 2.0 miles. The sediments within this floodplain attain a maximum depth of approximately 100 feet. The floodplain shows very little relief, either longitudinally or perpendicular to the direction of flow. This lack of relief has resulted in a very sinuous river course with numerous oxbow lakes and other abandoned channels.

Geologic evidence indicates that the Chehalis River has reworked its valley since the deposition of the glacial alpine outwash sand and gravel. This sand and gravel forms the older river terraces that line the valley margins. This timeline would make the recent river deposits less than 7,000 to 10,000 years old. Canyon wall conditions imply a mature topographic landscape prior to river sedimentation. This type of landscape would contribute to the long-term, slow aggradation by the river system with deposition of fine sand and some fine gravel, but a predominance of silt, clay, and organic mud. Mapping of the Centralia-Chehalis area by the Soil Conservation Service (SCS) confirms that at least 50 percent of the deposits in the upper 5 feet of the valley sediments are organic mud, silt, and plastic clay. The longer-term, more active stream channels contain coarser grained sediments.

2.2.2 Soils and Vegetation

The SCS published a soil survey of Lewis County in May 1987. Much of the information in this section is excerpted from that document (SCS 1987). Soils in the floodplain tend to be a silty clay loam. These soils tend to be very deep and range from poorly drained to well drained. The native vegetation is wetland plants, deciduous plants, and conifers. The common wetland plants include bull thistle, cattail, peachleaf willow, reed canarygrass, and soft rush. The main woodland species are Douglas fir and red alder. Among the trees of limited extent are black cottonwood, western red cedar, and bigleaf maple. Among the common forest understory plants are western swordfern, vine maple, cascade Oregon grape, red huckleberry, western brackenfern, Pacific trillium, and trailing blackberry.

Soils on plains, terraces and uplands tend to be very deep, and range from well-drained gravelly sand to poorly drained silty clay. The main woodland species are Douglas fir and red alder. Other trees found in limited quantities are western hemlock, western red cedar, and bigleaf maple. Among the common forest understory plants are cascade Oregon grape, rose, red huckleberry, western brackenfern, violet, and salal.

Soils on uplands, mountains, and high terraces tend to be very deep, well-drained silt loam. The main woodland species are Douglas fir and red alder. Other trees found in limited quantities are western hemlock, western red cedar, and bigleaf maple. Among the common forest understory plants are cascade Oregon grape, salmonberry, red huckleberry, western brackenfern, vine maple, and red elderberry.

All soils in the basin fall predominately within AASHTO hydrologic group A. Soil permeability typically ranges from 0.6 to 2 inches per hour.

2.3 Climate

The Centralia-Chehalis area has a predominately marine climate characterized by mild temperatures both summer and winter. Extreme temperatures are unusual for the area because prevailing westerly winds bring maritime air over the basin and provide a moderating influence throughout the year.

During the spring and summer, high-pressure centers predominate over the northeastern Pacific, sending a northwesterly flow of dry, warm air over the basin. The dry season extends from late spring to midsummer, with precipitation frequently limited to a few light showers. Average summer temperatures are in the 50s or 60s (degrees Fahrenheit), but occasionally hot, dry easterly winds cross the Cascade Mountains and raise daytime temperatures into the 90s. The Aleutian low-pressure center normally predominates during the winter, causing a counterclockwise circulation of cool, moist air over the basin and prevailing southwesterly winds.

The area from the Pacific Ocean to the crest of the Olympic Mountains, the western slopes of the Cascade Range, and the Black and Willapa Hills receives the full force of winter storms. Virtually every fall and winter (October through March), strong winds and heavy precipitation occur throughout the basin. Storms are frequent and may continue for several days. Successive secondary weather fronts with variable rainfall, wind, and temperatures may move onshore at daily intervals or less. Heavy orographic-type rainfall is frequently produced by these storm conditions when warm, maritime, saturated winds rise over the coastal range and west slopes of the Cascade Range. Occasional short cold periods are experienced when movement of arctic air into the Northwest interrupts the usual weather pattern.

The locations of the climatological stations in the region are shown in Figure 2-1. A summary of pertinent data for these stations is shown in Table 2-1. The first eleven stations listed are all National Weather Service (NWS) stations, and the final station is at the Centralia Steam Plant where climatological data is collected by plant operators.

Table 2-1: Climatological Stations and Data Summary

Station Name	NWS Station ID	Data Type	Eleva-tion	Avg. Annual Precip. (in.)	Period of Record
Aberdeen	8	Daily	10	58.5	1931-Present
Aberdeen 20 NNE	13	Daily & Hourly	435	130.29	1948-Present
Centralia 1W	1277	Hourly	185	41.64	1931-Present
Chehalis	1330	Hourly	180	40.62	1948-1968
Cinebar 2E	1457	Hourly	1040	72.44	1948-Present
Doty 3E	2220	Daily	260	51.91	1978-Present
Elma	2531	Daily	69	66.83	1948-Present
Frances	2984	Hourly	231	71.91	1948-Present
Montesano 1S	5549	Hourly	25	76.79	1954-Present
Oakville	6011	Daily	80	56.06	1948-Present
Olympia AP	6114	Daily & Hourly	165	50.24	1948-Present
Centralia Steam Plant	N/A	Daily	200	49.72	1968-Present

Source: National Weather Service and PacifiCorp

Precipitation in the basin is affected by distance from the Pacific Ocean, elevation, and seasonal conditions. Generally, the southern slopes of the Olympic Range and the more easterly, higher slopes along the Cascade Range receive the greatest precipitation. The Black Hills in the northeast portion of the basin and Willapa Hills between the coast and the Centralia-Chehalis area often receive moderate to heavy rainfall during the movement of oceanic storms through the basin.

The greatest amount of rainfall occurs between the months of October and March. The abundance of rainfall during this period is due to the frequent storm systems that pass over western Washington. In Centralia, monthly rainfall totals for this period typically range between 5 and 8 inches. For the rest of the year, average monthly rainfall totals range only between 0.8 and 2 inches. The month with the highest average rainfall is November, with 7.77 inches. The month with the lowest average rainfall is July, with only 0.84 inches. Annual precipitation averages 41.64 inches, with a record low of 28 inches and a record high of 60 inches.

Temperature variations in the Skookumchuck basin depend on elevation, season, and several climatological factors. The weather station at Centralia has recorded temperature extremes of 105 to –16 degrees. The mean monthly temperature is 52 degrees with the monthly means of January and July being 39 and 65 degrees respectively. The growing season (the average period between killing frosts) is about 180 days.

Snowfall in the region is not heavy, but potential does exist for extremely large amounts on occasion. The average annual snowfall is approximately nine inches, with recorded extreme annual maximums at 45 inches. Most of the snowfall occurs in the month of January, with the monthly average at about 4.5 inches.

Snowfall occurs occasionally at Centralia but warm temperatures typically limit any snow accumulation over prolonged periods. Very little of the Upper Chehalis basin is above 3,000 feet. Consequently, a significant snow pack generally does not build up even in the higher areas of the basin.

Winds in the region rarely exceed 30 mph; winds of this speed usually only occur during the fall and winter months in conjunction with rainstorms and/or thunderstorms that pass through the vicinity. Approximately 10 percent of the winds between the months of November and February have speeds between 15 and 30 mph, compared with approximately two percent of the winds for the other months. The rest of the wind speeds typically range between zero and 15 mph, about 90 percent of the time. Wind speeds have been measured in excess of 70 mph during the winter months. The majority of the highest wind speeds measured have originated from the south and southwest directions.

2.4 STREAM FLOW CHARACTERISTICS

2.4.1 Streamgage Stations

Figure 2-2 shows locations of the U.S. Geological Service (USGS) streamgage stations currently in operation in the Upper Chehalis River Basin. Table 2-2 summarizes pertinent data for these stations. In addition to the USGS streamgage stations, the NWS maintains wire weight stage gages at the Mellen Street and Pearl Street Bridges. The gages are used by the NWS for flood forecasting and warning.

The available streamgage records for the Upper Chehalis basin can also be found in Table 2-2. Chehalis River near Grand Mound, Newaukum River near Chehalis, and Chehalis River near Doty all have at least 55 years of record. Skookumchuck River near Vail, Skookumchuck River near Centralia, Skookumchuck River below Bloody Run Creek, Skookumchuck River near Bucoda, South Fork Chehalis River at/near Boistfort, and Chehalis River at Porter all have at least 30 years of record. These gages with extended records represent each of the four main subbasins discussed in section 2. Additionally, there are seven other gages on smaller streams to help identify the flow characteristics of the smaller streams.

2.4.2 Runoff

Stream flow generated within the Chehalis River Basin originates primarily from rainfall; although, snowmelt occasionally augments runoff in the highest elevation reaches of the basin. The average annual runoff of the Chehalis River at its mouth (drainage area 2,114 square miles) and at the USGS streamgage near Grand Mound (drainage area 895 square miles), are estimated to be 6.4 million ac-ft and 2.0 million ac-ft, respectively.

Flows in the rivers and creeks of the Chehalis River Basin show seasonal variation characterized by sharp rises of relatively short duration from October to March, corresponding to the period of heaviest rainfall. After March, the flows tend to gradually decrease to a relatively stable base flow, which is maintained from July into October.

Major flooding occurs during the winter season, usually from November through February, as the result of heavy rainfall occasionally augmented by snowmelt. Flooding may be either widespread throughout the Chehalis River Basin or localized in subbasins. Some storms may cover the entire basin and cause widespread flooding. Other storms may center over the Willapa Hills and cause flooding of the upper Chehalis River or center over the Black Hills and Cascade Foothills and result in flooding of the Skookumchuck and Newaukum Rivers.

Table 2-2: USGS Streamgage Information

Station Name	Station ID	Drainage Area (sq. mi.)	River Mile	Record Period
Chehalis River near Doty	12020000	113	101.8	1939-Present
Elk Creek near Doty	12020500	46.7	2.5	1942-1970
S.F. Chehalis River near Boistfort	12020900	44.9	8.0	1965-1980
S.F. Chehalis River at Boistfort	12021000	48	6.0	1942-1965
Chehalis River near Chehalis	12023500	434	77.5	1929-1931
M.F. Newaukum River near Onalaska	12024000	42.4	8.0	1944-1971
N.F. Newaukum River near Forest	12024500	31.5	6.5	1960-1966
Newaukum River near Chehalis	12025000	155	4.1	1929-1931 1942-Present
Salzer Creek near Centralia	12025300	12.6	3.9	1968-1971
Skookumchuck River near Vail	12025700	40	28.8	1967-Present
Skookumchuck River near Centralia	12026000	61.7	21.0	1929-1969
Skookumchuck River below Bloody Run Creek	12026150	65.9	20.7	1969-Present
Skookumchuck River near Bucoda	12026400	112	6.4	1967-Present
Lincoln Creek near Rochester	12027000	19.3	9.0	1942-1950
Chehalis River near Grand Mound	12027500	895	59.9	1928-Present
Chehalis River at Porter	12031000	1,294	33.3	1952-Present

Source: U.S. Geological Survey

2.4.3 Historical Floods

General

Precipitation totals at Centralia (Centralia 1W) for the 10 largest 1-day, 2-day, and 3-day storms of record are presented in Table 2-3. In comparison, the estimated 100-year 24-hour rainfall from the NOAA Atlas 2 varies in the basin from 4 inches in the Centralia area, to 8 inches in the higher elevation areas of the upper basin, and 12 to 13 inches in the headwaters of the Wynoochee drainage.

Table 2-3: Precipitation Totals Ranked for 10 Largest Storms at Centralia 1W

One-Day Storm		Two-Day Storm		Three-Day Storm	
Month & Year	Total Precip. (in.)	Month & Year	Total Precip. (in.)	Month & Year	Total Precip. (in.)
Jan. 1990	4.13	Nov. 1986	6.09	Nov. 1986	6.49
Nov. 1990	3.96	Dec. 1933	5.10	Feb. 1996	6.40
Dec. 1933	3.95	Feb. 1996	5.02	Jan. 1990	5.87
Nov. 1986	3.22	Jan. 1990	4.96	Dec. 1933	5.49
Oct. 1942	3.22	Nov. 1990	4.82	Dec. 1937	5.41
Feb. 1996	3.34	Nov. 1932	4.02	Nov. 1990	5.25
Feb. 1951	3.15	Feb. 1951	3.84	Nov. 1932	4.47
Nov. 1932	3.07	Oct. 1942	3.59	Feb. 1951	4.22
Dec. 1937	2.10	Dec. 1937	3.58	Oct. 1942	4.20
Jan. 1972	1.95	Jan. 1972	3.13	Jan. 1972	3.64

Source: USACE, 1997b

The greatest flood discharge on the Chehalis River in the Centralia-Chehalis area during the last 70 years occurred in February 1996. Table 2-4 summarizes the largest floods of record in the basin.

Table 2-4: Ten Largest Floods on the Chehalis, Skookumchuck, and Newaukum Rivers (Since 1971)

Gage	Chehalis River near Grand Mound			Skookumchuck River near Bucoda			Newaukum River near Chehalis		
Year	Stage (ft.)	Disch. (cfs)	Rank	Stage (ft.)	Disch. (cfs)	Rank	Stage (ft.)	Disch. (cfs)	Rank
Feb. ‘96	20.04	74,900	1	17.87	9,370	1	13.34	13,800	1
Apr. ‘91	17.66	42,800	7	16.82	7,860	5	12.07	9,210	7
Nov. ‘90	18.12	48,000	5	17.23	8,400	3	12.73	10,300	4
Jan. ‘90	19.34	68,700	2	17.33	8,540	2	12.75	10,400	3
Nov. ‘86	18.41	51,600	3	15.01	5,770	10	12.76	10,700	2
Dec. ‘77	16.79	36,500	10	16.18	7,170	6	12.49	10,300	5
Dec. ‘75	17.73	44,800	6	15.42	6,110	8	10.85	8,020	10
Jan. ‘74	16.88	37,400	9	15.30	5,950	9	11.17	8,440	8
Jan. ‘72	18.21	49,200	4	16.82	8,190	4	12.12	9,770	6
Jan. ‘71	17.29	40,800	8	15.82	6,630	7	11.99	8,390	9

Source: USACE, 1997b

Brief descriptions of the three most recent, largest floods in the Centralia-Chehalis area (the January 1990, November 1990, and February 1996 floods) are provided below. Descriptions for the two 1990 events came from USGS Open File Reports (Hubbard, 1991,1994), and the description for the 1996 event came from the USACE After Action Report (USACE, 1996a).

January 1990 Flood

The January 1990 flood was primarily the result of a series of back-to-back storms accompanied by heavy rainfall over the eight-day period of January 3-10. The heaviest rainfall occurred on the seventh day of the storm, January 9, causing extreme flooding because the rain fell on soils that were saturated from the preceding rainstorms.

The complex storm system included high winds and strong surges of precipitation. The Centralia climatological station recorded 8 inches of rain during the eight-day period. This eight day total precipitation represents 19 percent of the total average yearly precipitation recorded at the station. The most intense precipitation in the basin occurred near the headwaters of the Skookumchuck and Newaukum Rivers.

The surges in precipitation resulted in more than one flood peak in many of the rivers and creeks in the basin. The streams did not return to base flow between storm surges. The early precipitation saturated soils in the basin and added greatly to runoff potential when the heaviest rains arrived on January 9. Peaks of record, up to this event, were recorded at the following gaging stations: Chehalis River near Doty, Chehalis River near Grand Mound, and Chehalis River at Porter. These flood peaks were estimated at the time to be the 100-year flood.

November 1990 Flood

Above average precipitation in October and early November resulted in saturated soils that contributed to flooding potential when the major storm arrived during the period of November 21-25. Between the occurrences of a smaller storm in early November and the major storm, wet weather accompanied by cool temperatures continued and snow levels descended to about the 1,000-foot elevation. The Cascade Foothills averaged 6 inches at elevations of 1,000 to 2,000 feet, 12 inches at 2,000 to 3,000 feet, and 12 to 18 inches at 3,000 to 4,000 feet. The water content of the snow was generally 10 percent or higher. As a warm front moved through western Washington on Wednesday, November 21, snow changed to rain and temperatures rose. The warm front caused melting of snow up to elevations of 5,500 feet. Over the next three days, intense rain fell on drainages that were starting to swell from snowmelt runoff resulting in disastrous flooding. A cold front moved in from the north on November 26, 1990, lowered freezing levels, and diminished precipitation, finally ending the severe flooding.

February 1996 Flood

The February 1996 flood is the flood of record to date, on all the major drainages in the Chehalis River Basin. Several of the main ingredients for a major storm flood were in place by February 5. The ground throughout the basin was at or near saturation due to above average precipitation, during the preceding weeks. In addition, snow had recently fallen as low as 500 feet above sea level during a cold snap. Warm, moist subtropical air was also being transported from the Pacific Ocean into the Pacific Northwest and the freezing level in this subtropical air mass was well above 8,000 feet, which meant warm rains on the snow pack in the foothills.

A strong polar jet stream with core wind speeds in excess of 150 knots extended into the central and western Pacific. Storms fed upon the stream and this powerful jet sustained and strengthened the storms as they moved in from the eastern Pacific. At the same time, the atmosphere had formed a blocking pattern, causing the major troughs and ridges around the Northern Hemisphere to remain stationary. The Pacific Northwest was situated between a major trough to the west and a major ridge to the east, ideal conditions for enabling weather systems to be at maximum strength when they reached the area. The atmosphere remained in this general pattern for at least 96 hours, during which copious amounts of rain fell and large quantities of water in the existing snow pack were released into the rivers.

2.4.4 Flood Exceedance Frequency

USACE recently updated their flood frequency curves for the Chehalis River in the vicinity of Centralia (USACE, 1997b). USACE had previously published flood frequency curves for the Chehalis River for a 1980 Federal Emergency Management Agency (FEMA) report (ENSR 1994), and made revisions to the curves in 1989 (USACE 1992). Since 1980, there have been three floods of record, and several other major floods on the Chehalis River. USACE incorporated the data acquired after 1980 and recomputed the frequency curves. The recomputed frequency curves data, shown as years of recurrence interval, are listed in Table 2-5. The recomputed frequency curves are significantly higher than those published both in 1980 and 1989.

Table 2-6 shows a comparison of estimated flood recurrence intervals for the Chehalis River at Grand Mound, using frequency numbers computed by the USACE and used by FEMA on various occasions.

Table 2-5: Peak Discharge Frequency Data for Selected Locations

Location	2-Year Flow (cfs)	10-Year Flow (cfs)	25-Year Flow (cfs)	50-Year Flow (cfs)	100-Year Flow (cfs)
Chehalis near Grand Mound	25,000	43,800	55,000	64,300	74,300
Skookumchuck at Mouth	5,200	9,000	10,600	11,900	13,000
Skookumchuck at Pearl St.	4,800	8,450	10,100	11,300	12,500
Skookumchuck near Bucoda	3,900	6,900	8,300	9,300	10,400
Chehalis at Mellen St.	18,400	32,700	41,400	49,000	57,200
Chehalis above Salzer Creek	17,900	31,900	40,400	47,600	55,700
Newaukum near Chehalis	5,800	9,300	11,200	12,400	13,800

Source: USACE, 1997b

Table 2-6: Comparison of Flood Recurrence Intervals at Grand Mound

Year	Date	Maximum Flow (cfs) at Grand Mound Gage	Flood Recurrence Interval (years)		
			USACE (1998 update)	USACE (1989 update)	FEMA (1980-present)
1996	Feb. 6	73,900	100	400	600
1990	Nov. 25	48,000	15	30	35
1990	Jan. 10	68,700	70	250	400
1972	Jan. 21	49,200	15	30	35

2.5 HYDROLOGY OUTPUT REQUIREMENTS FOR ANALYSIS OF PROJECTS

In order to analyze the proposed Flood Damage Reduction alternatives, representative hydrographs were determined for a number of locations within the project study area. The hydrographs were developed for the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year storm events. The locations chosen are:

- Chehalis River at Doty
- Elk Creek at Mouth
- Chehalis River above SF Chehalis River
- South Fork Chehalis River below Stillman Creek
- SF Chehalis River below Lake Creek
- SF Chehalis River at Mouth
- Bunker Creek at Mouth
- Chehalis River above Sterns Creek
- Sterns Creek at mouth
- Newaukum River below confluence of NF and SF Newaukum Rivers
- Newaukum River at gaging station (near Chehalis)
- Newaukum River at mouth
- Salzer Creek at RM 2.9
- Salzer Creek at mouth
- Chehalis River at Mellen Street bridge
- Skookumchuck River at Vail gaging station
- Skookumchuck River at Skookumchuck Dam
- Skookumchuck River at Bloody Run gaging station
- Skookumchuck River at Bucoda Gaging Station
- N. Hanaford Creek at approx. 2.8 miles above confluence with S. Hanaford Creek
- N. Hanaford Creek above S. Hanaford Creek
- S. Hanaford Creek at mouth
- Skookumchuck River at mouth
- Lincoln Creek below Sponenbergh Creek
- Lincoln Creek at mouth
- Chehalis River at Grand Mound gaging Station
- Chehalis River below Scatter Creek
- Chehalis River above Black River
- Black River at RM 11.1

- Black River at mouth
- Chehalis River at Porter gaging station

Pacific International Engineering (P.I. Engineering; PIE) has developed a UNET hydraulic model for the Upper Chehalis River Basin (see section 3 for more information about this model). The model requires input hydrographs, which is what the USACE was tasked to provide. The following is a list of locations where hydrographs were developed for input to the UNET model:

- Chehalis River at Doty gaging station
- Elk Creek at Mouth
- Hope Creek at Mouth
- South Fork Chehalis River at RM 5.84
- Stillman Creek at Mouth
- Lake Creek at Mouth
- Bunker Creek at Mouth
- Sterns Creek at RM 4.62
- Newaukum River at Chehalis gaging station
- Dillenbaugh Creek at RM 3.45
- Salzer Creek at RM 5.21
- Coal Creek at Mouth
- China Creek at Mouth
- Hanaford Creek at RM 6.28
- Packwood Creek at Mouth
- North Hanaford Creek at Mouth
- South Hanaford Creek at Mouth
- Skookumchuck Dam Outflow
- Bloody Run Creek at Mouth
- Johnson Creek at Mouth
- Thompson Creek at Mouth
- Salmon Creek at Mouth
- South Side of Bucoda Tributary at mouth
- Connor Creek at Mouth
- Coffee Creek at Mouth
- Lincoln Creek at RM 3.9
- Scatter Creek at Mouth

- Independence Creek at Mouth
- Black River at RM 11.1
- Garrard Creek at Mouth
- Shelton Creek at Mouth
- Rock Creek at Mouth
- Porter Creek at Mouth

Some of these locations were chosen because they are either located at a stream gage location, or they are located immediately upstream of areas where flood flows backwater. The upstream areas were chosen because PIE's UNET model takes into account the backwatering in these downstream areas and developing the hydrographs in these downstream areas would be more difficult than running the upstream areas through the UNET model.

2.6 HYPOTHETICAL HYDROGRAPH DEVELOPMENT METHOD

To determine the hypothetical flood hydrographs for each of the locations, the locations were broken down into full gage record sites, partial gage record sites, minimal gage record sites and ungaged sites. The fully gaged sites were defined as sites where there are lengthy historical records (greater than 50 years), and fairly continuous records through to the present. Gaged sites that either lacked data for the recent past (1990s), or that did not exist 40 years ago were considered partial gage records. This distinction is made because there have been several large events in the last 10 years, so gage records that did not include this data would under predict the flow for the basin and gage records that did not contain a significant record preceding the last 10 years of record would over predict the flow for the basin. Minimal gage record sites are sites with small records that could be used to provide rough flow comparisons between better gaged sites, but are difficult to use for full frequency analysis. Ungaged sites are areas where there are no gage records at all for the site.

2.6.1 Flood Frequency Analysis

For the fully gaged sites, the program HEC-FFA was used to perform the flood frequency analysis. This program computes flood frequencies in accordance with the publication titled "Guidelines for Determining Flood Flow Frequencies, Bulletin 17B of the US Water Resources Council". The flood frequency is determined by fitting a Log-Pearson Type III distribution to the data, and then making an expected probability adjustment. A generalized skew of 0.3 was used for the analysis of the peak events and a generalized skew of 0 was used for the 1-day, 3-day, 7-day, and 15-day analyses. With the fully gaged sites, the adopted skew used by the program is close to the actual skew of the data due to the long length of records at these sites. The sites that are considered to be fully gaged sites are: Chehalis River near Doty, Newaukum River near Chehalis, Chehalis River near Grand Mound, and Chehalis River at Porter. The results are through water year 1998, and the 2- to 500-year recurrence flows are listed in Table 2-7.

To perform a fully representative frequency analysis for the partially gaged sites, a two-station comparison is made to a fully gaged site that has similar characteristics. The two-station comparison is performed using the methodology outlined in the USACE manual EM 1110-2-1415 (1993) titled “Hydrologic Frequency Analysis”. These characteristics include drainage basin area, basin aspect, and basin elevations. This analysis indicates that the Upper Chehalis River above Doty, the South Fork Chehalis River, the Newaukum River, and Skookumchuck River have similar characteristics. The computed degree of correlation between each of the partially and fully gaged sites can be seen in Table 2-8. The fully gaged site’s skew was used for the two-station comparison. The 2- to 500-year recurrence flows are listed in Table 2-9.

An additional partially gaged site was developed by subtracting the Skookumchuck River near Bucoda gage from the Skookumchuck near Bloody Run gage. This site is called Bucoda Local. This was done because both gages by themselves are influenced by the regulation of the Skookumchuck Dam but the difference of the two is the unregulated flow between the two gage sites. This provides a partially gaged site for the lower Skookumchuck basin with a record of 30 years and includes the recent high flow events.

Two-station comparisons were not made with the minimal gage record sites because the limited data either did not result in good correlations with the fully gaged sites and/or the record did not provide a good representation of both high and low flows.

2.6.2 Correlation to Chehalis River at Grand Mound Gaging Station

Since the Grand Mound stream gage is the closest stream gage with a full record to the main damage center in the Centralia-Chehalis area, it was decided that the model should contain flows that represent the appropriate recurrence period at Grand Mound. This means that if a sub-basin of the Upper Chehalis has a pattern of running at a different recurrence interval than the one that Grand Mound is at, that recurrence flow would be the one that was input into the model. A correlation, therefore, was developed for each of the 8 recurrence intervals. This was done by setting a recurrence interval for each year’s peak event at Grand Mound, and then setting a recurrence interval for the same event at each subbasin. A best-fit line was then set to the data and the flows for the 8 recurrence intervals were extracted from that relationship. These relationships are shown in Table 2-10. These flows are the target volumes for the different duration events when developing the hypothetical hydrographs. The fully and partially gaged sites account for roughly 2/3 of the Grand Mound 1-day peak volume and over half of the longer duration peak volumes.

2.6.3 Shaping of the Hypothetical Hydrographs

Once these target volumes were established, an hour-by-hour hypothetical hydrograph could be developed. There are five fairly recent events (1/72, 1/90, 11/90, 12/94, 2/96) in which there is hourly data for the Chehalis River near Doty, Newaukum River near Chehalis, Skookumchuck River near Vail, Chehalis River near Grand Mound, and Chehalis River at Porter gage sites. These five events represent a broad range of recurrence intervals at the Chehalis River near Grand Mound site. Table 2-11 shows the recurrence intervals of the volumes observed at the Chehalis River near Grand Mound site for these five events.

Table 2-7: Expected Flood Frequency Discharges for Peak, 1-day, 3-day, 7-day, and 15-day Events for Fully Gaged Sites

Peak Recurrence (yrs)	Chehalis River near Doty Flow (cfs)	Newaukum River near Chehalis Flow (cfs)	Chehalis River near Grand Mound Flow (cfs)	Chehalis River at Porter Flow (cfs)
2	9,690	5,900	25,100	29,400
5	14,300	7,980	35,900	40,300
10	17,800	9,330	43,900	48,000
25	23,333	11,167	56,200	59,300
50	27,000	12,300	64,200	66,500
100	31,600	13,500	74,100	75,200
200	36,700	14,800	85,000	84,500
500	44,500	16,500	101,000	97,800
1-day				
2	6,760	4,620	23,700	28,500
5	9,420	6,170	32,900	38,200
10	11,400	7,230	39,400	44,500
25	14,500	8,783	49,167	53,200
50	16,500	9,750	55,300	58,400
100	19,000	10,900	62,700	64,300
200	21,800	12,100	70,600	70,400
500	25,900	13,800	81,900	78,600
3-day				
2	4,880	3,580	20,800	26,400
5	6,400	4,740	27,900	34,300
10	7,430	5,520	32,400	38,900
25	8,900	6,620	38,533	44,900
50	9,820	7,300	42,200	48,300
100	10,900	8,090	46,300	52,100
200	12,000	8,910	50,500	55,700
500	13,600	10,100	56,000	60,300
7-day				
2	3,510	2,650	16,300	22,100
5	4,440	3,440	21,400	27,900
10	5,000	3,930	24,400	31,200
25	5,710	4,583	28,200	35,433
50	6,130	4,970	30,400	37,900
100	6,580	5,400	32,700	40,400
200	7,020	5,840	35,000	42,900
500	7,590	6,410	37,900	46,100
15-day				
2	1,370	2,020	12,300	17,100
5	1,680	2,570	15,900	21,700
10	1,860	2,910	18,000	24,500
25	2,100	3,347	20,500	27,767
50	2,427	3,600	21,900	29,700
100	3,140	3,870	23,400	31,600
200	3,450	4,140	24,800	33,500
500	3,730	4,490	26,600	35,800

Table 2-8: Two Gage Comparisons of Partial Gage Records to Full Gage Records

Partially Gaged Site Name	Record Length (yrs)	Fully Gaged Site Name Comparison	Peak Degree of Correlation (R^2)	Equivalent Record Length (yrs)	1-day Degree of Correlation (R^2)	Equivalent Record Length (yrs)	3-day Degree of Correlation (R^2)	Equivalent Record Length (yrs)	7-day Degree of Correlation (R^2)	Equivalent Record Length (yrs)	15-day Degree of Correlation (R^2)	Equivalent Record Length (yrs)
South Fork Chehalis River at/near Boistfort	25*	Chehalis River near Doty	0.77	51	0.8	46	0.83	48	0.89	51	0.89	51
Skookumchuck near Vail	30	Newaukum near Chehalis	0.8	50	0.79	48	0.78	48	0.84	54	0.91	53
Skookumchuck near Centralia	28	Newaukum near Chehalis	0.7	45	0.56	39	0.68	42	0.66	41	0.86	50
Skookumchuck-Bucoda Local**	27	Newaukum near Chehalis	0.32***	32***	0.77	46	0.78	46	0.77	46	0.78	47

* Peak record has 36 years of record
** Bucoda Local is the subtraction of the Skookumchuck near Bucoda gage from the Skookumchuck near Bloody Run gage
*** Peaks calculated by peak-1-day relationship not by actual data

Table 2-9: Expected Flood Frequency Discharges for Peak, 1-day, 3-day, 7-day, and 15-day Events for Partially Gaged Sites

Peak Recurrence (yrs)	Skookumchuck River near Vail Flow (cfs)	South Fork Chehalis at/near Boistfort Flow (cfs)	Skookumchuck River near Centralia Flow (cfs)	Skookumchuck River Bucoda Local Flow (cfs)
2	2402	3183	4040	*
5	3617	4618	5809	*
10	4460	5678	6996	*
25	5658	7297	8635	*
50	6393	8334	9628	*
100	7243	9605	10756	*
200	8111	10970	11892	*
500	9291	12937	13415	*
1-day				
2	1591	2514	2525	1324
5	2335	3502	3474	2082
10	2878	4225	4134	2664
25	3695	5320	5087	3581
50	4214	6021	5678	4178
100	4842	6876	6374	4922
200	5510	7793	7098	5733
500	6461	9111	8103	6917
3-day				
2	1261	1811	1818	972
5	1783	2278	2369	1426
10	2145	2581	2728	1749
25	2664	2994	3217	2225
50	2986	3242	3512	2523
100	3362	3523	3846	2877
200	3751	3807	4181	3248
500	4289	4187	4632	3767
7-day				
2	1022	1273	1315	688
5	1326	1583	1684	957
10	1515	1764	1912	1134
25	1760	1989	2205	1373
50	1904	2118	2377	1517
100	2062	2254	2563	1677
200	2216	2383	2745	1838
500	2415	2546	2980	2051
15-day				
2	765	909	965	489
5	963	1149	1258	678
10	1081	1288	1435	799
25	1227	1458	1646	958
50	1311	1555	1768	1052
100	1401	1655	1898	1155
200	1486	1750	2022	1256
500	1594	1868	2181	1387

* - Insufficient data to calculate

Table 2-10: Correlated Flows to Grand Mound

	Chehalis-Doty		Newaukum-Chehalis		Skookumchuck-Vail		SF Chehalis River- Boistfort		Skookumchuck-Centralia	
Peak Recurrence (yrs)	Associated Recurrence (yrs)	Chehalis-Doty Flow (cfs)	Associated Recurrence (yrs)	Newaukum-Chehalis Flow (cfs)	Associated Recurrence (yrs)	Skookumchuck-Vail Flow (cfs)	Associated Recurrence (yrs)	ehalis River- Bois Flow (cfs)	Associated Recurrence (yrs)	okumchuck-Centra Flow (cfs)
Relationship Equation*	$y=0.6537*x+1.9579$		$y=0.6722*x+1.3407$		$y=1.284*x^{1.0145}$		$y=1.0288*x^{0.9798}$		$y=1.0761*x^{0.7951}$	
Degree of Correlation (R^2)	0.89		0.83		0.82		0.72		0.62	
2	3.27	11634	2.69	6375	2.59	2642	2.03	3492	1.87	3817
5	5.23	14458	4.70	7773	6.57	3882	4.98	5032	3.87	5142
10	8.49	16746	8.06	8807	13.28	4732	9.82	6159	6.71	6216
25	18.30	20871	18.15	10365	33.63	5791	24.10	7635	13.91	7443
50	34.64	24185	34.95	11447	67.95	6698	47.53	8962	24.14	8344
100	67.33	28594	68.56	12745	137.27	7566	93.74	10316	41.88	9225
200	132.70	33268	135.78	13965	277.31	8415	184.88	11755	72.68	10140
500	328.81	40049	337.44	15579	702.54	9664	453.71	13796	150.59	11331
1-day										
Relationship Equation	$y=0.8888*x+0.501$		$y=1.119*x^{0.8172}$		$y=1.1083*x^{1.0049}$		$y=0.8717*x^{0.9805}$		$y=1.147*x^{0.836}$	
Degree of Correlation (R^2)	0.94		0.71		0.8302		0.68		0.44	
2	2.28	7007	1.97	4578	2.22	1647	1.72	2483	2.05	2540
5	4.95	9371	4.17	5741	5.59	2399	4.22	3545	4.40	3286
10	9.39	11158	7.35	6667	11.21	2946	8.33	4351	7.86	3852
25	22.72	13772	15.53	7822	28.15	3647	20.47	5466	16.91	4588
50	44.94	15994	27.37	8656	56.49	4296	40.38	6208	30.19	5092
100	89.38	18469	48.22	9664	113.36	4932	79.68	7130	53.90	5732
200	178.26	21191	84.96	10554	227.49	5597	157.23	8082	96.21	6321
500	444.90	25147	179.65	12732	571.28	6572	386.11	9404	206.97	7121
3-day										
Relationship Equation	$y=1.1145*x^{-0.0817}$		$y=0.7649*x+0.6664$		$y=1.0521*x^{1.0013}$		$y=0.7247*x^{1.2558}$		$y=1.0869*x^{0.9639}$	
Degree of Correlation (R^2)	0.95		0.94		0.87		0.80		0.61	
2	2.15	4955	2.20	3656	2.11	1280	1.73	1839	2.12	1840
5	5.49	6501	4.49	4543	5.27	1802	5.47	2519	5.13	2378
10	11.06	7537	8.32	5257	10.55	2164	13.06	2915	10.00	2728
25	27.78	8798	19.79	6264	26.41	2606	41.28	3422	24.19	3132
50	55.64	9942	38.91	6923	52.87	3007	98.57	3839	47.19	3471
100	111.37	11025	77.16	7729	105.84	3385	235.37	4206	92.04	3793
200	222.82	12122	153.65	8530	211.87	3773	562.07	4612	179.54	4112
500	557.17	13905	383.12	9636	530.32	4315	1776.33	5392	434.24	4533
7-day										
Relationship Equation	$y=0.9255*x^{1.0941}$		$y=0.955*x^{1.0362}$		$y=0.975*x^{1.1311}$		$y=0.8301*x^{1.0638}$		$y=1.0873*x^{1.0251}$	
Degree of Correlation (R^2)	0.802		0.82		0.82		0.7728		0.69	
2	1.98	3485	1.96	2639	2.14	1036	1.74	1290	2.21	1341
5	5.38	4483	5.06	3446	6.02	1364	4.6	1684	5.66	1714
10	11.49	5075	10.38	3947	13.19	1570	9.61	1911	11.52	1943
25	31.32	5738	26.83	4522	37.17	1812	25.48	2141	29.47	2200
50	66.87	6282	55.01	5013	81.42	2003	53.27	2323	59.97	2414
100	142.75	6768	112.82	5456	178.32	2182	111.36	2478	122.05	2603
200	304.74	7219	231.38	5900	390.57	2343	232.79	2622	248.39	2783
500	830.46	8218	597.97	6596	1101.06	2595	617.01	2811	635.42	3027
15-day										
Relationship Equation	$y=1.012*x^{1.0031}$		$y=0.9219*x^{1.0576}$		$y=1.1169*x^{0.9478}$				$y=1.0417*x^{1.0542}$	
Degree of Correlation (R^2)	0.7622		0.84		0.85		0.84		0.67	
2	2.03	2595	1.92	1970	2.15	775	1.84	945	2.16	981
5	5.09	3145	5.06	2574	5.13	966	3.88	1157	5.68	1282
10	10.19	3455	10.53	2926	9.90	1078	6.82	1310	11.80	1462
25	25.55	3789	27.74	3318	23.60	1200	14.38	1465	31.01	1652
50	51.22	4056	57.75	3642	45.53	1293	25.28	1568	64.39	1805
100	102.66	4286	120.19	3925	87.82	1379	44.44	1669	133.70	1940
200	205.75	4495	250.18	4199	169.41	1460	78.13	1760	277.64	2063
500	515.84	4774	659.35	4676	403.74	1559	164.69	1875	729.45	2234
Method										

* y represents the gage site recurrence interval and x represents the Grand Mound recurrence interval

** - Insufficient data to calculate

*** - Does not include Skookumchuck - Bucoda Local or Skookumchuck - Vail because locations are not used directly

Table 2-11: Recurrence Intervals in Years of Flow Volumes for Chehalis near Grand Mound Gage

	12/94	11/90	1/72	1/90	2/96
Peak	5.0	13.3	14.7	64.7	103.8
1-day	5.5	14.9	20.1	75.8	134.4
3-day	4.1	7.4	18.7	32.9	104.9
7-day	3.3	3.1	11.5	12.1	29.0
15-day	6.5	3.5	7.7	4.2	6.0

The hypothetical hydrographs were shaped to match the shape of the observed event of the same recurrence at the gage site (i.e., 5-year hypothetical to 12/94 observed event). For the recurrences that do not have a matching observed event, the next closest event is chosen to shape from. This shape was smoothed to represent a more typical average condition. The flow volumes from early hydrograph humps due to an initial surge of runoff from impervious surfaces were accounted for in the smoother upward rising limb. These hydrographs are then adjusted to ensure they match the needed volumes for all of the time intervals (peak, 1-day, 3-day, 7-day, 15-day). Priorities were set to ensure that the peak and 1-day volumes are most accurate (+/- 1 percent), with the greater volume discrepancies being found in the longer durations (3-day is +/- 5 percent, and the 7- and 15-day are +/- 10 percent).

Base flow for each of the gaged sites was determined by examining the days surrounding the yearly peak in the gage records and selecting a base flow before the start of each of these events. The average of each of these peak event base flows is the base flow that was used for all of the hypothetical hydrographs for that gage location.

2.6.4 Development of Hydrographs for Minimally Gaged and Ungaged Sites

The sites where the flow records are not substantial enough for frequency analysis were sorted into basins with similar characteristics. The characteristics used were: aspect of the basin, drainage area, stream discharge per square mile of drainage area, and proximity to the mainstem Chehalis River. The knowledge that certain basins correlated well with others in the two-station analysis was used to further categorize the minimally gaged and ungaged sites. Once the sites were categorized, the minimal gage records were used to see if the observed flows match the flows derived from the categorization.

An analysis of discharge per square mile at each gage site was done to find relationships that could be used to scale the gaged hypothetical hydrographs to make ungaged hypothetical hydrographs. A ratio of discharge per square mile of basins whose drainages are close to the mainstem Chehalis (Elk Creek, Salzer Creek, Bucoda Local, Newaukum Local, Porter Creek, Rock Creek) to the upper basins which draw from basin areas that are further removed from the mainstem (Chehalis River near Doty, South Fork Newaukum River, Skookumchuck near Vail, Newaukum River near Chehalis, Skookumchuck River near Centralia) shows that these lower drainages have less runoff (see Table 2-12).

Table 2-12: Ratios of 1-day Discharge per Square Mile from Lower Basins to Upper Basins

Lower Basin to Upper Basin	Ratio of Discharge per Square Mile	Standard Deviation of Ratio	Years of Concurrent Record
Elk Creek/Chehalis River near Doty	0.44	0.11	5
Salzer Creek/Newaukum River near Chehalis	0.73	0.16	3
Bucoda Local/Skookumchuck River near Vail	0.73	0.22	29
Newaukum Local*/South Fork Newaukum River near Onalaska	0.72	0.16	18
Porter Creek/Skookumchuck near Centralia	0.75	0.11	4
Rock Creek/Skookumchuck near Centralia**	0.73	0.19	25
Black River/Skookumchuck near Centralia	0.39	0.06	6

* Newaukum Local was calculated by subtracting the South Fork Newaukum River near Onalaska gage from the Newaukum River near Chehalis record.
** Rock Creek/Skookumchuck near Centralia comparison is for peak flows because 1-day data is not available for Rock Creek.

These ratios were used to scale all of the ungaged basins that have drainage areas close to the mainstem Chehalis. The scaling factors are shown in Table 2-13.

Table 2-13: Flow Determination for Tributaries in Close Proximity to the Mainstem Chehalis River

Tributary Location	Ratio of Upper Basin Flows	Upper Basin Gage Used
Upper Chehalis River above South Fork Chehalis River	0.5	Chehalis River near Doty
South Fork Chehalis River down to Newaukum River	0.5	South Fork Chehalis at Boistfort
Newaukum River down to Skookumchuck River	0.7	Newaukum River near Chehalis
Skookumchuck River	1.0	Skookumchuck – Bucoda Local
Grand Mound to Porter excluding Black River	0.75	Skookumchuck near Centralia
Black River	0.4	Skookumchuck near Centralia

The limited gage record on Lincoln Creek shows that it has a similar discharge per square mile to both Newaukum and Bucoda Local. Additionally, Lincoln Creek and Bunker Creek have similar source locations and similar drainage areas, so hypothetical hydrographs for both are based off the Bucoda Local hypothetical hydrographs. When the flows for the larger events (100-, 200-, and 500-year) are routed downstream, the flow at Grand Mound is too high using these ratios. The only actual event that can provide a glimpse to how these ratios may differ in extreme events is the February 1996 event. The only discharge per square mile ratio from lower basins to upper basin that exists for that year is Bucoda Local to Skookumchuck near Vail, which has a ratio of 0.63. This is a tenth smaller than the average for the period of record. For these large events, a ratio of 0.4 and 0.6 was used for the Chehalis River near Doty/South Fork Chehalis River and Newaukum River areas.

2.6.5 Flood Timing

There are hourly records for five large events (1/72, 1/90, 11/90, 12/94, 2/96) at the Chehalis River near Doty, Newaukum River near Chehalis, Skookumchuck River near Vail, and Chehalis River near Grand Mound gage sites. As Table 2-11 shows, these events represent a good range of recurrence intervals. To ensure that the flows matched up correctly downstream, the timing was calculated based on the time of the gage peak in relation to the peak at the Chehalis River at Grand Mound gage site (see Table 2-14). A relation was made between the recurrence interval and the time to Grand Mound peak for these gaged sites. The December 1994 timing is an outlier at most sites so it was omitted in most of the relationships. Often the relationship broke down when evaluating the timing above a 100-year event, so a more reasonable timing was selected for those events.

P.I. Engineering set up HEC-1 models for each of the five events at all of the locations that are not represented by these gages. The timing of the HEC-1 runs for each of the basins was broken down into the same groupings (Chehalis River near Doty/South Fork Chehalis River, Newaukum River, and Skookumchuck River) as was done for the flow. An average of the timing for each of the subbasins was used to develop the recurrence versus time before Grand Mound peak relationship. The timing for all of the locations can be seen in Table 2-15.

2.6.6 Regulation of Skookumchuck Flows

The recurrence flows for Skookumchuck at Centralia represent the inflows to Skookumchuck Dam. To appropriately mimic existing conditions, this flow was routed through the dam to obtain a regulated outflow. This was done adapting a HEC-5 model that was developed in 1990, by Matt Johannson, for reservoir simulation of power loss. The reservoir elevation was assumed to start at the existing spillway crest height of 477 feet, as it usually is for most large events.

Table 2-14: Observed Flood Timing

Event Date/ Time to Peak (hrs)	Grand Mound Recurrence Interval (yrs)	Doty	Newaukum	Vail	Grand Mound
Feb-96	100	2/8/1996 14:00	2/8/1996 15:00	2/8/1996 14:00	2/9/1996 8:00
Time to Grand Mound (hrs)		18	17	18	0
Jan-90	65	1/9/1990 14:00	1/9/1990 20:00	1/9/1990 15:00	1/10/1990 12:00
Time to Grand Mound (hrs)		22	16	21	0
Jan-72	15	1/20/1972 18:00	1/21/1972 3:00	1/20/1972 18:00	1/21/1972 18:00
Time to Grand Mound (hrs)		24	15	24	0
Nov-90	13	11/24/1990 16:00	11/24/1990 22:00	11/24/1990 16:00	11/25/1990 19:00
Time to Grand Mound (hrs)		27	21	27	0
Dec-94	5	12/20/1994 9:00	12/21/1994 0:00	12/20/1994 19:00	12/21/1994 14:00
Time to Grand Mound (hrs)		29	14	19	0

Table 2-15: Chehalis River Subbasin Timing for Different Recurrence Intervals

Timing for Basins

(in hours that basin peaks prior to Grand Mound)

Recurrence (in years)	2	5	10	25	50	100	200	500
Skookumchuck-Vail	26	25	25	24	22	18	17	16
Tribs	29	27	26	25	24	23	22	21
Newaukum-Chehalis	15	15	15	15	16	16	16	17
Tribs	19	19	19	20	21	24	26	27
Chehalis-Doty	26	25	25	24	22	19	19	18
Tribs	29	27	26	24	23	22	20	19

3. BASELINE FLOOD MODELING

3.1 INTRODUCTION

To evaluate the potential effects of various flood control alternatives in reducing flood stages and corresponding damages in the Centralia-Chehalis floodplain, a baseline flood model was developed. The baseline flood model represents the existing conditions of the Upper Chehalis River Basin above the Porter gage including the recent completion of the Long Road Dike Project construction in February 2001. Development of the model was based on the February 1996 flood, which represents the new 100-year base flood in the mainstem of the Chehalis River. This flood event is the largest flood of record, and provides the most recent and complete observed flood stage data, allowing extensive calibration of the model. Upon calibration for the February 1996 flood, the model was verified against three other major flood events: the January and November 1990, and the January 1972 floods. The model developed for calibration and verification against these selected historical flood events does not include the Long Road Dike Project, slightly differing from the baseline flood model.

3.2 METHODOLOGY

The floodplain and floodway in the Centralia-Chehalis area present a complex flood hydraulic problem because of flat gradients, flow reversals, overland flow exchanges between subbasins, and local ponding created by existing dikes, levees, railroad embankments, bridge abutments, and Interstate 5 (I-5) fill in the floodplain. To adequately reproduce the historical flood flow and stage hydrographs in this area, the HEC-UNET (USACE 1996) software recently developed by Dr. Robert L. Barkau for the USACE Hydrologic Engineering Center (HEC) was used to model the upper Chehalis River Basin.

UNET is a one-dimensional, unsteady flow flood routing model that can simulate flood flow in a complex network of open channels including off-channel storage and overbank storage areas, as well as the split of flow into two or more channels and the combining of flow. The channel cross-section data used in the HEC-2 (USACE 1990) models previously developed by others (steady-state backwater model) can be readily adapted to the UNET input. Other input data includes flow and stage hydrographs, overflow spillways, bridges, culverts, and levee systems. Because of its capability to include off-channel and overbank storage areas, UNET is a quasi two-dimensional model and is considered to be the best tool available for modeling the upper Chehalis River Basin floods.

A stream network diagram of the UNET model for the Upper Chehalis River Basin, above the USGS streamgage at Porter, is provided in Figure 3-1. This figure shows the locations of 23 channel routing reaches and 69 overbank storage areas. Figure 3-2 shows how the subbasins were divided, and Table 3-1 tabulates the drainage areas for all 68 subbasins used in the Upper Chehalis River Basin UNET model. These routing reaches and subbasins were configured to facilitate accurate modeling without overly burdening the effort.

The UNET model requires input of flow hydrographs from all of the drainage subbasins at various stream locations, to account for total flood flow contribution in the upper Chehalis River stream network. Among these subbasins, three are gaged and the remaining are ungaged.

For the gaged subbasins, observed flow hydrographs were used as a direct input to the UNET model. For the ungaged subbasins, flood runoff hydrographs were simulated using USACE's HEC-1 computer program (Dodson 1995).

The HEC-1 program is a single-event flood rainfall runoff model which simulates flood runoff hydrographs from storm precipitation, taking into account antecedent ground conditions, loss rates, base flow, and snowmelt. The runoff hydrograph from each Chehalis River subbasin's response to a storm was derived by application of the Clark's unit hydrograph methodology to rainfall and snowmelt excesses.

A two-step approach was used in the HEC-1 modeling of the runoff from the upper Chehalis River subbasins. First, unit hydrograph base flow and loss rate parameters were optimized to achieve a best-fit with respect to observed hydrographs for gaged subbasins. Second, these optimized parameters were used with appropriate adjustments for drainage area and hydrologic characteristics (such as the time-of-concentration) for the rainfall runoff modeling of ungaged subbasins. Other HEC-1 input data included stream gage hydrographs, storm precipitation, and various meteorological and hydrological parameters.

Both UNET and HEC-1 use a large quantity of hydrologic data, including input and output data. The HEC-DSS program (USACE 1995) was used to provide a database system that enabled both UNET and HEC-1 to conveniently store and retrieve data from a central storage in a common format. The HEC-DSS database system used in this study includes observed hourly flow and stage hydrographs, hourly rainfall data, computed hourly flow, velocity, and stage hydrographs, and computed maximum flow, velocity and stage profiles.

Four recent major floods were selected for the Chehalis River Basin HEC-1 and UNET modeling: the February 1996, January and November 1990, and January 1972 floods. These events represent a spread of flood frequency between 15- and 100-year return intervals in the mainstem of the Chehalis River (Table 2-7). Selection of these floods for the modeling was based on criteria including availability and reliability of adequate observed meteorological and flood stage data, significant flooding in the Centralia-Chehalis area, and a representative spread of flood recurrence intervals. The computation steps for both HEC-1 and UNET were chosen to be on an hourly basis considering the drainage size and the modeling accuracy.

Further discussion of the HEC-1 and UNET model development for the upper Chehalis River Basin is provided in the following subsections.

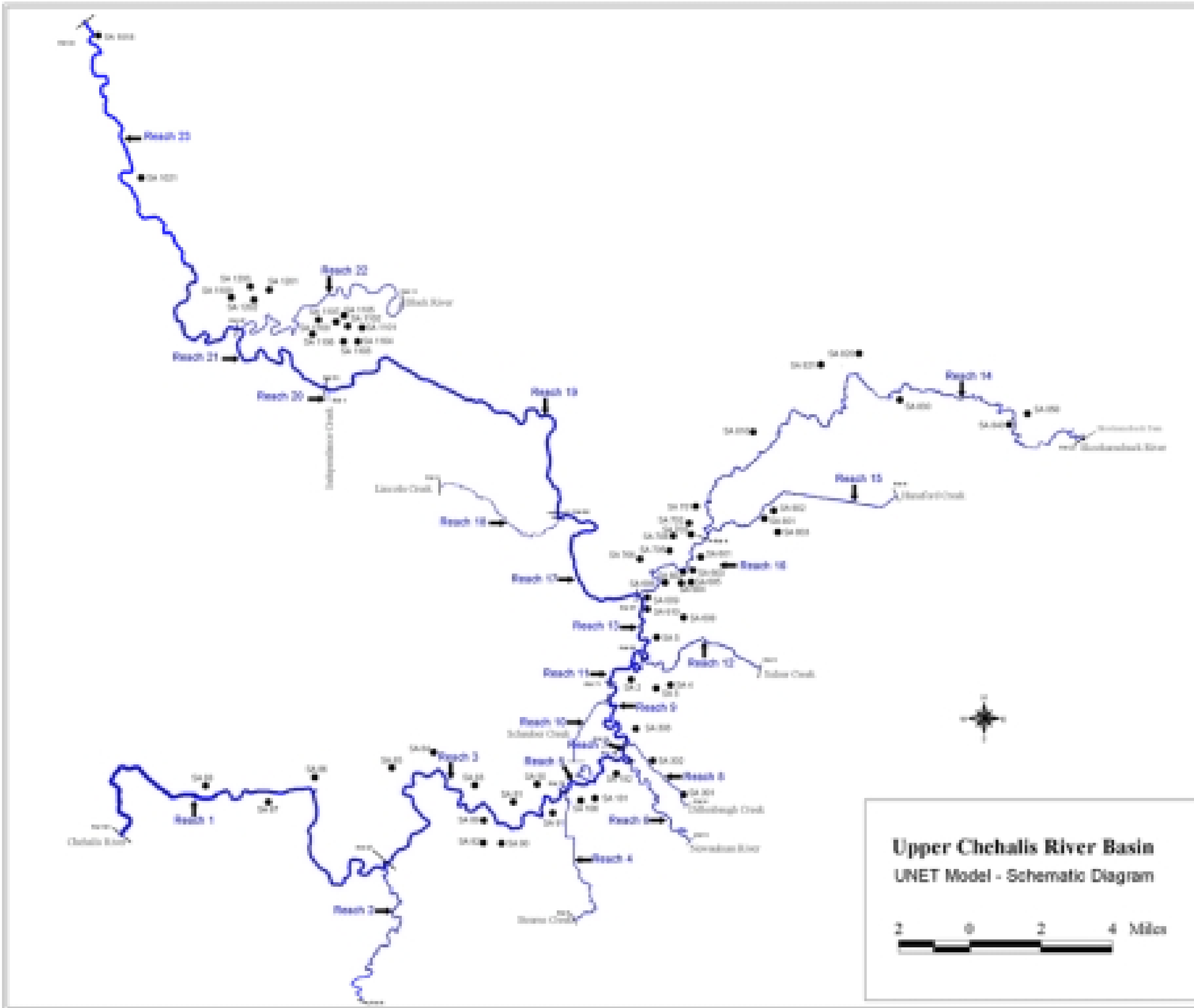


Figure 3-1: Upper Chehalis River Basin UNET Model – Schematic Diagram

Table 3-1: Upper Chehalis River Subbasin Division Summary

Symbol (see Fig. 3-2)	Subbasin Stream Name	Drainage Area (sq. mi.)	UNET Routing Reach (see Fig. 3-1)
C1	Chehalis River above Doty	113.00	1
C2	Elk Creek	46.70	1
C3	small creek d/s of Elk Creek, enters at RM 99.77	3.13	1
C4	Dunn Creek, enters at RM 98.47	5.56	1
C5	Marcusson Creek, enters at RM 97.06	2.94	1
C6	Dell Creek, enters at RM 95.16	3.63	1
C7	Garrett & Nicholson Creeks, lateral inflow to SA 86	4.00	1
C8	Hope Creek, lateral inflow to SA 87	6.30	1
C9	uniform flow area, RM 101.8-99.77	5.00	1
C10	uniform flow area, RM 99.77-94.76	13.75	1
C11	uniform flow area, RM 94.76-87.91	9.71	1
SF1	South Fork Chehalis River	52.42	2
SF2	Stillman Creek, enters at RM 5.29	45.14	2
SF3	Lake Creek, enters at RM 1.24	24.34	2
SF4	uniform flow area, RM 5.29-0.0	6.62	2
C12	Bunker Creek, lateral inflow to SA 85	34.10	3
C13	Van Orum Creek, lateral inflow to SA 84	2.16	3
C14	small creek d/s of Van Orum Creek, lateral inflow to SA 83	1.25	3
C15	small creek u/s of Stearns Creek, lateral inflow to SA 82	4.10	3
C16	Mill Creek, lateral inflow to SA 80	6.56	3
C17	uniform flow area, RM 87.90-77.96	16.98	3
ST1	Stearns Creek	23.23	4
ST2	uniform flow area, RM 4.62-0.0	11.61	4
C18	uniform flow area, RM 77.95-75.21	2.49	5
N1	Newaukum River	138.35	6
N2	uniform flow area, RM 4.11-0.1	8.08	6
C19	uniform flow area, RM 75.20-74.74	5.37	7
D1	Berwick Creek	3.51	8
D2	Dillenbaugh Creek, enters at RM 2.86	6.50	8
D3	uniform flow area, RM 3.45-0.029	2.16	8
SC1	Scheuber Creek	3.51	10
C20	uniform flow area, RM 71.48-69.23	6.43	11
SA1	Salzer Creek	12.21	12
SA2	Coal Creek	5.37	12
SA3	uniform flow area, RM 5.21-0.0	3.22	12
C21	China Creek, lateral inflow to SA 603	4.32	13
C22	Centralia area, lateral inflow to SA 609	1.00	13
S1	Skookumchuck River above dam	62.00	14
S2	Bloody Run Creek, enters at RM 21.31	3.90	14

Symbol (see Fig. 3-2)	Subbasin Stream Name	Drainage Area (sq. mi.)	UNET Routing Reach (see Fig. 3-1)
S3	Thompson Creek, lateral inflow to SA 850	7.09	14
S4	John Creek, lateral inflow to SA 840	9.77	14
S5	Salmon Creek, enters at RM 17.52	4.52	14
S6	small south side creek, lateral inflow to SA 830	3.17	14
S7	Connor Creek, later inflow to SA 810	3.29	14
S8	uniform flow area, RM 21.05-17.52	2.89	14
S9	uniform flow area, RM 17.52-11.92	10.71	14
S10	uniform flow area, RM 11.93-6.17	4.64	14
H1	Hanaford Creek	21.10	15
H2	Packwood Creek, enters at RM 5.604	7.71	15
H3	North Hanaford Creek, lateral inflow to SA 804	6.93	15
H4	South Hanaford Creek, lateral inflow to SA 803	15.00	15
H5	uniform flow area, RM 6.278-0.0	8.16	15
S11	Coffee Creek, lateral inflow to SA 704	6.21	16
S12	uniform flow area, RM 3.84-0.0	3.76	16
C23	uniform flow area, RM 66.88-61.71	10.74	17
L1	Lincoln Creek	31.84	18
L2	uniform flow area, RM 3.9-0.0	10.74	18
C24	Scatter Creek, enters at RM 54.90	41.43	19
C25	uniform flow area, RM 58.91-51.07	24.40	19
I1	Independence Creek	26.00	20
C26	uniform flow area, RM 51.06-47.42	18.30	21
B1	Black River	112.32	22
B2	uniform flow area, RM 11.11-0.0		22
C27	Garrad Creek, enters at RM 46.80	26.00	23
C28	Shelton Creek, lateral inflow to SA 1021	35.94	23
C29	Rock Creek, lateral inflow to SA 1021	24.80	23
C30	Porter Creek, lateral inflow to SA 1018	35.30	23
C31	Uniform flow area		23

3.3 SUBBASIN RAINFALL-RUNOFF MODELING

3.3.1 General

The subbasin rainfall runoff modeling through application of the HEC-1 program produced flow hydrographs required as input to the UNET flood routing model for ungaged subbasins. The HEC-1 modeling requires input of subbasin drainage geometric data, meteorological data, hydrological parameters including Clark's unit hydrograph parameters, precipitation losses, and base flow estimates. To improve the accuracy of estimating ungaged subbasin flow hydrographs, hydrological parameters were optimized using observed hydrographs at gaged subbasins. The optimized hydrological parameters were then adjusted for application to the ungaged subbasins.

3.3.2 Subbasin Definition

All subbasin geometric data, including drainage boundary, area, stream length, and slope, were delineated by utilizing the Watershed Modeling System (WMS) developed by the Engineering Graphics Laboratory of Brigham Young University (BYU) in cooperation with the USACE, Waterways Experiment Station (WES) (BYU 1996). The digital terrain modeling functions of WMS were used to create terrain models using Triangulated Irregular Networks (TINs), which automatically delineated watersheds, streams, subbasins, and all required geometric data.

3.3.3 Meteorological Input

The network of meteorological stations used in the study consisted of daily and hourly reporting climatological stations in and near the Chehalis River Basin. A total of 12 reporting precipitation stations were used. The stations and the type of data (either daily or hourly) for each station used in the HEC-1 modeling are listed in Table 2-1. Station locations are shown in Figure 2-1.

The station records available for each storm period differ due to equipment or recording problems that result in data missing for some of the stations. To help fill gaps in the hourly precipitation records, daily reporting precipitation was converted to hourly precipitation based on the nearest hourly reporting precipitation patterns. The subbasin average total and time distribution of storm precipitation were computed based on a composite weighted precipitation method. The accumulated rainfall data recorded at several hourly climatological stations for each of the four selected storm events are shown in Figure 3-3.

Figure 3-2: Upper Chehalis River Subbasin Division Map

Preliminary examination of gaged runoff for the upper Skookumchuck River Valley indicated that the adjoining meteorological stations of Centralia and Olympia did not appear to adequately account for the strong orographic rainfall component present in the upper Skookumchuck Valley. In this particular case, data from the Frances, Doty, and Cinebar stations was combined with data from the Centralia and Olympia stations in order to properly account for the orographic effects.

3.3.4 Optimization of Hydrological Parameters for Gaged Subbasins

Modeling flood runoff with the HEC-1 program requires complete definition of unit hydrograph and precipitation loss rate criteria for each subbasin within the upper Chehalis drainage area. The controlling parameters can be estimated by correlating flood runoffs with storm precipitation, using a suitable number of gaged subbasins. HEC-1 provides an optimization subroutine in which these variables are optimized by comparing the simulated flood (derived from rainfall volume) and its time distribution and drainage area, with the observed flood hydrograph. The "best" reconstitution is considered to be that which minimizes the weighted squared deviations between the observed hydrograph and a reconstituted hydrograph.

This optimization process for unit hydrograph parameters and ground loss rates was carried out for three upper Chehalis River subbasins having historical records of flood hydrographs and storm precipitation. These subbasins are the Chehalis River above Doty, Newaukum River, and Skookumchuck River above Vail.

The HEC-1 computer program derives unit hydrographs by the Clark Method. The Clark Method requires two parameters: time of concentration (*Tc*) and basin storage coefficient (*R*), both in hours. Loss rates were typically computed by the HEC exponential loss rate function, which relates loss rates to rainfall and to accumulated losses. For some of the subbasins, an initial and uniform loss rate was used. With this method, all rainfall is lost until the volume of initial loss is satisfied. After the initial loss is satisfied, rainfall is lost at a constant rate. Both the loss rate parameters and unit hydrograph parameters were determined through the process of optimization. Each of these optimizations led to a reasonably consistent, though slightly different, set of values from event to event in the same subbasin. The optimization results of unit hydrograph parameters are summarized in Table 3-2.

The base flow quantities were also estimated through the optimization process. Base flow was determined from the exponential recession limb preceding the storm runoff hydrograph. This base flow was added to the computed runoff hydrograph ordinates to obtain the total subbasin hydrograph. When the base flow is below a recession threshold flow, the program prevents it from receding faster by using the pre-flood base flow recession rate.

The reproduced and observed flow hydrographs for the selected four flood events at Doty, Newaukum, and Vail subbasins are shown in Figures 3-4 through 3-7, and indicate reasonable results of the optimization.

Table 3-2: HEC-1 Optimization Results

Subbasin/ Flood Event	Clark's Unit Hydrograph Parameters (Hours)	
	Tc	R
Chehalis River above Doty:		
Feb-96	5.21	8.88
Nov-90	5.70	9.70
Jan-90	4.33	7.37
Jan-72	5.36	9.13
Newaukum River basin:		
Feb-96	10.45	17.80
Nov-90	12.41	21.12
Jan-90	12.30	20.95
Jan-72	12.76	21.73
Skookumchuck River above Vail:		
Feb-96	4.57	6.85
Nov-90	6.26	9.39
Jan-90	4.35	6.52
Jan-72	7.36	11.04

3.3.5 Derivation of Hydrological Parameters for Ungaged Subbasins

Upon optimization of hydrological parameters for gaged subbasins, a consistent relationship between the two Clark's unit hydrograph parameters (*R* and *Tc*) was established. A constant ratio of $R/(Tc+R) = 0.63$ was used for all subbasins and flood events.

The *Tc* parameter as optimized by HEC-1 was then compared with a computed *Tc* using the Kirpich Equation (Chow 1964), resulting in an adjustment factor being applied to the computed *Tc* value for each gaged subbasin and flood event. Applying a similar adjustment *Tc* factor and the constant $R/(Tc+R)$ ratio to a *Tc* value computed by the Kirpich Equation, final values for both *Tc* and *R* were derived and used as input to the HEC-1 rainfall runoff model for each of the 65 ungaged subbasins for each of the five selected flood events.

Other hydrological parameters, including precipitation losses and base flows for the ungaged subbasins, were estimated and were part of the HEC-1 input for flow hydrograph computations.

For small, ungaged subbasins that provide uniform flow to a UNET routing reach, hydrographs were developed with the use of index subbasins. Hydrographs for the index subbasins were first developed as described above. For uniform flow area subbasins between two index stations, hydrographs were based on a ratio of the approximate proportionate distance to the two index stations. The three index stations used were Hope Creek, Coal Creek, and Gibson Creek. Hope Creek is located just downstream of Elk Creek in the upper part of the basin and has a drainage area of 6.25 square miles. Coal Creek is roughly in the middle of the basin, flows into Salzer Creek, and has a drainage area of 5.37 square miles. Gibson Creek is located at the downstream end of the model area near Porter and has a drainage area of 5.7 square miles.

3.4 FLOOD ROUTING MODELING

3.4.1 General

As shown in Figure 3-1, the UNET model for the Upper Chehalis River Basin was developed to route flow hydrographs from headwater and intermediate subdrainage areas along the floodplain routing reaches to the downstream end at the Porter gage. Modeled flow hydrographs include observed hydrographs for gaged subbasins and computed hydrographs as described in Section 3-3 for ungaged subbasins. Stage-discharge rating data at the Porter gage provided by USGS were used as downstream boundary conditions of the UNET model.

3.4.2 Development of the UNET Model

Development of the UNET model was based on expansion of USACE's 1997 UNET model, which consists of one 21-mile reach of the Chehalis River between Adna (RM 81.14) and Grand Mound (RM 59.93). The expansion in the upper part of the basin includes a 20-mile reach above Adna to the Doty stream gage (RM 101.8), a 5.8-mile reach of the South Fork Chehalis River, and a 4.6-mile reach of Stearns Creek. In the middle portion of the basin, expansion included a 4-mile reach of the Newaukum River from its mouth to the Newaukum gage (RM 4.12), a 3.5-mile reach of Dillenbaugh Creek, a 2.6-mile reach of the Scheuber drainage ditch, a 5.2-mile reach of lower Salzer Creek, a 22-mile reach of the Skookumchuck River from its mouth to the Skookumchuck Dam (RM 21.9), and a 6.3-mile reach of Hanaford Creek. In the lower portion of the basin, expansion included a 26.6-mile reach of the Chehalis River to the Porter gage (RM 33.29), a 3.9-mile reach of Lincoln Creek, an 11-mile reach of the Black River, and a 1-mile reach of Independence Creek. The developed model includes 23 routing reaches above Porter, and 69 storage areas along the routing reaches. Characteristics of these routing reaches are provided in Table 3-3, which shows stream reach river mile range, number of cross-sections used, Manning's 'n', and contributing subbasins. The model has a total of 676 cross-sections and covers approximately 138 stream miles.

Table 3-3: Characteristics of UNET Routing Reaches

UNET Reach (see Fig. 3-1)		River MileRange (RM)	No. ofCross-sections	Range of Manning's 'n'		Contributing Subbasins (see Fig. 3-2)
No.	Stream Name			Channel	Overbank	
1	Chehalis River	101.80 to 87.91	49	0.048 to 0.055	0.07 to 0.15	C1 to C11
2	S.F. Chehalis River	5.84 to 0.00	19	0.07	0.075	SF1 to SF4
3	Chehalis River	87.90 to 77.96	42	0.045 to 0.055	0.070 to 0.12	C12 to C17
4	Stearns Creek	4.62 to 0.00	17	0.06 to 0.07	0.07	ST1 and ST2
5	Chehalis River	77.95 to 75.21	23	0.05 to 0.054	0.070 to 0.10	C18
6	Newaukum River	4.11 to 0.01	31	0.06 to 0.07	0.01 to 0.12	N1 and N2
7	Chehalis River	75.20 to 74.74	7	0.065	0.15	C19
8	Dillenbaugh Creek	3.45 to 0.0	32	0.08 to 0.09	0.15 to 0.18	D1 to D3
9	Chehalis River	74.73 to 71.49	18	0.06 to 0.065	0.09 to 0.18	N/A
10	Scheuber Drainage	2.598 to 0.0	17	0.075 to 0.08	0.12	SC1
11	Chehalis River	71.48 to 69.23	12	0.06	0.09	C20
12	Salzer Creek	5.21 to 0.02	55	0.08 to 0.09	0.075 to 0.18	SA1 to SA3
13	Chehalis River	69.22 to 66.89	38	0.042 to 0.065	0.09 to 0.18	C21 and C22
14	Skookumchuck River	21.77 to 3.85	81	0.04 to 0.08	0.10 to 0.18	S1 to S10
15	Hanaford Creek	6.278 to 0.0	44	0.07 to 0.08	0.12 to 0.18	H1 to H5
16	Skookumchuck River	3.84 to 0.0	36	0.045 to 0.08	0.12 to 0.18	S11 to S12
17	Chehalis River	66.88 to 61.71	29	0.036 to 0.052	0.10 to 0.12	C23
18	Lincoln Creek	3.9 to 0.0	14	0.07	0.15	L1 and L2
19	Chehalis River	61.70 to 51.07	25	0.038 to 0.049	0.08 to 0.13	C24 and C25
20	Independence Creek	0.95 to 0.0	7	0.065	0.12	I1
21	Chehalis River	51.06 to 47.05	20	0.038 to 0.053	0.15 to 0.20	C26
22	Black River	11.11 to 0.0	28	0.045 to 0.053	0.07 to 0.15	B1 and B2
23	Chehalis River	67.00 to 59.33	32	0.032 to 0.060	0.065 to 0.130	C27 to C31

3.4.3 Geometric Data

All cross-section data above RM 41.10 on the mainstem of the Chehalis River and outside of Thurston County, was based on 2-foot contour topographic mapping developed by the Seattle District USACE from August 1999 aerial photography. Cross-section data for areas within Thurston County was based on 2-foot contour topographic mapping developed by Thurston County from 1996 aerial photography.

Much of the bridge cross-section data for the Chehalis River reach between Grand Mound and Adna, the Newaukum River reach, and the Skookumchuck River reach, were obtained from USACE. All these data were surveyed for USACE's earlier steady-state backwater analysis during the 1970s and the 1980s. The Seattle District USACE also performed additional surveying in February and March of 2001, including data for 21 bridges within the project area. Design drawings for a number of bridges were obtained from both Lewis and Thurston County. Additional bridge and culvert design data along I-5 and SR-12 were obtained from the Washington State Department of Transportation (WSDOT).

The low flow main channel portion of the recently surveyed cross-sections used in the developed UNET model comes from the following sources:

- From RM 101.80 (Doty gage) to RM 75.09 of the Chehalis River, the Seattle District USACE surveyed 45 sections in Feb/Mar 2001.
- From RM 65.90 to RM 41.89 of the Chehalis River, the Seattle District USACE surveyed 25 sections in Feb/Mar 2001.
- From RM 5.84 to RM 0.14 of the South Fork Chehalis River, the Seattle District USACE surveyed seven sections in Feb/Mar 2001.
- From RM 3.80 (downstream of the Newaukum gage) to RM 1.30 of the Newaukum River, the Seattle District USACE surveyed three sections in Feb/Mar 2001.
- From RM 21.31 to RM 4.80 of the Skookumchuck River, the Seattle District USACE surveyed 15 sections in Feb/Mar 2001.
- From RM 11.11 to RM 0.20 of the Black River, the Seattle District USACE surveyed 15 sections in Feb/Mar 2001.
- 12 new cross-sections were surveyed in 1997 by PI Engineering's survey subconsultant, Duane Hartman and Associates, Inc. (DHA) within the 3-mile "hump" reach of the Chehalis River below the Skookumchuck River mouth.
- From RM 67 to RM 76, including the lower Newaukum River to RM 1.49, DHA surveyed 35 sections in 1998.

For model cross-sections without recent channel survey data, the low flow channel was estimated based on nearby surveyed sections, as well as surveyed sections from USACE's steady-state backwater analysis from the 1970s and 1980s. Specific cross-section source data is noted in each cross-section of the final UNET model.

The upstream boundary of the model in the Newaukum River reach is the Labree Road Bridge at RM 4.11. Upstream of the bridge, high flows break out across the north bank of the Newaukum River and flow first into Berwick Creek, then into Dillenbaugh Creek. To account for this flow split, a separate reach was created to model the flows entering Dillenbaugh Creek. A preliminary UNET model, extending up the Newaukum River above the Labree Road overflow area at the right bank, was used to estimate the 100-year flood hydrograph for flows overflowing into Dillenbaugh Creek upstream of the Labree Road Bridge. Preliminary modeling indicated that for the floods examined, only the 100-year or larger floods had significant overflow into Dillenbaugh Creek. The January 1990 flood (70-year recurrence interval) was shown to have only negligible overflow.

3.4.4 UNET Model Calibration

The Upper Chehalis River Basin UNET model was initially calibrated using observed stage and flow hydrographs at the Mellen Street, Pearl Street, Bucoda, and Grand Mound gages for the February 1996 flood event. The calibration procedures primarily involved adjusting both channel and overbank Manning's 'n' values, as well as the geometry (both elevation and width) of storage areas and overflow connections. Upon satisfactory calibration of the stage and flow hydrographs, further calibration was performed using high water mark data provided by USACE, the City of Centralia, the City of Chehalis, and WSDOT. The original calibration model (referred to as the May 15, 2001 model) was submitted to USACE to be reviewed by WEST Consultants. The UNET model was modified to incorporate the review comments. The updated model is referred to as the September 20, 2001 model. The calibration results of the September 20, 2001 model are presented in Table 3-4, which shows a good match between the observed and the computed stage. Comparisons of stage and flow hydrographs at the Mellen Street, Pearl Street, Bucoda, and Grand Mound gages are shown in Figures 3-8 through 3-11.

Table 3-4: Comparison of Computed and Observed Maximal Water Surface Elevations (February 1996 Flood)

Stream	Location (River Mile)	Computed Elevation (ft)	Observed Elevation (ft)	Difference (ft)
Chehalis River	97.00	284.34	284.46	-0.12
Chehalis River	89.86	228.95	228.90	0.05
Chehalis River	81.03	195.64	195.97	-0.33
Chehalis River	76.19	182.73	182.53	0.20
Chehalis River	75.09	182.04	182.35	-0.31
Chehalis River	74.82	181.54	181.50	0.04
Chehalis River	74.02	179.61	179.98	-0.37
Chehalis River	72.88	178.65	178.56	0.09
Chehalis River	72.80	178.57	178.50	0.07
Chehalis River	67.86	175.83	176.21	-0.38
Chehalis River	67.44	174.04	174.30	-0.26
Chehalis River	66.88	173.01	173.14	-0.13
Chehalis River	66.75	172.64	172.21	0.43
Chehalis River	66.36	169.38	169.72	-0.34
Chehalis River	64.22	161.18	161.13	0.05

Stream	Location (River Mile)	Computed Elevation (ft)	Observed Elevation (ft)	Difference (ft)
Chehalis River	63.20	155.65	155.50	0.15
Chehalis River	62.01	153.01	153.33	-0.32
Chehalis River	59.88	143.63	143.55	0.08
Chehalis River	54.60	120.98	121.03	-0.05
Chehalis River	54.09	116.33	116.71	-0.38
Chehalis River	53.93	114.58	114.46	0.12
Chehalis River	53.90	114.41	114.45	-0.04
Chehalis River	53.30	111.42	111.00	0.42
Chehalis River	51.06	103.28	102.96	0.32
Chehalis River	49.95	96.16	96.32	-0.16
Chehalis River	45.25	83.86	83.81	0.05
Chehalis River	41.30	68.29	67.80	0.49
Chehalis River	33.29	48.95	48.86	0.09
Dillenbaugh Creek	1.25	183.56	183.70	-0.14
Dillenbaugh Creek	0.09	182.02	182.01	0.01
Salzer Creek	1.56	176.79	177.00	-0.21
Salzer Creek	1.28	176.78	177.00	-0.22
Salzer Creek	0.36	176.68	176.72	-0.04
Newaukum River	4.11	201.96	202.28	-0.32
Newaukum River	1.66	184.11	184.50	-0.39
Skookumchuck River	20.70	330.40	330.58	-0.18
Skookumchuck River	6.40	212.91	212.47	0.44
Skookumchuck River	3.84	197.98	198.26	-0.28
Skookumchuck River	2.42	187.36	187.29	0.07
Skookumchuck River	2.18	185.20	185.00	0.20
Skookumchuck River	2.00	184.39	184.30	0.09
Skookumchuck River	1.90	183.85	184.10	-0.25
Black River	9.09	109.30	109.60	-0.30
Black River	4.54	97.12	97.55	-0.43
Black River	3.45	94.21	94.08	0.13
Black River	2.48	92.25	92.72	-0.47

3.4.5 UNET Model Verification

The Upper Chehalis River Basin UNET model calibrated for the February 1996 flood event (September 20, 2001 model) was verified against observed stage and flow hydrographs at the Mellen Street, Pearl Street, Bucoda, and Grand Mound gages for the other three selected flood events, the November and January 1990, and January 1972 floods. During the model verification, Manning's 'n' was at times modified slightly. Slight changes in Manning's 'n' values within a reasonable range helps to account for differences between flood events due to factors such as: seasonality differences, changes in vegetative growth levels and patterns in different years and months, as well as differences in flow depths. These slight changes to Manning's 'n' were back checked by running the 1996 flood event and comparing the results to the results from the calibration model. The maximum change in flow was a 3.5 percent increase at RM 70.67 for the

Manning's 'n' values used from the January 1972 flood verification. The maximum change in stage was –1.05 feet at RM 67.44, using the Manning's 'n' values from the January 1972 flood verification.

Table 3-5 shows a comparison of the computed and observed maximum water surface elevations for the model verification run for the January 1990 flood event. No high water marks were collected for the November 1990 and January 1972 flood events. Figures 3-8 through 3-23 show a comparison of the computed and observed hydrographs at the four selected gages. The comparison shows that the UNET model produces satisfactory results in reproducing these flood stage hydrographs.

The calibrated UNET model was also run for the 2-, 5-, 10-, 25-, 50-, 100-, 200- and 500-year statistical flood hydrographs developed by USACE. The UNET results appear to produce a flow-versus-stage rating curve at Grand Mound consistent with the USGS rating curve for that gage. Figure 3-24 shows a comparison of the USGS discharge-rating curve and the UNET computed discharge-rating curve using USACE's statistical flood hydrographs.

Table 3-5: Comparison of Computed and Observed Maximal Water Surface Elevations (January 1990 Flood)

Stream	Location (River Mile)	Computed Elevation (ft)	Observed Elevation (ft)	Difference (ft)
Chehalis River	75.09	181.55	181.54	0.01
Chehalis River	74.71	180.41	180.10	0.31
Chehalis River	72.80	178.00	177.15	0.85
Chehalis River	67.44	173.64	73.50	0.14
Chehalis River	66.30	168.47	168.74	-0.27
Chehalis River	63.20	155.19	156.93	-1.74*
Chehalis River	59.89	143.04	143.00	0.04
Chehalis River	54.09	115.91	112.66	3.25**
Chehalis River	53.93	114.40	113.56	0.84
Chehalis River	51.06	103.02	103.10	-0.08
Chehalis River	50.00	96.00	95.32	0.68
Salzer Creek	0.38	175.82	174.88	0.94
Skookumchuck River	6.40	210.80	212.30	-1.50
Skookumchuck River	4.53	200.68	204.00	-3.32^
Skookumchuck River	3.42	196.00	196.90	-0.09
Skookumchuck River	2.90	191.60	191.60	0.00
Skookumchuck River	2.42	186.95	187.10	-0.15
Skookumchuck River	1.58	179.80	180.80	-1.00
Skookumchuck River	1.52	179.00	180.00	-1.0
Skookumchuck River	0.61	174.62	174.50	0.12
Skookumchuck River	0.21	172.05	172.10	-0.05
Black River	9.00	107.60	108.45	-0.85
Black River	8.41	105.70	105.88	-0.18
Black River	7.03	102.62	101.50	1.12
Black River	6.80	100.60	100.01	0.59
Black River	6.41	98.41	99.20	-0.79
Black River	4.36	95.77	95.88	-0.11

Stream	Location (River Mile)	Computed Elevation (ft)	Observed Elevation (ft)	Difference (ft)
Black River	3.45	93.48	93.08	0.40
Black River	2.49	91.44	92.17	-0.73
Black River	1.18	89.49	90.57	-1.08
SA 202	N/A	90.13	88.23	1.90
SA 103	N/A	105.42	103.10	2.32
SA 102	N/A	99.64	99.45	0.19
SA 101	N/A	106.69	108.51	-1.82

3.4.6 UNET Model Sensitivity Analyses

A sensitivity analysis on model parameters was performed to better understand the model response and calibration. All the sensitivity analyses were based on the May 15, 2001 model except the sensitivity analysis on the parameter of Manning's 'n', which was based on September 20, 2001 model.

Implicit weighting factor THETA

The implicit weighting factor THETA was changed to 0.6 from 1.0 using the upstream model (RM 101.8-RM 59.89). A value of 1.0 provides maximum stability for the model. A value of 0.6 provides maximum accuracy, however, the model may be susceptible to instabilities. Comparing the results (2-96 flood event) with the theta value of 1.0 used in the calibration model, the maximum difference in peak flow was within 2.9 percent (RM 66.47), and maximum stage within +0.25 feet (RM 68) and –0.08 feet (RM 88).

Computational time step

A computational time step of 5 minutes was used in the calibration model (May, 15 2001 model). Time-steps of 5-minutes, and 6-minutes were run with the Feb. 1996 flood event. The difference was within a range of –0.02 feet (RM 71) to +0.04 feet (RM 87.9) for maximum water surface elevation. The maximum difference in peak flow was within 0.45 percent (RM 71.38).

Distance step XMINC

Noting the large reach length between some sections in Reach 19, a sensitivity analysis on the distance step (XMINC value in field 6 of the XK record) values was first performed in Reach 19. A smaller XMINC, approximately half of the original value, was used for Reach 19. For the Feb. 1996 flood event, the maximum stage difference at RM 59.64 was less than 0.30 feet. Above RM 59.64 and below RM 57.56, there was no significant effect.

The sensitivity analysis was then expanded to cover the entire model. To analyze the sensitivity of maximum interval in miles between interpolated cross sections for the whole model, two different Xminc values, 0.07 and 0.15, were used. The results were compared with the results in which the original value of 0.10 was used. The difference was found to be local and insignificant. The peak flow difference is within +3,038 cfs(RM 63.5) and –3,734 cfs (RM 76.36), while peak stage is within +0.33 ft (RM 54.09) to –0.4 ft (RM 54.09). In the project area, the peak stage differences are significantly less. The results are shown in Figure 3-25

Initial flow condition

All inflow hydrographs were extended (constant flow) further backward in time to the beginning of February 1, 1996, which is five days before the beginning of the Feb-96 flood event. The model was rerun without the “hot start” file involved. The comparison of the results shows that there is a slight decrease in peak flow and stage. The peak flow decreases 1 percent at Grand Mound and 0.75 percent at the Mellen Street Bridge. The maximum stage decreased 0.05 ft at Grand Mound and 0.09 ft at the Mellen Street Bridge.

Manning’s ‘n’, storage volume and weir flow ‘c’ coefficients

An analysis was performed to check the sensitivity of the model to storage volumes in the Centralia-Chehalis area (RM 65.2-RM 74.02) using the calibration model. For a 50 percent increase / decrease in storage volume, the stage change for the Feb. 1996 flood event was in the range of -0.02 feet (RM 67.45) to 0.27 feet (RM 63.80). When a weir flow ‘c’ 2.9 was used instead of a value of 2.6, the stage change for the Feb. 1996 flood event was also in the range of -0.02 feet (RM 67.46) to 0.27 feet (RM 63.80).

An analysis was also run to check the sensitivity of the model to Manning’s ‘n’ values in the Centralia-Chehalis area using the September 20, 2001 model. For a 20 percent increase / decrease in Manning’s ‘n’ value, the stage change for the Feb. 1996 flood event was in the range of -1.62 ft (RM 66.36) to +1.35 ft (RM 66.36) in the Centralia-Chehalis area (RM 65.2-RM 74.02).

Changes Made to the Calibration Model

Sensitivity analyses were performed on all the review comments, but not all of the recommended changes were incorporated into the September 20, 2001 UNET model since some of the changes have only local or insignificant effects. The changes that were made to the initial May 15, 2001 model to produce the September 20, 2001 model are listed below:

1. Additional cross-sections were added for bridges at RM 100.43, RM 82.6, RM 81.0, RM 77.94 and RM 77.64 of the Chehalis River, and the bridge at RM 18.31 of the Skookumchuck River.

2. The ineffective flow area option was added to cross-sections 2 and 3 for most all of the bridges using the special bridge method of computation. The exceptions are the bridges at RM 77.94 of the Chehalis River, at RM 0.22 of the Skookumchuck River, and at RM 7.04 of the Black River.

3. The width of the effective flow areas described on the X3 records was adjusted for the bridges at RM 97.87 and RM 75.08 of the Chehalis River.

4. The X3 record describes left and right encroachment stations and elevations in fields 4 through 7. In Reach 1 at RM 97.89, the X3 record has values in fields 3 through 6. This was a mistake that has been corrected in the model.

5. The bridges at RM 18.31, RM 17.51 and RM 14.56 of the Skookumchuck River were changed from “normal bridge” method to the “special bridge” method of computation. The BT and GR cards of these bridges were also adjusted slightly according to USACE survey data of February 2001.

6. All bridges have the NC card with field 6 added.

7. The starting time in the gn.bc file was corrected to 06 Feb 1996 0500. The computation time step interval was changed from 10 minutes to 5 minutes.

8. The bridge at RM 4.685 of Salzer Creek was removed to ensure the stability of the model.

9. The bridge deck at RM 3.002 of Hanaford Creek was raised above the water to ensure the stability of the model.

10. The elevation increment in field 5 of the XK cards was changed from 3.00 to 2.75 in reach 14 and 15 to be consistent with the other reaches.

Cumulative Effects

To better understand the sensitivity of the model and the cumulative effects of all the changes, the model was modified to incorporate all the review comments. In addition to the changes made to model listed above, the following additional changes were made to the model:

1. Two new cross sections (cross-section 2 and 5) were added upstream and downstream of the BNSF Railroad Bridge at RM 9.81 of the Skookumchuck River.

2. A new cross-section was added at RM 17.80 of the Skookumchuck River, which is half way between two bridges: the bridge at RM 18.31 and the bridge at RM 17.51

3. An X3 card assigned with an ineffective flow area was added to the bridge at RM 7.04 of the Black River for the right bank.

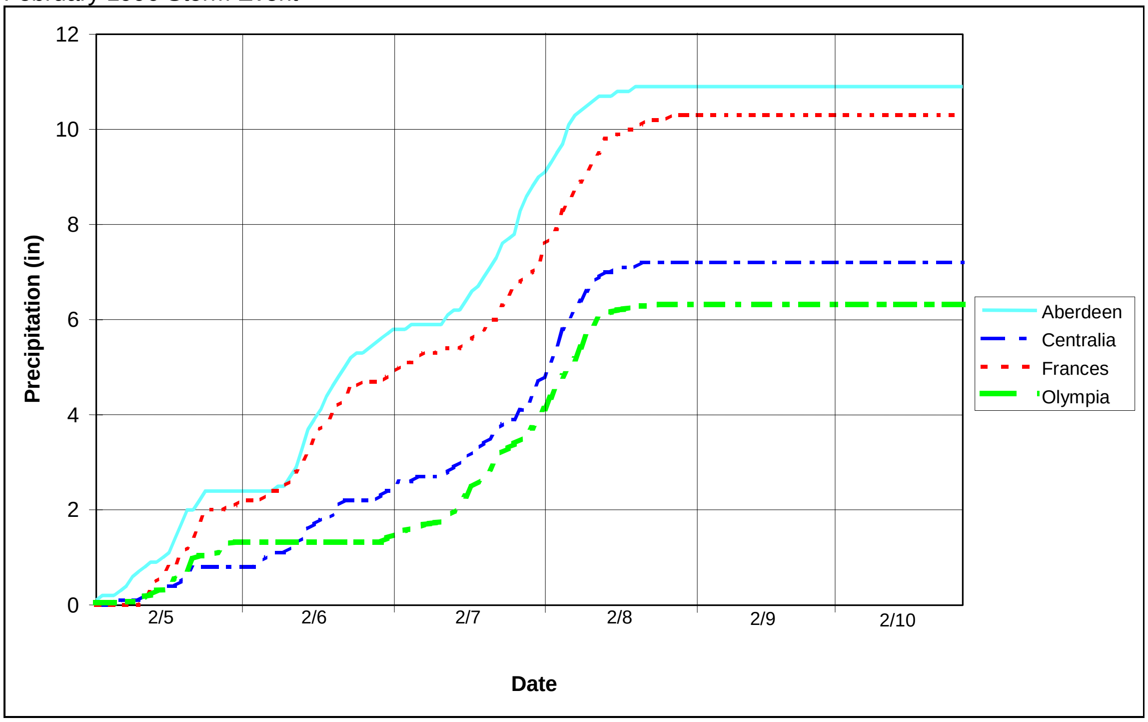
4. At bridges at RM 7.31, RM 9.81 and RM 10.85 of Skookumchuck River, the X3 cards were changed according to the "FOLLOW-UP TO BACKCHECK 1.7"(WEST Review, September 25,2001).

5. The bridge deck at RM 0.62 of Skookumchuck River was raised above the water to ensure the stability of the model.

The cumulative effects of all the changes are insignificant. Comparing with the results of May 15, 2001 model, the maximum change in stage is less than 0.5 feet at high water calibration points listed in Table 3-4. The accuracy of the computed water surface elevation is within 0.5 feet compared with observed high water marks.

Figure 3-3: Accumulated Rainfall Curves

February 1996 Storm Event



November 1990 Storm Event

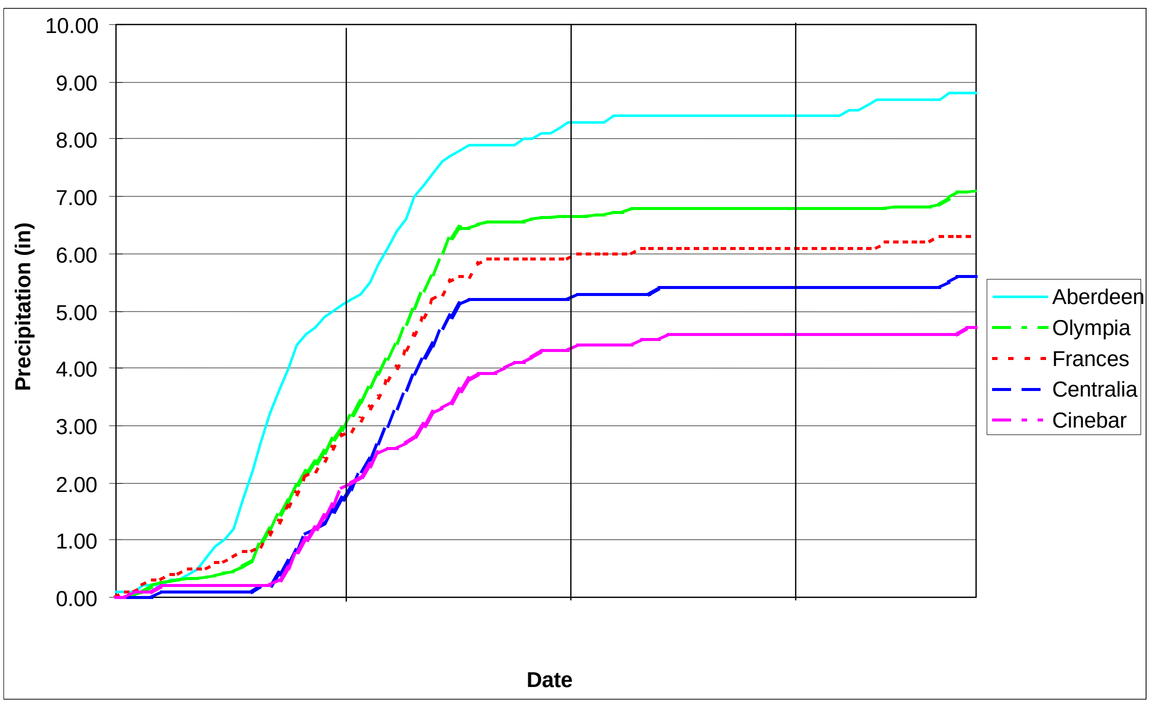
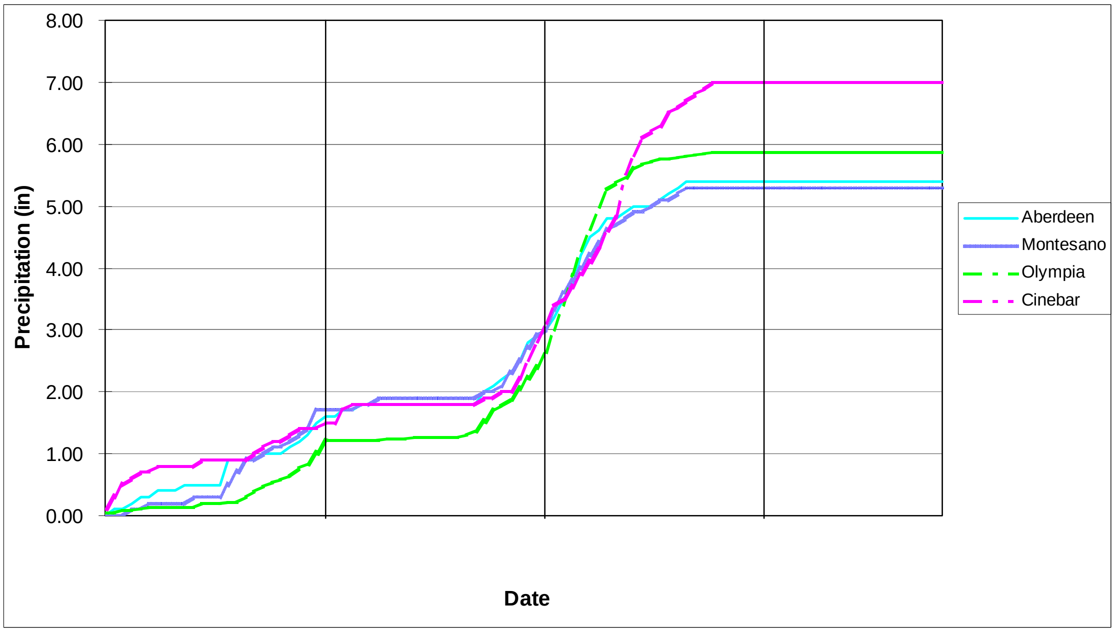


Figure 3-3:(continued)

Accumulated Rainfall Curves

January 1990 Storm Event



January 1972 Storm Event

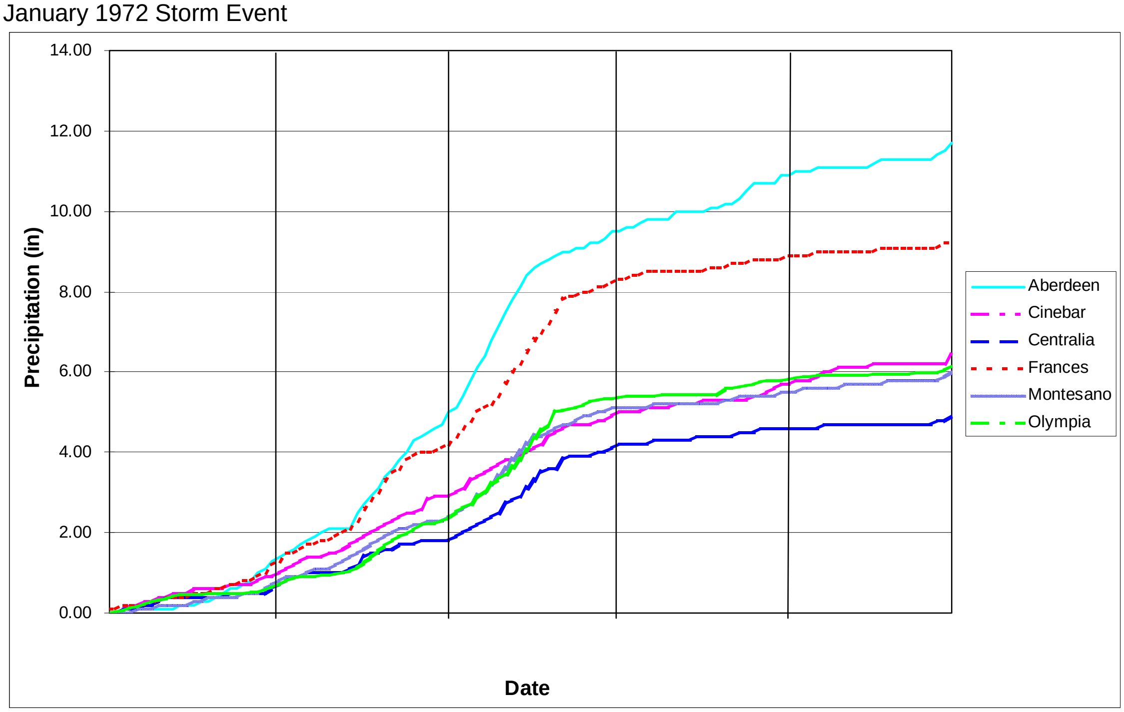
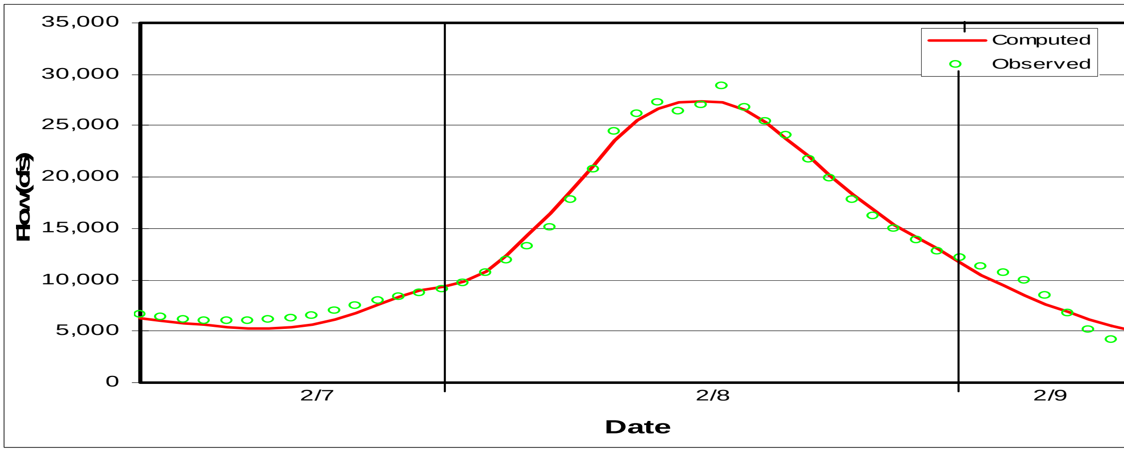
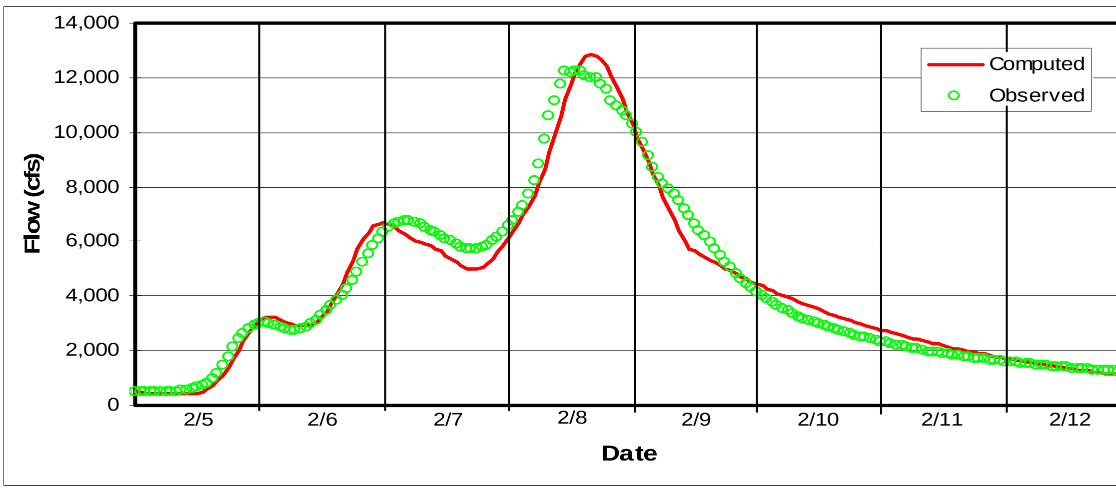


Figure 3-4: Comparison of Computed and Observed Hydrographs for the February 1996 Flood

Chehalis River near Doty



Newaukum River near Chehalis



Skookumchuck River near Vail

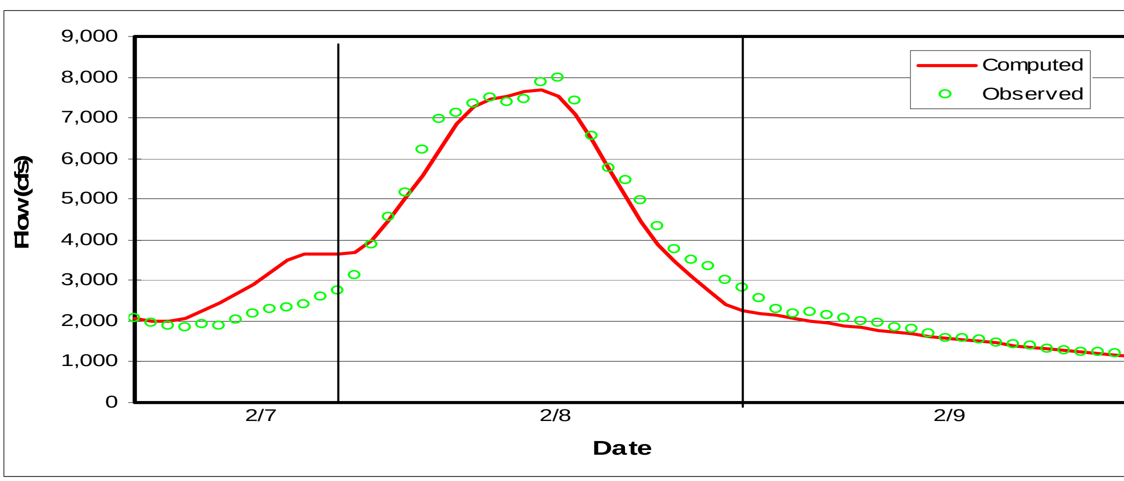
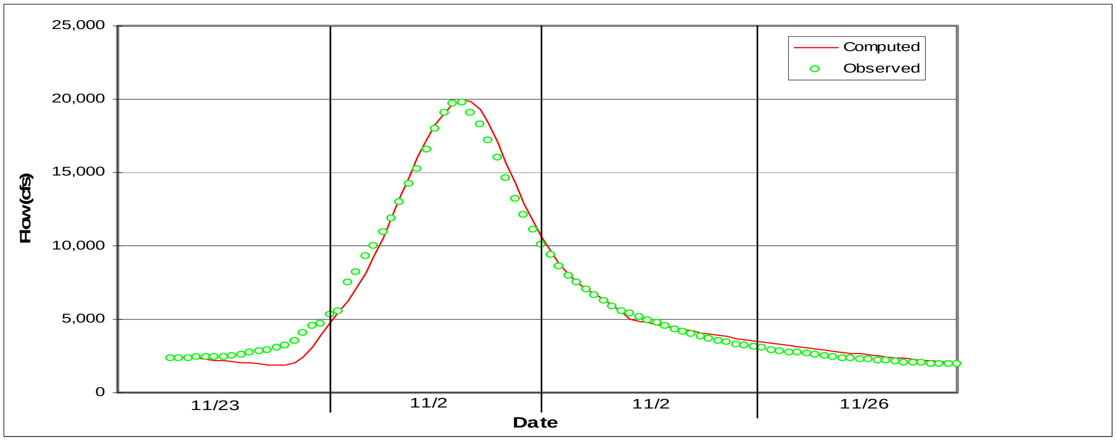
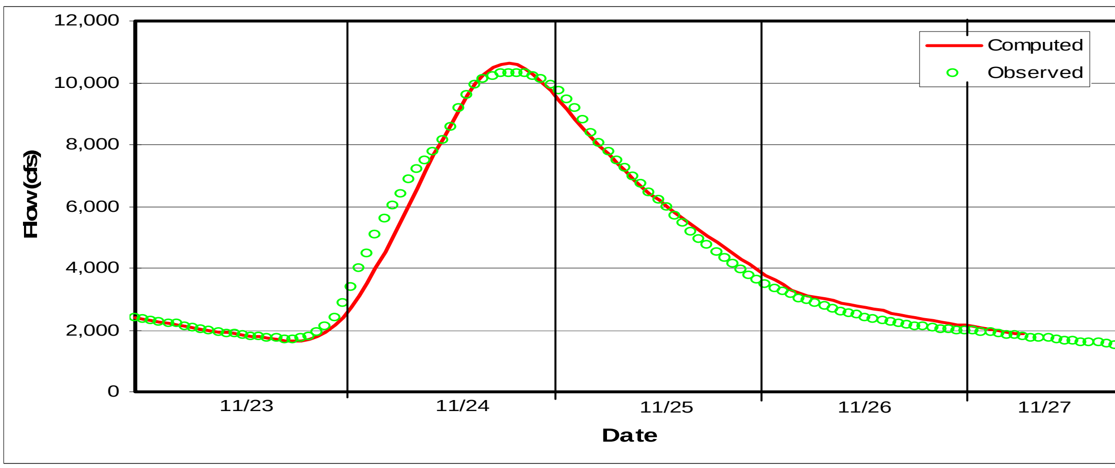


Figure 3-5: Comparison of Computed and Observed Hydrographs for the November 1990 Flood

Chehalis River near Doty



Newaukum River near Chehalis



Skookumchuck River near Vail

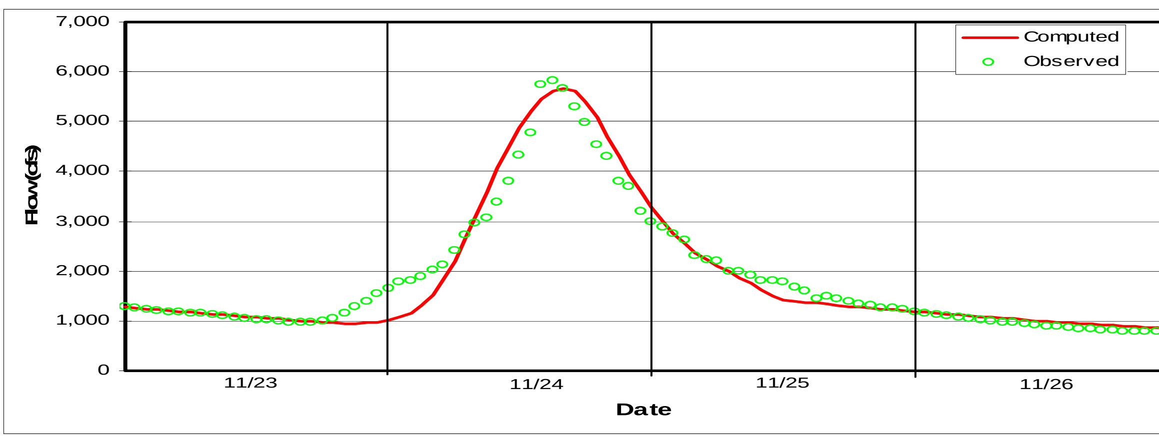
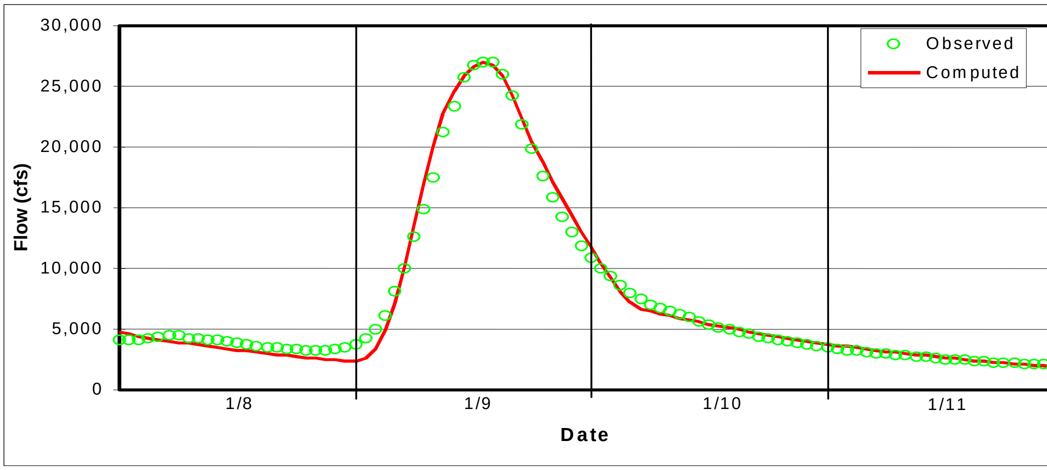
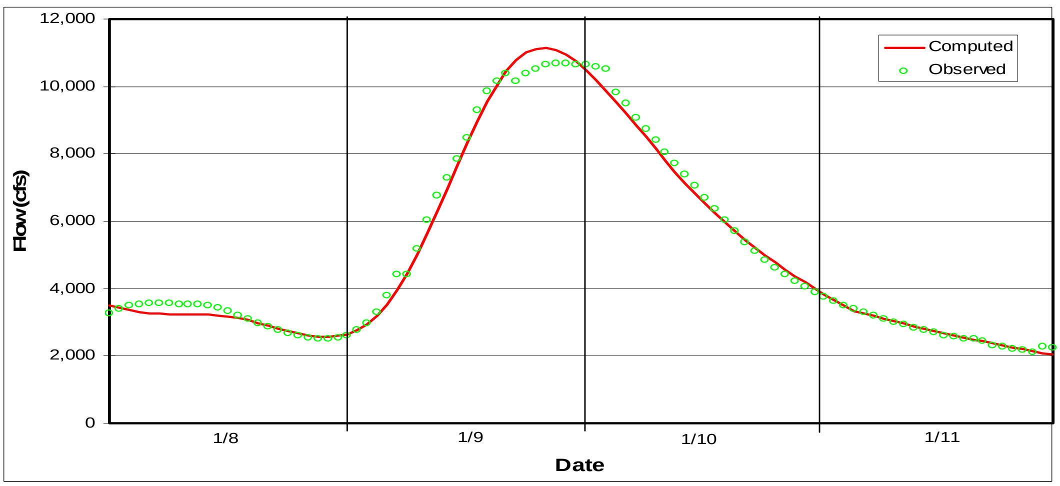


Figure 3-6: Comparison of Computed and Observed Hydrographs for the January 1990 Flood

Chehalis River near Doty



Newaukum River near Chehalis



Skookumchuck River near Vail

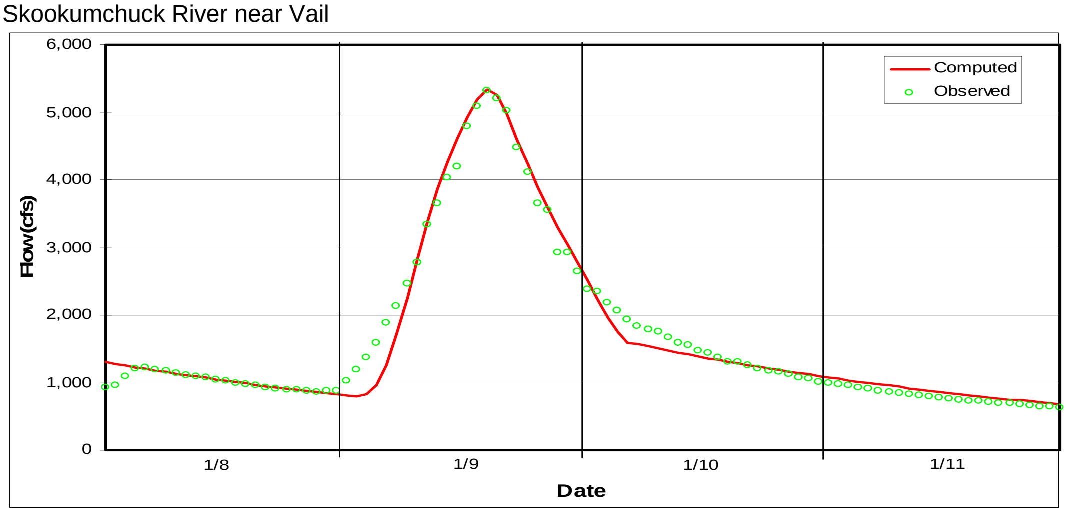
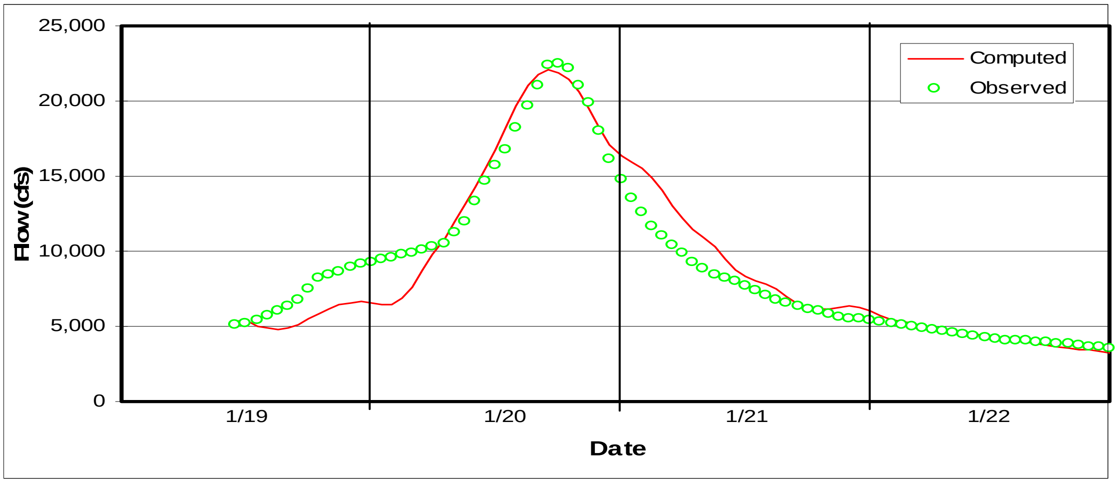
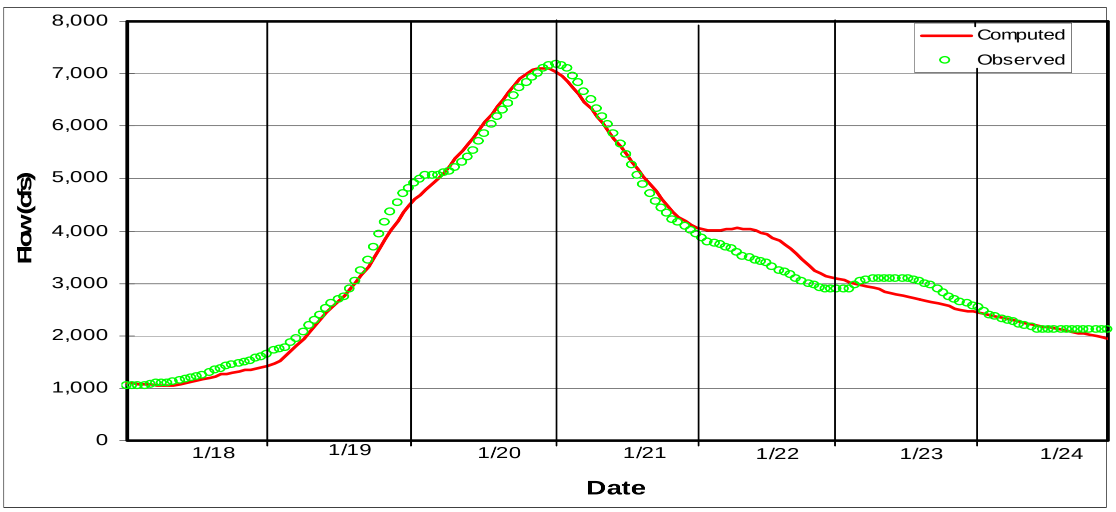


Figure 3-7: Comparison of Computed and Observed Hydrographs for the January 1972 Flood

Chehalis River near Doty



Newaukum River near Chehalis



Skookumchuck River near Vail

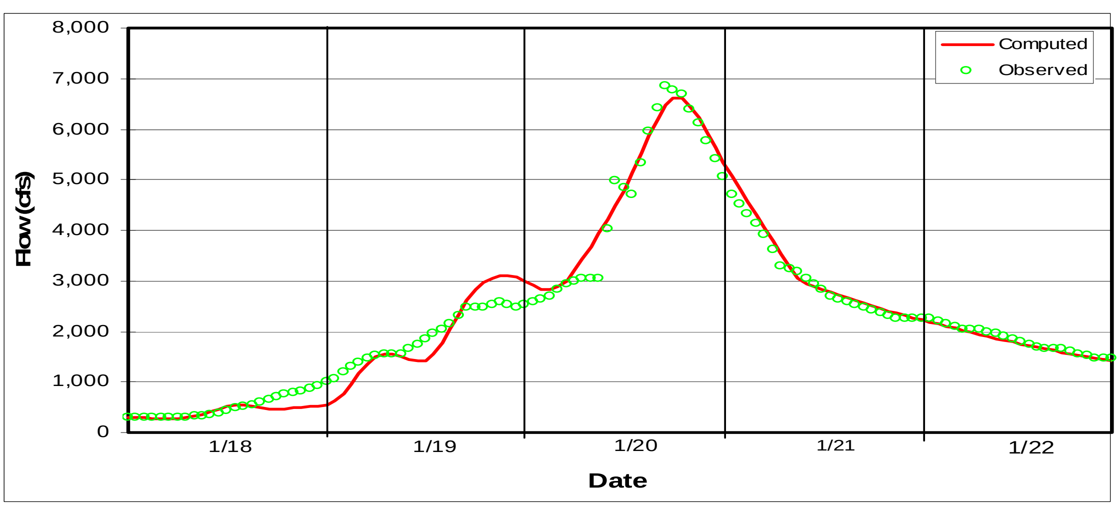
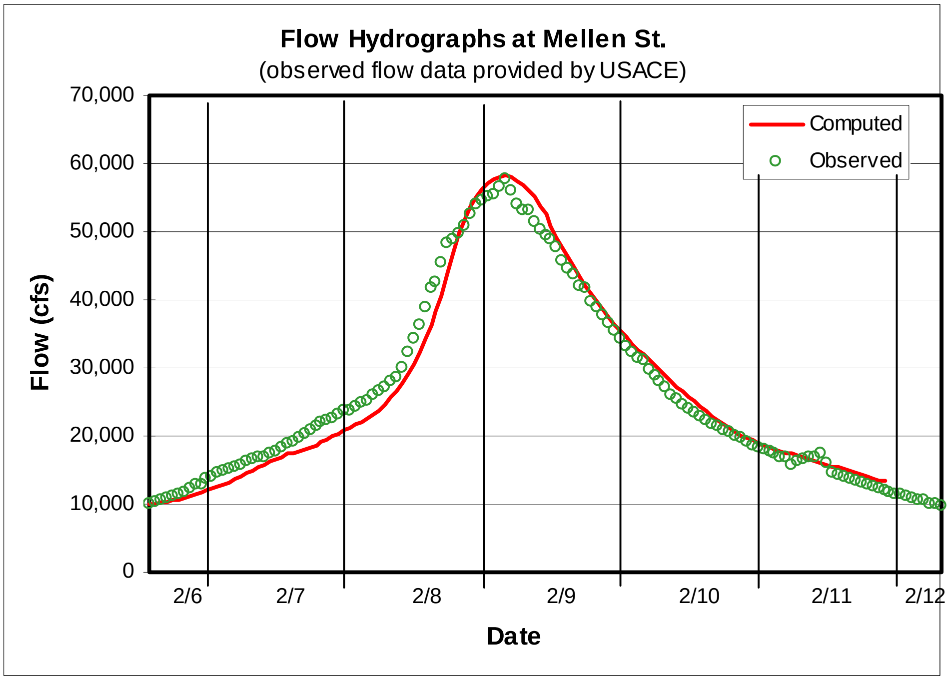


Figure 3-8: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street - February 1996 Flood



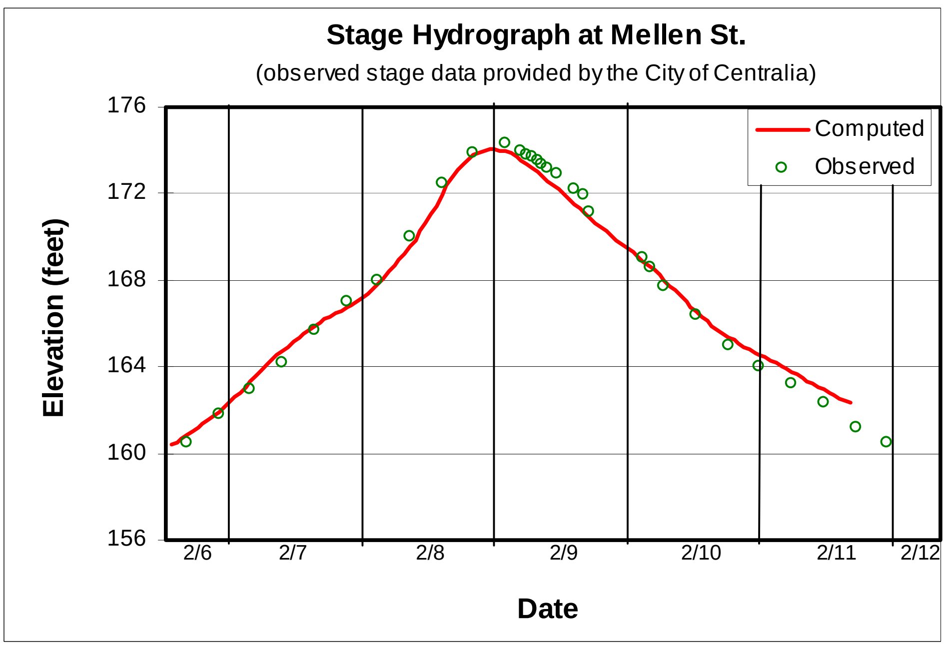
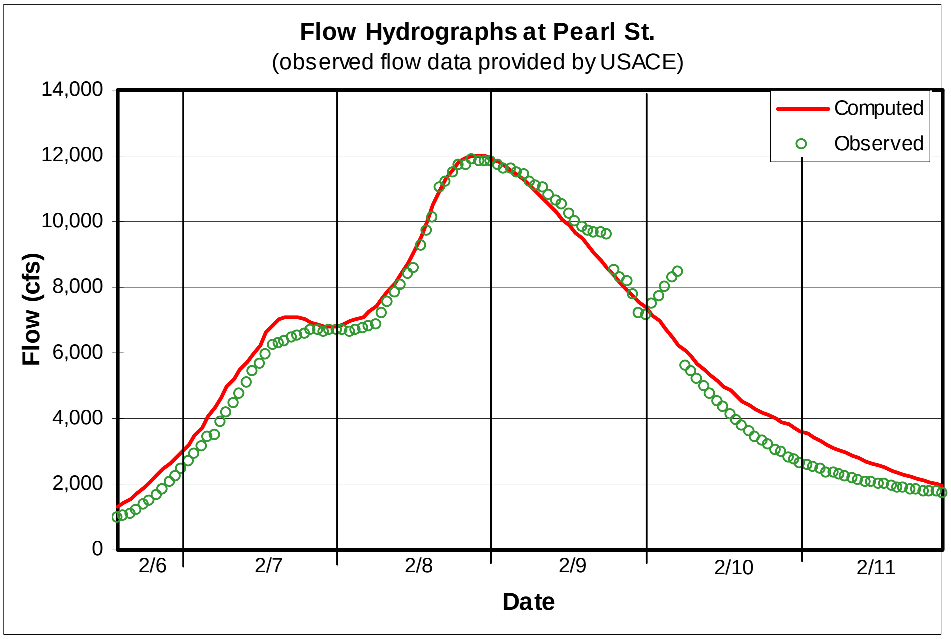


Figure 3-9: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street - February 1996 Flood



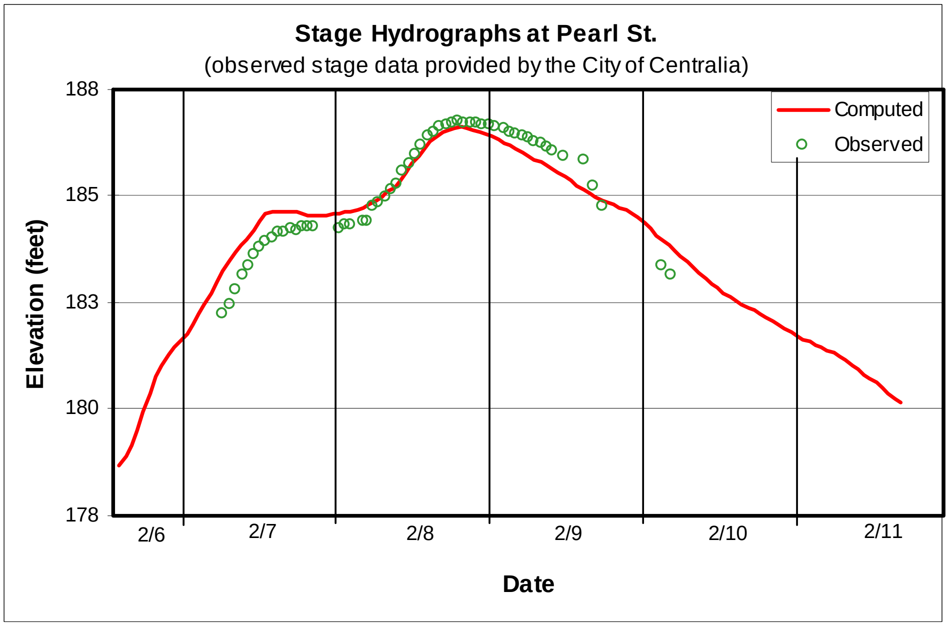
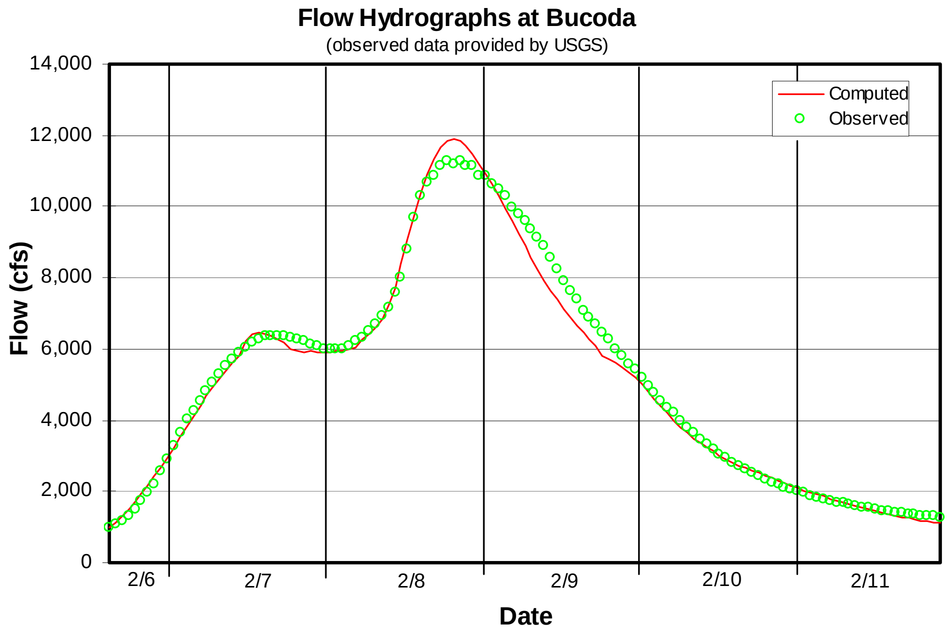


Figure 3-10: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda - February 1996 Flood



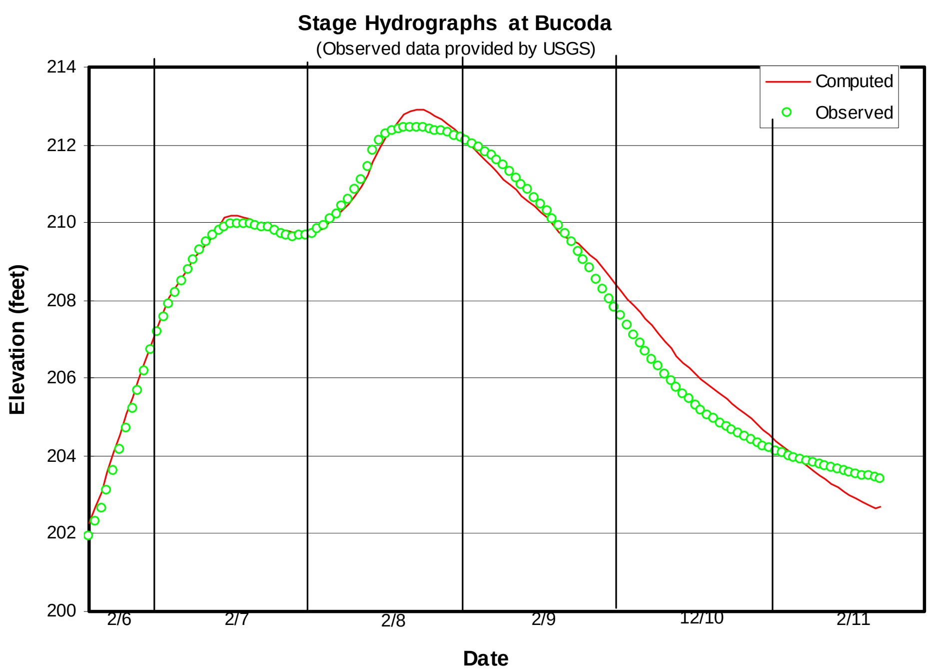
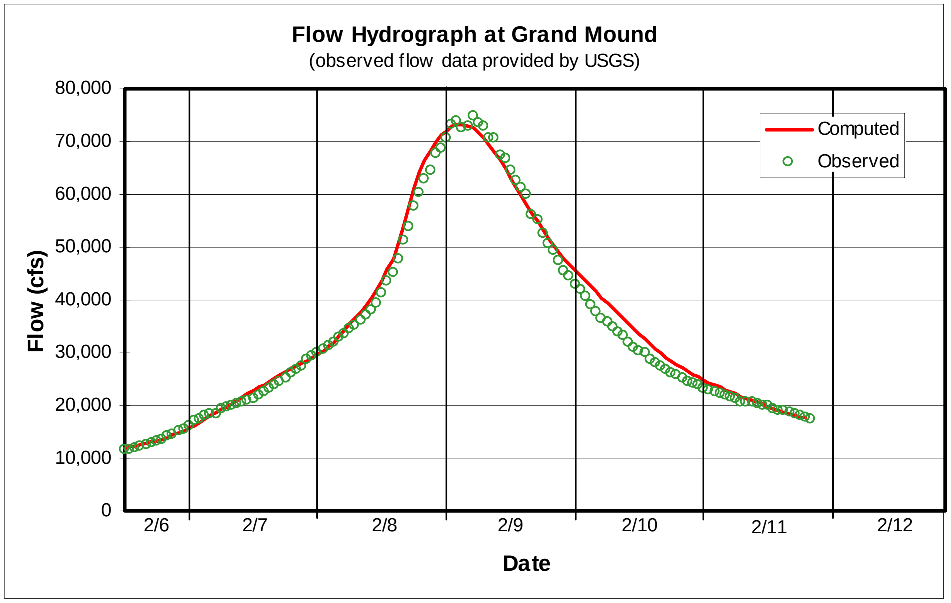


Figure 3-11: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound - February 1996 Flood



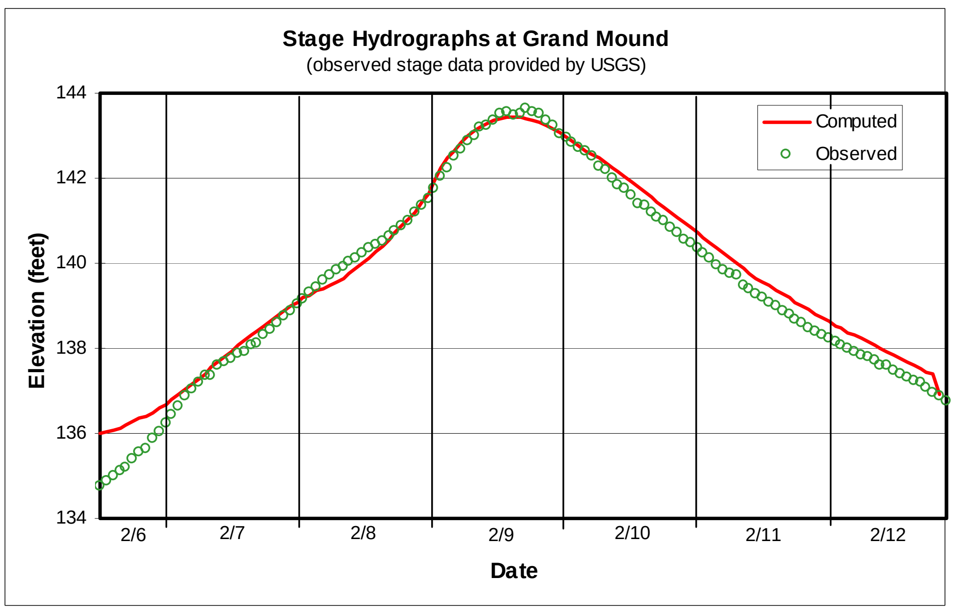


Figure 3-12: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street – November 1990 Flood

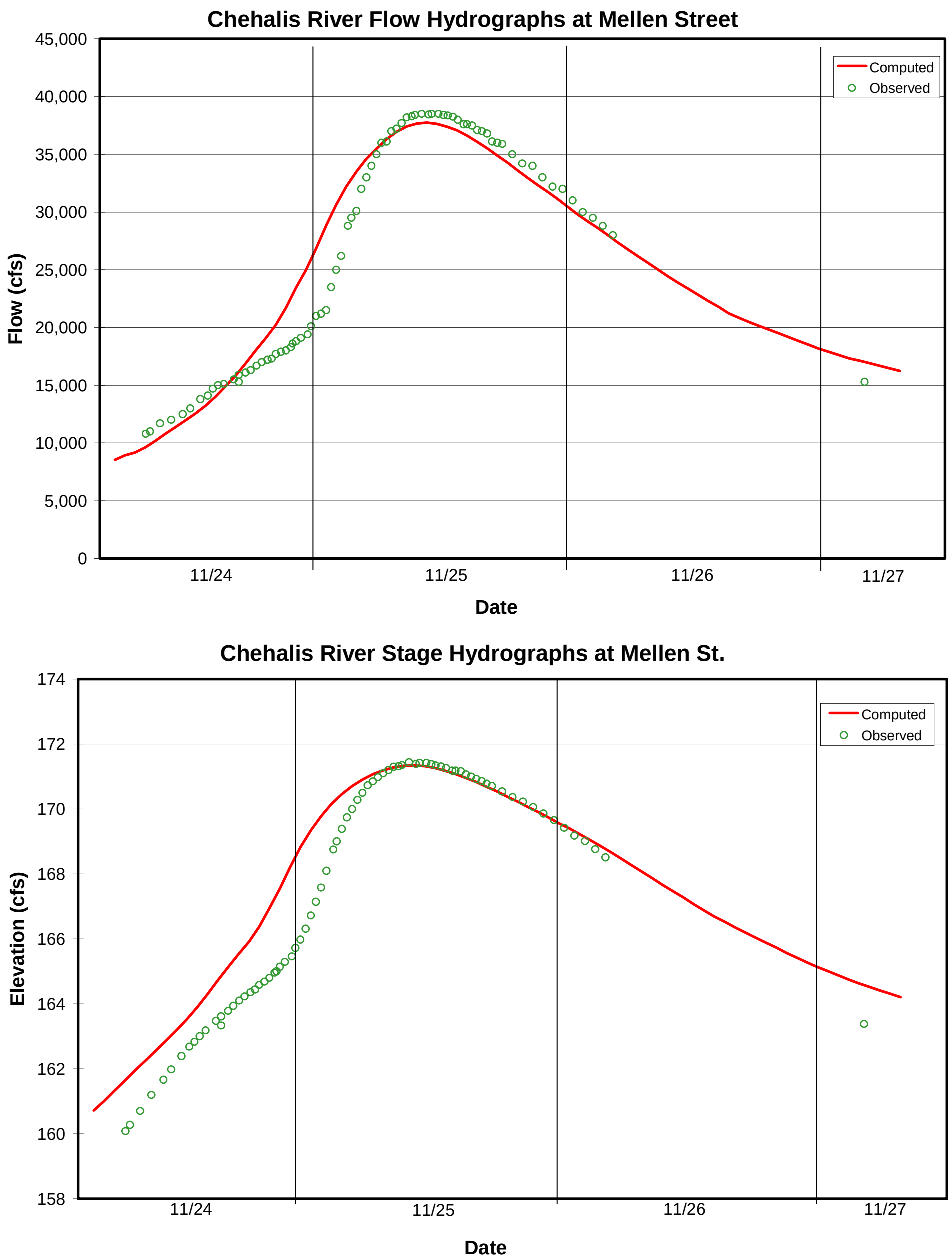
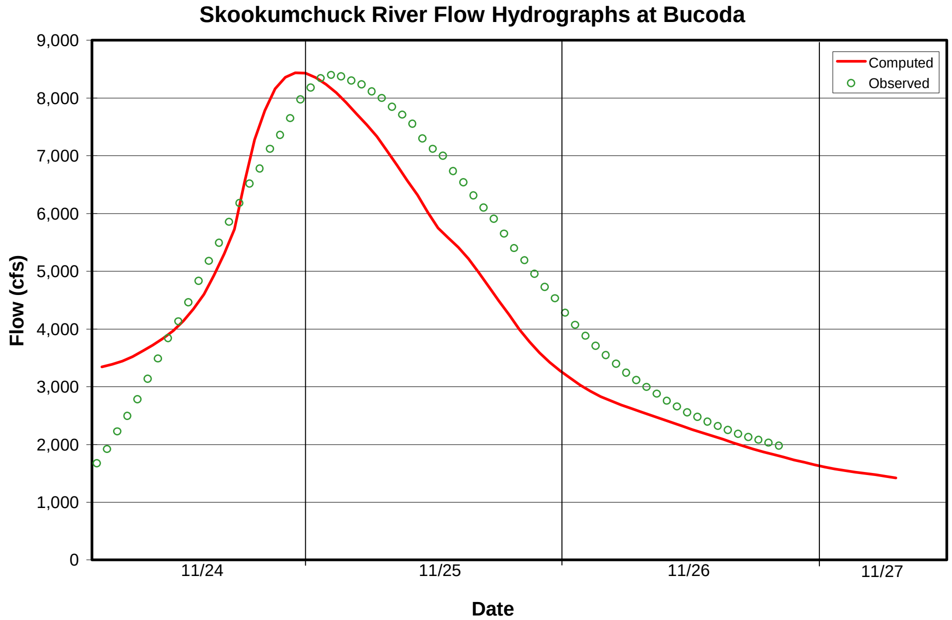


Figure 3-13: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda – November 1990 Flood



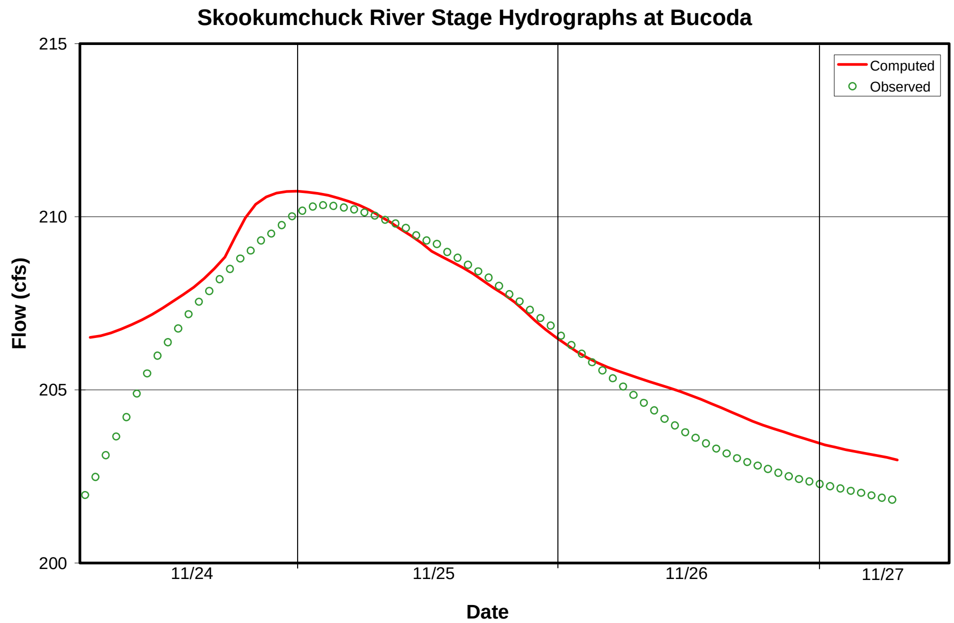
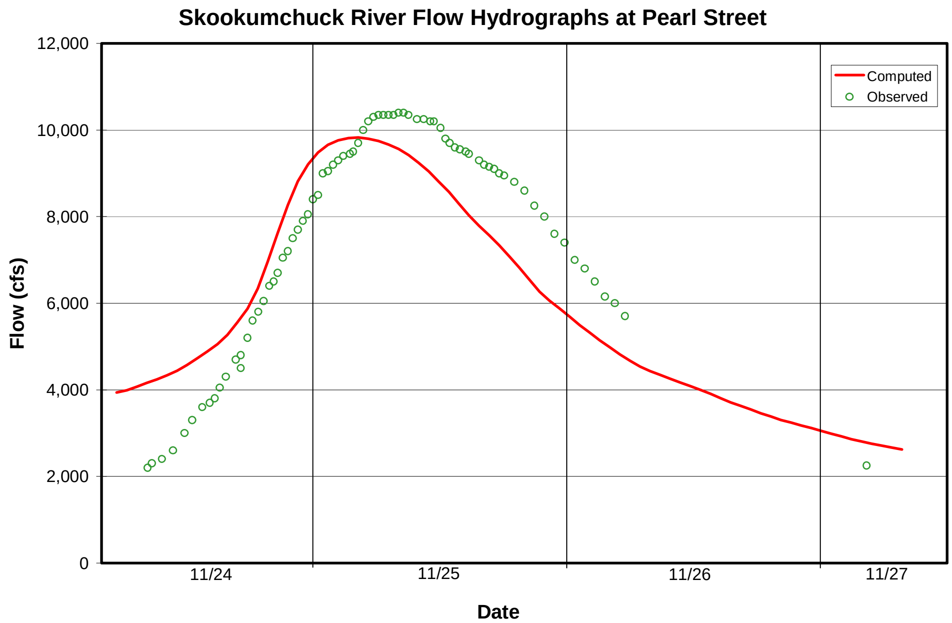


Figure 3-14: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street – November 1990 Flood



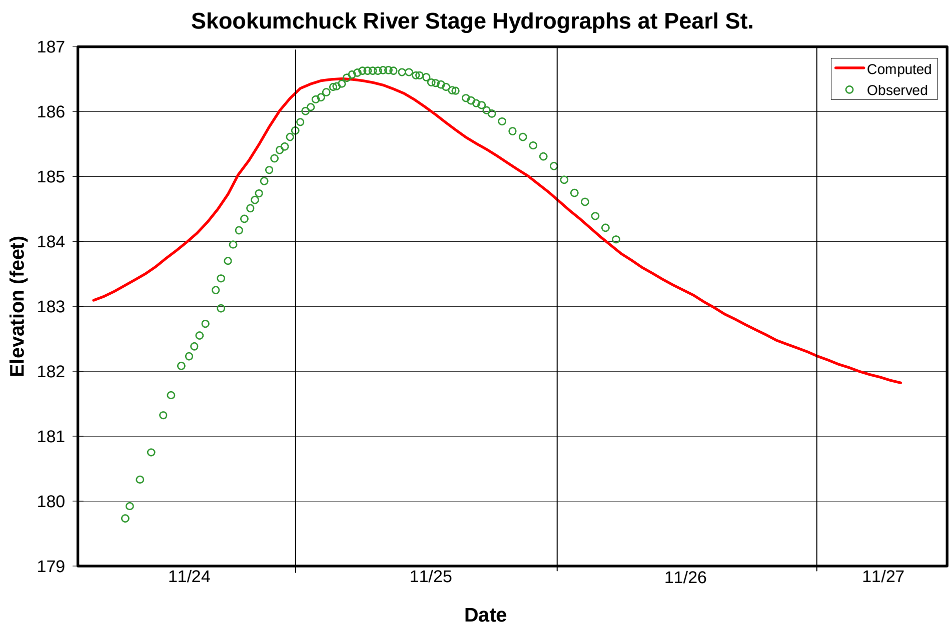
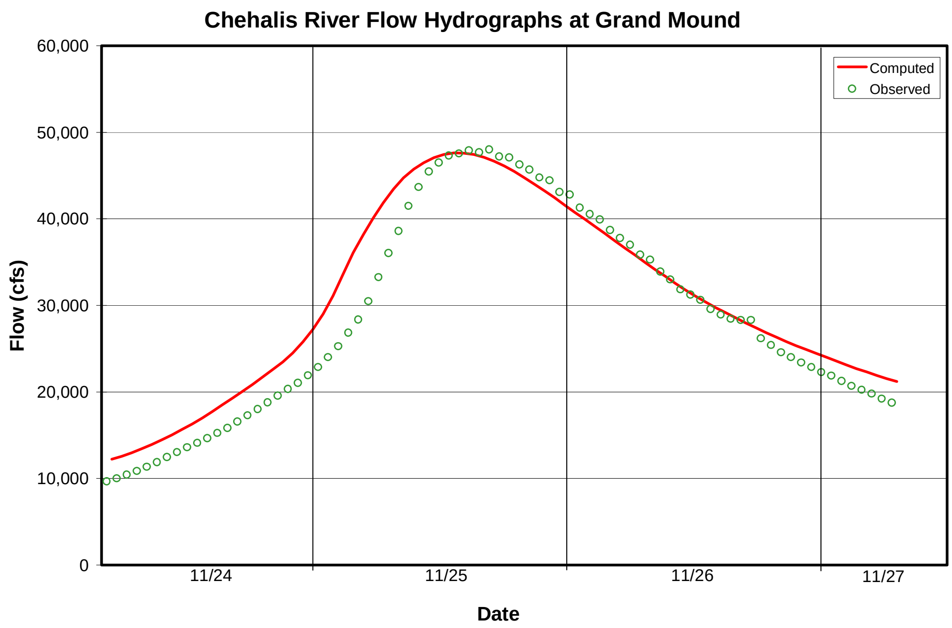


Figure 3-15: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound – November 1990 Flood



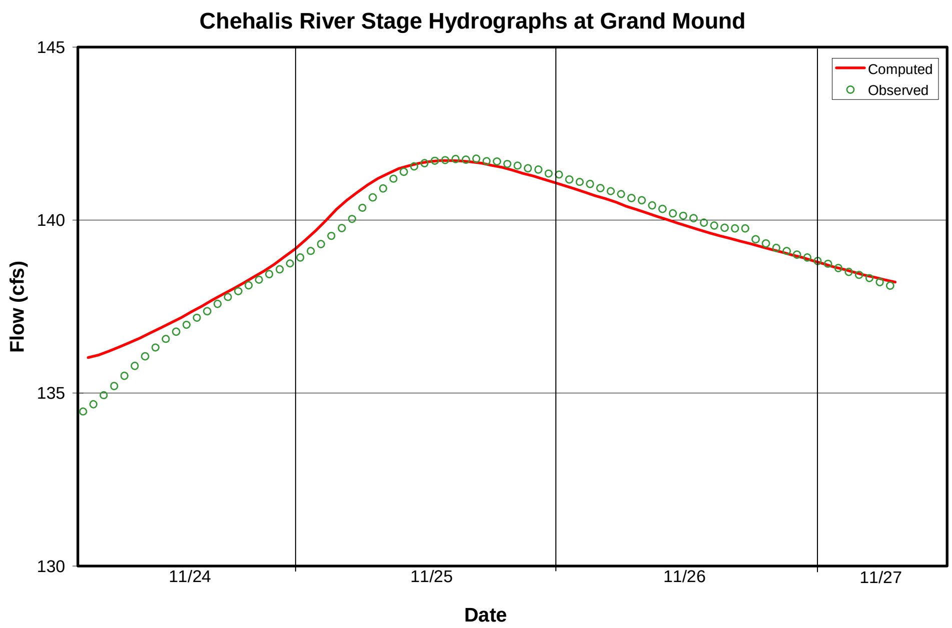
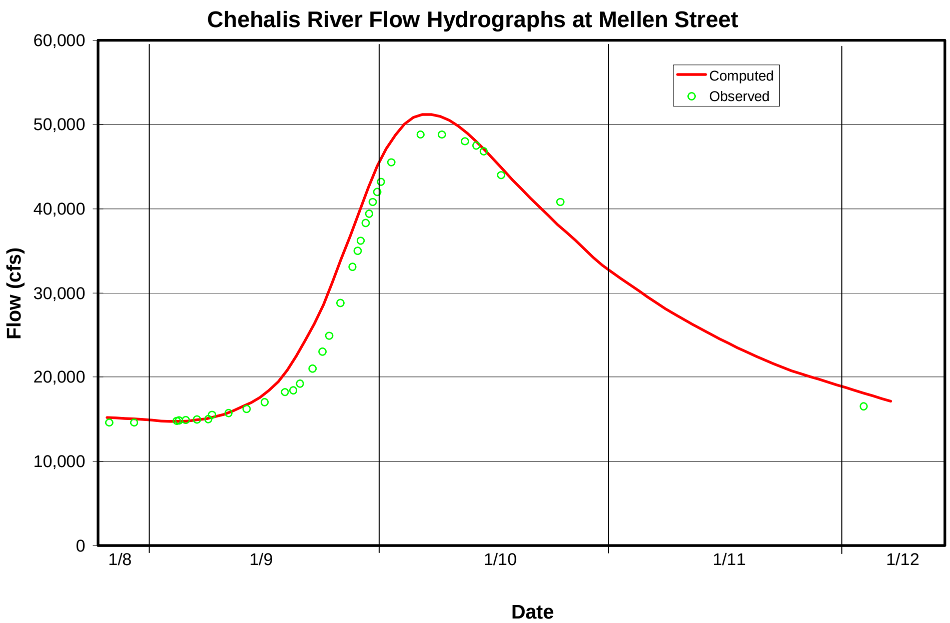


Figure 3-16: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street – January 1990 Flood



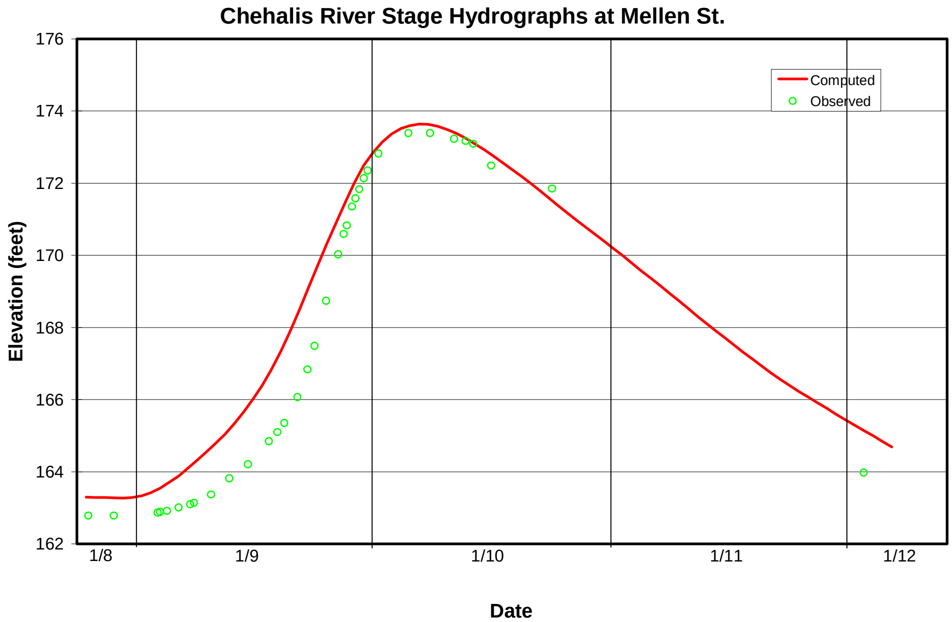
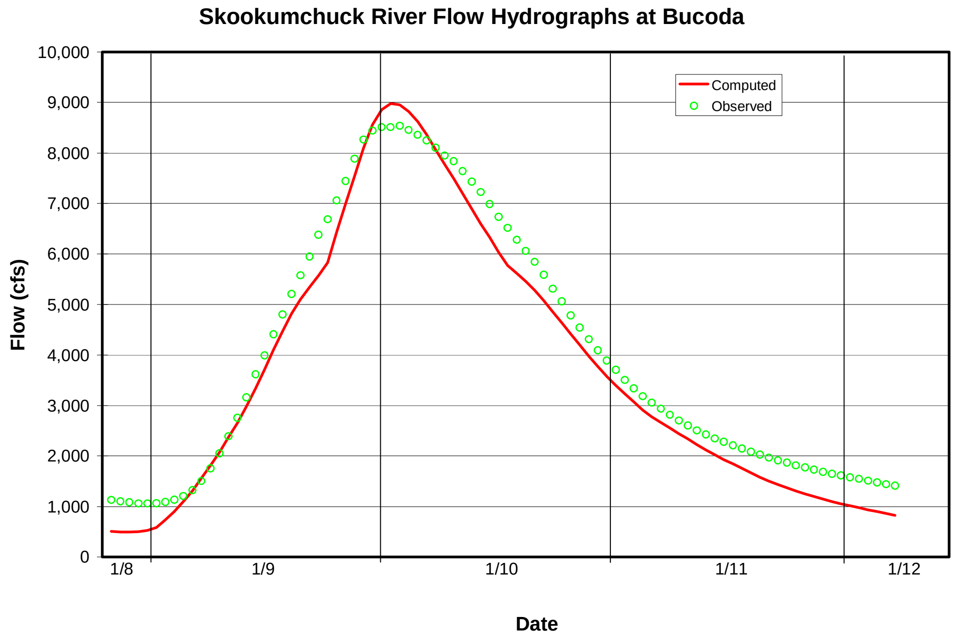


Figure 3-17: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda – January 1990 Flood



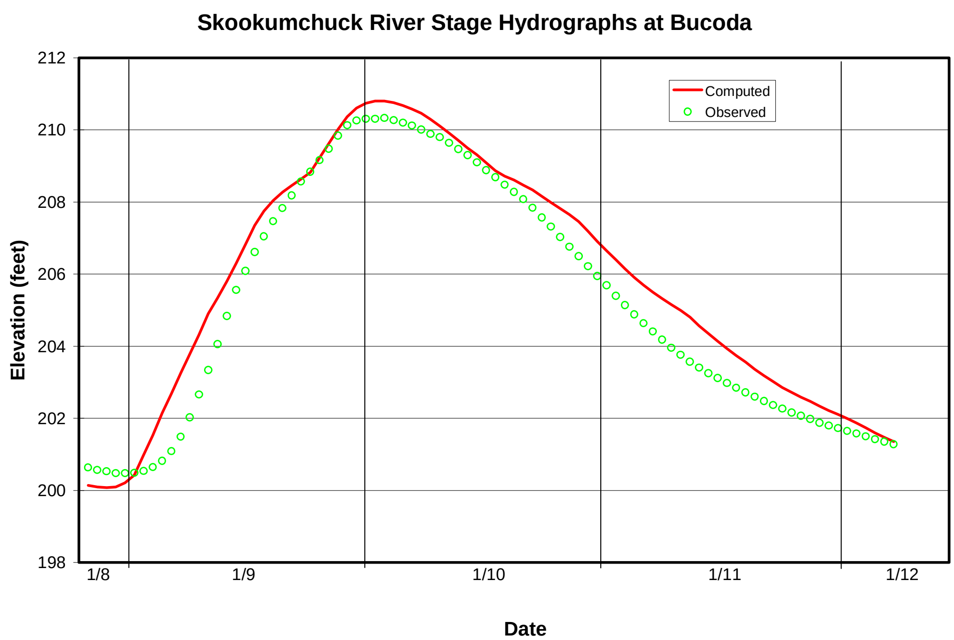
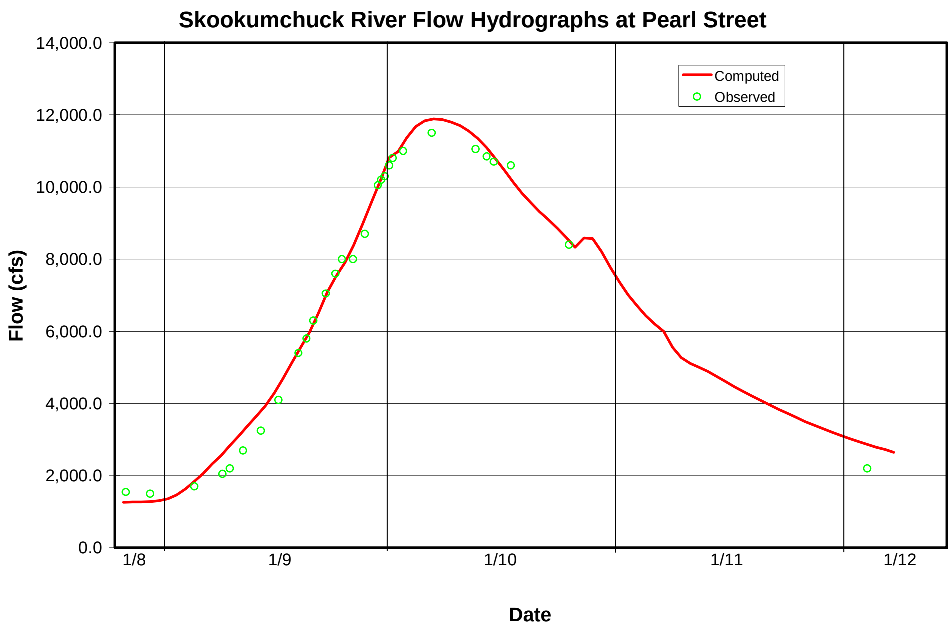


Figure 3-18: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street – January 1990 Flood



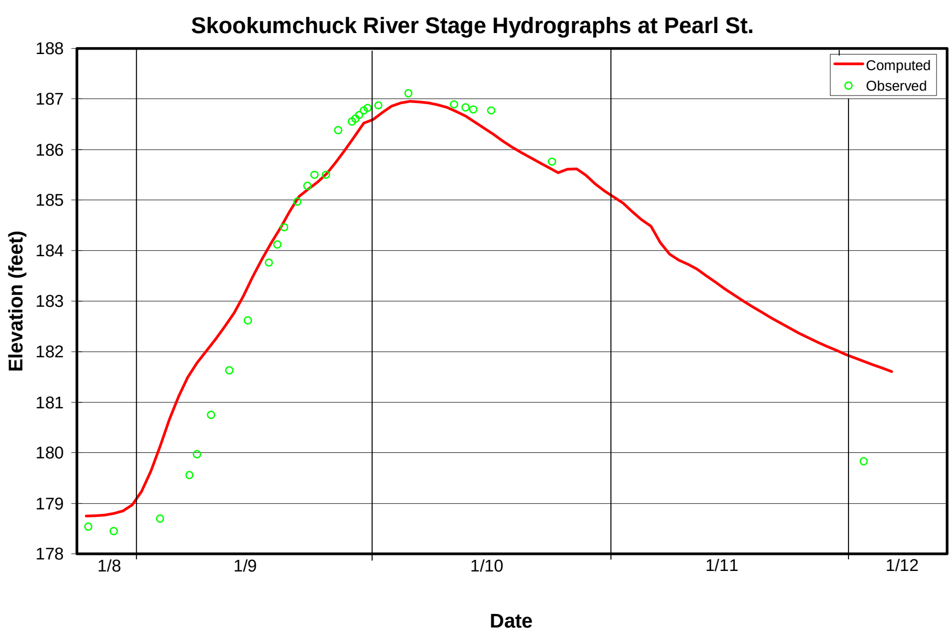
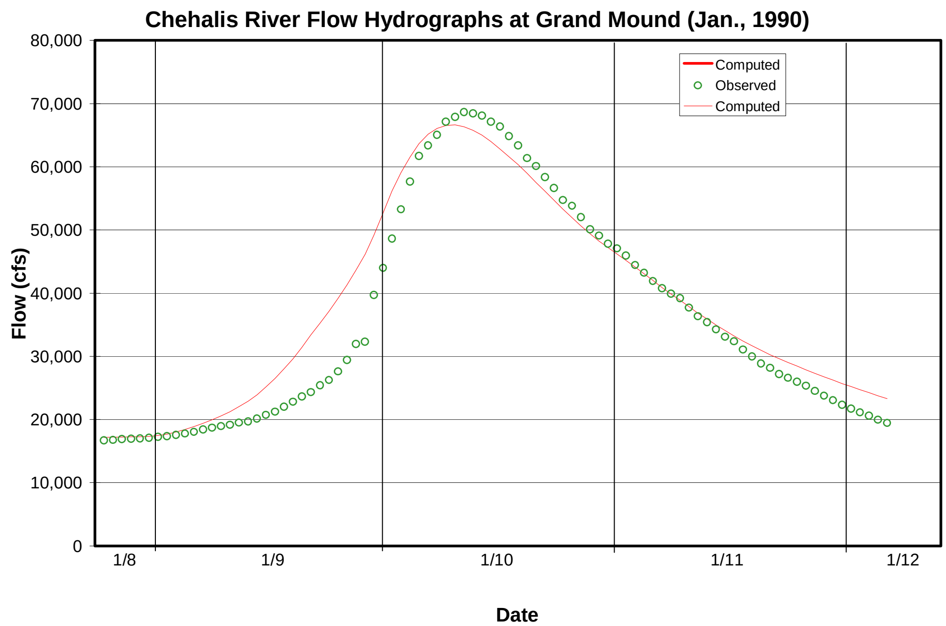


Figure 3-19: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound – January 1990 Flood



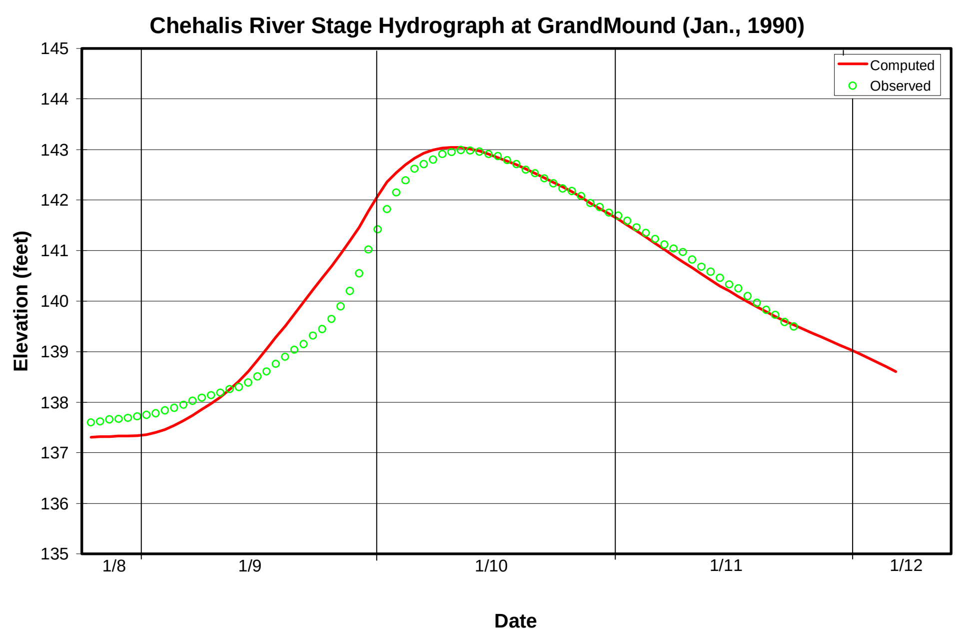
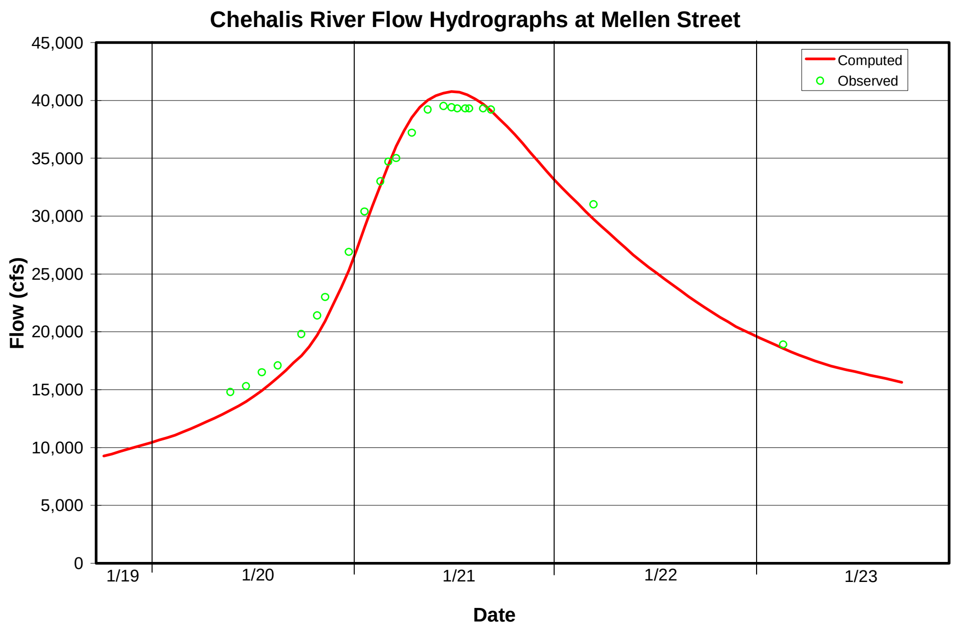


Figure 3-20: Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen Street – January 1972 Flood



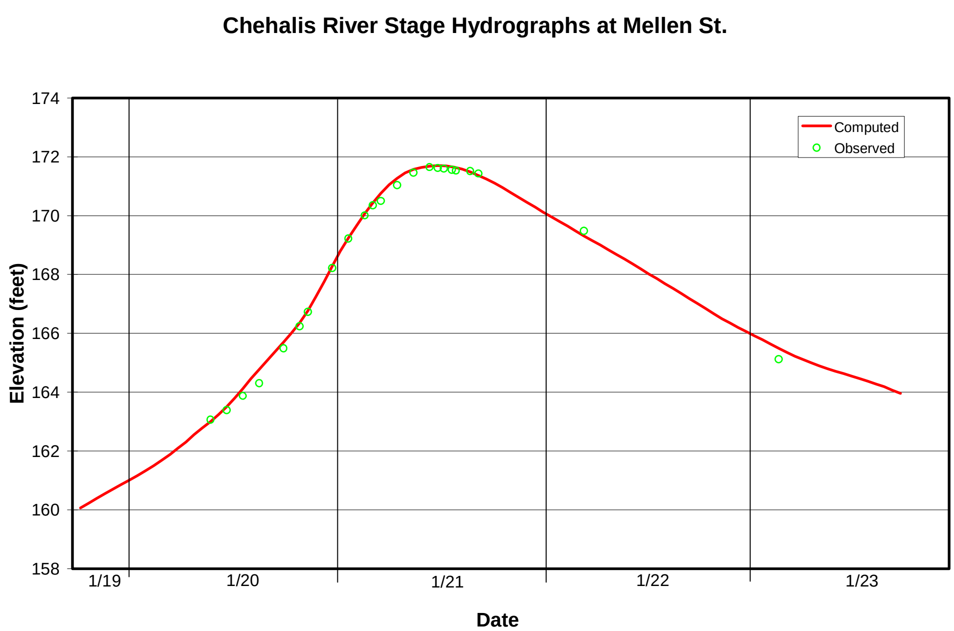
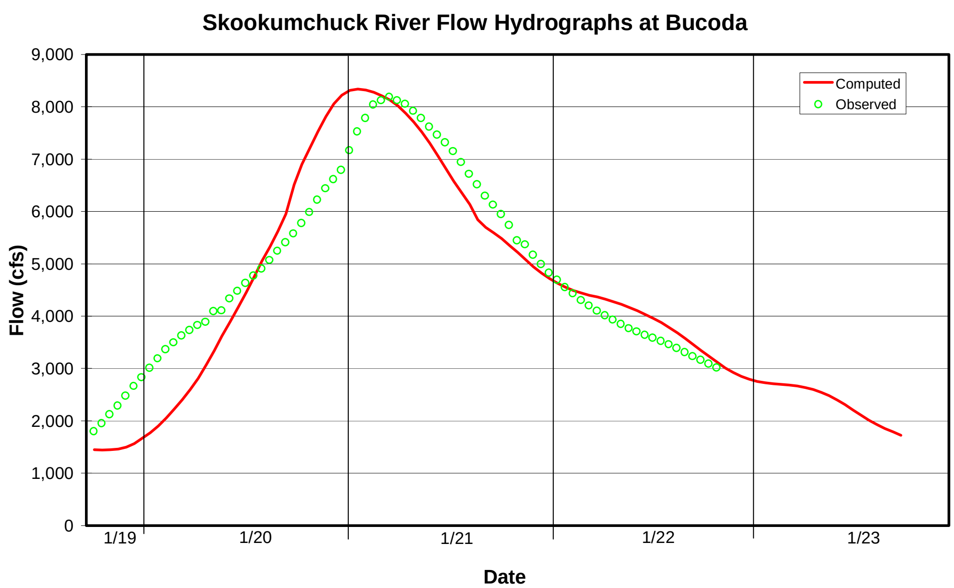


Figure 3-21: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda – January 1972 Flood



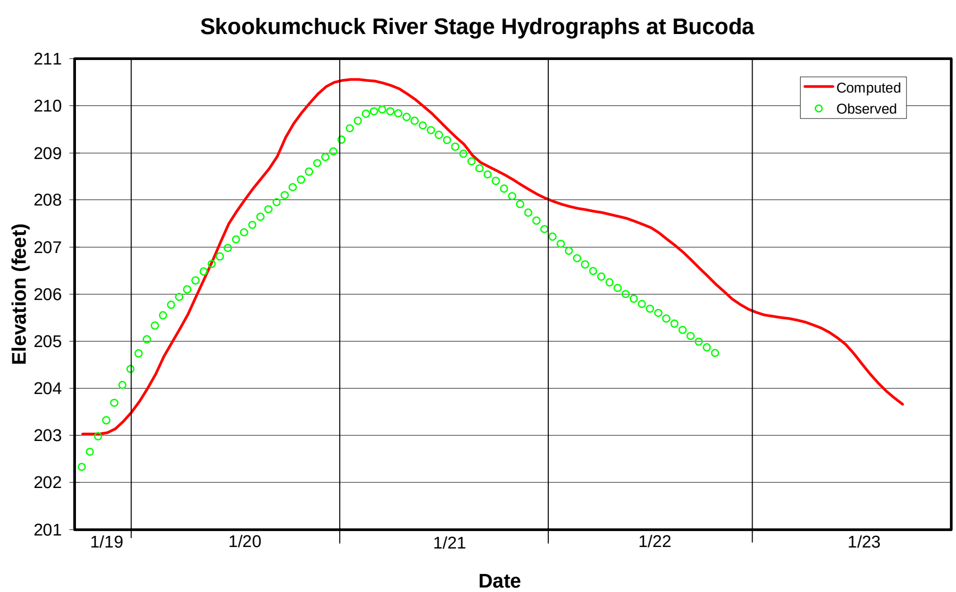
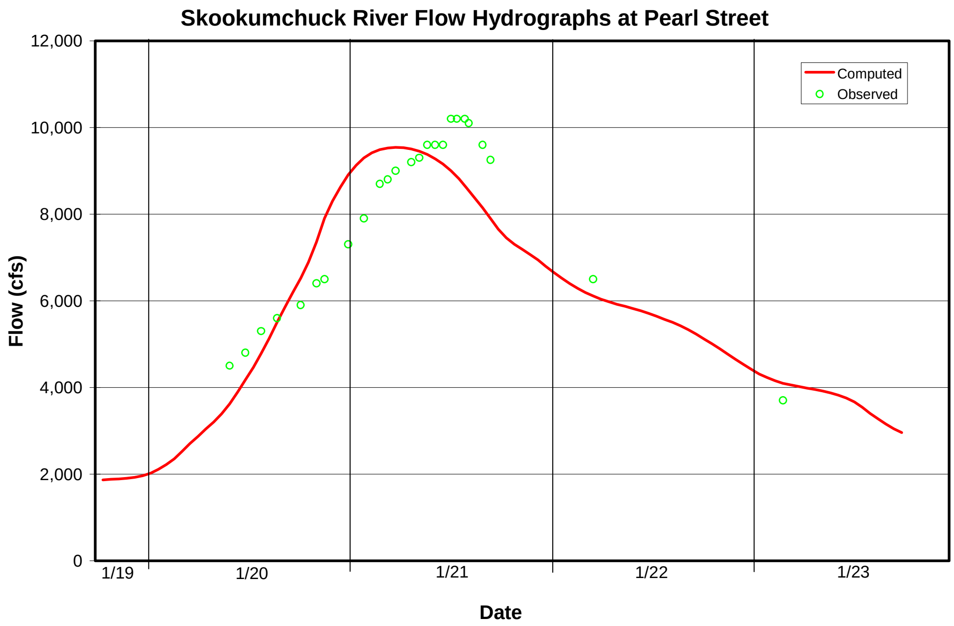


Figure 3-22: Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl Street – January 1972 Flood



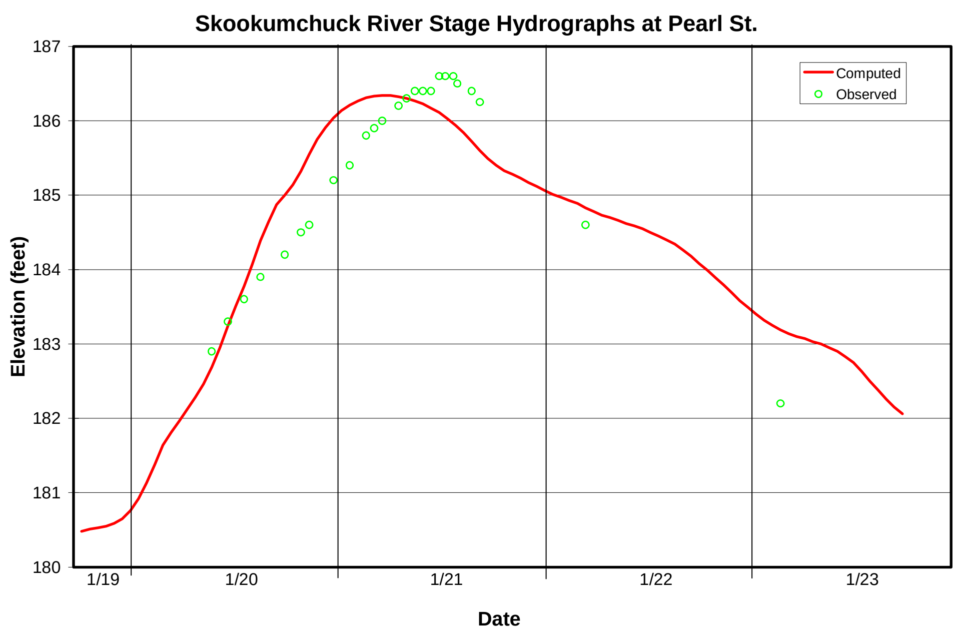
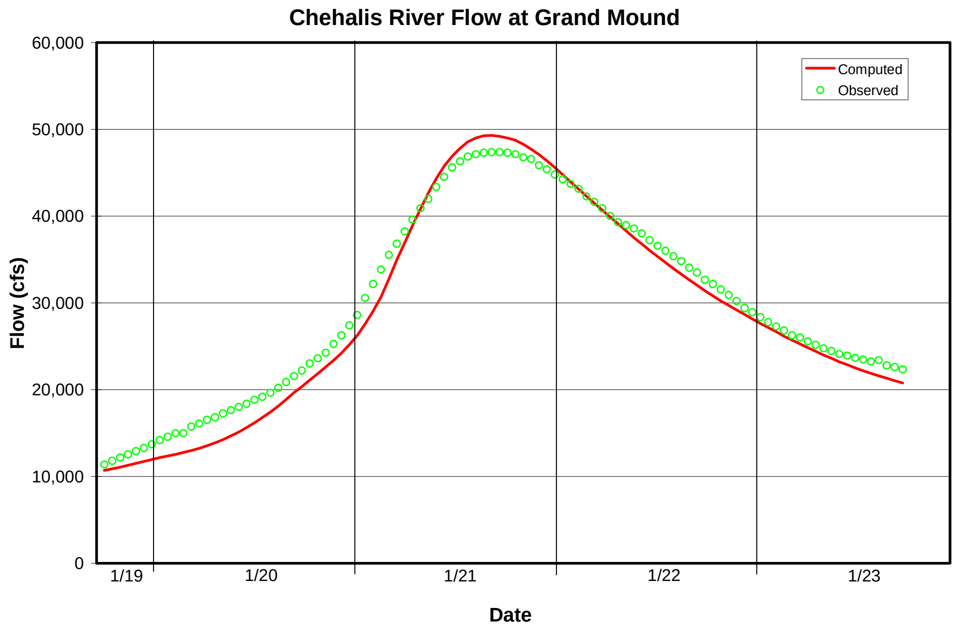


Figure 3-23: Comparison of Computed and Observed Hydrographs on the Chehalis River at Grand Mound – January 1972 Flood



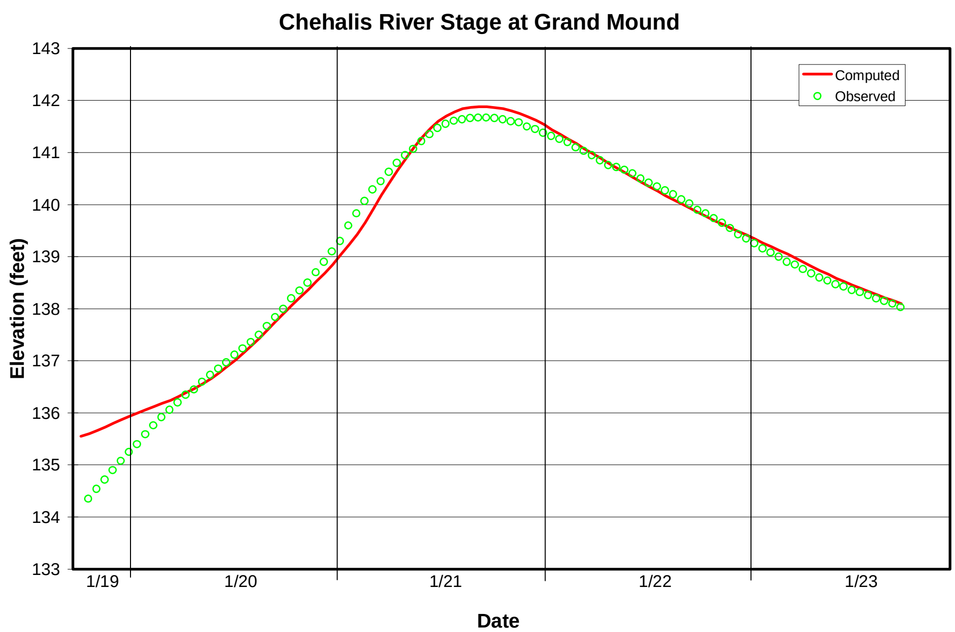


Figure 3-24: Comparison of Computed and Existing USGS Discharge Rating Curve for the Chehalis River at Grand Mound – USACE Statistical Flood Hydrographs

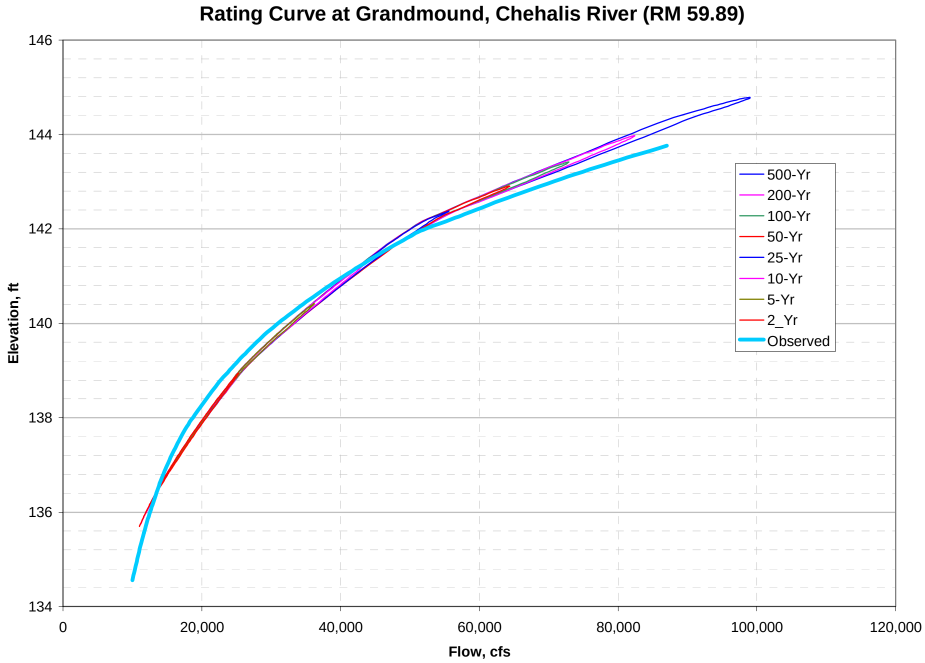
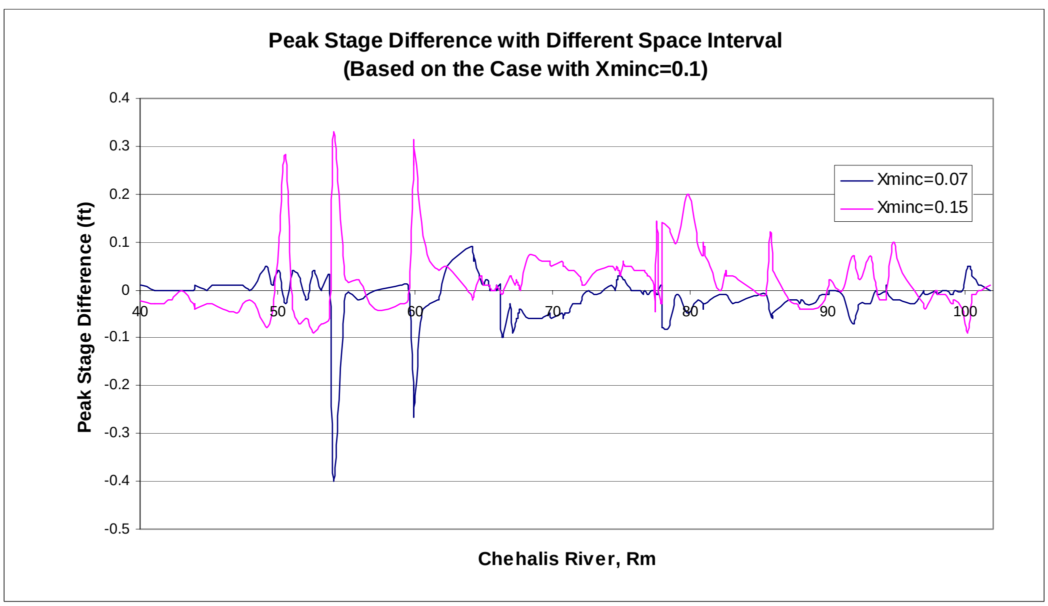


Figure 3-25: Comparison of Distance Step Value - Chehalis River



4. HYDRAULIC DESIGN

4.1 Design Considerations and Criteria

4.1.1 General

Hydraulic design was performed using the general design objectives and criteria for the project as discussed in Section 4.3.4.4 of the General Reevaluation Report. Additionally, a general objective of the proposed levee alignment was that it should reliably protect against the 100-year flood of the Chehalis River. This includes protection from induced backwater flooding from the Chehalis River on tributaries including Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek, and the Skookumchuck River.

4.1.2 Water Surface Profiles

Water surface profiles are provided in Appendix C, Levee Plan and Civil Design.

4.1.3 Levee Height Analysis

The proposed levees were designed to reliably protect against the 100-year flood. The project formulation adhered to the policy and guidance set forth in ER 1105-2-101, Risk Based Analysis (RBA) for Evaluation of Hydrology /Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies. Details of the RBA and formulation can be found in Section 3.4 and Section 4.0 of the GRR. Optimization of the levee height on the Chehalis and Skookumchuck rivers was preformed.

4.2 The Levee Plan

The levee plan consists of several components; the plan includes a levee system and modifications to the existing Skookumchuck dam. The proposed levee system includes levees along the Chehalis River and its tributaries Dillenbaugh Creek, Salzer Creek, and the Skookumchuck River. In addition to proposed modifications to Skookumchuck for flood control storage.

4.2.1 Levee / Floodwall System

Design of the levee/floodwall system took advantage of opportunities to maximize levee setbacks, allowing floodplain and channel connectivity for environmental purposes. And also took advantage of using floodwalls where traffic control barriers could serve multi-purposes or where it was necessary to reduce the project footprint. The setback levee alignment would protect existing residential and commercial structures, highway and other transportation infrastructure from flooding while not encouraging new floodplain development. Proposed protection would extend along the Chehalis River from approximately RM 75 to RM 64, as well as along most of the lower two miles of both Dillenbaugh Creek and Salzer Creek. In addition, levee protection will be provided on the Skookumchuck River for backwater effects of the Chehalis River. The effected reach is approximately 2 miles upstream on the Skookumchuck to the confluence with Coffee Creek.

The levee system is intended to provide flood protection against the base 100-year Chehalis River flood level with a degree of certainty. The 100-year protection is coordinated with FEMA flood maps, so that they will be compatible. This protection also extends to the tributaries of the Chehalis River. The Chehalis backwater flooding is prevented from going upstream on the following tributaries: Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek and the Skookumchuck River.

4.2.2 Levee Design Criteria

The standard Corps levee design consists of a 12-foot top width and 2:1 side slopes (2 horizontal to 1 vertical). The fill material must meet the gradation specification and be compacted to Corps standards for levees discussed in paragraph 2.1.3.2. A 6-inch layer of gravel will be placed on the top surface to provide access during flood events and maintenance. Both sides of the levee will be hydro seeded with grass with 4 inches of topsoil over compacted embankment material. Most levees are set back levees, which will not require rock bank protection. For those few areas that do require bank protection. The protection will include 30 inch minus riprap about 3 feet thick, with a 1-foot layer of quarry spalls between the riprap and compacted embankment material.

The concrete floodwall design has a spread footing buried below existing grade; only the vertical portion of the floodwall will be visible after construction. The base width will vary with the height to a maximum of approximately 20 feet and a top width of approximately 1 foot. They will often serve as traffic barriers along the road right-of-way.

As a general rule if the levee or Berm along the highway was less than 1.5 feet a floodwall was used instead of the standard earthen levee.

4.3 Skookumchuck Dam Description

4.3.1 General

Skookumchuck Dam is located on the Skookumchuck River about 12 miles northeast of Centralia, Washington, at Skookumchuck RM 21.9. The dam was constructed in 1970 to supply cooling water to the coal-fired Centralia steam electric plant. The dam has a rolled earthfill central core, buttressed by an earth and rockfill shell. The structure is approximately 190 feet high, with the top of the dam at elevation 497 feet. All elevations referred to in this report are based on NGVD 29 with the 1947 adjustment.

The dam has a 130-foot wide uncontrolled side-channel spillway in a rock cut on the left abutment. The spillway is a concrete ogee with a crest at elevation 477 feet. The spillway invert is at elevation 465 feet. Water passes over the ogee and spills into a 130-foot long by 40-foot wide concrete lined trough. Water then spills down a concrete lined chute. The chute is almost 600 feet long and has a bottom slope that varies from 17 percent to 25 percent. The spillway chute ends in a stilling basin that directs the discharge into a rock cut leading back to the natural river channel.

Facilities are located adjacent to the stilling basin to trap migrating salmon and steelhead for truck transport over the dam.

During low flow months, water released from storage travels downstream to a diversion pumping station at RM 7.3. From there water is pumped through a 3-mile pipeline to the steam electric plant. Under an agreement between the dam owner and state agencies, additional releases are made from the reservoir to supplement flows in the Skookumchuck River to improve fishery habitat.

Outflow from the reservoir is currently either over the spillway crest at elevation 477 feet, or through the outlet works. The existing outlet works consist of an inclined, multilevel intake structure that connects to the construction diversion tunnel and discharges through two 24-inch Howell-Bunger valves into the spillway stilling basin. The intake gates are set at elevations 449, 420, and 378 feet. The discharge capacity of the outlet works is approximately 220 cubic-feet-per-second (cfs) when the pool elevation is at the spillway crest.

Storage behind the dam is essentially a fill and spill operation. The limited outlet capacity of the dam causes the reservoir to fill to the spillway crest at elevation 477 feet early in the flood runoff season. Once the reservoir is full, flood inflow to the reservoir passes over the un-gated spillway, which was originally designed for a discharge capacity of 28,000 cfs with the reservoir pool at elevation 492 feet.

Storage capacity of the reservoir between the normal minimum pool at elevation 400 feet and the spillway crest at elevation 477 feet is 38,700 ac-ft. Additional usable storage of 3,170 ac-ft is available between elevations 378 feet and 400 feet. Dead storage is approximately 1,420 ac-ft between elevations 378 and the base of the dam.

Additional studies that would need to be performed in the next phase of studies would include the following:

- Finalize PMF analysis.
- Detailed numerical analysis of the spillway, chute, and outlet works.
- Structural design of outlet works and spillway and chute modifications.
- Development of flood control regulation rule curves.
- Evaluation of any downstream environmental effects related to reservoir operation and flood control regulation.
- Evaluation of reservoir sedimentation and bank stability.
- Assessment of potential downstream scour and bank erosion.
- Determination of freeboard requirements.
- Assessment of downstream fish passage.
- Evaluation of cavitation potential.

4.3.2 Proposed Dam Modifications

The proposed alternative would consist of constructing a short outlet works tunnel in the left abutment of the dam between the existing spillway and dam crest. An outlets works tower with slide gates would be built at the entrance to the new tunnel. The tunnel would discharge into the existing spillway chute. For the high flood storage pool option, three steel tainter gates would be added to the top of the existing ogee spillway. See Appendix B, Skookumchuck Dam Modifications, for conceptual drawings of the alternative.

Feasibility level hydraulic analyses have been conducted for the outlet works and spillway to determine the approximate configuration and dimensions of the project components necessary to fulfill the project design objective.

The intake structure would be constructed just upstream of the right abutment of the existing spillway bridge. The intake would lead to a short tunnel constructed in the rock forming the left abutment of the embankment dam. The intake would have two control gates and two guard gates. The slide gates would be approximately 8 feet by 11 feet in size. A 3,000 cfs capacity at minimum reservoir pool was used for the preliminary sizing of the gates. Capacity of the outlet works would be approximately 8,000 cfs at the maximum reservoir pool.

Flow would discharge through the tunnel into the existing spillway chute. The outlet tunnel and spillway chute confluence will be a very complex feature to hydraulically design and analyze and a physical model investigation may be required in the final design phase.

The existing uncontrolled overflow spillway would also be modified for the proposed alternative. A few different options were considered for providing spillway crest control including an inflatable rubber weir and steel bascule gate. For purposes of costs and preliminary engineering, it was decided to go with steel tainter gates. There would be three steel tainter gates approximately 39.3 feet wide and 15 feet tall on the spillway crest with two concrete piers between. The spillway would have a total capacity of approximately 25,500 cfs at maximum reservoir pool. The total capacity of the outlet works and spillway would be approximately 32,500 cfs at maximum reservoir pool.

4.4 Reservoir Regulation Considerations

4.4.1 Existing Operations

Skookumchuck Dam currently operates on a fill and spill regime. The reservoir fills each year with the first heavy rains of the fall and then allows all subsequent inflow to spill uncontrolled over the dam until summer when the reservoir lowers as inflow drops.

The existing flow management agreement between PacifiCorp and the Washington Department of Fish and Wildlife (WDFW) for Skookumchuck Dam was completed in May 1998 and is intended to provide benefits to downstream fish resources and the needs of the Steam Plant. There are also provisions for steelhead production and other requirements unrelated to water control. The agreement specifies minimum flows throughout the year, water temperature objectives, reservoir elevations, as well as water use limitations and general guidelines for ramping, coordination and operations. There is no existing flood control capacity at the dam. In the summer, inflow drops off and causes the reservoir to lower until such time the fall or winter rains arrive and fill the reservoir.

Water discharge from the existing outlet tunnel is dependant on reservoir elevation. As the reservoir rises and reaches each intake, the corresponding outflows adjust on a continuum from 95 cfs with one outlet submerged, 140 cfs with two outlets submerged and as much as 220 cfs with all three outlets submerged. After the reservoir fills, discharge is passed both through the sluiceways and over the spillway. Although it varies each year, monthly outflow averages generally range between 95 cfs and 1200 cfs depending on the month. During high flow conditions, discharge from the dam can greatly exceed monthly averages with a 5-year event passing 4,000 cfs and a 100-year event passing 7,425 cfs.

4.4.2 Flood Control Operations

Modifications to Skookumchuck Dam are intended to support limited flood control operations at Skookumchuck Dam. Specifically, reservoir operations will change to allow drawdown in the fall to elevation 444 by early November. It is anticipated that this flood control capacity will remain until a flood event occurs. During a flood event, outflows from the dam will be reduced in order to prevent flow at Pearl Street from exceeding 5,000 cfs. Depending on the magnitude of the event, discharge will be limited to no more than 3,000 cfs. After the event passes, water stored in the reservoir will be released at volumes high enough to reach but not exceed 5,000 cfs at the Pearl Street river gage in Centralia.

Discharge from the project would be via two new 8-foot by 11-foot slide gates located on the dam with a bottom elevation of 436 and a common discharge tunnel entering into the existing spillway on the right bank. The gates purpose will be to pass flood flows through the flood season. The maximum storage pool elevation will be 492 and would require the use of spillway crest control gates. The spillway control gates would be utilized only during events that would require use of the additional flood control storage. This additional storage would be reserved for flood above the 70-year event and not fully utilized until around the 100-year event.

4.4.3 Routine Operations (Post Construction)

In the absence of a flood, Skookumchuck Dam is expected to operate for the benefit of both PacifiCorp, and the natural resources of the River. However in the existing operations guidance, not all areas of routine operation are clearly described. For instance, there is little discussion of proper ramping rates. The WDFW/PacifiCorp agreement of May 1998 simply states: “Flow reductions under this Agreement shall be accomplished in a manner that minimizes the stranding of juvenile fish”. Specific criteria were not provided initially because the bypass reach between the dam and its hydropower unit was so short and no other opportunities to significantly modify flows existed at the dam. With the installation of flood control capability however, large changes in river stage will become possible.

Other Western Washington flood control projects were reviewed on order to develop more specific guidelines. This review revealed that both up and down ramping should contain restrictions based on the season and fish resources. With the exception of special operational needs, routine ramping rates between projects were reasonably consistent

In addition to the ramping rates for routine operations, several specific criteria were described for times of flood control or sensitive spawning periods. For instance, ramping rate guidelines for Mud Mountain Dam are more flexible during times of flood control where the tailwater elevation may increase as much as 1 foot/hour. It is however, specifically requested that great consideration be given to public safety prior to changes of that magnitude. At Howard Hanson Dam, special ramping criteria are given during the steelhead spawning and incubation periods (April- July). To protect eggs incubating in redds near the river margins, ramping is not allowed to alter river stage greater than 1 foot below the highest average mean daily flow for the previous 10 days.

4.4.4 Reservoir Operations

Post project reservoir operations will be tied primarily to flood control where a requirement will be in place to ensure the reservoir elevation is at or below 444 prior to the onset of flood control season in early December. During the summer to fall drawdown period, flows from the project will be passed through the outlet structures such that the reservoir lowers to elevation 444. When drawdown is complete, inflow will be passed through the outlet works to maintain reservoir elevation so long as flows at Pearl Street remain under 5,000 cfs. It is expected that project discharges would meet or exceed the minimum instream flows of 90 cfs except if reservoir inflow fell below 90 cfs. The reservoir should remain relatively constant throughout the late spring, summer and early fall. In winter, larger reservoir fluctuations may occur as the project reacts to flood events and the reservoir fluctuates between elevations 492 and 444.

4.4.5 Downstream Flows

Flow operations from Skookumchuck Dam during non-flood events will be similar to the operation that is in place today. Except for flood events, post-project outflows should continue to follow historic outflows as recorded by the Bloody Run gage located slightly downstream of the dam.

The Bloody Run gage shows wide flow variations through the years. In general, daily discharge trends show flow increasing from a low of about 100 cfs in the late summer (August) to a mean monthly flow in January and February around or exceeding 1000 cfs. This pattern can vary widely by year although the summer month regimes are quite consistent.

Maximum flows can be much higher than the average mean of around 1000 cfs. During flood season, high water releases of between 2000 and 3500 cfs are not uncommon. These events tend to be relatively short in duration lasting around 4 to 6 days. Bankfull flows in the upper reaches but below the dam occur at discharges of 3,000 cfs.

4.5 Recommendations for an Operations Plan

Beyond describing and identifying potential biological benefits and impacts of providing flood control at Skookumchuck Dam, is it the goal of this report to propose a plan for operating Skookumchuck Dam. The operating plan developed here is designed to take into consideration the environmental conditions at the site and provide for their protection. The recommendations below are proposed for consideration and review in hopes that they provide a basis for operating Skookumchuck Dam for the highest practical protection of biological resources.

4.5.1 Flood Control Rule Curve and Discharges

The development and adoption of a rule curve is a major operational feature associated with the addition of flood control at Skookumchuck Dam. The rule curve guides decisions on dam releases during flood control operations as well as guiding the rate of reservoir evacuation.

The rule curve also serves as a guide for refill and drawdown planning. Since a rule curve affects reservoir elevation and downstream releases so significantly, it should be developed with consideration for biological resources.

Initial discussions with hydrologists at the Corps resulted in the development of a provisional rule curve based on initial review of flood control data and the biological information provided in earlier sections (Figure 4-1). While it is not a formal and binding rule curve, it does provide a proposal for the protection of biological resources. The provisional rule curve was based on the following assumptions

- Flood storage drawdown to provide at least 11,000 ac-ft.
- Refill initiated based on water forecasts but completed by April 1
- Drawdown initiated when inflow to reservoir is less than instream minimums or when necessary to ensure drawdown by target date of October 31.
- Minimum instream flows are 95 cfs (Nov 1 - Sept 9) and 140 cfs (Sept 10 - Oct 31).
- Minimum pool is 455.
- Maximum pool is 477.

Based on the information available at the time of this report, it is recommended that the provisional rule curve be used as a starting point for hydraulic evaluation. Although it is recognized that the final rule curve may deviate from this provisional rule curve, the curve is considered to be consistent with the most significant biological needs of the system and where changes are made, the rational for the deviation should be documented.

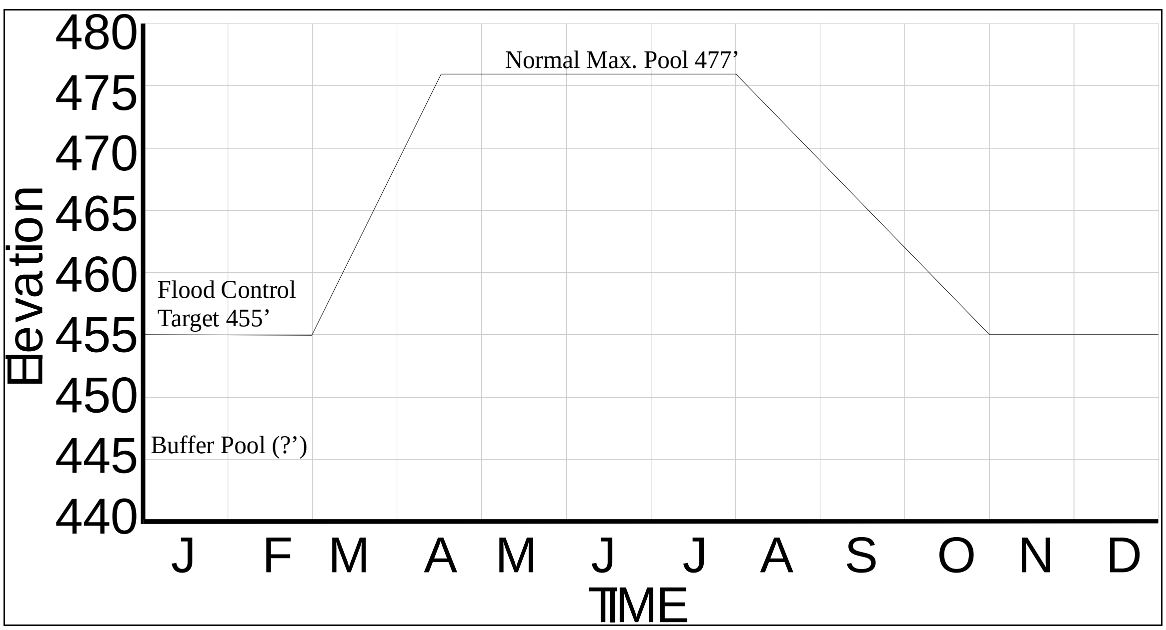


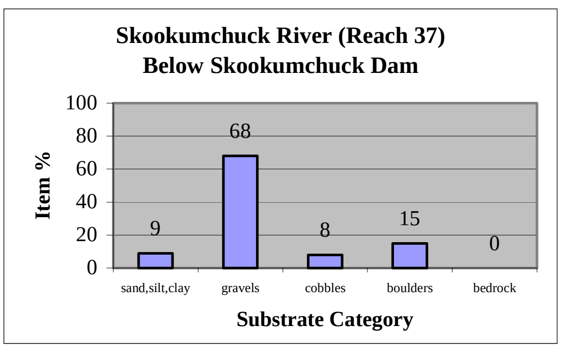
Figure 4-1: Provisional Rule Curve for Skookumchuck Dam

4.5.2 Maximum flows

Rule curves are paired with flood control objectives and forecasted inflows to regulate discharge from the dam for the purpose of managing high flow events. For the Skookumchuck River, discharges above the 2-year event are captured within the reservoir and held to ensure the Pearl Street objective of 5,000 cfs is not violated. After the peak of the high flow event passes, stored water is released to remain within the Pearl Street objectives until the reservoir is evacuated and ready for the next event. The evacuation of the reservoir adds additional flow to the end of each event extending bank full flows beyond the baseline condition. The impacts of this are described in earlier sections but it appears there are two significant physical considerations when managing these high flows. First it is critical that the existing gravels and fines be allowed to continue moving towards the Chehalis River. Bedload movement and channel scour processes are critical to maintaining spawning gravels, woody debris recruitment, undercut banks and other mainstem habitats. Secondly, it is critical to ensure the reduction in high flows to levels at or below the 2-year event will allow for adequate maintenance of important off-channel habitats.

4.5.3 Bedload Movement and Channel Processes

Bedload characteristics of the Skookumchuck River are predominantly gravel and cobble. The results of pebble counts done in 2000, showed no clear trend except that larger substrate types were found closer to the dam and finer materials tended to show up down towards the mouth or in flat reaches such as near the town of Bucoda (Figures 4-2 and 4-3)



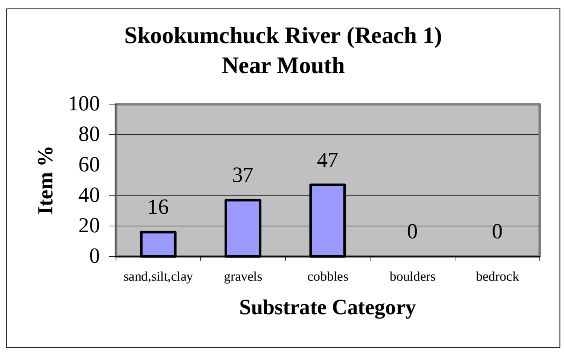


Figure 4-2: Pebble Count Data at Reach 37 (left)
Figure 4-3: Pebble count data at Reach 1 (right)

The disposition of substrate after the proposed flood control operations are in effect will be linked to the rivers ability to recruit and move material downstream. The flood control project proposes limiting downstream discharge to the 2-year flood, which represents a restriction to higher flows from the existing condition. The pebble count data from the Skookumchuck River appears to indicate that Skookumchuck Dam may be restricting some gravel recruitment from the upper watershed but that the input of gravels from tributaries such as Bloody Run Creek, Hanaford Creek and others are currently providing gravel adequate for spawning by anadromous fish. The size and distribution of the gravel appears to be small enough to allow mobilization and transport at moderate to small flood flows such as the 2-year event although more information may be needed to confirm this. Although it is less clear whether the 2-year event will allow for enough movement often to prevent gravel build up at tributaries mouths. A common problem in small to medium sized tributary systems, the Skookumchuck appears large enough to make the 2-year flood flow potential (3,000 to 5,000 cfs) likely to move the gravel size common within its banks and manage the deposition potential at the mouths of the tributaries.

Similarly, the 2-year event is expected to continue the processes of erosion on unstable and unconsolidated banks. Also, the reduction in peak flows may lengthen residency times for woody debris which will likely offset initial limitations to woody debris recruitment from reduced flood discharges.

Based on the above information, it is recommended that the proposed project allow the 2-year event be passed and not stored for flood control or other purposes. The 2-year flood events appear vital to the maintenance of the Skookumchuck River channel and may be particularly necessary in the Bucoda reaches. It is further recommended that no levee structures be constructed that limit the ability of the 2-year event to deposit and erode channel materials.

4.5.4 Minimum Flows

Minimum flows are dictated by the ability of inflow to support the existing summer requirement of 95 cfs. In most years, inflow appears capable of meeting or exceeding this standard. When minimum flows are elevated to 140 cfs between September 1 and October 31, inflows are not always able to meet the demand. The impact of this lies principally to adult chinook salmon which migrate upstream during this time. Inadequate flows during this period may increase travel time and availability of spawning habitat. The WDFW has informally expressed an interest to improve flows between September and October from 140 cfs to 160 cfs to ensure adequate flows for adult chinook. The difficulty rests in getting additional water without impacting resources during other times of the year. The provisional rule curve provides for drawdown to October 31 thereby allowing flexibility to provide some additional water during this period depending on water availability and reservoir management. Additional efforts are needed to provide insight into the reliability of providing additional water in the late summer.

An engineering study should be conducted to investigate the possibility of storing water to allow an additional release of 20 cfs to increase the minimum flows between the months of September 1 and October 31. It is recommended that this study include discussion of impacts to flows elsewhere during the year and the reliability of providing the water. It is also recommended that the existing minimum flows criteria of 95 cfs be maintained and not reduced in support of this action.

4.5.5 Ramping Rates

An expansion on the limited guidance given in the PacifiCorp and WDFW agreement appears to be warranted. The operation plan recommends using guidance from elsewhere to ensure river levels are manipulated such that they minimize concerns over fish stranding or spawning impacts but no specifics are given.

In reviewing projects with established ramping rate criteria, it appeared the ramping rates reflect a high degree of consistency and giving some confidence that ramping rates could be transferred between projects and remain adequate for resource protection (Table 4-1). There are however, discrepancies within our examples. These were seen in the areas of winter daytime ramping rates as well as spring ramp up rates (both daytime and nighttime). Also, the seasonal calendar is different between the two projects with the dates June 1- June 16 included in the spring period for the White River.

For the calendar discrepancies, it is recommended that the early June period remain within the spring ramping period to ensure ramping rates are sufficient for late outmigrating steelhead. Similarly, it is recommended that conservative daytime spring ramp-up rates be adopted for the protection of juvenile protection. It is also recommended that a 2-inch/hour ramping ability in the nighttime be allowed for quicker maintenance operations and minimal disruption to steelhead spawning.

Table 4-1: Recommended Ramping Rates for the Skookumchuck River

Season	Direction	Time	Rate
February 15-June 15	Up	Day	0"/hr
		Night	2"/hr
	Down	Day	No ramping
		Night	2"/hr
June 16-October 31	Up	Day	1"/hr
		Night	1"/hr
	Down	Day	1"/hr
		Night	1"/hr
November 1-February 14	Up	Day	1"/hr
		Night	1"/hr
	Down	Day	2"/hr
		Night	2"/hr

4.5.6 Upstream Fish Passage Operations

Upstream fish passage operations are limited to the passage of adult steelhead around the dam between the months of September 15 and November 15. The option to haul coho and chinook remains open but the current focus is to rebuild steelhead populations before allowing additional salmon above the dam. In addition, most spawning habitat for chinook was lost through the creation of the reservoir. The operation is conducted at a fish trap located at the base of Skookumchuck Dam. The trap appears to be adequate for its purposes. The need to provide access to the productive habitats of the upper Skookumchuck watershed is recognized and it is proposed that the operation continue with one modification.

To ensure the adult steelhead continue their upstream travels with a minimum of disruption, it is recommended that they be transported and released above the upper end of the reservoir. The release site should also be maintained to minimize injury and fallback. It is also recommended that they transfer truck be maintained in good condition with proper aeration equipment.

4.5.7 Downstream Fish Passage Operations.

Downstream passage occurs primarily between the months of April 15 and May 31 with juvenile steelhead as the only anadromous outmigrant. To date, there are no other juvenile anadromous salmon above the project. The existing downstream passage plan for Skookumchuck Dam relies heavily on a full pool condition arising prior to the onset of outmigration. Full pool allows outmigrants access to the spillway and the fish passage chute both designed to pass fish via surface flow down the spillway and into the river below. During periods of use, the existing outlet gates are also a potential source of exit for the outmigrants. They are located within a reachable depth but probably don't exhibit enough attraction to induce many fish to use the outlets for passage. A new gate located adjacent to the dam would likely attract more fish than the existing outlet gates.

Based on the need for a full pool to pass juvenile fish most successfully, it is recommended that the pool be refilled at the end of the flood control period or no later than April 1. This condition should be allowed to continue until natural inflows cause the reservoir elevations to drop. It is critical to design any new outlet gates and tunnels such that safe fish passage through that structure can be assured. In years of drought, the reservoir may refill slowly or not at all and increase the use of outlet gates for outmigration. Similarly, the potential for forecasting late flood events may cause the reservoir to remain evacuated, delaying refill and increase the use of outlet gates for outmigration.

4.6 UNET Hydraulic Model

To evaluate the potential effects of various flood control alternatives in reducing flood stages and corresponding damages in the Centralia-Chehalis floodplain, a baseline flood model was developed. The baseline flood model represents the existing conditions of the Upper Chehalis River Basin above the Porter gage including the recent completion of the Long Road Dike Project construction in February 2001. A complete discussion of the UNET hydraulic model developed for the Chehalis River can be found in Section 3.

The calibrated UNET model of the Chehalis River was modified to incorporate the levee alternative elements including levee segments along the Chehalis River, Skookumchuck River, Salzer Creek, and Dillenbaugh Creek, flood control boxes in Dillenbaugh Creek, and modifications to the hydrographs input to Reach 14 of the UNET model to represent the proposed flood control operations at Skookumchuck Dam. Eight flow events were modeled, ranging from the 2-year to the 500-year event.

4.7 Modification of UNET Model

4.7.1 Skookumchuck Dam Modification

Two options for Skookumchuck dam modification were examined for this alternative. Option 1 would provide flood control storage of approximately 11,000 ac-ft between pool elevation 455 and 477 feet. Option 2 would provide flood control storage of approximately 20,000 ac-ft between pool elevation 455 and 492 feet. Future reservoir operations based on these two options were simulated using a reservoir operations model. Output from the reservoir model (time-series of simulated discharge from the reservoir) was used as an input hydrograph to Reach 14 of the UNET model to represent reservoir discharge to the Skookumchuck River. The outflow hydrographs from the dam for the proposed reservoir operation scenarios were developed for eight flood events. For the flood events less than or equal to the 50-year flood, the outflow hydrographs would be the same for both options. For flood events larger than or equal to the 100-

year flood, the outflow hydrographs would be different for the two options (this suggests that flood storage in the reservoir above elevation 477 feet would only be utilized for flood events on the order of a 100-year flood event or larger). A detailed discussion of flood control operation can be found in Technical Report 2.

4.7.2 Levee Segments

Changes made to the UNET model to represent the proposed levee segments included modification of topographic information to represent the levee alignment and elimination of certain hydraulic connections between river reaches and off-channel storage areas. For instance, channel cross-sections depicted in UNET were modified where appropriate to represent the proposed levee system. The proposed levees were designed to reliably provide protection against the base 100-year flood level. Hydraulic connections modeled in UNET between river reaches and off-channel storage areas were eliminated as appropriate to simulate the proposed levee alignment. For instance, hydraulic connections in the model that allow the transfer of water between the Chehalis River and the Chehalis airport area under existing conditions were removed from the model since proposed levee segments around the airport are designed to prevent future flooding in this area.

4.7.3 Flood control boxes

Two flood control boxes were added at RM 0.623 and RM 0.064 of Dillenbaugh Creek. The flood control boxes were operated during the flood to prevent the city of Chehalis from being inundated.

4.8 Hydraulic Modeling Results

4.8.1 Alternative 4 only

Modeling of Alternative 4 indicates that most of the urban flooding in the vicinity of Chehalis and Centralia from the Chehalis River and its main tributaries (i.e., Skookumchuck River, Salzer and Dillenbaugh Creeks) would be eliminated under Alternative 4 during flood events up to at least a 100-year magnitude. Most of this benefit is derived from the proposed system of setback levees, which will protect Interstate 5 as well as much of the urban areas to the east of I-5 from flooding. Reduction of flooding from the Skookumchuck River would be limited to areas along the most downstream reach of the river where levees are proposed as part of this alternative. Peak stages and associated flooding along the Skookumchuck River upstream of the levees would be the same as under existing conditions.

Alternative 4 is expected to have little change to the peak stage within the Chehalis River and its tributaries relative to existing conditions because most of the proposed levees are setback significantly from the affected river channels. For instance, levees proposed along the Chehalis River floodplain will be limited to the right (east) bank of the river and will be setback from the existing banks sufficiently to have little impact to the active portion of the floodplain. As a result, active floodplain areas where most of the flood flow is typically conveyed during flood events will still function as they currently do under existing conditions. The primary function of the proposed levees will be to eliminate flooding of I-5 and primarily urban areas (mostly on the east side of I-5) that have historically functioned as backwater storage areas during flood events but have had very limited function in terms of providing downstream conveyance of flood flows. For instance, UNET modeling of Alternative 4 suggests a slight increase in the peak stage in the Chehalis River downstream of roughly RM 74 during a 100-year flood event, with a maximum increase of about 5 to 6 inches in the vicinity of RM 72 to 73. It should be noted that these potential stage increases are in addition to peak 100-year flood depths on the order of 5 to 10 feet or greater within this reach under existing conditions. Furthermore, these potential stage increases would be limited to floodplain areas that would not be protected by the proposed levees such that only a small number of homes would be affected.

The UNET modeling also suggests the potential for slight increases in peak flood stage in the Chehalis River downstream of the project area as a result of Alternative 4. However, projected increases in the 100-year peak stage are roughly one-tenth of a foot or less, which represents a stage increase that would be virtually undetectable and essentially insignificant when compared with peak stage and flood depths under existing conditions.

Along the lower four miles of the Skookumchuck River (vicinity of Centralia), peak flood stages would decrease in the range of 0.5 to about 1.5 feet relative to existing conditions during a 100-year flood event for the combination of Option 1 Skookumchuck reservoir flood control with Alternative 4. These estimated reductions in peak stage are attributable to proposed improvements to flood control operations at Skookumchuck reservoir.

4.8.2 Alternative 4 and Skookumchuck Dam Modifications

Two options of Skookumchuck Dam operation for flood control purposes were used in combination with Alternative 4. The addition of improved flood control operations at Skookumchuck dam has two primary benefits to Alternative 4. First, improved flood control operations at the dam would provide flood reduction benefits to the Skookumchuck River valley downstream of the dam. Second, while flood control operations at the dam would provide limited flood reduction benefit to the Chehalis River valley, there does appear to be a sufficient reduction in flood stage to offset any potential stage increases attributable to the proposed levee system.

For the combination of Option 1 Skookumchuck reservoir flood control with Alternative 4, the peak flood stage in the Chehalis River would decrease relative to existing conditions over most reaches. For instance, UNET modeling suggests slightly lower peak stages in the Chehalis River downstream of RM 71 relative to existing conditions. The peak flood stage in the Chehalis River would still increase slightly between RM 71 and RM 74 with a maximum increase of about 5 to 6 inches during a 100-year flood. As noted under Section 4.5.1, these potential stage increases are in addition to peak 100-year flood depths on the order of 5 to 10 feet or greater within this reach under existing conditions and would only affect a small number of homes within the floodplain that would not be protected by the proposed levees.

For the combination of Option 2 Skookumchuck reservoir flood control with Alternative 4, the peak flood stage in the Chehalis River would decrease relative to existing conditions over most reaches. UNET modeling suggests slightly lower peak stages in the Chehalis River downstream of RM 71 relative to existing conditions similar to the combination of Option 1 Skookumchuck reservoir flood control with Alternative 4. Similar to Option 1, the peak flood stage in the Chehalis River would still be increased slightly between RM 71 and RM 74 with a maximum increase of about 5 inches near RM 73. As noted above, these potential stage increases are in addition to peak 100-year flood depths on the order of 5 to 10 feet or greater within this reach under existing conditions and would only affect a small number of homes within the floodplain that would not be protected by the proposed levees.

Along the lower four miles of the Skookumchuck River (vicinity of Centralia), peak flood stages would decrease in the range of 0.5 to about 2.0 feet relative to existing conditions during a 100-year flood event for the combination of Option 2 Skookumchuck reservoir flood control with Alternative 4. These estimated reductions in peak stage during a 100-year flood event are slightly greater than the modeled stage reductions attributable to Option 1 Skookumchuck reservoir flood control operations. Estimated stage reductions in the Skookumchuck River in the vicinity of Centralia during flood events smaller than a 100-year event should be the same for either Option 1 or Option 2 flood control at Skookumchuck reservoir due to similar flood control operation.

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U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington
General Reevaluation Report

Appendix B:
Skookumchuck Dam Modifications

June 2003

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TABLE OF CONTENTS

Section/Paragraph **Page No. B-**

1. INTRODUCTION 1
2. EXISTING CONDITIONS 2
2.1 General 2
2.2 Probable Maximum Flood 3
2.3 Dam Safety Considerations 4
2.4 Reservoir Regulation Considerations 5
3. PREVIOUS CORPS OF ENGINEERS ALTERNATIVES 11
3.1 General 11
3.2 Spillway Modifications 11
3.3 Steel Crest Gate Alternative 12
3.4 Short Tunnel Concept 12
4. CURRENT ALTERNATIVES 13
4.1 Alternative 2B1 – Spillway Sluices 14
4.2 Alternative 2B2 – Short Tunnel with Slide Gates 15
4.3 Alternative 2B3 – Short Tunnel with Submerged Tainter Gate 16
4.4 Alternative 2B4 – Tainter Gates in Spillway Chute 17
5. COST ESTIMATES 19
6. REFERENCES 20

FIGURE & PLATES

Figure 1: Peak PMF Outflow and Reservoir Elevation 4
Plate S-1: Project Location and Vicinity Map 7
Plate S-2: General Plan 8
Plate S-3: Embankment As-built Sections 9
Plate S-4: Spillway – General Arrangement 10

ADDITIONAL PLATES (SHEETS S-5 THROUGH S-22)

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1. INTRODUCTION

This appendix summarizes the reconnaissance level analysis of modifications to the existing Skookumchuck Dam for the purpose of flood control. Modifications to Skookumchuck Dam are being considered as part of the Centralia, Washington, Flood Damage Reduction Project. The other potential elements and alternatives of the project are discussed in separate technical reports (not included here). The alternatives being studied for the project are listed below. Each alternative has its own corresponding technical report. A discussion of the hydraulic modeling used to evaluate the various project components and alternatives, including modifications to Skookumchuck Dam, is presented in Technical Report No. 8. A summary of the modeling results may also be found in the Hydrology and Hydraulics Appendix A to this GRR.

The Skookumchuck Dam modifications could provide flood control storage of 11,000 to 20,000 acre-feet (ac-ft), and could significantly reduce flood stages along the Skookumchuck River floodplain. For the U.S. Army Corps of Engineers (the Corps, USACE) developed synthetic 100-year hydrograph, peak flood stages would be reduced in the town of Bucoda by approximately 1.78 feet for the 11,000 ac-ft alternative, and 3.22 feet for the 20,000 ac-ft alternative when the dam modifications are combined with the Corps-recommended levee arrangement. In the town of Centralia, the peak flood stages would be reduced approximately 0.79 feet for the 11,000 ac-ft alternative, and 1.37 feet for the 20,000 ac-ft alternative.

The pre-feasibility analysis indicated that modifications to Skookumchuck Dam would provide the most cost effective flood control storage. In addition, modifications to Skookumchuck Dam would have the least environmental impact of all the storage dam alternatives previously considered. While modifications to Skookumchuck Dam do not result in significant flood stage reductions on the main stem of the Chehalis River, the dam is an essential component to the overall project. The flood control storage provided by the dam aids in reducing flood stages along the Skookumchuck River, as well as offsetting any increases caused by the flood reduction measures in the Centralia-Chehalis area.

2. EXISTING CONDITIONS

2.1 GENERAL

Skookumchuck Dam is located on the Skookumchuck River about 12 miles northeast of Centralia, Washington, at Skookumchuck river mile (RM) 21.9. (See Plate S-1 for a location map.) The dam was constructed in 1970 to supply cooling water to the coal-fired Centralia steam electric plant. The dam has a rolled earthfill central core, buttressed by an earth and rockfill shell. The structure is approximately 190 feet high, with the top of the dam at elevation 497 feet. All elevations referred to in this appendix are based on National Geodetic Vertical Datum (NGVD) 29 with the 1947 adjustment.

The dam has a 130-foot wide uncontrolled side-channel spillway in a rock cut on the left abutment. The spillway is a concrete ogee with a crest at elevation 477 feet. The spillway invert is at elevation 465 feet. Water passes over the ogee and spills into a 130-foot long by 40-foot wide concrete lined trough. Water then spills down a concrete lined chute. The chute is almost 600 feet long and has a bottom slope that varies from 17 percent to 25 percent. The spillway chute ends in a stilling basin that directs the discharge into a rock cut leading back to the natural river channel. Facilities are located adjacent to the stilling basin to trap migrating salmon and steelhead for truck transport over the dam. See Plates S-2, S-3 and S-4 for a plan and sections of the dam and spillway.

During low flow months, water released from storage travels downstream to a diversion pumping station at RM 7.3. From there water is pumped through a 3-mile pipeline to the steam electric plant. Under an agreement between the dam owner and state agencies, additional releases are made from the reservoir to supplement flows in the Skookumchuck River to improve fishery habitat.

Outflow from the reservoir is either over the spillway crest at elevation 477 feet, or through the outlet works. The existing outlet works consist of an inclined, multilevel intake structure that connects to the construction diversion tunnel and discharges through two 24-inch Howell-Bunger valves into the spillway stilling basin. The intake gates are set at elevations 449, 420, and 378 feet. The discharge capacity of the outlet works is approximately 220 cubic feet per second (cfs) when the pool elevation is at the spillway crest.

Storage behind the dam is essentially a fill-and-spill operation. The limited outlet capacity of the dam causes the reservoir to fill to the spillway crest at elevation 477 feet early in the flood runoff season. Once the reservoir is full, flood inflow to the reservoir passes over the un-gated spillway, which was originally designed for a discharge capacity of 28,000 cfs with the reservoir pool at elevation 492 feet.

Storage capacity of the reservoir between the normal minimum pool at elevation 400 feet and the spillway crest at elevation 477 feet is 38,700 ac-ft. Additional usable storage of

3,170 ac-ft is available between elevations 378 feet and 400 feet. Dead storage is approximately 1,420 ac-ft between elevations 378 and the base of the dam.

Preliminary investigations by the Corps indicated that flood control storage at Skookumchuck Dam could be feasible without jeopardizing the steam plant water supply. The Corps investigated several alternatives for modifications, which are presented in detail in the Corps' December 1982 and February 1992 reports (USACE 1982, 1992).

2.2 PROBABLE MAXIMUM FLOOD

The Probable Maximum Flood (PMF) is defined as the flood that could be expected to occur from the most severe combination of hydrometeorological conditions reasonably possible in the region. The existing spillway was originally designed to pass a peak PMF outflow of 28,000 cfs at a maximum reservoir pool elevation of 492 feet, with a freeboard of 5 feet to the top of the dam at elevation 497 feet. A PMF analysis was performed for this study to verify or revise the PMF value of 28,000 cfs used in the original design of the existing spillway. Bechtel Civil & Mineral, Inc., performed the original PMF analysis and spillway design in the late 1960s.

The revised PMF was derived by using the HEC-1 computer program applying a Clark's hourly unit hydrograph to the PMP plus snowmelt excess while accounting for base flow. The PMP was determined from HMR 57 (Hydrometeorological Report 57, *Probable Maximum Precipitation - Pacific Northwest States; National Weather Service; October 1994*) to be 24.73 inches for a 72-hour November-February general storm. December snowmelt was used as the December persisting dew points and realistic snow pack would produce the highest snowmelt during the PMP. Snowmelt during the PMP storm was computed to be 7.44 inches using procedures outlined in EM 1110-2-1406, "Runoff from Snowmelt". It was assumed that there would be a 75 percent availability of the computed snowmelt, or 5.58 inches of snowmelt during the December PMP. Precipitation was distributed based on pattern 'e' in HMR 57.

The Clark Unit Hydrograph parameters and basin losses were calibrated from an optimization study based on observed events of January 1972, January and November 1990, and February 1996 at the streamgage near Vail (upstream of Skookumchuck Dam). Unit hydrograph parameters derived for the Vail gage were transposed to the dam by adjusting for travel time and the ratio of Tc to the attenuation constant R. Loss rates were considered the same at the gage and the dam site. The exponential loss rate parameters and the Clark Unit Hydrograph parameters derived from the optimization studies were adjusted to reflect conditions associated with the larger PMF. Basin losses during the PMF were defined by a zero initial loss rate, assuming a saturated ground due to an antecedent storm, and a uniform loss rate of 0.05 inches per hour. The Clark Unit Hydrograph used in computing the PMF was specified by the Tc and R values of 5.02 and 7.52, respectively.

Base flow was estimated as the recession flow from a 100-year flood assumed to occur 3 days prior to the PMP storm. The estimated base flow had an initial value of 500 cfs and receded to approximately 30 cfs at 96 hours during the PMF. The spillway design flood (SDF) for the Skookumchuck Dam was determined by routing the PMF inflow through the reservoir and spillway. An initial reservoir elevation of 478 feet was used in routing the PMF through the reservoir based on antecedent flow conditions.

The results of analysis indicate that the PMF has a peak inflow of 32,500 cfs, a peak outflow from the current spillway of 30,600 cfs, and a mean 3-day inflow 15,000 cfs, or 89,500 ac-ft. The study also showed a maximum reservoir elevation of 492.68 feet, leaving a freeboard of 4.32 feet. These results indicate a higher PMF in comparison with the original spillway design PMF, which had a peak flow of 28,000 cfs. The original design PMF discharge, together with the calculated PMF discharge and reservoir elevations is shown in Figure 1. A study performed by Bechtel Civil & Mineral, Inc., for PacifiCorp in 1987 estimated a maximum reservoir wave run-up of 3.8 feet, 0.52-feet lower than the available freeboard of 4.32 feet during the PMF.

The Corps performed a preliminary review of the PMP and PMF calculations in January 2000, and an acceptance of the calculations was recommended. The new PMF was not routed through the various alternatives being considered for dam modification. The peak PMF outflow and peak reservoir pool level could change slightly depending on the spillway and outlet works modifications proposed. Additional analyses will need to be performed in the next phase of studies.

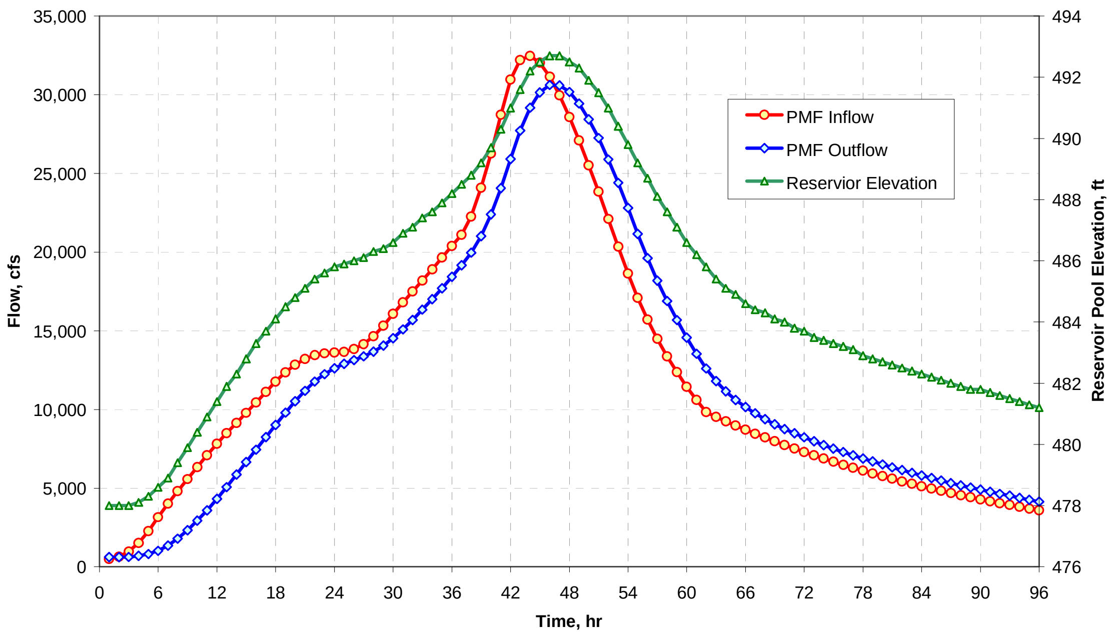


Figure 1: Peak PMF Outflow and Reservoir Elevation

2.3 Dam Safety Considerations

Any proposed modifications to Skookumchuck Dam must enable the project to safely pass the PMF at the maximum design pool. The dam embankment elevation must be sufficient to prevent overtopping during the PMF, while accounting for contingencies such as surcharge, wind wave run-up, and embankment settlement. The dam embankment currently has a top elevation of 497 feet. The current maximum design pool level is at elevation 492 feet, and the current estimated peak reservoir pool level during PMF is at elevation 492.68 feet. The 4.32 feet between the estimated maximum pool elevation and the top of the dam was considered to be adequate freeboard for this study. More detailed analyses should be performed in the next phase of the study to determine the appropriate freeboard for the structure.

PacifiCorp (formerly Pacific Power and Light, the dam operator) had a dam safety and seismic stability analysis performed on the dam in 1988, which the Corps later reviewed. The Corps determined that, with the new operation for flood control, the embankment would suffer distress during the design earthquake, but would not fail and did not require any modification (USACE 1992). More recently, PacifiCorp had a FERC (Federal Energy Regulatory Commission) Part 12 dam safety inspection performed in 1996. Stability analyses were performed for normal operating conditions, PMF, rapid drawdown, and seismic loading conditions. The embankment dam, spillway and all other structures were found to be safe for all cases investigated (Black and Veatch 1996).

Due to uncertainties about the nature of the foundation materials and properties, the Corps of Engineers, PacifiCorp, and the FERC are currently reviewing foundation liquefaction and stability. The proposed changes to the reservoir operation for flood control will be taken into account as part of the study.

Other issues related to dam safety and operation could be any potential problems with debris or sediment. In discussions with the dam operating personnel, it was determined that there have not been any significant problems related to either sediment or debris in the operation of the spillway or outlet works. Additional investigations may need to be performed in the next phase of studies.

2.4 Reservoir Regulation Considerations

The Corps developed a preliminary flood control operation rule curve as part of its flood control operations investigation (USACE 1992). The Corps' rule curve provided flood control storage of approximately 11,900 ac-ft between elevations 453 and 477 feet, from November 1 to February 1. After February 1, the reservoir would be allowed to refill. Drawdown of the reservoir would begin each year in early to mid September and would continue until elevation 453 feet was reached, usually around the first of November.

The Corps performed a water supply study of the Skookumchuck reservoir as part of its investigation to determine if sufficient storage would be available to meet water supply and minimum instream flow requirements for fisheries and power diversion with storage operations for flood control (USACE 1992). The Corps assumed that PacifiCorp would divert its entire 81 cfs water right, and determined that minimum instream flow and water supply requirements could be met in all years with the Corps-proposed flood control operation rule curve. The steam plant currently uses only up to 54 cfs for the two existing steam turbine units.

The flood control operation rule curve must also ensure releases in accordance with the existing fishery flow agreement. The agreement between PacifiCorp and Washington Department of Fish and Wildlife (WDFW) provides a minimum instream flow of 140 cfs from September 10 to October 31 for salmon spawning. Incubation flows begin on November 1, or at the completion of spawning, as determined by WDFW. A minimum of 95 cfs is supplied until March 31. From

April 1 through August 31 rearing flows are set at a maximum of 95 cfs, or natural river flow plus 50 cfs, whichever is less. Rearing flows may be adjusted downward as determined by WDFW to preserve water for use during the spawning period. The instream flow agreement also provides for instream water temperatures of 50° to 55° F. These temperatures must be maintained, to the maximum extent possible, depending on reservoir and climatic conditions.

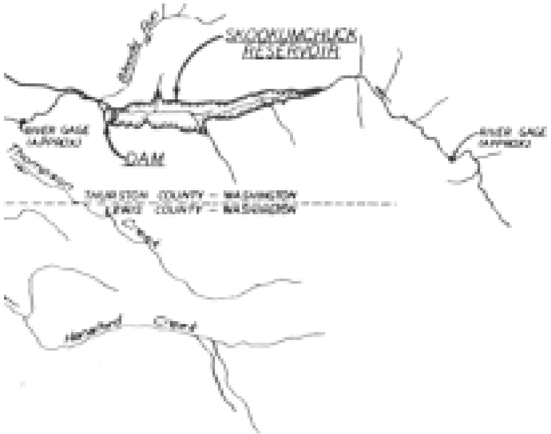
Flood regulation at the Skookumchuck Reservoir would seek to maintain the 4,900 cfs control flow at the Pearl Street Bridge in Centralia. Discharge would be reduced in increments of not more than 500 cfs per hour to a minimum flow of 95 cfs. Inflow would be stored until the routed releases plus local inflows do not exceed control flows and the possibility of adding to the Chehalis River peak has passed.

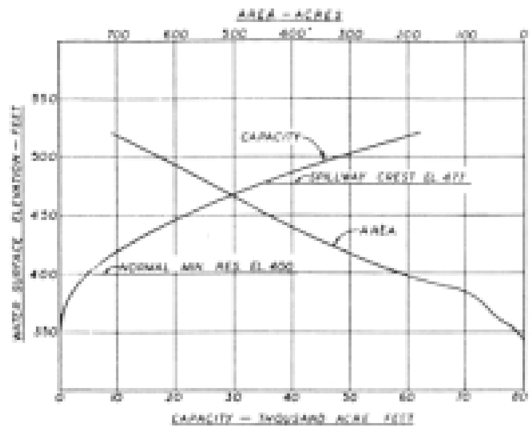
Reservoir evacuation should take place as soon as possible to provide storage for subsequent storm events. The reservoir would be evacuated by releasing outflows that, combined with local inflows, yield near control-flow levels. The evacuation releases would be greatly reduced as the minimum flood control level is approached.

Reservoir evacuation after a large storm would take 3 to 5 days. Consequently, a maximum outflow of 4,000 cfs may be achieved while maintaining river flows below control levels. Although a maximum discharge of 4,000 cfs may be desirable to minimize evacuation time, a discharge as low as 3,000 cfs would still meet evacuation requirements. A 3,000 cfs outlet capacity conforms to the guidelines in ER 1110-2-50 for establishing minimum reservoir outlet capacity for drawdown of lakes impounded by civil works projects. A low pool discharge capacity of at least 3,000 cfs would be required to evacuate Skookumchuck Reservoir from elevation 492 feet within five days.

A 3,000-cfs outlet capacity at minimum reservoir pool was used in the earlier Corps study, and was assumed for the purposes of this study. The minimum reservoir pool was assumed to be at elevation 455 feet. It has also been assumed that low flow releases would continue to be made through the existing outlet works consisting of the multi-level intake and two 24-inch Howell-Bunger valves. The hydraulic design of the flood control outlet works, and the flood control regulation rule curves will need to be refined and finalized in the next phase of studies. In addition to hydraulic and engineering considerations, any downstream environmental effects related to reservoir operation and flood control regulation will need to be considered.

The dam modifications currently being proposed could provide, approximately, an additional 9,000 ac-ft of storage between pool elevation 477 and 492 feet. This additional storage could potentially be available to augment summer low flows downstream if it were determined that this would be environmentally beneficial. This would, however, require a change in the current reservoir conservation pool level and is not being proposed at this time for the flood reduction project. If this action were to be pursued in the future, any potential environmental impacts and dam safety issues associated with a higher conservation pool would need to be addressed.

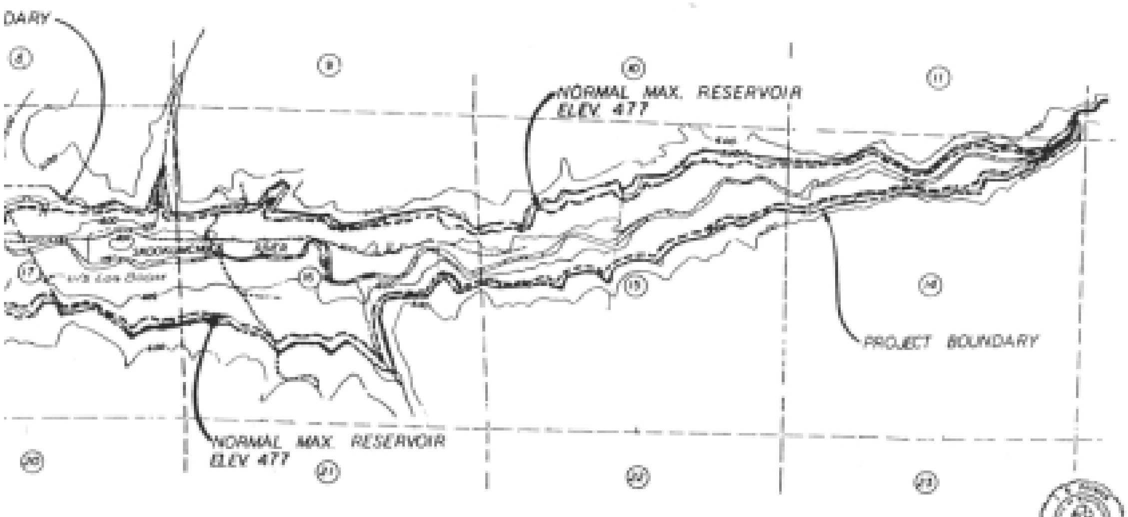




RESERVOIR AREA-CAPACITY CURVES

NOTES

1. Reservoir and Site Topography based on Topographic Maps prepared by H.G. Chickering Jr. by aerial photogrammetry in 1967.
2. Horizontal Datum, Washington Coordinate System (South Zone)
3. Vertical Datum, U.S. Coast & Geodetic Survey, North American 1947 Adjustment



UMCHUCK RESERVOIR AND PROJECT BOUNDARY

1 IN = 1 MILE

1 IN = 1000 FT

As Built

ISSUED FOR CONSTRUCTION

ISSUED FOR PREPARATION OF PROPOSALS

BECHTEL CORPORATION

SAN FRANCISCO

PACIFIC POWER & LIGHT COMPANY

and

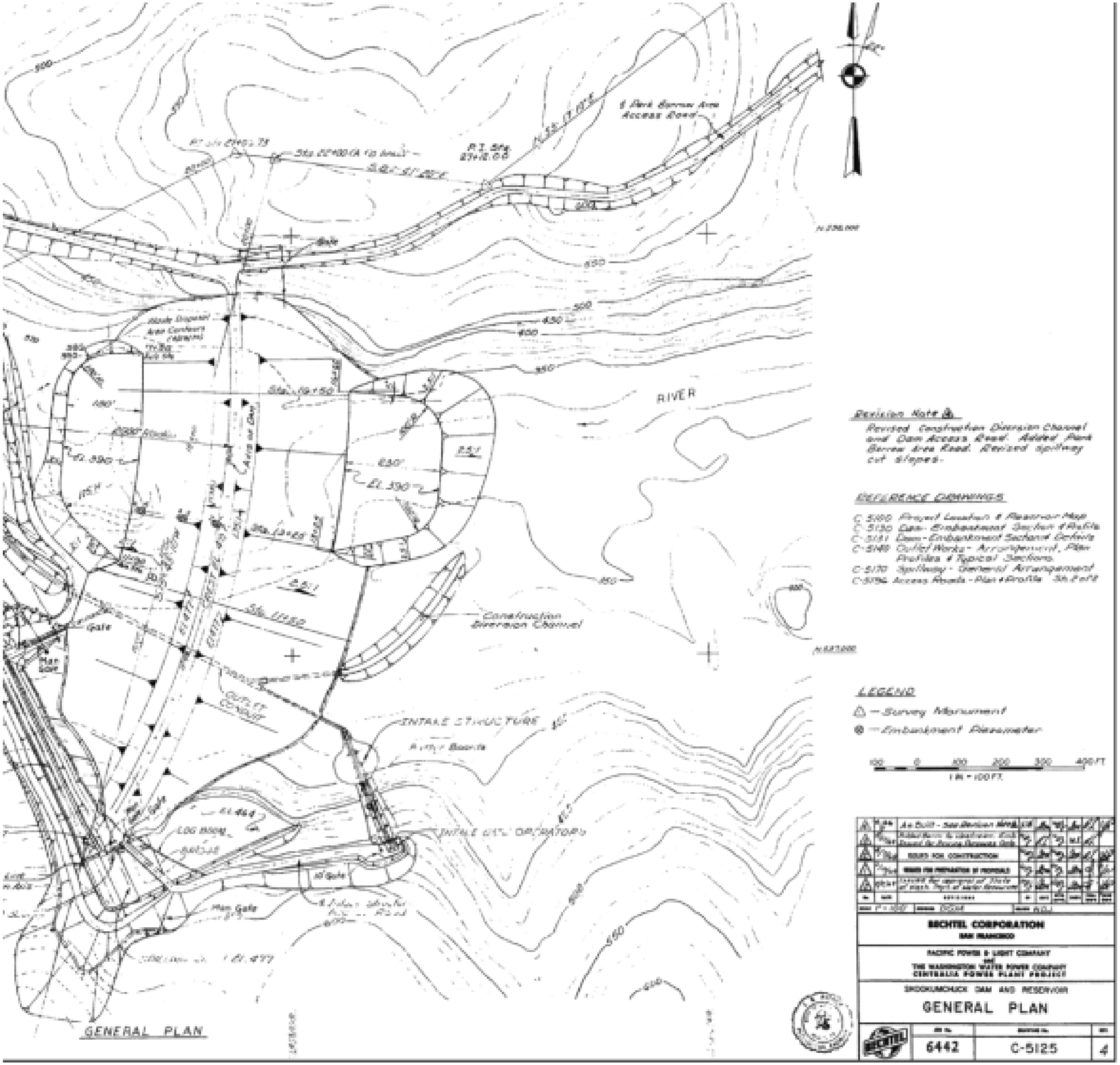
THE WASHINGTON WATER POWER COMPANY

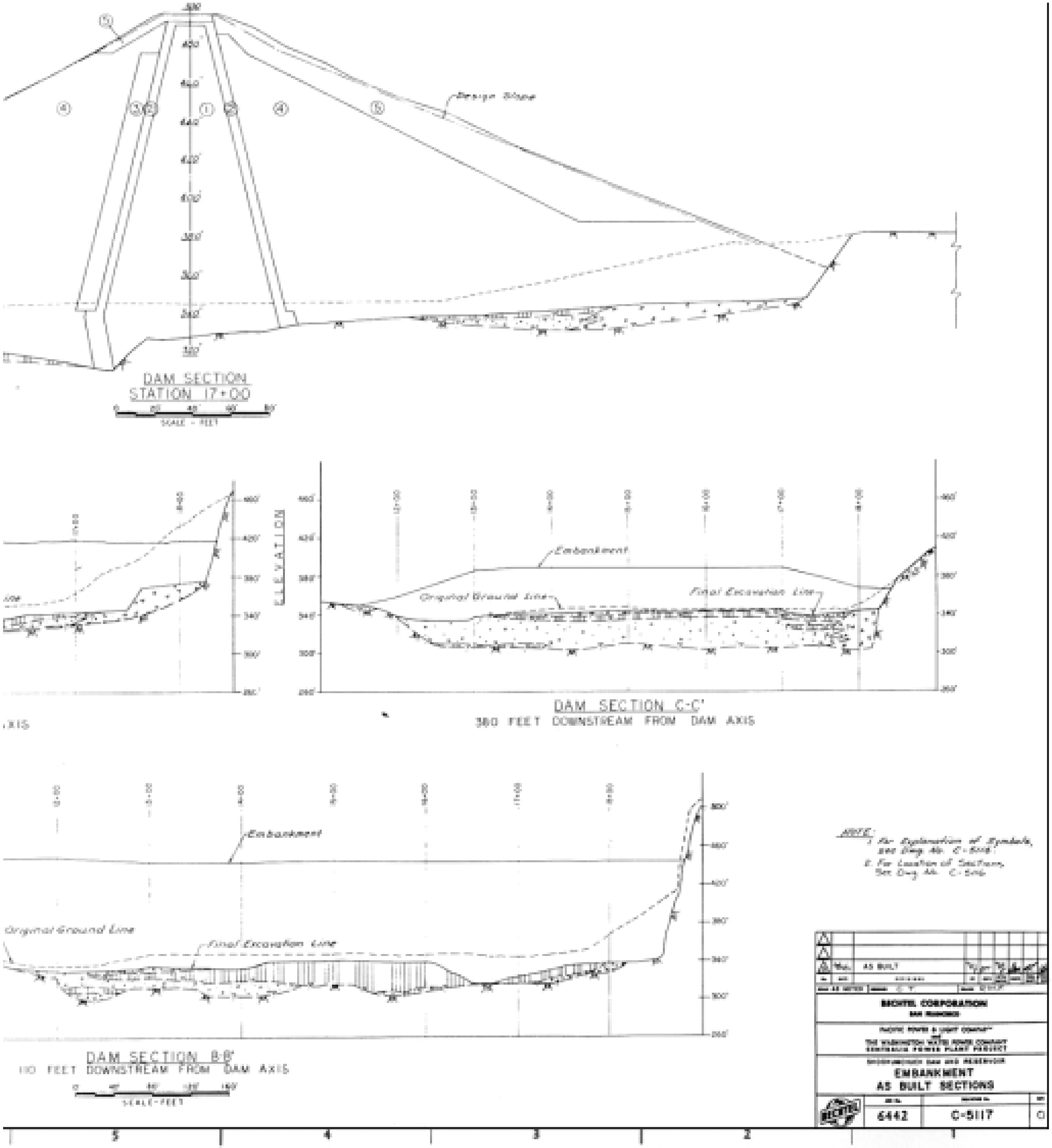
CENTRALIA POWER PLANT PROJECT

SKOOKUMCHUCK DAM AND RESERVOIR

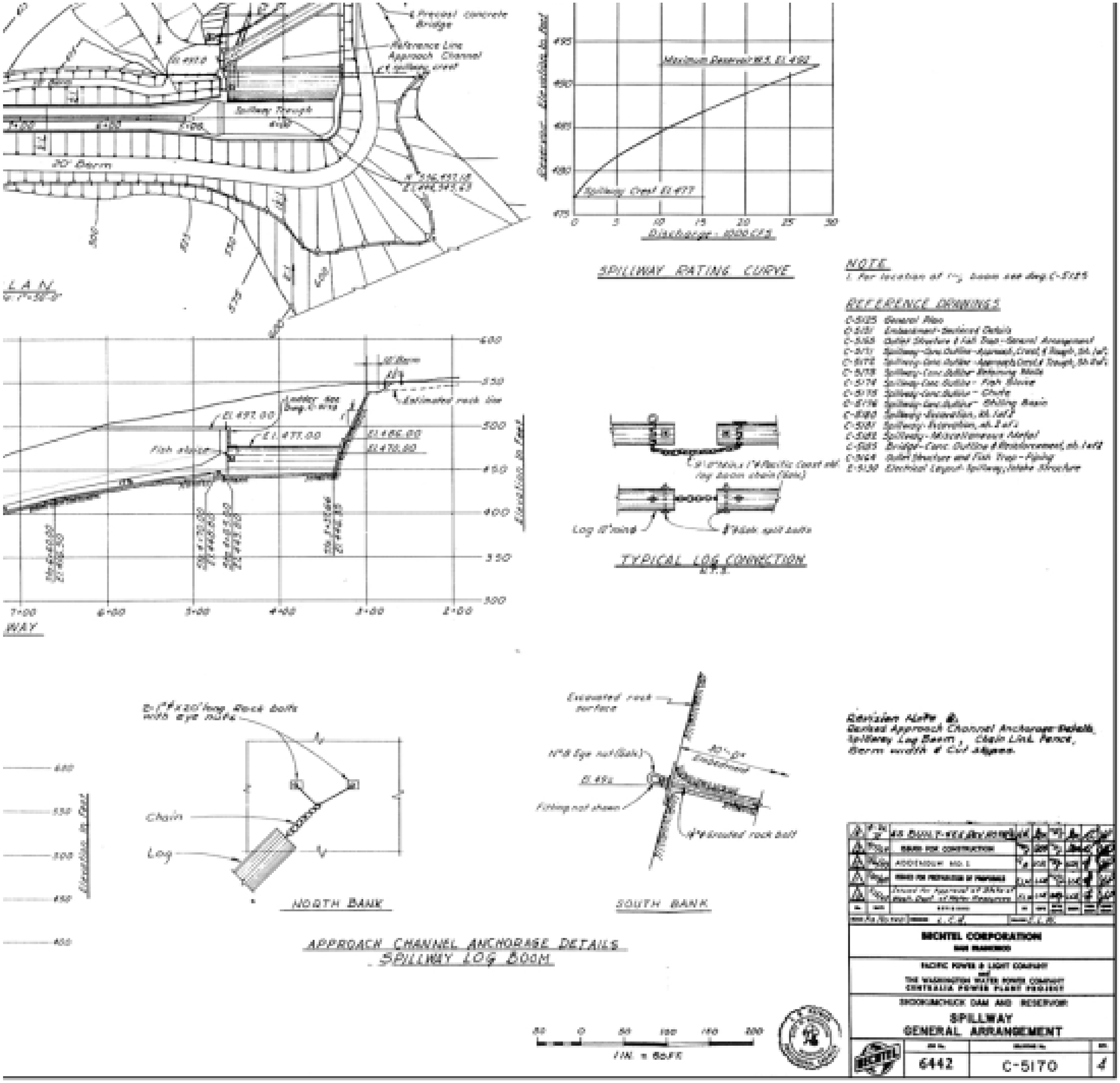
PROJECT LOCATION AND RESERVOIR MAP

6442	C-5100


RIVER
Construction Diversion Channel
INTAKE STRUCTURE
INTAKE GATE OPERATOR
OUTLET CONDUIT
LOG BOOM
Gate
Revision Note
Revised Construction Diversion Channel and Dam Access Road. Added Park Borrow Area Road. Revised spillway cut slopes.
REFERENCE DRAWINGS
C-5100 Project Location & Reservoir Map
C-5130 Dam-Embankment Section & Profile
C-5131 Dam-Embankment Sections & Details
C-5140 Outlet Works - Arrangement, Plan Profiles & Typical Sections
C-5170 Spillway - General Arrangement
C-5194 Access Roads - Plan & Profile Sh. 1 of 2
LEGEND
— Survey Monument
— Embankment Piezometer
100 0 100 200 300 400 FT
1 IN = 100 FT
ISSUED FOR CONSTRUCTION
BECHTEL CORPORATION
SAN FRANCISCO
PACIFIC POWER & LIGHT COMPANY
and
THE WASHINGTON WATER POWER COMPANY
CENTRALIA POWER PLANT PROJECT
SKOOKUMCHUCK DAM AND RESERVOIR
GENERAL PLAN
6442
C-5125
4
GENERAL PLAN



Design Slope
DAM SECTION
STATION 17+00
SCALE - FEET
Embankment
Original Ground Line
Final Excavation Line
ELEVATION
DAM SECTION C-C'
380 FEET DOWNSTREAM FROM DAM AXIS
Embankment
Original Ground Line
Final Excavation Line
DAM SECTION B-B'
110 FEET DOWNSTREAM FROM DAM AXIS
SCALE-FEET
NOTE:
1. For Explanation of Symbols, see Dwg. No. C-5116.
2. For Location of Sections, See Dwg. No. C-5116.
AS BUILT
BECHTEL CORPORATION
SAN FRANCISCO
PACIFIC POWER & LIGHT COMPANY
and
THE WASHINGTON WATER POWER COMPANY
CENTRALIA POWER PLANT PROJECT
EMBANKMENT
AS BUILT SECTIONS
6442
C-5117
0



Precast Concrete Bridge
Reference Line Approach Channel
Spillway Trough
20' Berm
Maximum Reservoir W.S. El. 492
Spillway Crest El. 477
Discharge - 1000 CFS
SPILLWAY RATING CURVE
NOTE
1. For location of log boom see dwg C-5125
REFERENCE DRAWINGS
C-5125 General Plan
C-5131 Embankment-Sectional Details
C-5165 Outlet Structure & Fish Trap-General Arrangement
C-5174 Spillway-Conc. Outline- Fish Sluice
C-5175 Spillway-Conc. Outline - Chute
C-5176 Spillway-Conc. Outline - Stilling Basin
C-5182 Spillway - Miscellaneous Metal
C-5164 Outlet Structure and Fish Trap - Piping
El. 497.00
El. 477.00
El. 486.00
El. 470.00
Fish sluice
Estimated rock line
Elevation in Feet
7+00
6+00
5+00
4+00
3+00
2+00
WAY
Log 18" min.
TYPICAL LOG CONNECTION
Chain
Log
NORTH BANK
Excavated rock surface
Fitting not shown
SOUTH BANK
APPROACH CHANNEL ANCHORAGE DETAILS
SPILLWAY LOG BOOM
Revision Note 4.
Revised Approach Channel Anchorage Details, Spillway Log Boom, Chain Link Fence, Berm width & Cut slopes.
ISSUED FOR CONSTRUCTION
ADDENDUM NO. 1
BECHTEL CORPORATION
PACIFIC POWER & LIGHT COMPANY
and
THE WASHINGTON WATER POWER COMPANY
CENTRALIA POWER PLANT PROJECT
SKOOKUMCHUCK DAM AND RESERVOIR
SPILLWAY
GENERAL ARRANGEMENT
6442
C-5170
4
1 IN. = 80 FT.

3. PREVIOUS CORPS OF ENGINEERS ALTERNATIVES

3.1 GENERAL

Studies in the early 1980s by the Corps of Engineers proposed modifications to Skookumchuck Dam to provide flood control and regulation. The initial proposal suggested a separate intake tower with an open-channel tunnel in the right abutment along with addition of a 12-foot high steel bascule gate on the existing uncontrolled spillway. Further studies recommended deletion of the spillway gate due to reliability concerns of gate operation during floods. The additional studies also suggested that modifications of the existing spillway to permit reservoir drawdown and withdrawal capability were more cost effective than construction of the right abutment tunnel.

3.2 SPILLWAY MODIFICATIONS

The Corps' alternative incorporated two 10-foot high by 12-foot wide hydraulically operated slide gates into the existing spillway. An approximately 25-foot width of the existing spillway would be removed down to elevation 440 feet and reconstructed to incorporate the two slide gates. The gates were sized to discharge 3,000 cfs at a pool elevation of 452 feet with critical depth control (8 feet) at the gate entrance. The gates would be regulated to discharge no more than 3,000 cfs for pool elevations between 453 feet and 477 feet. The gates would be completely closed at pool elevations of 480 feet and greater, at which time all flow would pass over the existing uncontrolled spillway. Gate operating equipment would be enclosed in a cavity within the ogee crest. The exact location of the sluice along the existing spillway was not finalized.

The existing spillway chute and trough would be lowered approximately 10 feet in order to prevent a flow control shift from the gated entrances to the chute. The chute entrance would be lowered to elevation 438 feet and would have a width of 35 feet. With this geometry, the control would remain at the gates. The tailwater depth at the slide gates, for a discharge of 3,000 cfs, would be approximately 7 feet, which is 1 foot below the critical depth control at the gate.

From the chute entrance, the chute would slope at about 12 percent to meet the existing chute invert in a distance of about 200 feet. The chute walls are concrete lined 7 to 13 feet vertically above the invert, with excavated rock side slopes above the concrete lining. The chute lining was originally designed to be sufficient to contain a discharge of about 10,000 cfs, which corresponds to approximately the 100-year flood peak discharge. The Corps proposed extending the concrete lining 4 to 13 vertical feet to fully contain the PMF. The spillway chute appears to have more than adequate freeboard to contain the PMF.

The construction cost of this alternative was estimated to be approximately $5,748,000 in 1989. The total project cost, including engineering and construction management, was estimated to be $11,928,000. Escalated to 2002 price levels, using the ENR construction cost index, results in a total project cost of approximately $16,818,480.

The Corps initially considered locating the outlets works on the right abutment. The scheme involved a freestanding tower intake and open channel tunnel through the right abutment. A couple of tunnel alignments were investigated, along with placing the tunnel control at the upstream, mid-tunnel, and downstream. In all cases, the alternatives proved to be very costly.

In an effort to minimize costs, the Corps developed other outlet works arrangements: Modified Spillway With Gate in Slot, Modified Spillway With Spillway Sluice, and Short Spillway Tunnel. The first of these alternatives involved cutting a 37-foot deep by 24-foot high slot in the existing spillway, and providing a gate in the slot. This alternative was dropped by the Corps over concerns about gate vibration during operation, potential debris problems, and maintenance and repair of the submerged gate.

3.3 STEEL CREST GATE ALTERNATIVE

As mentioned previously, the Corps considered installing a steel bascule gate on the existing spillway crest. As a general policy, the Corps does not recommend the use of spillway crest gates for dams that control flows from small drainage basins, which have short times of concentration during flood. The concern is that dam operation personnel would not be able to respond quickly enough during flash flood events. This is much more of a concern in portions of the country where thunderstorms and flash floods are common. In practice, there are a number of dams with spillway gates in the Northwest that are in small basins and that are operated successfully by the Corps or others.

This was reviewed again briefly in the previous study to determine the approximate current cost of a steel gate structure. From the USACE 1982 report, the cost for just the steel bascule gate and operating equipment was estimated to be $2,330,000 (Oct. 1982 prices). Using the ENR construction cost index, the current cost of a steel bascule gate would be approximately $3,975950. In addition to the high costs, there were concerns about debris preventing full closure or opening of the gate, and potential interference problems with the spillway sluice gate outlet works alternative. Other forms of steel gates, such as radial gates, were not examined due to the need for placement of intermediate piers, which would require a significant spillway expansion to accommodate.

3.4 SHORT TUNNEL CONCEPT

In an attempt to minimize costs, the concept of a short tunnel located between the spillway and dam embankment was briefly evaluated by the Corps. The concept included an intake tower located in the spillway approach channel with an approximately 165-foot long tunnel exiting into the right wall of the existing spillway chute. This concept appeared to be the least costly; however, it was still not deemed cost effective, and it presented numerous technical concerns. The construction cost of this alternative was estimated to be approximately $3,779,000 in 1989. The total project cost, including engineering and construction management, was estimated to be $9,959,000. Escalated to 2002 price levels, using the ENR construction cost index, results in a total project cost of approximately $14,042,190. This concept was updated and reevaluated as Alternative 2B2.

4. CURRENT ALTERNATIVES

Four basic alternatives are currently being studied. They are:

1. Alternative 2B1 – Spillway Sluices

2. Alternative 2B2 – Short Tunnel with Slide Gates

3. Alternative 2B3 – Short Tunnel with Submerged Tainter Gate

4. Alternative 2B4 – Tainter Gates in Spillway Chute

These alternatives were chosen by the Corps and were based on the previous studies by the Corps and P.I. Engineering. The following sections describe each of the alternatives in greater detail. Initially, each alternative was developed for a flood control pool having a minimum elevation of 455 feet and a maximum elevation of 492 feet. This flood storage pool elevation would provide approximately 20,000 ac-ft of flood control storage.

After the initial analysis, it was decided to also look at a couple options for a flood storage pool at elevation 477 feet. This is the elevation of the existing spillway crest. This flood storage pool elevation would provide approximately 11,000 ac-ft of flood control storage. This option was looked at for Alternatives 2B1 and 2B2. It was not looked at for Alternative 2B3, since that alternative is so similar to 2B2. It was also not considered for Alternative 2B4 since the outlet structure for this alternative is sized to convey the entire PMF outflow from the dam and a lower flood control pool level would not affect the design of this alternative. It has also been assumed that low flow releases would continue to be made through the existing outlet works consisting of the multi-level intake and two 24-inch Howell-Bunger valves.

A 3,000 cfs capacity at minimum reservoir pool was used for the preliminary sizing of each of the outlet works. The Bernoulli energy equation, as well as the standard equations for flow over a weir and through a gate, was used in the sizing of the project features. A detailed numerical analysis has not been performed for this phase of the studies.

Additional studies that would need to be performed in the next phase of studies would include the following:

- Detailed numerical analysis of the spillway, chute, and outlet works.
- Structural design of outlet works and spillway and chute modifications.
- Development of flood control regulation rule curves.
- Evaluation of any downstream environmental effects related to reservoir operation and flood control regulation.
- Evaluation of reservoir sedimentation and bank stability.
- Assessment of potential downstream scour and bank erosion.
- Determination of freeboard requirements.

- Assessment of downstream fish passage.
- Evaluation of cavitation potential.

4.1 Alternative 2B1 – Spillway Sluices

This alternative would involve excavating out a portion of the existing ogee spillway and installing sluice gates. The spillway approach channel would be excavated down to accommodate the new sluice gates, and the spillway chute entrance would be lowered and widened to allow the passage of the new PMF flow. For the high flood storage pool option, an inflatable rubber weir would be installed on top of the ogee spillway.

A section of the existing ogee spillway would be removed and a new spillway section containing three gated sluices would be constructed. The three sluice gates would each be approximately 10 feet wide and 10 feet high. Bulkhead slots would be provided upstream of the gates to allow for dewatering of the gates for maintenance and repair. Plates S-5, S-6, and S-7 show a conceptual plan and sections for the 20,000 ac-ft option.

The existing spillway approach channel is excavated in rock to an invert elevation of 464 feet. A trapezoidal-shaped channel, approximately 250 feet long, would be excavated within the existing spillway approach channel. The hydraulic efficiency of the spillway structure would be affected slightly by the lowering of the spillway approach channel, but it was assumed in the design of this alternative that the effects would be negligible. The new sluiceway approach channel would have a bottom width of about 40 feet, an invert elevation of approximately 442 feet, and 1 horizontal (H) on 4 vertical (V) sloping sides. Approximately 10,500 cubic yards of rock would need to be excavated to construct the channel.

The existing spillway chute is located in a rock excavation on the left abutment. The chute bottom converges from a width of 40 feet to 25 feet and has 1H on 4V side slopes. The walls are concrete lined 7 to 13 feet vertically above the invert, with excavated rock side slopes above the concrete lining. In order to pass the full PMF flow, the chute entrance would have to be lowered approximately two feet and widened approximately five feet.

The discharge capacity of the existing uncontrolled spillway is approximately 28,000 cfs at the maximum design pool elevation. However, in a PMF discharge event of 32,500 cfs, the existing spillway crest would be submerged by water backing up from the spillway chute entrance. By lowering and widening the spillway chute entrance, hydraulic control would remain at the gates

The three spillway sluice gates would have a total capacity to pass approximately 9,062 cfs at a reservoir pool elevation of 492 feet. For flood flows greater than the 9,062 cfs, the rubber weir would be very gradually deflated, and flows allowed to pass over the spillway crest. The deflation sequence would be carefully designed to ensure that downstream ramping rates are not exceeded. In the completely deflated position, the full PMF flow would be able to pass over the spillway crest.

A 15-foot high by 130-foot wide inflatable rubber weir would be added to the existing spillway crest for the 20,000 ac-ft option. Inflatable rubber weirs have been used very successfully in North America, Europe, and Asia. The weir consists of a heavy-duty, reinforced rubber body that is anchored to a concrete foundation and inflated with air. The height of the weir can be varied by adjustments of the pressure within the tube. If necessary, the weir can be deflated to allow for unrestricted flow of water over the spillway. Controlled deflation of the weir is by a manual system that is backed up by one or two automatic systems. The automatic systems are by a simple float or bucket system that does not require electricity to operate. The rubber dam inflation and deflation mechanism is very simple in design, with a minimum of moving parts. This provides high reliability, minimizing the possibility of any mechanical malfunctions. The flexible structure of the rubber dam also virtually eliminates the influence of any downstream debris or sediment, allowing the dam to be deflated.

During the PMF discharge, the water surface in the chute would overtop the current concrete lined portion of the walls, but would still be contained within the excavated rock channel. This rock material has been identified as being highly fractured and susceptible to freeze-thaw damage. In order to protect the rock portion of the chute, the rock slopes would probably be lined with shotcrete up to the new PMF water surface profile. The invert of the plunge pool below the spillway ogee crest would also be excavated out and lowered to make room for the new spillway sluices.

For the 11,000 ac-ft option with the flood control storage pool at elevation 477 feet, the rubber weir on top of the spillway crest would be omitted. For this option, the three spillway sluice gates would have a total capacity to pass approximately 7,100 cfs at a reservoir pool elevation of 477 feet. For flood flows greater than the 7,100 cfs, flows would start to pass over the uncontrolled spillway crest. Plates S-8, S-9 and S-10 show the plan and section for the 11,000 ac-ft option.

4.2 Alternative 2B2 – Short Tunnel with Slide Gates

This alternative would consist of constructing a short outlet works tunnel in the left abutment of the dam between the existing spillway and dam crest. An outlets works tower with slide gates would be built at the entrance to the new tunnel. The tunnel would discharge into the existing spillway chute, which would be modified to handle the full PMF flow. For the high flood storage pool option, three steel tainter gates would be added to the top of the existing ogee spillway. Plates S-11, S-12, S-13 and S-14 show a conceptual plan and sections for the high flood storage pool option, and Plates S-15, S-16, S-17 and S-18 show a conceptual plan and sections for the low flood storage pool option.

The Corps of Engineers originally developed this alternative in an attempt to avoid some of the high cost items associated with the spillway sluice design. This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a short tunnel constructed in the rock forming the left abutment of the embankment dam. The intake would have two 8-foot by 11-foot slide gates. Flow would discharge through the tunnel into the existing spillway chute. The outlet tunnel and spillway chute confluence will be a very complex feature to hydraulically design and analyze and a physical model investigation may be required in the final design phase.

Due to concerns that the left abutment rock may be highly weathered or fractured, and thus not very suitable for tunneling, it was assumed that the tunnel would be constructed as a cut and cover structure. A trench would be cut down in stages, with rock anchors being placed prior to the next excavation cut. A cast-in-place concrete tunnel would then be constructed at the bottom of the trench. Approximately 12,600 cubic yards of rock would have to be excavated for the tunnel construction. Concrete walls would be constructed at both the upstream and downstream ends of the trench, and the space between backfilled. New grout curtain holes would be drilled to prevent the flow of water through the dam embankment.

The intake structure would be a freestanding tower with an invert elevation of 438 feet, and a top deck at elevation 497 feet. For purposes of the cost estimate, it was assumed that the tower would be cast-in-place concrete, and a precast concrete bridge would provide access. The tower would be approximately 28 by 30 feet in plan, and would contain the two control gates, two guard gates, and all the necessary hydraulic control equipment. An inclined trashrack would be provided at the tunnel entrance, as would bulkhead slots.

The existing uncontrolled overflow spillway would be modified for the 20,000 ac-ft option. A few different options were considered for providing spillway crest control including an inflatable rubber weir and steel bascule gate. For purposes of costs and preliminary engineering, it was decided to go with steel tainter gates. There would be three steel tainter gates approximately 39.3 feet wide and 15 feet tall on the spillway crest with two concrete piers between. An access bridge would be constructed over the top of the gates and piers. This gate arrangement would likely be more expensive than an inflatable rubber crest weir, but would be considered a more traditional design. The exact arrangement for the spillway crest control will be examined more closely in a later design stage.

The outlet tunnel would be designed to discharge up to approximately 8,000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway. The overflow spillway would have a total capacity of approximately 25,500 cfs.

For the 11,000 ac-ft option, the existing overflow spillway would remain as it is with no control gates. For this case, the overflow spillway would have a total capacity of approximately 28,000 cfs. In order for the spillway to pass the full PMF flow of 32,500 cfs, the spillway chute entrance would have to be modified as was assumed in Alternative 2B1.

4.3 ALTERNATIVE 2B3 – SHORT TUNNEL WITH SUBMERGED TAINTER GATE

This alternative is similar to Alternative 2B2 described above. This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a channel constructed in the rock forming the left abutment of the dam. The intake would have a single 16-foot wide by 15-foot high submerged tainter gate. Flow would discharge through the channel into the existing spillway chute. An inflatable rubber weir would be added to the existing ogee spillway. No low flood storage pool options were investigated for this alternative. Plates S-19, S-20, S-21 and S-22 show a conceptual plan and sections.

As in Alternative 2B2, the outlet channel would be cut down in stages, with rock anchors being placed prior to the next excavation cut. A cast-in-place concrete lining would then be constructed. Shotcrete could be used above the estimated water line. Approximately 12,600 cubic yards of rock would have to be excavated for the channel construction. A bridge structure would be incorporated to allow vehicles to pass over the outlet channel. New grout curtain holes would be drilled to prevent the flow of water through the dam embankment.

The intake structure would be a freestanding tower with an invert elevation of 438 feet, and a top deck at elevation 497 feet. For purposes of the cost estimate, it was assumed that the tower would be cast-in-place concrete, and a precast concrete bridge would provide access. The tower would be approximately 20 by 45 feet in plan, and would contain the submerged tainter gate, and all the necessary hydraulic control equipment. An inclined trashrack would be provided at the tunnel entrance, as would bulkhead slots.

The existing uncontrolled overflow spillway would be modified, and a 15-foot high inflatable rubber weir would be constructed on top. The outlet channel would be designed to discharge up to 8,000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway. In order for the spillway to pass the full PMF flow of 32,500 cfs, the spillway chute entrance would have to be modified as was assumed in Alternative 2B1.

4.4 Alternative 2B4 – Tainter Gates in Spillway Chute

This alternative would involve constructing a new outlet works tower at the top of the existing spillway chute. Two large steel tainter gates would control flow through the outlet works tower. The existing concrete ogee spillway would be removed, and the spillway approach channel would be lowered to accommodate the outlet works. This alternative was not analyzed further; therefore no drawings are included.

A concrete control structure would be constructed at the top of the existing spillway discharge chute (SDC). Plan dimensions of the structure would be approximately 64 feet wide by 94 feet long. The height of the structure would vary from a top elevation of 497 feet at the spillway crest (Station 0+00) to elevation 403 feet at the downstream toe of the structure (Station 0+80). A 14-foot wide concrete center pier and 8-foot wide concrete side abutments would house twin welded steel tainter gates and gate hoisting machinery. Each tainter gate would be approximately 54 feet high by 17 feet wide. Slots would be provided immediately upstream of the gates for inserting emergency stoplogs. A new concrete overflow spillway would be constructed transverse to the SDC centerline with ogee crest at elevation 443 feet. A new low flow outlet pipe would be installed through the new spillway ogee and the center pier to provide fish passage. Fish would enter the pipe at the upstream sill of the new spillway at elevation 430 feet and exit into the invert of the new SDC low flow notch at the downstream end of the new control structure at elevation 403 feet.

The existing trapezoidal-shaped SDC is currently incapable of handling the revised PMF of 32,500 cfs. The 285-foot long upstream portion of the existing SDC would be demolished and replaced with the new 95-foot long control structure and a new 190-foot long SDC transitioning from rectangular at Station 0+80 to trapezoidal at Station 2+70. Both reinforced concrete sidewalls of the existing SDC would have to be extended at least 5 feet for the remaining 1,200 lineal feet to the exit into the Skookumchuck River.

The existing concrete overflow spillway has an ogee crest at elevation 477 feet and is located just south of the low flow intake access bridge and just north of and parallel to the SDC. The majority of this spillway would be demolished and a new curved intake channel would be excavated in the existing bedrock for a distance of approximately 440 feet upstream of the new spillway. The width of the new channel including side slopes would vary from 95 feet wide at the new spillway crest to 70 feet wide at the upstream end of the channel. Since the new excavation would undermine the center pier of the existing access bridge to the low flow intake, the pier bottom would have to be replaced.

Approximately 265 lineal feet on both sides of the SDC rock walls downstream of the new spillway would require excavation and rock bolting. Approximately 70 lineal feet of the SDC south rock wall upstream of the new spillway would also require excavation and rock bolting.

5. COST ESTIMATES

Cost estimates have been developed for the various Skookumchuck Dam Modification Alternatives. All costs are presented in 2002 dollars and exclude interest during construction. The estimates include contractor's overhead and profit, sales tax, and a construction contingency appropriate to this phase of studies.

Quantity estimates were made from work items and materials for the main components of the proposed design. Approximate unit prices were developed from previous cost estimates by the Corps and Washington State Department of Transportation (WSDOT), bid prices from similar projects, quotes from manufacturers and contractors, and from current R.S. Means construction cost guides. Construction work was assumed to be limited to 8 hours a day, 5 days a week.

For the cost estimates, it was assumed that carefully controlled blasting would be used for all rock excavation. It is not known at this time whether there would be concerns with blasting adjacent to the dam. If mechanical excavation methods are required, excavation costs could increase significantly.

Mobilization and demobilization costs were taken as 5 percent of the direct cost subtotal. Sales tax was applied only to materials and equipment rental and not to labor costs. Contractor overhead and profit was taken as 25 percent of the direct cost with mobilization and sales tax added. A 25 percent construction contingency was then added to come up with a total direct cost.

Direct cost summaries for the selected alternative is presented in Appendix D of the GRR.

6. REFERENCES

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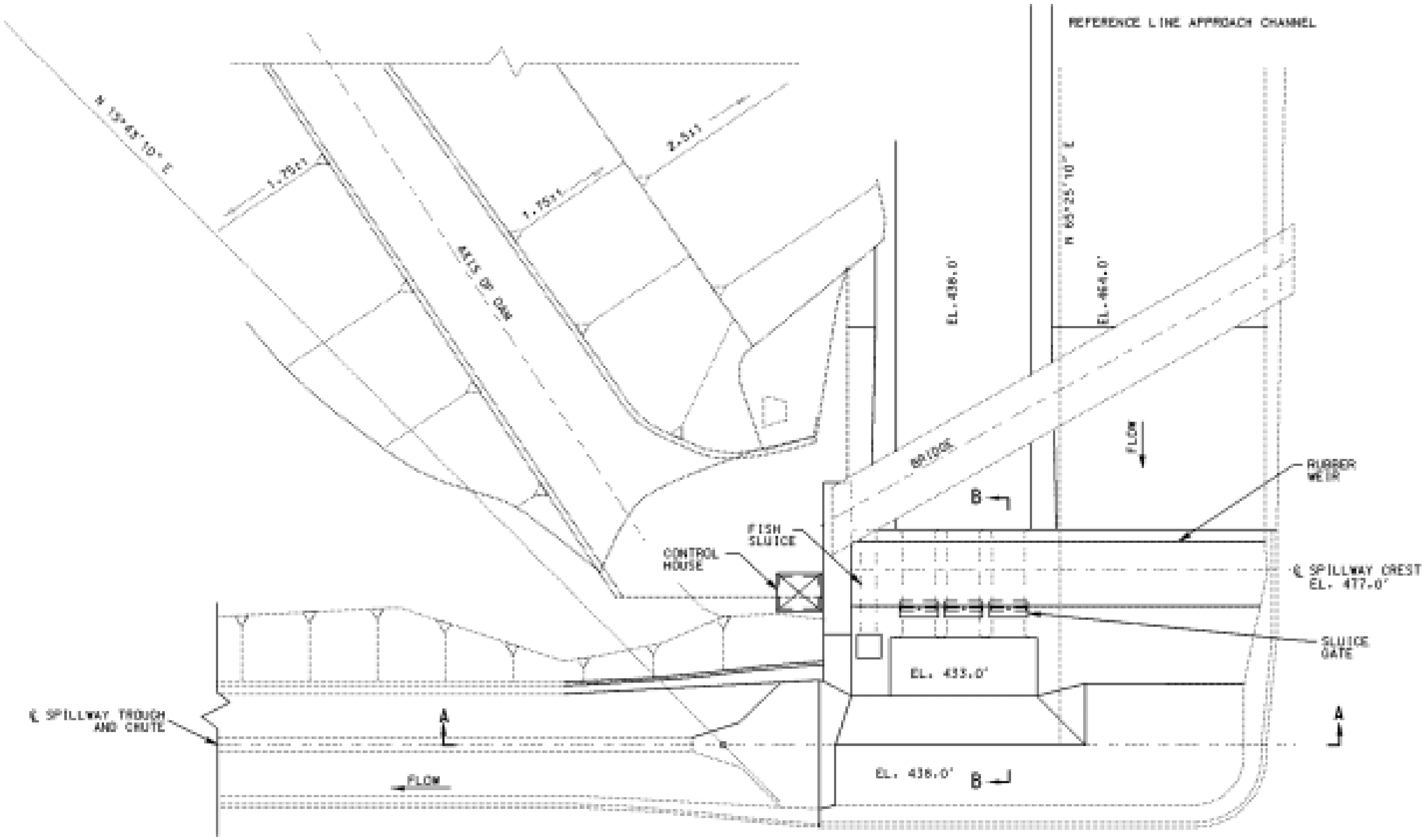
ADDITIONAL PLATES: SHEETS S-5 THROUGH S-22



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CENTRALIA, WA FLOOD DAMAGE REDUCTION PROJECT

ALTERNATIVE 2B1 (20,000AF) – SPILLWAY SLUICES

CENTRALIA	PN C1919	WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
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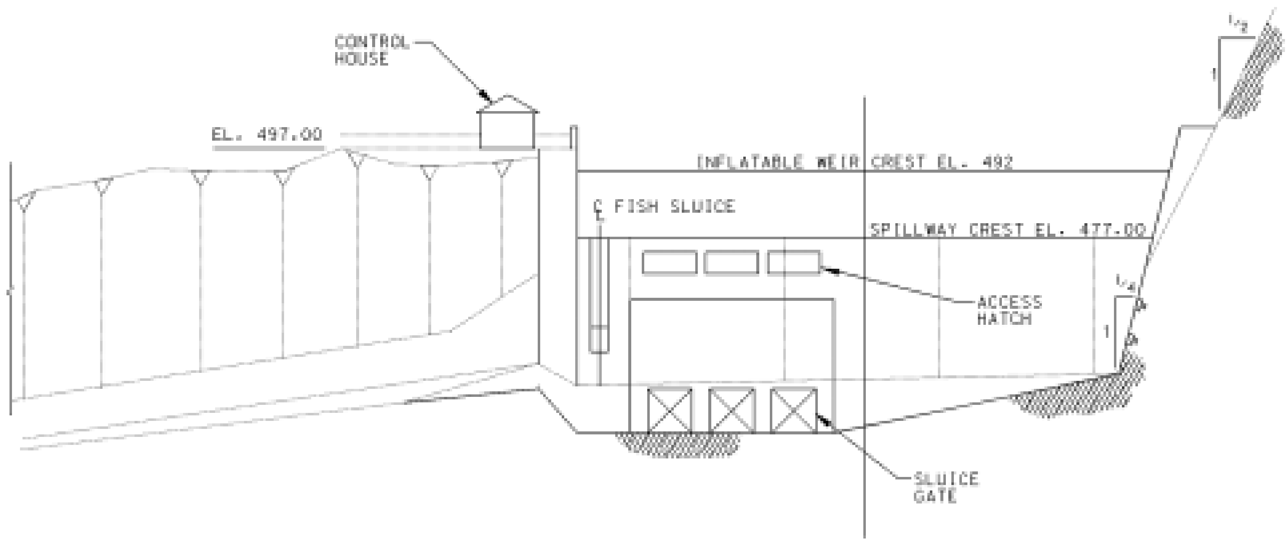

SECTION A-A

1" = 500'   500' 250' 0 500' 1000'

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SIZE	INVITATION NO.	FILE NO.	PLATE
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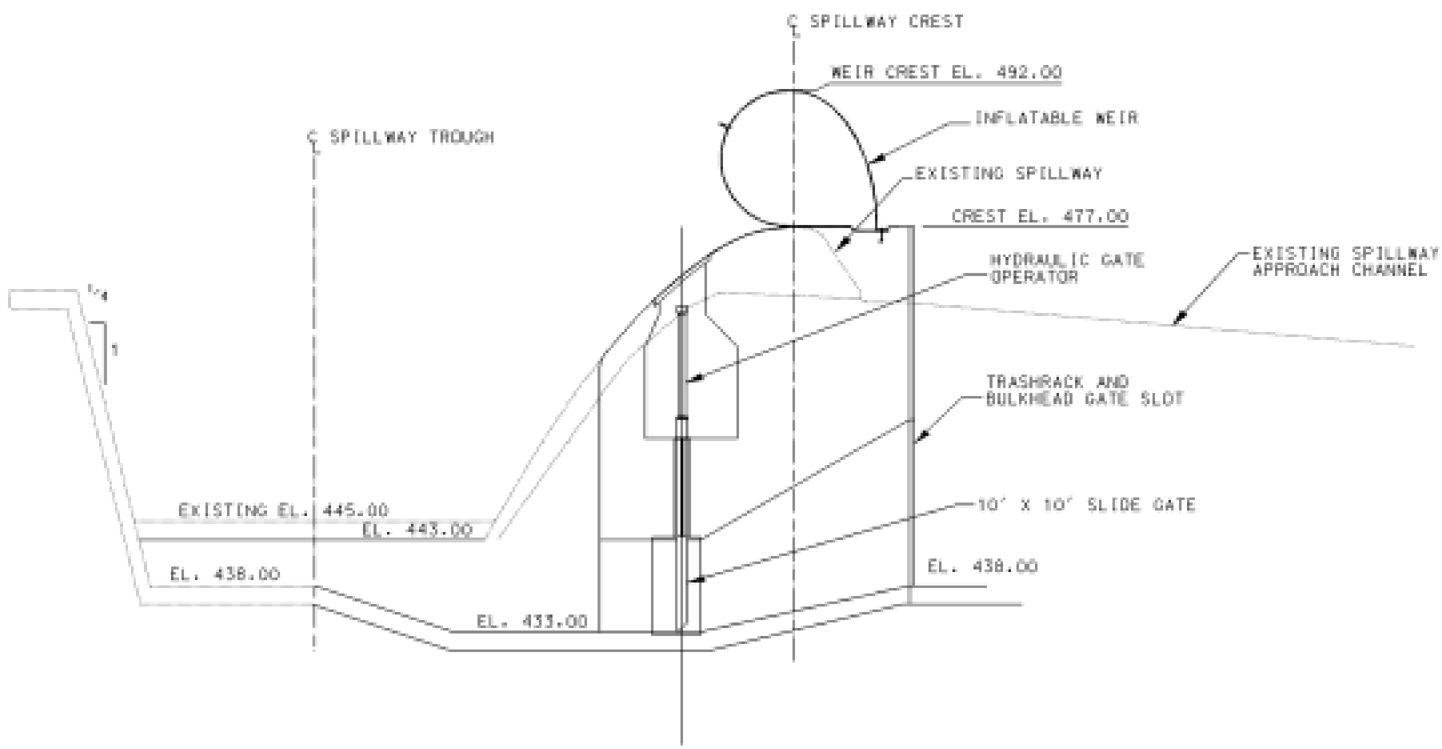

SECTION B-B

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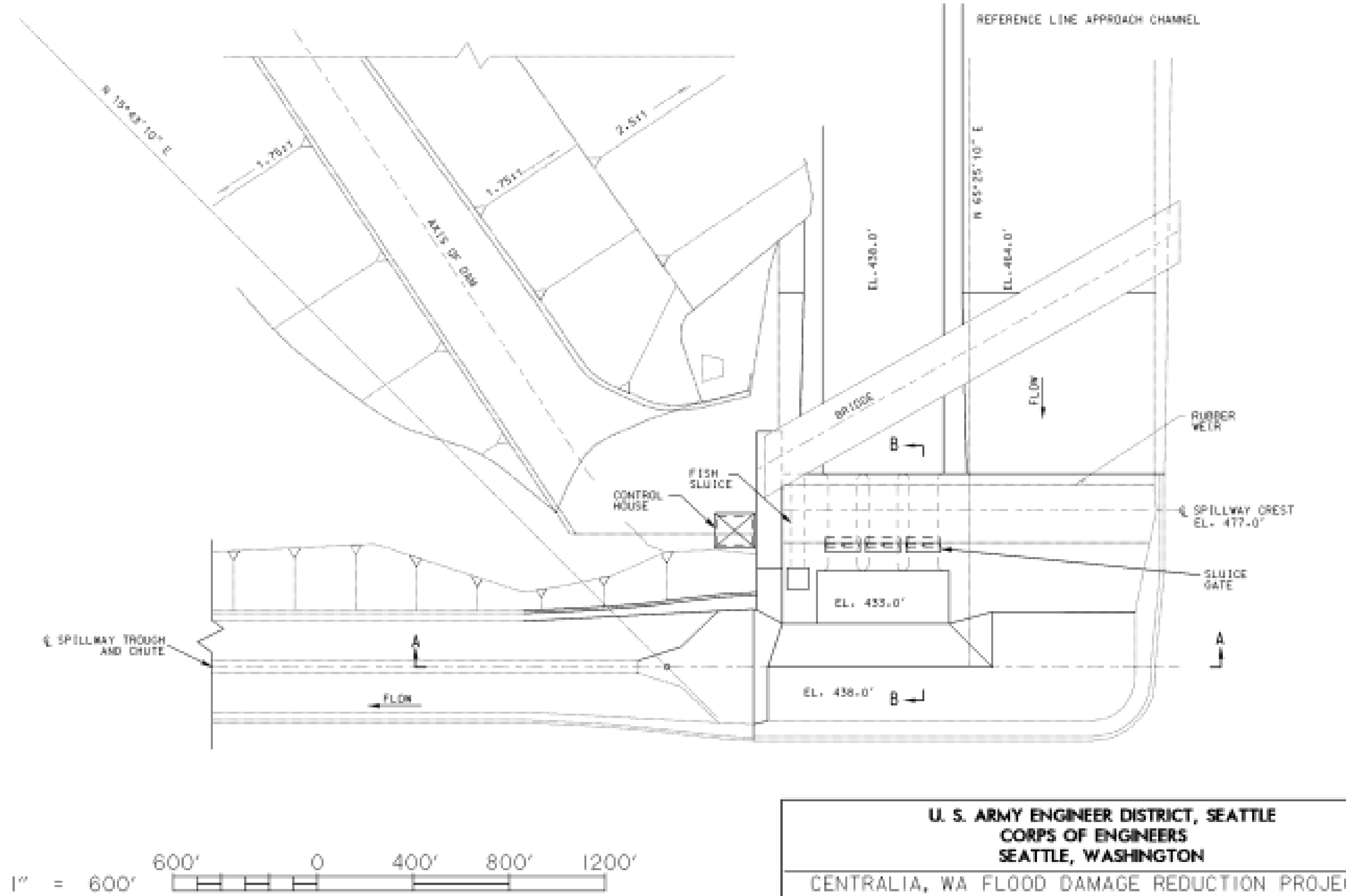

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ALTERNATIVE 2B1 (11,000AF) – SPILLWAY SLUICES

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SIZE	INVITATION NO.	FILE NO.	PLATE
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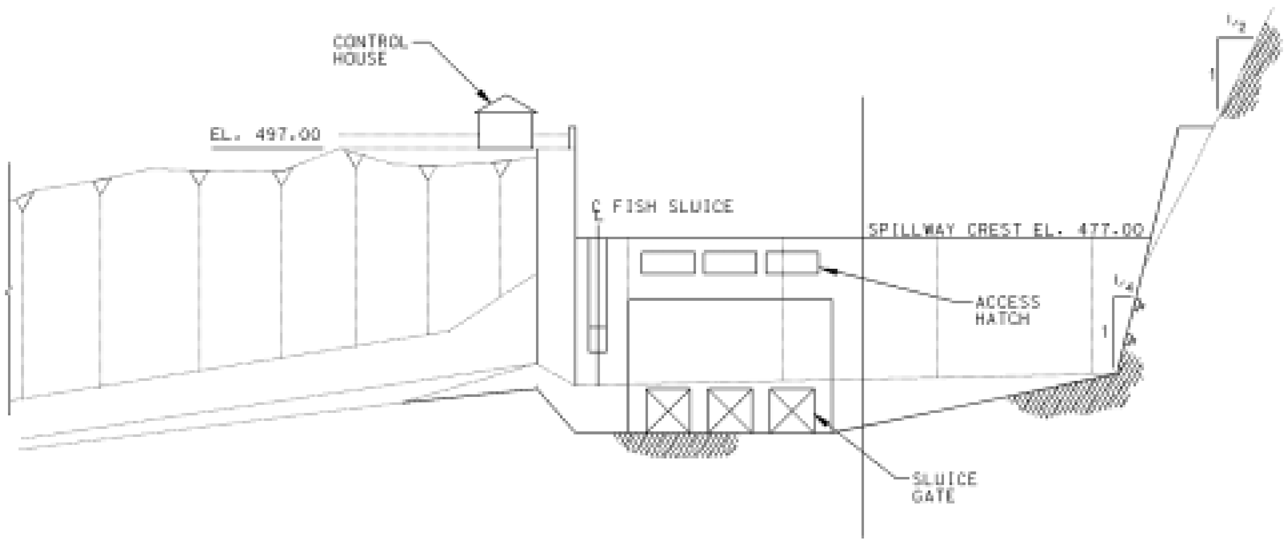

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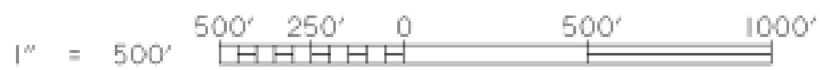

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ALTERNATIVE 2B1 (11,000AF) – SPILLWAY SLUICES

CENTRALIA	PN C1919	WASHINGTON	
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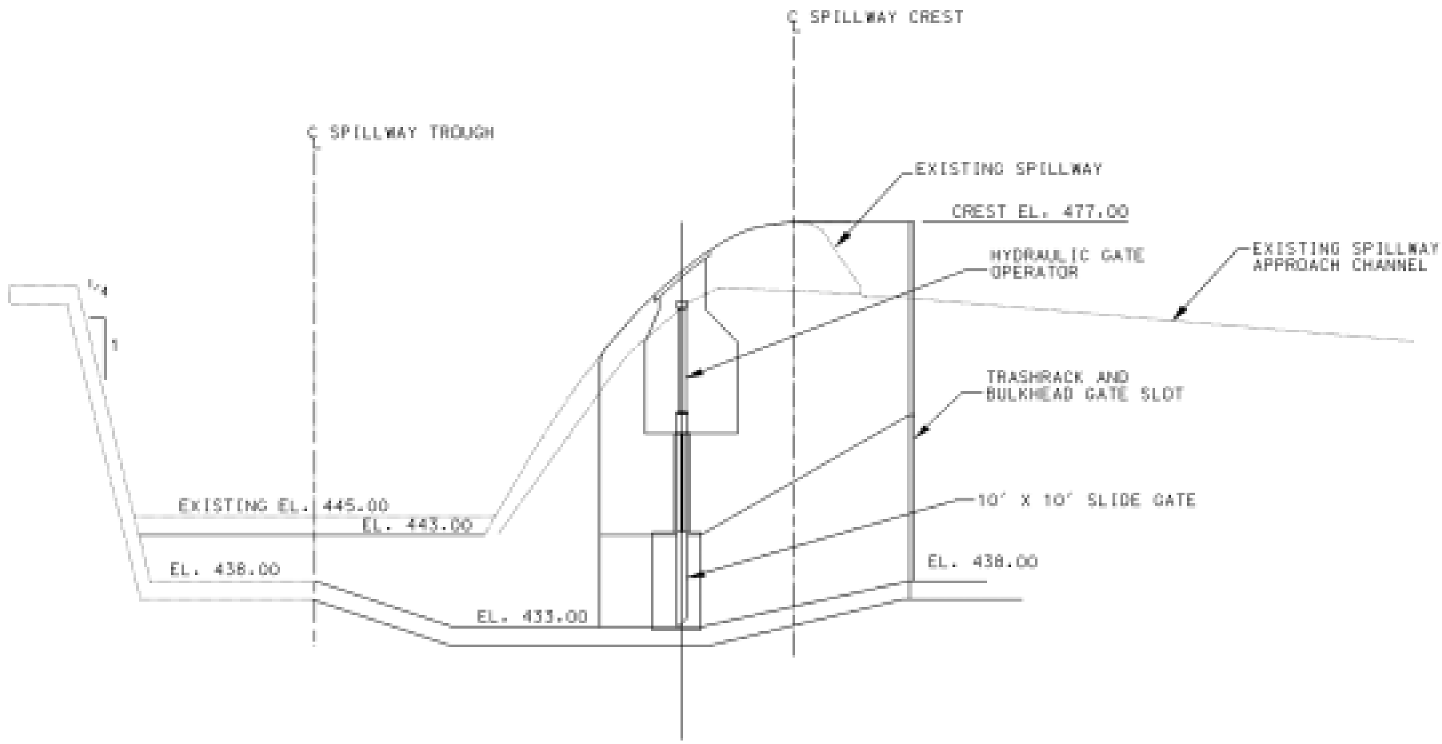

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ALTERNATIVE 2B1 (11,000AF) – SPILLWAY SLUICES

CENTRALIA PN C1919 WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
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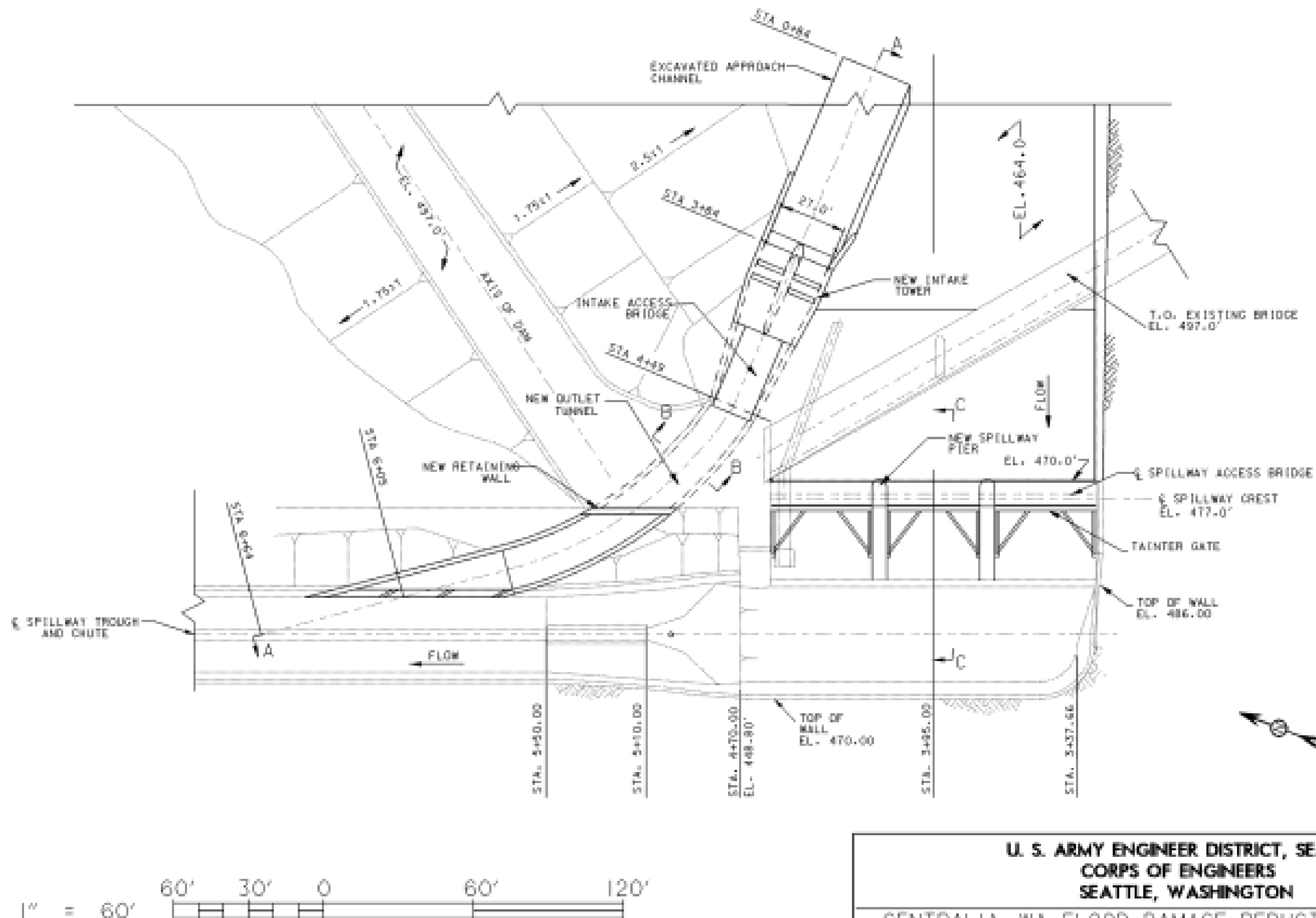

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CENTRALIA, WA FLOOD DAMAGE REDUCTION PROJECT

ALTERNATIVE 2B2 (20,000AF) – SHORT TUNNEL WITH SLIDE GATES

CENTRALIA PN C1919 WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
A		E-5-14-196	S-11

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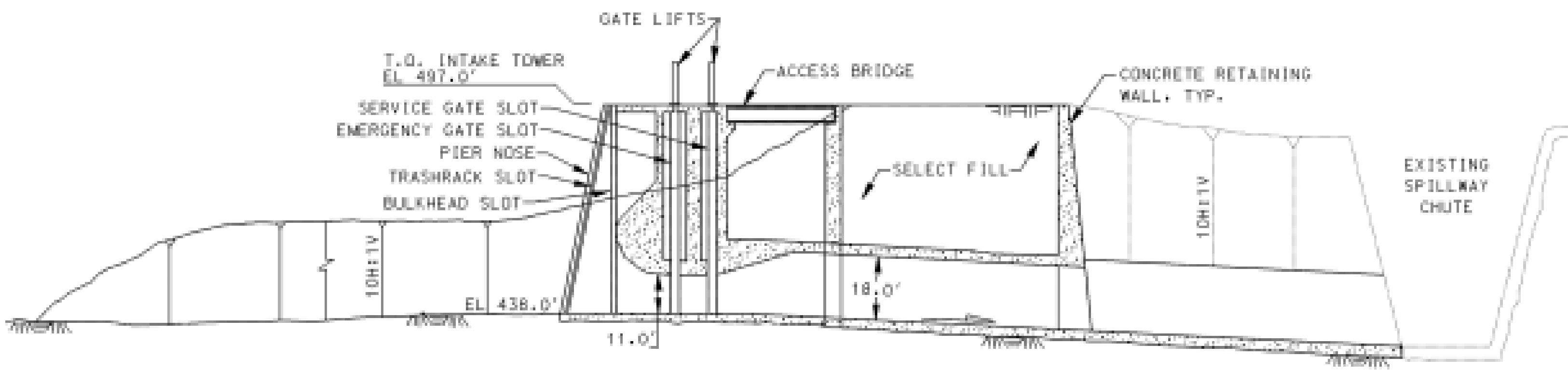

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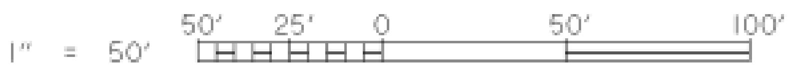

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ALTERNATIVE 2B2 (20,000AF) – SHORT TUNNEL WITH SLIDE GATES

CENTRALIA PN C1919 WASHINGTON

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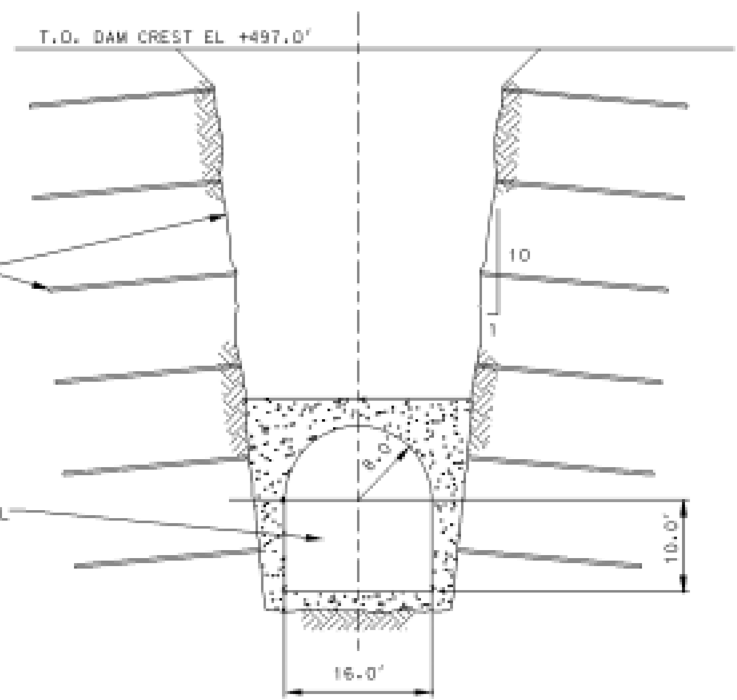

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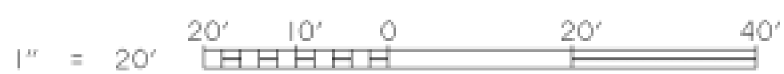

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ALTERNATIVE 2B2 (20,000AF) – SHORT TUNNEL WITH SLIDE GATES

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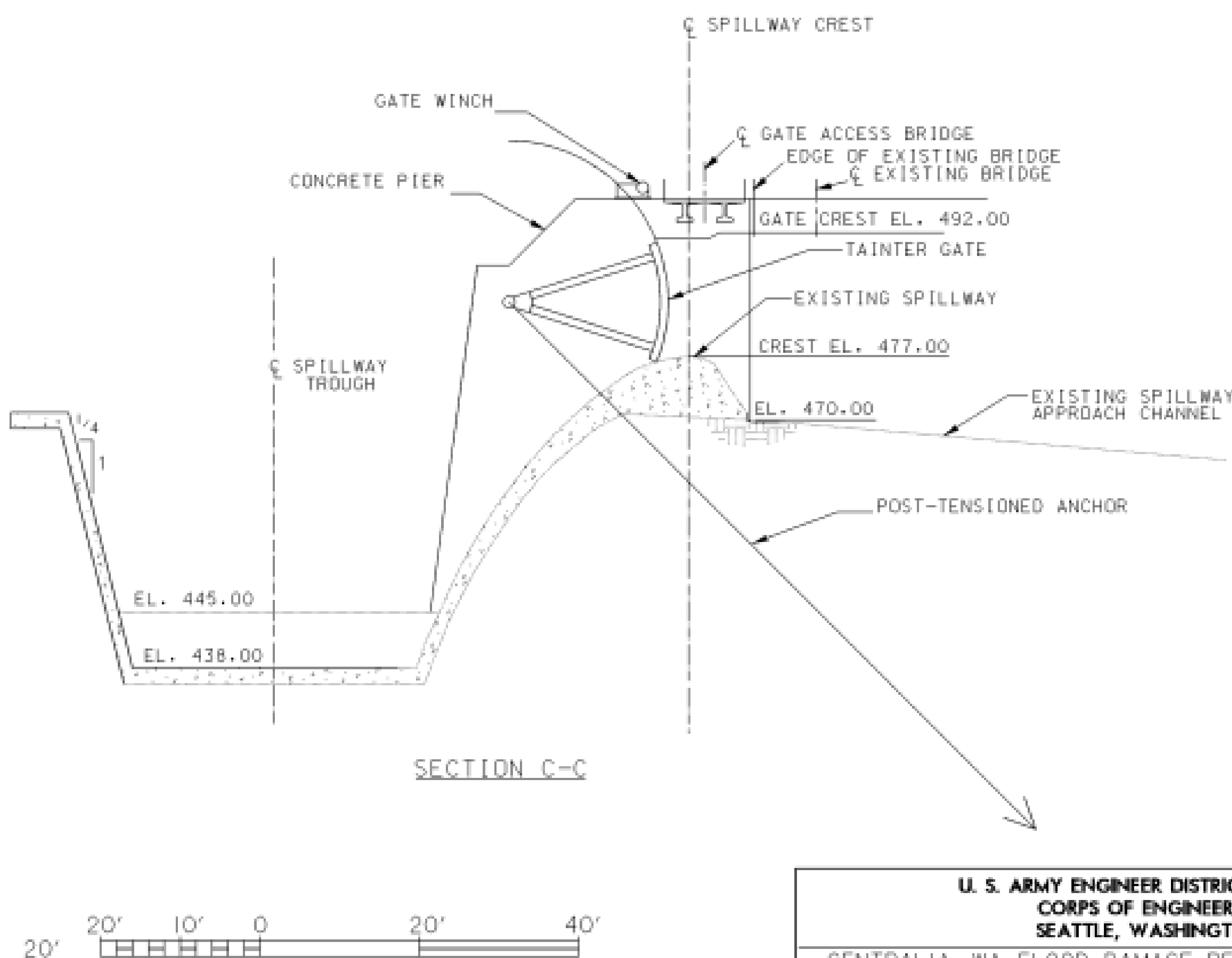

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ALTERNATIVE 2B2 (20,000AF) – SHORT TUNNEL WITH SLIDE GATES

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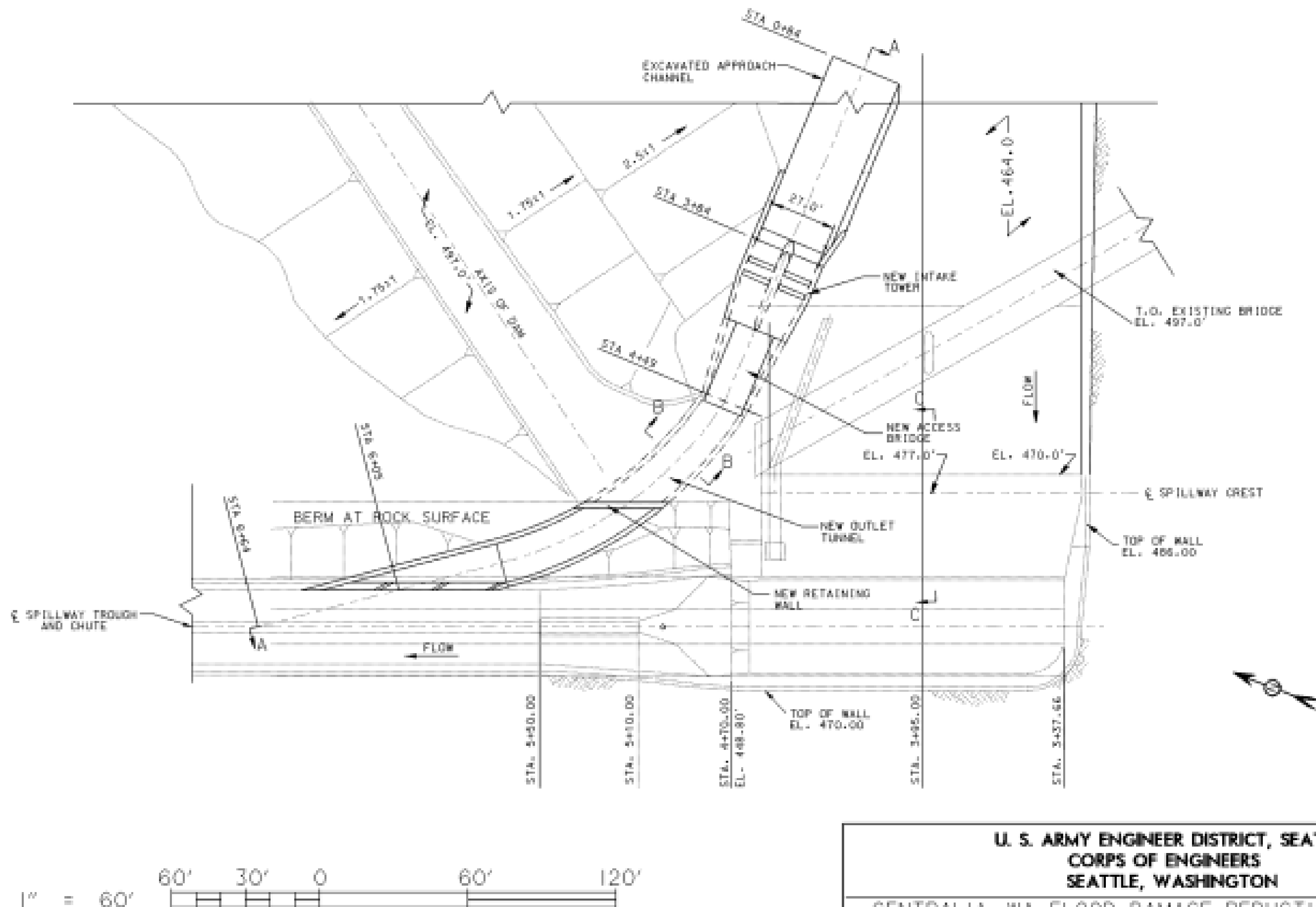

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ALTERNATIVE 2B2 (11,000AF) – SHORT TUNNEL WITH SLIDE GATES			
CENTRALIA	PN C1919	WASHINGTON	
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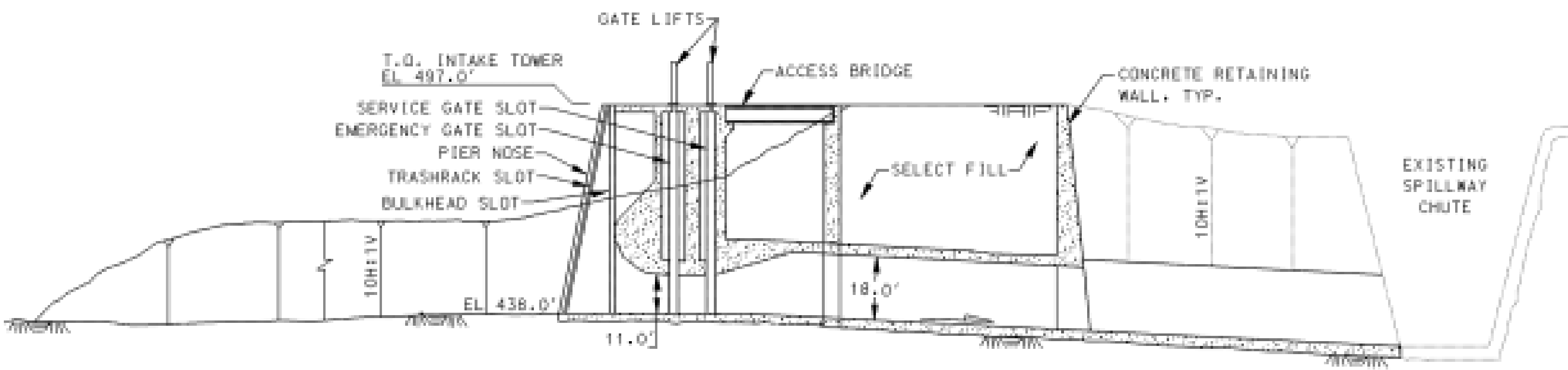

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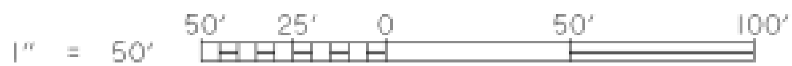

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CENTRALIA, WA FLOOD DAMAGE REDUCTION PROJECT

ALTERNATIVE 2B2 (11,000AF) –
SHORT TUNNEL WITH SLIDE GATES

CENTRALIA PN C1919 WASHINGTON

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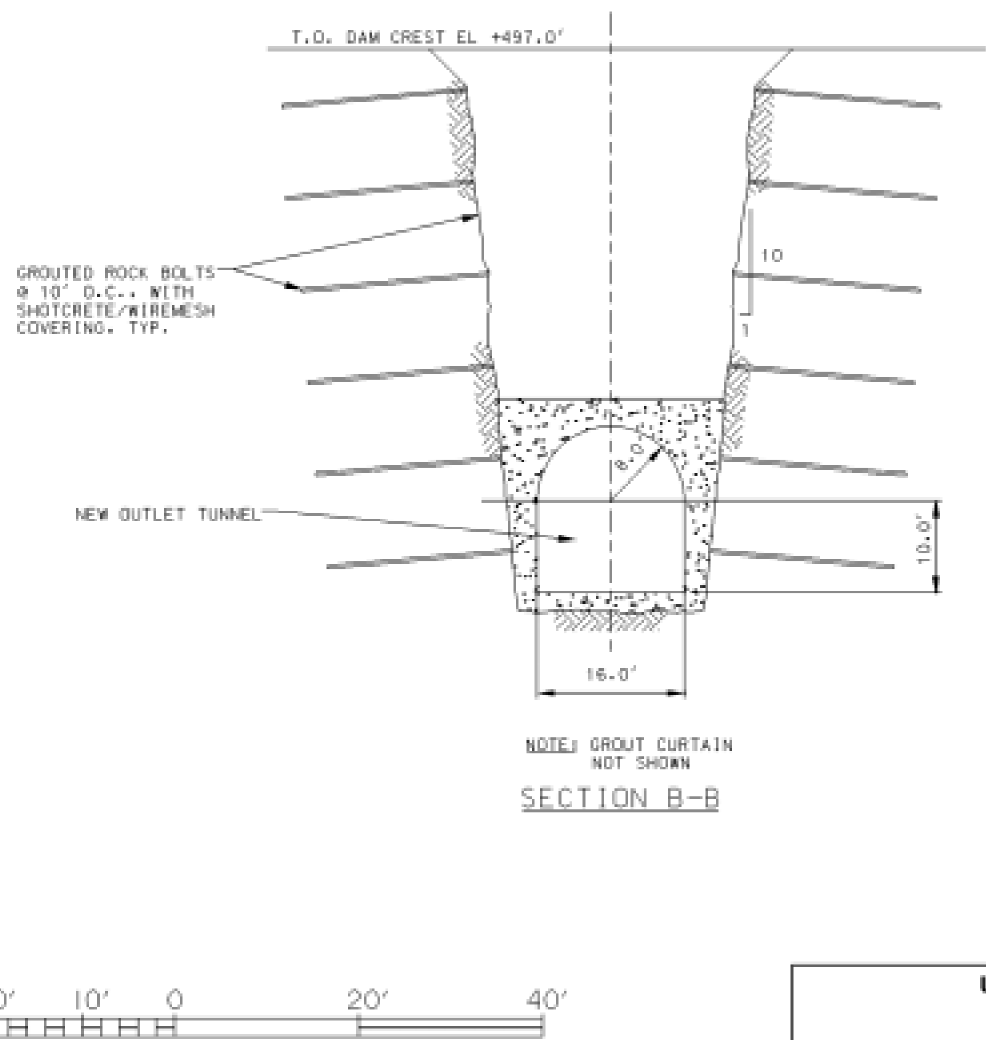

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CENTRALIA, WA FLOOD DAMAGE REDUCTION PROJECT

ALTERNATIVE 2B2 (11,000AF) – SHORT TUNNEL WITH SLIDE GATES

CENTRALIA PN C1919 WASHINGTON

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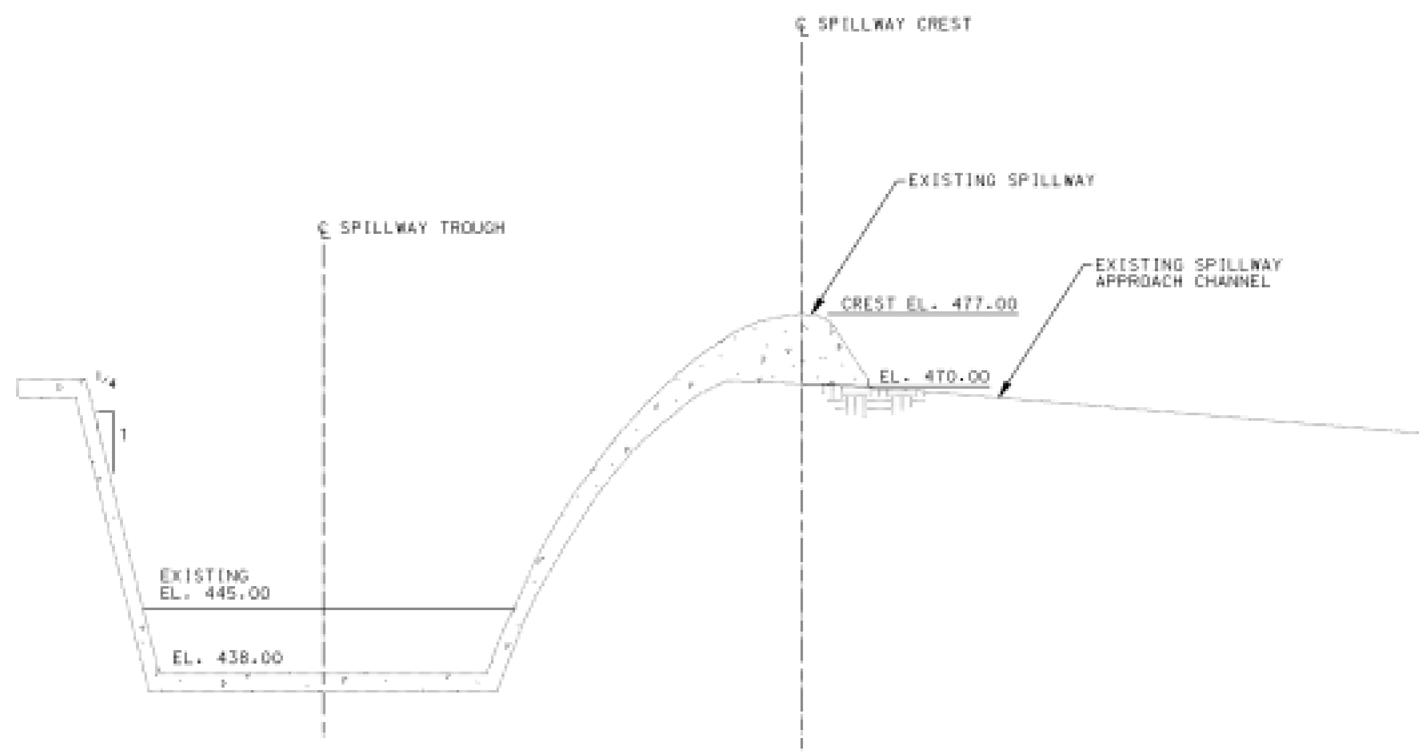

SECTION C-C

1" = 20'

20' 10' 0 20' 40'

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ALTERNATIVE 2B2 (11,000AF) – SHORT TUNNEL WITH SLIDE GATES			
CENTRALIA	PN C1919	WASHINGTON	
SIZE A	INVITATION NO.	FILE NO. E-5-14-196	PLATE S-18
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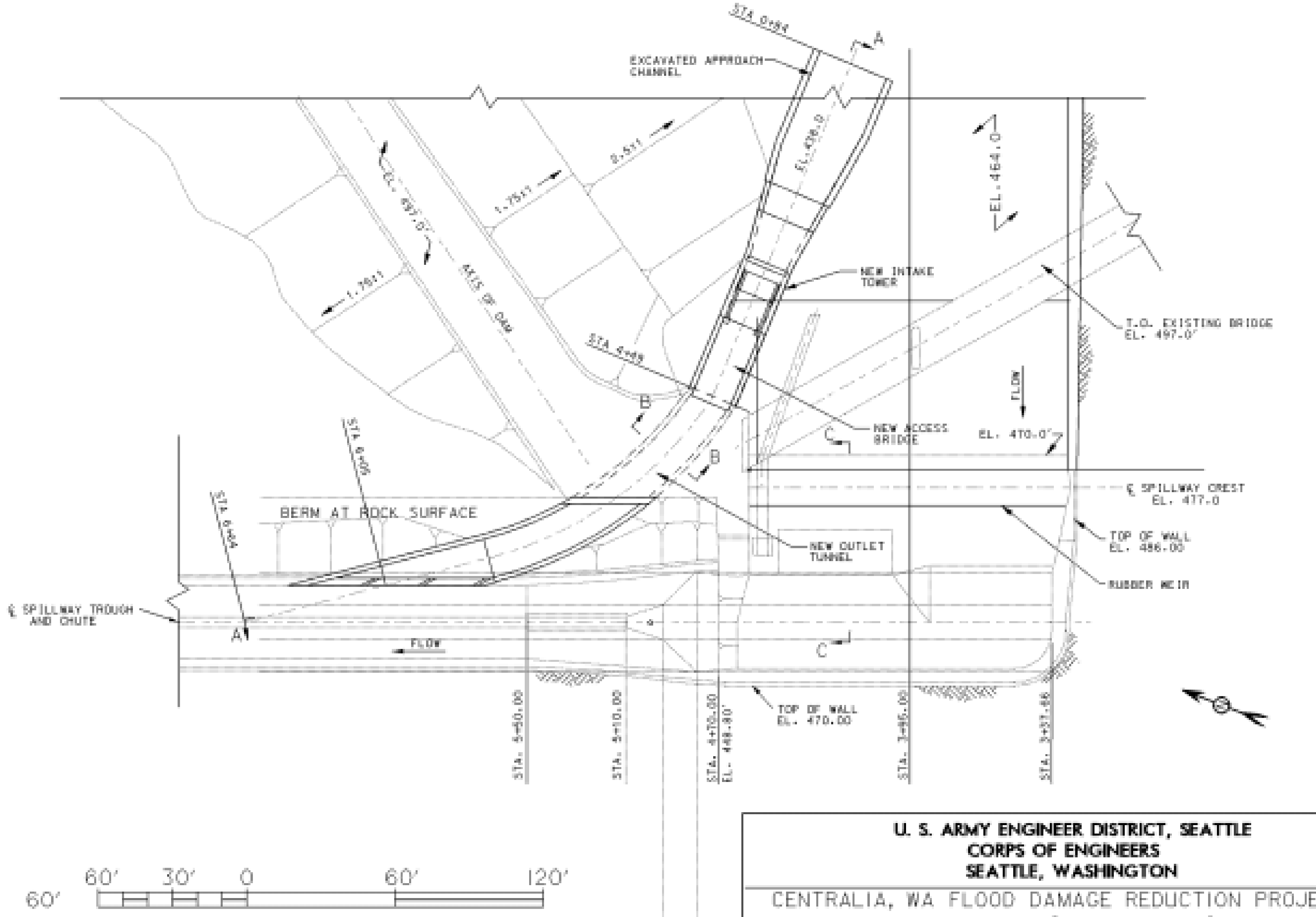

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CENTRALIA, WA FLOOD DAMAGE REDUCTION PROJECT

ALTERNATIVE 2B3 (20,000AF) – SHORT TUNNEL W/SUBMERGED TAINTER GATE

CENTRALIA	PN C1919	WASHINGTON	
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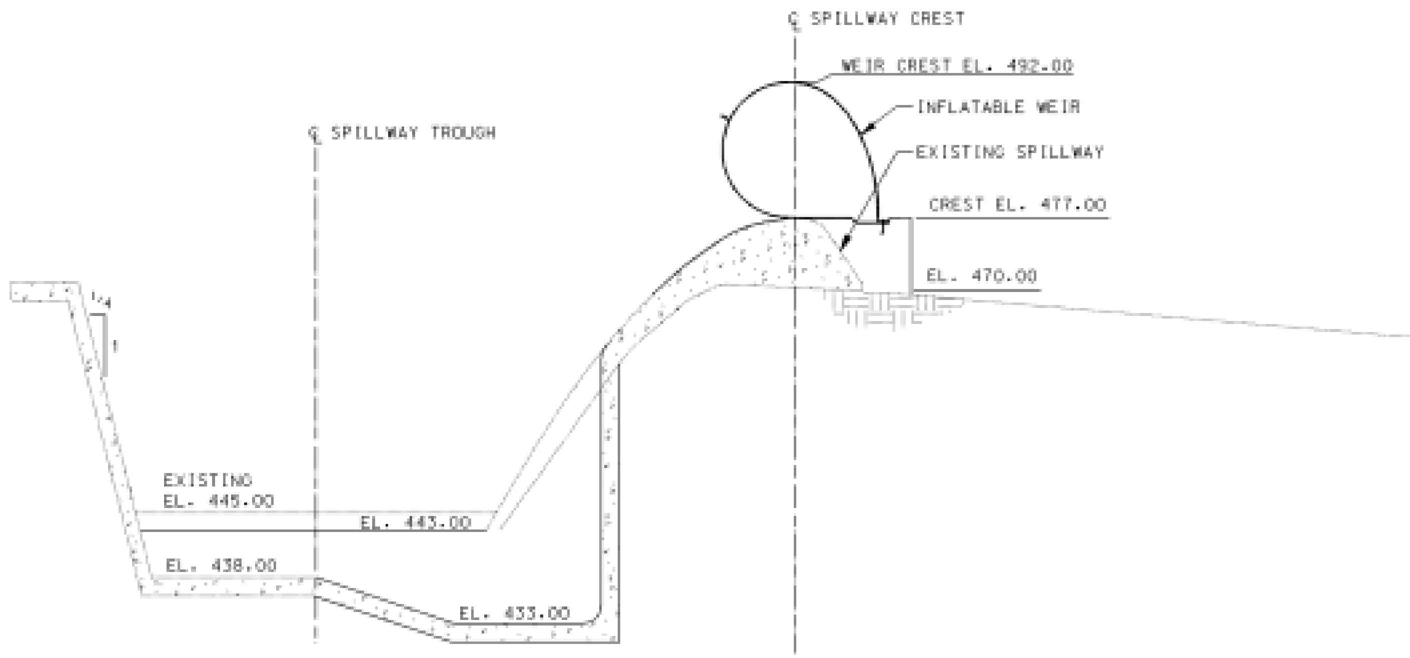

SECTION C-C

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ALTERNATIVE 2B3 (20,000AF) – SHORT TUNNEL W/SUBMERGED TAINTER GATE

CENTRALIA   PN C1919   WASHINGTON

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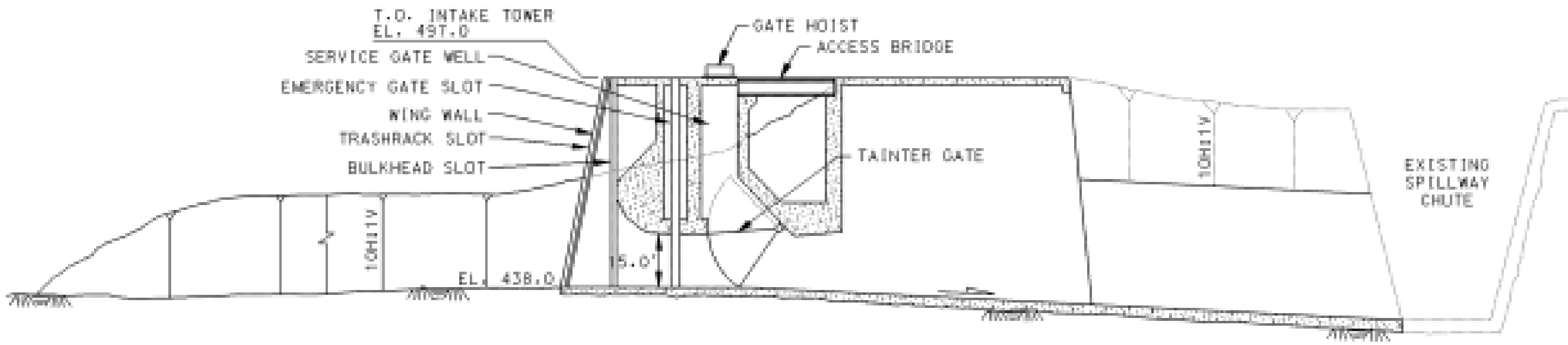

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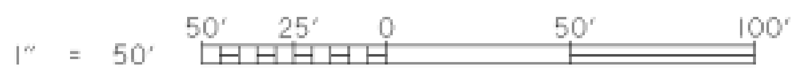

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ALTERNATIVE 2B3 (20,000AF) - SHORT TUNNEL W/SUBMERGED TAINTER GATE			
CENTRALIA	PN C1919		WASHINGTON
SIZE A	INVITATION NO.	FILE NO. E-5-14-196	PLATE 5-21
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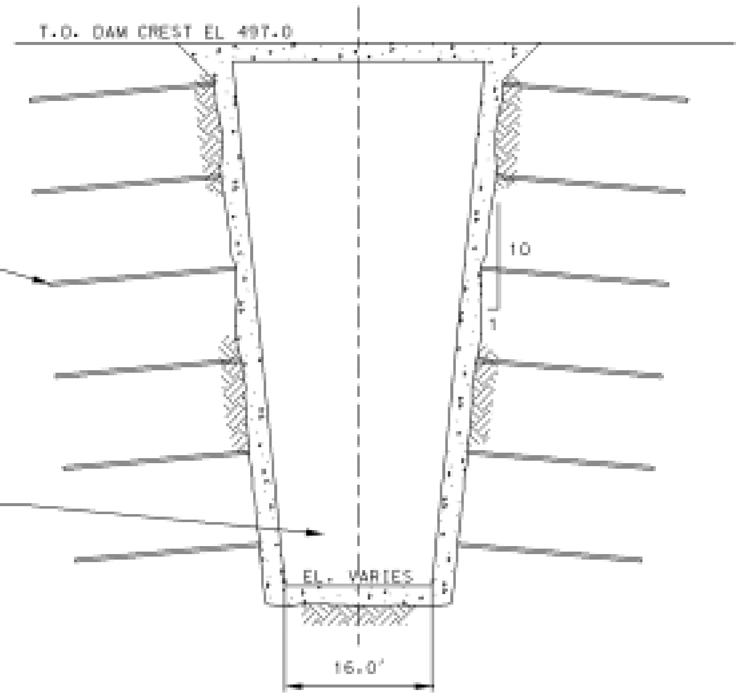
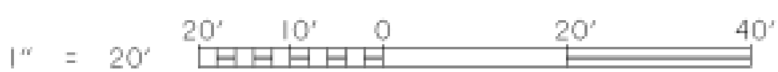


NOTE: GROUT CURTAIN NOT SHOWN

SECTION B-B



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SIZE	INVITATION NO.	FILE NO.	PLATE
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U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington
General Reevaluation Report

Appendix C:

Levee Plan and Civil Design

June 2003

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TABLE OF CONTENTS

Section/Paragraph	Page No. C-
1. DESCRIPTION OF THE LEVEE PLAN	**1**
1.1 The Levee Plan	1
1.2 Levee / Floodwall System	1
2. BASIS OF DESIGN FOR LEVEE PLAN	**2**
2.1 Setback Levee System	2
2.1.1 Background	*2*
2.1.2 Design Philosophy	*2*
2.1.3 Levee Design Criteria	*3*
2.2 Relocations	7
2.2.1 Roads	*7*
2.2.2 Driveways	*7*
2.2.3 Utilities	*7*
2.2.4 Dillenbaugh Creek	*8*
3. DETAILED DESCRIPTIONS BY REACH	**9**
3.1 Chehalis Reach	9
3.1.1 Reach 1 - Fords Prairie	*9*
3.1.2 Reach 2, Sewage Treatment Facility	*10*
3.1.3 Reach 3, Mellon Street Bridge to Salzer Creek Bridge	*11*
3.2 Salzer Reach	12
3.2.1 Reach 4, Salzer Creek Right Bank	*12*
3.2.2 Reach 5, Salzer Creek Left Bank	*13*
3.2.3 Reach 6, Coal Creek	*13*
3.3 Dillenbaugh Reach	13
3.3.1 Reach 7A, Salzer Creek to Airport	*13*
3.3.2 Reach 7B	*14*
3.3.3 Reach 8, SR-6 to Railroad Underpass	*15*
3.3.4 Reach 9A, Dillenbaugh Creek	*15*
3.3.5 Reach 10 Dillenbaugh South	*16*
3.4 Skookumchuck Reach	16
3.4.1 Reach 11, West Reynolds Avenue to BNSF Railroad	*17*
3.4.2 Reach 12, Chehalis Western Railroad to Harrison Street Bridge	*17*
3.4.3 Reach 13, Harrison Street Bridge to I-5 Right Bank	*18*
3.4.4 Reach 14, Left Bank I-5 to Harrison Street Bridge	*18*
3.4.5 Reach 15, Harrison Street Bridge to Chehalis Western Railroad	*19*
3.4.6 Reach 16, Chehalis Western Railroad to Existing Left Bank Levee	*19*
4. INTERIOR DRAINAGE IMPROVEMENTS	**21**
4.1 China Creek	21
4.2 Dillenbaugh Creek	21
4.3 Scammon Creek	22
4.4 Coal Creek	22
5. MITIGATION	**23**
5.1 State Route 6 Floodplain Reconnection	23
6. CONSTRUCTION CONSIDERATIONS	**25**
6.1 Haul Roads	25
6.2 Materials	25
6.3 Disposal	26
6.4 Fish Windows	26
7. OPERATION, MAINTENANCE, REPAIR & REHABILITATION (OMR&R)	**27**
8. DESIGN AND CONSTRUCTION SCHEDULE	**29**

8.1 Design....29
8.2 Construction Schedule....29
9. Cost Estimate 31
10. Special Considerations 33
10.1 WSDOT....33
10.2 Sewage Treatment 33

Tables

Table 1: Reach 1 10
Table 2: Reach 2 11
Table 3: Culverts in Reach 3 11
Table 4: Reach 3 11
Table 5: Reach 4 12
Table 6: Reach 5 13
Table 7: Reach 6 13
Table 8: Reach 7A 14
Table 9: Reach 7B 14
Table 10: Reach 8 15
Table 11: Reach 9A 16
Table 12: Reach 9B 16
Table 13: Reach 9C....16
Table 14: Reach 10 16
Table 15: Reach 11 17
Table 16: Reach 12 18
Table 18: Reach 13 18
Table 19: Reach 14 19
Table 20: Reach 15 19
Table 21: Reach 16 20

Plates

(attached in a separate binding)

1. DESCRIPTION OF THE LEVEE PLAN

1.1 THE LEVEE PLAN

The levee plan consists of several components, including a levee/floodwall system and modifications to the existing Skookumchuck Dam for flood control storage. The proposed levee system includes levees along the Chehalis River and its tributaries Dillenbaugh Creek, Salzer Creek, and the Skookumchuck River.

1.2 LEVEE / FLOODWALL SYSTEM

Design of the levee/floodwall system took advantage of opportunities to maximize levee setbacks, allowing floodplain and channel connectivity for environmental purposes. The plan also utilizes floodwalls where traffic control barriers could serve multi-purposes or where it was necessary to reduce the project footprint. The setback levee alignment would protect existing residential and commercial structures, highway and other transportation infrastructure from flooding while not encouraging new floodplain development. Proposed protection would extend along the Chehalis River from approximately river mile (RM) 75 to RM 64, as well as along most of the lower 2 miles of both Dillenbaugh Creek and Salzer Creek. In addition, levee protection will be provided on the Skookumchuck River for backwater effects of the Chehalis River. The affected reach is approximately 2 miles upstream on the Skookumchuck River to the confluence with Coffee Creek.

The levee system is intended to protect against the base 100-year Chehalis River flood level with a minimum 95 percent reliability performance. The 100-year protection is coordinated with the Federal Emergency Management Agency (FEMA) flood maps, so that they will be compatible. (See the General Reevaluation Report (GRR) for further details on plan formulation and risk-based flood management analysis.) This protection also extends to the tributaries of the Chehalis River. The Chehalis backwater flooding is prevented from going upstream on the following tributaries: Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek and the Skookumchuck River.

2. BASIS OF DESIGN FOR LEVEE PLAN

2.1 SETBACK LEVEE SYSTEM

2.1.1 Background

The levee alternative has been evolving over the last 27 years and builds upon the findings of the many studies of various river sections completed over this period, as well as a study of the entire basin completed in 1979, the Centralia-Chehalis Flood Control Study. That study saw several public meetings and reviews of a comprehensive levee alignment.

The current levee alternative incorporates many improvements on the 1979 design, including modifications to Skookumchuck Dam, reconfiguration of levee alignments to maximize levee setbacks, coordination with the Washington State Department of Transportation (WSDOT) to lower construction costs by combining the levee with the I-5 corridor where possible, and incorporation of ecosystem restoration features to address important fish and wildlife habitat needs in the study area.

Several major floods occurring since the 1979 design have helped refine the design in this study. The 1986, 1991, and in particular the 1996 floods provided valuable benchmarks to calibrate the numerical model with actual flood data. The 1996 flood provided high water close to a 100-year event. These floods also provided more data to update and refine the 100-year flood level, which is now also being used as a basis for design of this levee system.

2.1.2 Design Philosophy

In reviewing the work of previous studies, considering the increased importance placed on environmental concerns, and conducting site visits with shareholders, it became apparent that much coordination was necessary. This made it important to incorporate as many concerns as possible early in the design effort to avoid impacts later in the study. To facilitate the expedited study some guiding design principles were considered throughout the project. These principals also correlate to the project criteria and include:

- Avoid environmental impacts to the maximum extent possible
- Minimize the environmental impact as much as possible
- Minimize the initial construction and long term maintenance
- Provide a minimum of a 50 year project life
- Minimize project-induced damages, both within the project area and downstream
- Avoid inundating or excavating hazardous materials

- Maximize the transportation corridor benefits
- Maximize local infrastructure benefits
- Incorporate restoration opportunities into project

In addition, a general assumption in the levee system design was that it would provide 100-year protection from flooding of the Chehalis River. This includes protection from Chehalis River backwater on the tributaries, including on Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek and the Skookumchuck River.

2.1.3 Levee Design Criteria

The standard Corps levee design consists of a 12-foot top width and 2:1 side slopes (2 horizontal to 1 vertical). The fill material must meet the gradation specification and be compacted to Corps standards for levees discussed in paragraph 2.1.3.2. A 6-inch layer of gravel will be placed on the top surface to provide access during flood events and for maintenance. Both sides of the levee will be hydroseeded with grass with 4 inches of topsoil over compacted embankment material. Most levees are set back levees, which will not require rock bank protection. For those few areas that do require bank protection, the protection will include 30-inch minus riprap about 3 feet thick, with a 1-foot layer of quarry spalls between the riprap and compacted embankment material.

The concrete floodwall design has a spread footing buried below existing grade; only the vertical portion of the floodwall will be visible after construction. The base width will vary with the height to a maximum of approximately 20 feet and a top width of approximately 1 foot. They will often serve as traffic barriers along the road right-of-way. As a general rule if the levee or berm along the highway was less than 1.5 feet, a floodwall was used instead of the standard earthen levee.

Environmental impacts were identified and then avoided in the design to the maximum extent possible. Unavoidable impacts were minimized, with design modifications; for example, changing from a levee to a floodwall in certain areas of concern to reduce the footprint of the structure. A mitigation plan was prepared as part of the Environmental Impact Statement (EIS).

2.1.3.1 Hydrologic and Hydraulic Modeling

The design is based in part on the results of hydrologic and hydraulic modeling of the Chehalis River and tributaries conducted as part of this study. One-dimensional, unsteady flow, UNET software was used to develop the flood model employed in determining water surface elevations and maximum channel velocity. This flood model consisted of the upper Chehalis river basin from Pe Ell (RM 101.80) to Porter (RM 33.28). The topographic maps used to develop this model were provided by the U.S. Army Corps of Engineers (the Corps, USACE), Seattle District, and are based on aerial photography taken in August 1999 at a scale of 1 inch to 200 feet, with 2-foot contour intervals. The flood model was calibrated against the February 1996 flood event. The modeling effort and its results are described in further detail in the Hydrology and Hydraulics Appendix to this General Reevaluation Report (Appendix A).

2.1.3.2 Geotechnical Investigations

General. Geotechnical studies for the project to date have consisted of subsurface explorations along the various proposed levee alignments, flow net analyses to aid in estimating seepage in the levee embankments and foundations, and settlement calculations for the various foundations. Exploration boring logs of earlier subsurface investigations performed by others within the project area were obtained from WSDOT and Hart Crowser (under contract to Pacific International Engineering). Criteria have been established for levee design and an assessment has been made of construction material.

Geology. The Chehalis Valley occupies the southernmost portion of the Puget Sound Lowland of western Washington and a swath through the subdued coast range to the river mouth at Grays Harbor. A broad, flat valley floor surrounded by subdued and deeply weathered hills of Tertiary sandstone, shale, and basaltic lavas generally characterizes the valley.

Prior to Pleistocene glaciation of the Puget Lowlands, the upper portion of the Chehalis River drained north into Puget Sound and the lower portion drained the western flank of the subdued coast range. The advance of ice south into the Puget Lowland reaches an area just north of Grand Mound. Not only was the Chehalis River diverted westward by this event, but all the drainage from the west slope of the Cascade Range and the eastern slope on the Olympic Mountains was diverted southward along the margins of the ice mass, thence westward via the Black and lower Chehalis Rivers to the sea. Sea level was several hundred feet lower at this time and the extended lower Chehalis River, swollen with ice meltwaters and most of the drainage from the Puget Lowland, was rapidly deepened, and controlled by this lowered base level. The heavily laden glacial meltwater stream built a fan of coarse detritus (sand, gravel, and boulders) across the old valley just north of Centralia and deposited the coarse material downstream. The fan impounded a lake in the upper valley south of Centralia in which fine-grained sediments (sand, silt, and clay) were deposited. Coincident with ice melting worldwide, sea level and, therefore, the base level of the Chehalis River rose, providing an extensive estuarine area in the downstream reaches for the accumulation of fine-grained sediments over the coarse-grained glacial outwash.

The stream, therefore, occupies an inherited valley, largely a product of concentrated glacial meltwater. The valley can be geologically divided into three segments, which reflect the geologic history, characteristics of materials beneath the valley floor, and the stream gradient. The downstream segment from the mouth of the river at Grays Harbor to Oakville (RM 45) is that portion of the river under more or less direct influence of the tidal base level. The valley floor is underlain by a substantial thickness of fine-grained estuarine and alluvial sediments overlying, in part inter-fingering with, coarser grained glacial outwash sands and gravels. The stream is highly sinuous and has a gradient of less than 1 foot per mile, often about 0.5 foot per mile in this reach except between RM 19 and 21 where the detrital fan of a major tributary, the Satsop River, has caused a steepening of gradient to 4.4 feet per mile. A less significant steepening (1.6 feet per mile) for about 5 miles downstream from the confluence of Porter Creek with the Chehalis Valley is presumably caused by the addition of detritus from that stream.

Between Oakville and Centralia (RM 67.5) the valley floor is underlain by a substantial thickness of glacial outwash consisting of coarse gravel, cobbles, and sand, locally with a thin mantle of fine-grained material over bank alluvium. The gradient of the river is between 4 and 5 feet per mile throughout this reach and the stream is considerably less sinuous. The stream is generally shallow throughout this reach with rapids and riffles being common due to the heavy cobble pavement of the channel and the presence of glacial outwash and braided channel bars. Upstream from Centralia, and south to beyond Chehalis, the valley is underlain by a thick sequence of soft glacial lake sediments consisting of silts, clays, and fine sands mantled by over bank alluvium. The stream is again highly sinuous with a gradient of about 1 foot per mile. The gradient of its major tributary, the Skookumchuck River, is crudely controlled by the passage of the stream across the coarse-grained outwash fan northwest of Centralia. The project area is in this reach of the Chehalis and Skookumchuck Rivers.

The Skookumchuck River between Bucoda and Centralia occupies an old ice meltwater channel cut during the maximum advance of Pleistocene ice. The valley floor, while mantled by fine-grained material (fine sand and silt) over bank alluvium, is underlain by coarse glacial outwash (sand, gravel, and cobbles) locally interbedded with glacial lake deposits as the Chehalis Valley is approached. The stream in this segment has a highly variable gradient (4.7 to 22 feet per mile) and sinuosity reflecting its adjustment to an inherited valley.

Soils

a. Subsurface Exploration. Subsurface exploration by the Corps' Seattle District consisted of six rotary drill holes (78-RD-1 through 6) drilled in March and April 1978 and 24 power auger holes (79-PA-2 through 21 and 79-PA-23 through 26) drilled in April 1979, all drilled for the September 1982 Interim Feasibility Report. Forty-one boring logs (numbered 1 through 41) of holes drilled by others in the general vicinity of the proposed work were obtained from WSDOT. Approximate locations are shown on Plate GT-1. All boring logs are shown on plates GT-2 thru GT-6. In addition to the subsurface exploration noted above, additional foundation exploration performed by Hart Crowser under contract to Pacific International Engineering was reviewed and confirmed the general foundation conditions.

Subsurface investigations by the Corps of Engineers generally included Standard Penetration Tests (SPT) using a 2-inch-diameter split-spoon sampler and a 140-pound hammer dropped 30 inches. These tests were usually made at 5-foot increments of depth to provide SPT "N" values and disturbed samples for classification. Samples were visually classified in the field according to the "Unified Soils Classification System" and retained in quart-sized jars. Disturbed samples of the more granular materials were also taken with a 3-inch-diameter split-spoon sampler.

To determine the character of the foundation materials rotary drill holes were drilled by the Corps to depths ranging from 41.4 to 70.5 feet and the power auger drill holes were drilled by the Corps to depths ranging from 10.5 to 19.2 feet. Rotary drill holes were held open by 4-inch-diameter steel casing. Power auger drill holes were drilled with uncased 12-inch-diameter hollow stem augers using a truck-mounted power auger. In most cases the power auger drill holes caved in below the groundwater level, preventing the auger from advancing deeper.

b. Foundation Conditions. Foundation soils in the project area are generally composed of glacial outwash materials (sands and gravels) and latchstring sediments (clays, silts, and fine sands.) Organic and wood debris also exist in some areas. In most areas, the proposed levee system would be founded on sands having loose-to-medium relative densities and soft-to-medium dense clays and silts. In a few areas the foundation is relatively dense where gravel deposits exist. The new levee embankment load on the fine-grained foundation soils is calculated to cause post-construction settlement between 7 and 14 inches; therefore, the levees will be overbuilt by 1 foot to allow for this ultimate settlement. The surficial, highly organic soils encountered in a few borings at the south end of the project should be removed from the levee foundation to avoid excessive foundation settlement and embankment stability problems. Undetected, shallow, highly compressible soils may exist in some other areas of the project that would require the same treatment.

Construction Materials

a. Borrow Sources. Potential sources for levee embankment materials are located within 10 miles of the project location. Rock for riprap is potentially available about 20 miles west of Chehalis. All stripped material beneath the levee alignment suitable for topsoil would be stockpiled for later use on embankment slopes. Sampling and testing of all borrow material will be conducted during final design phase.

b. Concrete and Asphalt. Asphalt paving will be designed and constructed according to WSDOT Standards. Specifications for Portland cement concrete structures will be in accordance with WSDOT Standards, American Society for Testing and Materials, and/or American Concrete Institute Standards. Asphalt and Portland cement concrete would be obtained from local and/or nearby asphalt plants and ready-mix concrete companies.

I-5 Freeway Assessment

An assessment of the freeway embankment material will be done to verify that the use of the freeway as a levee will not affect the integrity of the roadway or embankment. Permeability check may include borings at locations where the freeway road elevation is 3 feet or more above the 100-year flood elevation. These areas will not have a levee protecting them from flooding.

2.1.3.3 Survey & Mapping

Engineering surveys were conducted as part of this study in 1999 through 2000. Aerial photographic/topographic surveys were used to develop 2-foot contour maps of the entire basin. These contours were then used to develop a digital terrain model used to calculate levee quantities. Bathymetry cross-sectional river survey was completed in 2000, and input to the UNET Model. High water marks from the 1996 flood event, which was approximately a 100-year event, were surveyed. These high water marks and aerial photographs were used to calibrate the UNET model. These data points combined helped field-verify the project datum used for this project, the National Geodetic Vertical Datum (NGVD) 1988. Other sources of data were used, specifically WSDOT datum, which is approximately a 4-foot difference in datum. Permanent survey monuments will be added to the drawings during the plans and specifications phase of the project.

2.1.3.4 Structural Design

The structural design effort has been concentrated on the dam. For the levee plan it has been at the conceptual level. For cost estimating purposes standard designs for common items were used. For example, two designs were used for generic floodwalls (traffic barriers): one for the majority of floodwalls, which were for heights below 5 feet; the other for floodwalls with heights above 5 feet, borrowed from another project. Minimum facilities to provide interior flood relief were designed per EM 1110-2-1413, Hydrologic Analysis of Interior Areas. Standard culvert flap gates were used, but in the next phase environmental considerations will be incorporated. This will complicate the design effort. For example, since the flap gates on several culverts will only need to be used during extreme events, they could be designed to stay open until a certain flood elevation is reached similar to a tide gate in tidal water. These items will be site-specific designed in the next phase.

Features in the levee plan that will require additional work include the following: flap-gated culverts, flood control boxes, sluice-gated box culverts, bridge abutment modifications, floodwalls that also serve as either crash barriers on the highway or retaining walls of various heights from 1 to 20 feet high, sewer main crossings, flood gates for floodwall, temporary floodwall such as a stop log structure.

Environmental mitigation and restoration projects may require structural features, which will also be designed in this next phase.

2.2 Relocations

2.2.1 Roads

Several roads in the project area may be raised or relocated on top of the proposed levee sections. The local sponsors will review the options and determine what is best for the local community. Typically the options are to build a wall or levee parallel to an existing road.

Real estate becomes a cost factor since the existing road right-of-way is publicly owned and a levee would require new real estate to be purchased. In some areas this real estate appears to be wetlands. In these areas the preference would be to use the existing road. Similarly, if the road was an important access route, such as Hospital Road, raising the road has community benefits by maintaining critical emergency routes open during a major flood event.

2.2.2 Driveways

Raising a road or placing a levee near residences will require work on personal driveways to either ramp up and over or establish a flood fight plan that includes closing off these low driveways with flood gates or sandbags.

2.2.3 Utilities

Existing utilities will be considered in the detailed design after coordinating with local utility owners. Major utility issues have been avoided.

2.2.4 Dillenbaugh Creek

The creek bed becomes a ditch along and paralleling I-5 between the Rice Road interchange north to the Burlington Northern-Santa Fe (BNSF) Railroad. This area in particular and possibly other reaches further south on Dillenbaugh Creek will need to be relocated. This area is under study for WSDOT freeway widening project and may be built before this flood control project. To accommodate this possibility, the toe of the levee alignment was moved to a location 78 feet from the existing freeway centerline. Placing the levee here will require the creek to be relocated. A detailed design of this feature and costs have not been included in this appendix.

3. DETAILED DESCRIPTIONS BY REACH

The following sections provide specific details by levee design reach and by station. The length, average height of the top elevation, the average width at the toe of the levee, and type of structure are shown by sub-reaches.

A general map showing the location of the various study reaches is provided as Plates C-1 and C-2. More specific details are shown on Plates C-3 through C-57. (Note that the levee design reaches are different from the study reaches presented in other parts of the General Reevaluation Report).

3.1 Chehalis Reach

3.1.1 Reach 1 - Fords Prairie

The levee starts at Galvin Road in the Fords Prairie area (Township 14 North (T14N) section 39). It is approximately one-half mile east of the Galvin Bridge over the Chehalis River at approximately RM 64.

The levee heads south following the high ground plateau area surrounding a dairy and the Port of Centralia Industrial Area. It then crosses a Port of Centralia and Ecology nature trail from Russell Road to the Chehalis River. It continues south along the edge of a riparian buffer protecting a residential neighborhood, where there is a pasture on one side and tree farm on the riverside of the levee. The levee continues south until it crosses a trail, which is an extension of Mayberry Road. It continues south on the inside of the riparian buffer around the high school and Washington State Fish and Wildlife Bird Farm. The levee comes within 1800 feet of the water's edge at the Bird Farm.

The levee then heads east following the Bird Farm fence line through a commercial quarry area and crosses Oakland Avenue, just behind the houses on Southgate Drive. The levee continues east following the property line to Bryden Avenue; this area has a new drainage channel on the east side of Bryden with culverts going under Bryden Avenue. The proposed levees are compatible with, and would be located on the landward side of, the new drainage channel.

The levee then heads north for approximately 800 feet on the east side of Bryden Avenue, continuing north to the high school track and stadium. (A potential option is to build the levee over the existing 24-foot wide Bryden Avenue and repave.) The levee turns east behind the stadium, past the flood proofed water pump station, and across the paved parking area. It then turns north and follows the fence line of the baseball fields, swinging east behind the backstop, crossing a gravel access road, and then turning to the north. This alignment leaves the baseball fields, soccer fields and historic buildings (The Borst Family Farm near the confluence of the Skookumchuck and Chehalis River and a log Fortress north of Borst Lake) on the riverside of the levee. The alignment comes within 250 feet of Borst Lake and becomes a floodwall along the west edge of the property line of the Fort Borst Park entrance road. Ending at the east end of Borst Avenue near the Harrison Avenue I-5 interchange. At approximately a 100-year event minor flood fighting with sand bags may be used to cross Borst Avenue to an existing Texaco Gas Station floodwall which heads east. Another minor flood fight area to close is a 75-foot gap between the floodwall and the I-5 southbound on-ramp.

The I-5 southbound lanes then become a part of the flood protection system, by possibly adding a layer of impervious material to the freeway embankment. At interstate milepost 82.47 it is proposed that a flap gate be installed to the west end or the Borst Lake side of the 36-inch concrete culvert which connects Hayes Lake on the east side of the interstate.

The levee continues south to the right bank of the Skookumchuck River and ties into the bridge abutment. From the left bank of the Skookumchuck River, near the confluence of the Chehalis River, the levee heads south crossing a 5-foot boxed culvert, which drains China Creek, the culvert will be flap-gated on the riverside at the existing sewage treatment plant. Minimum facilities to provide interior flood relief were designed per EM 1110-2-1413 and will not increase interior flooding.

TABLE 1: REACH 1

Plan view:	Plates C-1, C-3, C 15 through C-22
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 78+50	Cross-section A - typical new levee over soil
Comments:	The levee starts at Galvin Road
Station 78+50 to Station 81+50: Station 138+00 to Station 139+00	Cross-section C - typical new levee over road
Station 81+50 to Station 126+75	Cross-section A - typical new levee over soil
Station 126+75 to Station 133+90 Station 135+40 to Station 138+00 Station 139+00 t0 Station 142+65	Cross-section B - typical new floodwall
Length:	14,676 feet
Avg. Height:	5.5 feet
Avg. Width:	34 feet
Fill Quantity:	69266 cubic yards (cy)

3.1.2 Reach 2, Sewage Treatment Facility

The City of Centralia is removing the existing sewage treatment facility after a new facility is built, scheduled for completion prior to construction of this proposed project. The levee design incorporates the proposed future pump station, which will be based around a flood-proofed structure to house the proposed pumps. The construction of this project has also avoided interfering with proposed and existing sewer mains. This section consists of a floodwall that connects the freeway to the existing treatment facility.

The proposed wall is not expected to impact and will not involve any excavation of hazardous material in this area. From the floodwall, the levee is built to the south connecting with Mellen Street, with a small berm or floodwall that ties into high ground about 200 feet east of the Mellen Street Bridge right bank abutment. This reach of flood control structure will allow for WSDOT to modify the proposed interchange widening project. It will also prevent Chehalis backwater from flooding the Mellen Street underpass area. This will also maintain a critical access route to the hospital.

TABLE 2: REACH 2

Plan view:	Plates C-1 and C-4, C-23
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 6+30:	Cross-section B - typical new floodwall
Station 6+30 to Station 7+04:	Cross-section C - typical new levee over road
Length:	658 feet
Avg. Height:	5.1 feet
Avg. Width:	33 feet
Fill Quantity:	2779 cy

3.1.3 Reach 3, Mellon Street Bridge to Salzer Creek Bridge

This reach of levee begins as a floodwall approximately 200 feet east and 300 feet south of the Mellon Street Bridge abutment and heads south along the riverside of Airport Road right-of-way, which is an arterial road paralleling I-5, until it reaches a commercial area. At this point the Chehalis River makes a horseshoe bend at RM 68.5. Active erosion is occurring on the outside bend. WSDOT has developed a conceptual idea of placing a series of rock groins or bendway weirs in this area. This area will require further investigation due to lack of space between the river and the freeway. The design needs to accommodate flood protection, an arterial road and any freeway widening in this particular area.

Current design for this area is a vertical wall to minimize the footprint and any impacts on wetlands. Riprap, bank protection or groins are possible solutions proposed for this area. From this area, the levee changes to an earthen levee along Airport Road right-of-way. The levee crosses Airport Road and is built along the I-5 right-of-way. Before intersecting with the Salzer Creek Bridge abutment, the levee changes to a 700-foot long floodwall. All culverts will be extended and flap-gated on the riverside; these include the following:

TABLE 3: CULVERTS IN REACH 3

Types of Culverts	RM Locations
12-inch culvert	milepost 81.27
18-inch concrete culvert	milepost 81.10
12-inch culvert	milepost 81.05
36-inch concrete culvert	milepost 80.78
12-inch culvert	milepost 80.72

Minimum facilities to provide interior flood relief were designed to pass the local system design event with no increase in interior flooding as specified in EM 1110-2-1413.

TABLE 4: REACH 3

Plan view:	Plates C-1 and C-5, C-24, C-26, C-27
Cross-Sectional Views:	Plate C-1
Station 0+00 to Station 7+00:	Cross-section B - typical new floodwall
Station 7+00 to Station 37+00:	Cross-section A - typical new levee over soil

Station 37+00 to Station 43+50	Cross-section B - typical new floodwall
Station 43+50 to Station 73+05	Cross-section A - typical new levee over soil
Length:	7305 feet
Avg. Height:	9.2 feet
Avg. Width:	49 feet
Fill Quantity:	79422 cy

3.2 Salzer Reach

3.2.1 Reach 4, Salzer Creek Right Bank

This reach of setback levees ends (Station 124+74) at the I-5 and Salzer Creek Bridge intersection at milepost 80.22. The levee then extends northward to the county transfer station (closed landfill area). The levee alignment then turns eastward on the edge of an existing forest area, as selected by the landowner, to eliminate inundation of the capped hazardous material area. The levee is set back farther away from Salzer Creek than the existing levee. This will minimize the impact to the Salzer Creek floodplain. Then the levees cross the railroad tracks and tie into the existing County Fairground levee, which was built to FEMA standards, so only minor effort to modify this levee is anticipated.

The levees will cross National Avenue and then follow Salzer Creek north to NE Kresky Avenue where it becomes a wall along the west side of the road. The floodwall will have openings for local shopping center traffic. These openings may have floodgates to close during major events or rely on flood fight efforts such as sandbagging. The floodwall continues until you reach one block south of Fair Street where minor flood fighting across Kresky and around two commercial buildings may be required. The alignment then heads northward in the general alignment of Pacific Avenue until it reaches the edge of a residential area at which point it turns eastward one block to the next county road. The alignment continues to switch northward and then eastward to until it ties to the high ground of Summa Street, start of the levee (Station 0+00).

Table 5: Reach 4

Plan view:	Plates C-1 and C-6
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 40+50	Cross-section A - typical new levee over soil
Station 40+50 to Station 61+00	Cross-section B - typical new floodwall
Station 61+00 to Station 79+50	Cross-section A - typical new levee over soil
Station 79+50 to Station 80+30	No Cross-section. Flood fight
Station 80+30 to Station 104+30	Cross-section E - typical new levee over existing levee
Station 104+30 to Station 105+30	Cross-section D - railroad intersection
Station 105+30 to Station 122+70	Cross-section A - typical new levee on soil
Station 122+70 to Station 123+10	Cross-section D - railroad intersection
Station 123+10 to Station 124+74	Cross section A - typical new levee on soil
Length:	12,599 feet
Avg. Height:	7.1 feet
Avg. Width:	40 feet
Fill Quantity:	86875 cy

3.2.2 Reach 5, Salzer Creek Left Bank

This reach starts at the south Salzer Creek Bridge abutment. At the abutment the levee will require riprap for stream bank protection until it crosses the railroad tracks. The levee then parallels the railroad south to Station 47+70 where it turns eastward and crosses the railroad tracks continuing eastward until it crosses Coal Creek at station 57+00 where a minimum facility flap-gated culvert will be installed. The levee then ties in with an existing levee system. It then crosses National Avenue. The current flood fight plan is to temporarily place ecology blocks across the road. The existing blocks are stored on site. The levee beyond this point is a floodwall, for the entire reach between National Avenue and NE Kresky Avenue. The floodwall is placed around the perimeter of a paved parking area.

TABLE 6: REACH 5

Plan view:	Plates C-2 and C-7
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 1+60:	Cross-section A - typical new levee on soil
Station 1+60 to Station 2+00	Cross-section D - railroad intersection
Station 2+00 to Station 47+70	Cross-section A - typical new levee on soil
Station 47+70 to Station 47+85	Cross-section D - railroad intersection
Station 47+85 to 57+50	Cross-section A - typical new levee on soil
Station 57+50 to 62+30	Cross-section E - typical new levee over existing levee
Length:	6,212 feet
Avg. Height:	7.3 feet
Avg. Width:	41 feet
Fill Quantity:	34037 cy

3.2.3 Reach 6, Coal Creek

This reach starts at National Avenue and heads east to Kresky Avenue. It consists of raising an existing floodwall around the perimeter of an existing parking lot.

TABLE 7: REACH 6

Plan view:	Plates C-2 and C-7
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 9+76:	Cross-section B - typical new floodwall
Length:	976 feet
Avg. Height:	7.5 feet
Avg. Width:	18 feet

3.3 DILLENBAUGH REACH

3.3.1 Reach 7A, Salzer Creek to Airport

This reach starts at the left bank of Salzer Creek Bridge abutment on the west side of I-5. The I-5 bridge abutment will require riprap bank protection. A 3-foot high wall will be placed on the shoulder of the southbound lanes to provide flood protection, to station 11+00. This wall will extend south of the existing riparian buffer and then the cross section will change to a standard levee from the freeway to Airport Road. The levee will parallel Airport Road heading south until it connects with an existing levee around the perimeter of the airport. This forms an area between Airport Road and the freeway that is surrounded by levee. This area is set aside for proposed for WSDOT infiltration ponds. From here the existing Airport levee will be widened and raised on the landward side of the existing levee. This will require some modification to the existing Airport pump station, which pumps local drainage and floodwaters over the top of the levee during major flood events. Potentially contaminated ground exists near the Airport World War II-vintage buildings. Excavation in this area will be monitored carefully if it cannot be avoided. The existing access road over the top of the levee will need to be relocated, possibly requiring a new ramp alignment. This levee section parallels northwest Airport Way to the south until it reaches the intersection of Arizona Avenue and Airport Way.

TABLE 8: REACH 7A

Plan view:	Plates C-2 and C-8
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 11+00:	Cross-section A - typical new levee over soil
Station 11+00 to Station 102+80:	Cross-section E - typical new levee over an existing levee
Length:	12,726 feet
Avg. Height:	8.8 feet
Avg. Width:	10280 feet
Fill Quantity:	123296 cy

3.3.2 Reach 7B

At this point a new levee will be built on the north side of NW Airport Way. This forms the south leg of the Airport levee. The existing levee is on the south side of Airport Way, and it will be removed out of consideration for environmentally sensitive area. The south leg of the levee travels from Arizona Way to NW Louisiana Avenue, at which point the flood control structure must cross the intersection of NW Louisiana Avenue and the NW West Street ramp. The flood control structure continues along the south bounds lanes of Louisiana Avenue, which is a frontage road paralleling I-5. An option for this reach would be to place the levee over an existing road, which would tie in with proposed WSDOT interchange improvements, and include modifying the interchange access ramp.

TABLE 9: REACH 7B

Plan view:	Plates C-2 and C-8
Cross-Sectional Views:	Plate C-13
Station 102+80 to Station 118+80:	Cross-section A - typical new levee over soil
Station 118+80 to Station 139+53	Cross-section C - typical new levee over existing road (including intersection)
Length:	1,305 feet
Avg. Height:	4 feet
Avg. Width:	28 feet
Fill Quantity:	3832 cy

3.3.3 Reach 8, SR-6 to Railroad Underpass

This reach of setback levees starts along the I-5 and SR-6 interchange southbound on-ramp. The flood control structure starts as a wall along the right shoulder of the road until it reaches Dillenbaugh Creek Bridge. There will be a flood control box between the bridge abutments tied in by the floodwall with a low-flow fish passage capability. During a major flood the control box is designed to close off the Chehalis backwater from going up Dillenbaugh Creek under the freeway. The flood control box will not increase interior flooding per EM 1110-2-1413. The alignment continues south as a typical levee until it reaches the Chehalis Railroad underpass. At this location a flood fight plan will include installing stop logs and sand bags between the two concrete wall sections tying into the ends of the levee section on both sides of the railroad track.

TABLE 10: REACH 8

Station 0+00 to Station 0+40	Cross-section B - typical new floodwall
Station 0+40 to Station 1+20:	Flood Control Box on Dillenbaugh Creek
Station 1+20 to Station 4+10	Cross Section B - typical new floodwall
Station 4+10 to Station 19+20	Cross-section F - typical new levee
Station 19+20 to Station 19+70:	Cross-section D - Railroad intersection
Station 19+70 to Station 20+50	Cross-section A - (tie into I-5)
Length:	1,911 feet
Avg. Height:	8.6 feet
Avg. Width:	46 feet
Fill Quantity:	14000 cy

3.3.4 Reach 9A, Dillenbaugh Creek

This reach starts on the north side of the I-5 bridge abutment at RM 0.5 on Dillenbaugh Creek. The levee alignment crosses two BNSF Railroad tracks and Dillenbaugh Creek. The location where the levee crosses the railroad tracks will continue to require flood fighting, which includes stop logs and sand bags across the tracks. During major flood events the flood control box would stop the flow of Dillenbaugh Creek, isolating it to the west side of the freeway. Simultaneously the flood control box at Reach 8 would prevent Dillenbaugh Creek from flowing east to west and from entering the Chehalis River.

These flood control boxes would be used only in a major flood event to maintain the inundation of the marsh and wetland area on the east side of I-5 to the zero damage line. The main purpose is to prevent Chehalis backwater from flooding the interstate and the City of Chehalis. Flood elevations in this area would be controlled to a maximum zero damage line, in other words the flood would not get higher than the zero damage line during a major event. The flood control boxes are designed to pass the local system design event with no increase in interior flooding during low exterior stages, per EM 1110-2-1413. Interior drainage will be further evaluated in the next phase design of the project. This levee alignment is offset 78 feet away from the existing I-5 centerline to allow for widening of the I-5 interchange. This will require the relocation of Dillenbaugh Creek by either WSDOT or this project.

TABLE 11: REACH 9A

Plan view:	Plates C-2 and C-10
Cross-Sectional Views:	Plates C-13
Structural Details Flood Control	Flood Control Box
Station 0+00 to Station 2+20:	Cross-section A - typical new levee on soil
Station 2+20 to Station 2+70	Cross-section D - railroad intersection
Station 2+70 to Station 2+86	Cross-section A - typical new levee
Station 2+86 to 3+66	Flood Control Box
Station 3+66 to Station 29+46	Cross-section A - typical new levee over soil
Length:	185 feet
Avg. Height:	6.9 feet
Avg. Width:	40 feet
Fill Quantity:	1228 cy

TABLE 12: REACH 9B

Length:	60 feet
Avg. Height:	2.8 feet
Avg. Width:	23 feet
Fill Quantity:	111 cy

TABLE 13: REACH 9C

Length:	2581 feet
Avg. Height:	10.1 feet
Avg. Width:	52 feet
Fill Quantity:	30946 cy

3.3.5 Reach 10 Dillenbaugh South

This reach will be a short wall along the southbound on ramp and the interchange area**.** It will not impact any wetlands and will not require any relocation of Dillenbaugh Creek. This reach will not be necessary if the Rice Road interchange is improved prior to construction of this project.

TABLE 14: REACH 10

Plan view:	Plates C-2 and C-10
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 17+50:	Cross-section B - typical new floodwall
Length:	1750 feet
Avg. Height:	1 foot
Avg. Width: (below ground)	10 feet

3.4 SKOOKUMCHUCK REACH

The levee protection provided by the levee system on the Skookumchuck River is principally for protection of the backwater effects of the Chehalis River. This effect reaches approximately 2.0 miles upstream to the confluence of Coffee Creek and the Skookumchuck River.

3.4.1 Reach 11, West Reynolds Avenue to BNSF Railroad

This reach of levee starts at West Reynolds Avenue, near the intersection of BNSF Railroad, Chehalis Western Railroad and I-5 underpass. The levee ties into West Reynolds Avenue at the 100-year plus 3-foot elevation so no flood fighting across Reynolds Avenue will be necessary. The levee section runs south, parallel and adjacent to BNSF Railroad tracks to a distance of approximately 200 feet from the Skookumchuck River. There is an optional cross-section for this entire reach; the optional design would be to utilize the existing railroad embankment. Placing an impervious layer of material on the east side of the railroad embankment would accomplish this. Work in this reach would also include raising the curb elevation of West River Road to a height of 4 inches or 0.3 feet (floodwall elevation). Also the high ground between BNSF and Chehalis Western Railroad tracks will need a small berm to bring its elevation to the required level of protection.

TABLE 15: REACH 11

Plan view	Plates C-1 and C-12
Cross-sectional Views:	Plate C-13
Station 0+00 to Station 20+60:	Cross-section A - typical levee on soil (option - railroad embankment upgrade)
Station 20+60 to Station 20+90	Cross-section railroad
Station 20+90 to Station 23+30	Cross-section A - typical levee on soil
Length:	2,331 feet
Avg. Height:	2.9 feet
Avg. Width:	24 feet
Fill Quantity	4059 cy

3.4.2 Reach 12, Chehalis Western Railroad to Harrison Street Bridge

3.4.2.1 Reach 12A, Chehalis Western Railroad to Borst Park

Reach 12A starts on the west side of the Chehalis Western Railroad, approximately 200 feet away from the edge of the Skookumchuck River. The levee starts as a typical levee over soil until it reaches an existing driveway at which point the levee takes advantage of the existing road elevation and footprint. However because the Skookumchuck River makes a 180 degree, or horseshoe, bend at this point, it will require riprap bank protection for approximately 200 linear feet of levee section. The intent in general is to setback the levee as close as possible to the residential houses. This gives the river more room to meander and some diversity along the shoreline, where it is currently constricted. Real estate investigations will be done in the next phase to determine the optimum levee alignment in this area. As currently designed, several residential and one commercial structure are left on the riverside of the levee. A possible non-structural solution or flood fight plan will be devised in the next phase of the project. The levee follows the high ground and it becomes a levee over the existing road through Borst Park, until it reaches I-5 embankment approximately 100 feet north of the Skookumchuck River.

3.4.2.2 Reach 12B, Borst Park to Harrison Street Bridge

Reach 12B is a floodwall and ties in to the Harrison Street right bank bridge abutment. It is assumed that some maintenance of the existing riprap will be necessary.

TABLE 16: REACH 12

Plan view:	Plates C-1 and C-11, C-50, 51,52,53
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 3+50	Cross-section A - typical levee over soil
Station 3+50 to Station 5+00	Cross-section C - typical new levee over road
Station 5+00 to 7+00	Typical new levee over road plus riprap
Station 7+00 to Station 7+70	Cross-section C - typical new levee over road
Station 7+70 to Station 24+00	Cross-section A - typical new levee over soil
Station 24+00 to Station 31+50	Cross-section C - typical new levee over road
Station 31+50 to Station 38+34	Cross-section A - typical new levee over soil
Length:	3834 feet
Avg. Height:	5 feet
Avg. Width:	32 feet
Fill Quantity:	15595 cy

3.4.3 Reach 13, Harrison Street Bridge to I-5 Right Bank

This reach starts on the right bank just downstream side of Harrison Street Bridge, and involves placing a floodwall from the bridge to an existing commercial flood proof building. It uses the building as a part of the flood control system and connects one building from one side of the parking lot to the next building and crosses Bridge Street. It then follows the perimeter of Hayes Lake utilizing existing high ground, floodwalls and flood proof buildings as part of the flood control system. The floodwall will continue between the last building and the freeway along the edge of an existing access road tying into I-5. A possible alternative alignment to take advantage of high ground would be to have a floodwall along the south side of Harrison Avenue from West High Street to the Harrison Street Bridge; however several openings would be required in the wall to allow access to the commercial buildings on Harrison Avenue.

TABLE 18: REACH 13

Plan view:	Plates C-1 and C-12, 52,53
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 30+50:	Cross-section B - typical new floodwall
Length:	3050 feet
Avg. Height:	5.7 feet
Avg. Width:	16 feet

3.4.4 Reach 14, Left Bank I-5 to Harrison Street Bridge

Reach 14 starts 100 yards south of the I-5 bridge abutment on the left bank of the Skookumchuck River. The levee alignment heads east following high ground contours with wetlands on both sides of the levee until it reaches the residential neighborhood. The levee continues to follow the high ground contours and then ties into a berm behind a Nursing Home.

From this point the alignment continues northeastward, following the contour line associated with the existing ordinary high waterline of the Skookumchuck River and ties into Denny Way. The embankment for Denny Way will require riprap bank protection plus a floodwall built along the riverside of the road. The floodwall will be built from Denny Way to Latona Street, where the cross-section will change to a typical earthen levee section. This levee will be built on top of an existing riprap embankment. The alignment continues from Latona Street to Harrison Street Bridge. From the upstream side of the Harrison Street Bridge, a short floodwall will be built on the left bank along First Street, continuing one block west of M Street. At this point it ties into existing high ground. The existing pavement on First Street to M Street and along M Street heading northward approximately one block will not require any modifications.

TABLE 19: REACH 14

Plan view:	Plate C-12, C-54
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 13+00:	Cross-section A - typical new levee over soil
Station 13+00 to Station 17+00	Cross-section B - typical new floodwall
Station 17+00 to Station 18+50	Cross-section C - typical new levee over road
Station 18+50 to Station 20+90	Cross-Section A - typical levee over soil
Length:	2,082 feet
Avg. Height:	6.6 feet
Avg. Width:	38 feet
Fill Quantity	12858 cy

3.4.5 Reach 15, Harrison Street Bridge to Chehalis Western Railroad

Reach 15 alignment begins at the Harrison Street Bridge along W First Street and turns north on M Street. M Street, which is a gravel road, will be raised for a distance of 1500 feet until it reaches an existing raised driveway (station 25+00). A new levee will be built to surround a residential neighborhood and tie into an existing Chehalis Western Railroad embankment approximately 200 feet away from the edge of the Skookumchuck River.

TABLE 20: REACH 15

Plan view:	Plates C-1 and C-55, 56
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 25+40	Cross-section C - typical levee over road
Station 25+40 to Station 38+40	Cross-section A - typical levee over soil
Length:	3,843 feet
Avg. Height:	3.4 feet
Avg. Width:	24.6 feet
Fill Quantity	9118 cy

3.4.6 Reach 16, Chehalis Western Railroad to Existing Left Bank Levee

3.4.6.1 Reach 16A, Chehalis Western Railroad to BNSF Railroad

Reach 16A is a levee section connecting high ground near the Chehalis Western Railroad to the BNSF Railroad embankment; it is approximately 500 feet from the edge of the Skookumchuck River. Flood fight operations consisting of sandbags may be necessary to cross the railroad tracks connecting to reach 16B.

3.4.6.2 Reach 16B, BNSF Railroad to Existing Levee Left Bank

Reach 16B follows an existing ridgeline along the Skookumchuck River floodway. The levee is aligned as close as possible to an existing residential area, where it will tie into an existing levee built to FEMA standards near the intersection of West 7th Street and G Street. In this reach several existing storm drain outlets will need to have flap gates installed to prevent floodwaters from backing up the storm drain system. The outlets are designed to meet the minimum facilities specifications as described in EM 1110-2-1413. There will not be any increase to interior flooding during low exterior stages as a result of the project.

TABLE 21: REACH 16

Plan view:	Plates C-1 and C-57, 58
Cross-Sectional Views:	Plate C-13
Station 0+00 to Station 8+70:	Cross-section A - typical levee over soil
Station 8+70 to Station 9+10	Flood Fight Railroad Crossing
Station 9+10 to Station 34+14	Cross-section A - typical levee over soil
Length:	3,419 feet
Avg. Height:	3.2 feet
Avg. Width:	21 feet
Fill Quantity	1162 cy

4. INTERIOR DRAINAGE IMPROVEMENTS

At the minimum, the mainline project levee will include “minimum facilities” to provide interior flood relief such that, during low exterior stages (gravity conditions), the local storm drainage system functions essentially as it would without the levee in place, for floods up to that of the storm sewer design, as specified in EM 1110-2-1413. The minimum facilities are designed so that no additional interior flooding will be caused by the levee project. Therefore, additional formal ponding areas are not required on the landward side of the levee.

Additionally, the local community may choose to construct interior flooding improvements to provide a greater level of protection at some locations. Potential local betterment projects are described in the following sections.

4.1 CHINA CREEK

The existing China Creek discharge overflows into Plumber Lake during flood events. Proposed minimum facilities design on China Creek consists of adding a control structure for the 5-foot box culvert under I-5 to prevent Chehalis backwater from entering the China Creek basin.

A possible upgrade the local community may consider is a culvert placed in the proposed levee allowing the floodwaters in Plumber Lake to drain into the Skookumchuck River. Because the Skookumchuck River is controlled by the Skookumchuck Dam, several feet of head difference between China Creek and the Chehalis River will allow China Creek to drain naturally for a longer period of time. A flap gate will be added to the riverside of the proposed culvert between Plumber Lake and Skookumchuck River, to prevent the Chehalis River backwater from traveling up the river into Plumber Lake.

A more elaborate investigation of China Creek involving possible embankment dams, upstream diversion, ring dikes around containment ponds and pumping or draining of China Creek water to the Skookumchuck River is being completed by the City of Centralia. This investigation will be conducted in the next phase of the project to determine if the China Creek drainage qualifies for federal interest under Corps authorities. Interior drainage problems from China Creek, flowing from the railroad grade and high ground, flows south to Salzer Road which acts as a levee. An existing culvert system that goes under Salzer Road may require modifications, such as extending it to the riverside of the proposed Salzer Creek levee, in Reach 6. This would allow China Creek floodwater to drain into Salzer Creek Basin without creating a ponded area on the landward side of the proposed Salzer Creek right bank levee.

4.2 DILLENBAUGH CREEK

Existing local runoff drains into Dillenbaugh Creek and marsh area on the east side of I-5 as well as through culverts through I-5, and under the I-5 overpasses for the Chehalis Western Railroad and Dillenbaugh Creek.

Further investigation will be done in the next phase of study to assure that the flood control boxes shut off flow in Dillenbaugh Creek at two locations, one for flow to the east and one for flow to the west directions. The minimum facilities design of the flood control boxes allows for floodwaters from Dillenbaugh Creek, Chehalis River backwater and interior drainage to fill the area east of I-5 up to the zero damage line or flood stage for this area. A flood response plan will be developed and a specific water surface elevation will dictate when the gates on the flood control box need to be closed. The elevation is approximately 1 foot below the estimated 100-year flood elevation. Therefore it will take a major flood before the gates are closed. In any case, the impacts to local interior flooding would not increase as a result of this project, and no formal ponding areas are needed.

4.3 SCAMMON CREEK

The existing drainage system is conveyed through a culvert under Cook Road. The proposed levee and associated flap-gated culvert will not create additional interior flood damages. Chehalis backwater will be prevented from flooding a church and residential area on the south side of Cook Road.

The local community may choose to upgrade the level of protection for Cook Road in the next phase of the study. Cook Road is a main access route to the hospital. Further analysis is needed to determine if the road would be raised and/or combined with a floodwall and/or a small pump station to allow access during a 100-year event.

4.4 COAL CREEK

Existing conditions at Coal Creek include routing of the creek through a concrete box culvert around an industrial park and leveed commercial area. The proposed levee and associated flap-gated culvert through the levee would not create additional interior flood damages. Backwater from the Chehalis River and Salzer Creek floodwaters will be eliminated by the flap-gated culvert. Local betterment projects were not identified for this drainage system.

5. MITIGATION

The SR-6 Floodplain Reconnection Feature adds significant mitigation benefits while also providing additional incidental flood damage reduction benefits. This feature includes a 400-foot wide excavation of SR-6, with an invert elevation of 179 feet. This feature, in combination with several wetland areas, reconnection of an oxbow, enhancement of Scheuber ditch to reconnect the floodplain with the river downstream of SR-6, several riparian zones and a back channel area, are proposed for this restoration plan. (For further details, see the EIS.)

5.1 STATE ROUTE 6 FLOODPLAIN RECONNECTION

The feature includes a 400-foot wide excavation of SR-6. This would involve excavating and grading approximately 65,000 cubic yards of material, and elevating the roadway to provide clearance for reconnecting the floodplain by providing overbank flows, an environmental condition of significant importance to fish and wildlife species in the study area. Several limiting factors were identified during the study. They included loss of floodplain connectivity, loss of riparian zone, and altered hydrologic regime. The restoration proposed for this project focuses on these factors, such as reconnection of the floodplain and creation/enhancement of wetlands and riparian zones.

Restoration/mitigation actions at SR-6 will include a bridge or culvert crossing at SR-6 to allow floodwaters to flow across the historic floodplain to the north and will be combined with a year-round connection from the Chehalis River to the oxbow south of SR-6, an annually flooded wetland complex (approximately 80 acres) north of SR-6 that also receives water from an unnamed tributary. The restoration/mitigation actions will also include a new channel connecting the oxbow through the wetlands to Scheuber Ditch, channel meandering, and a 200-foot wide riparian restoration along Scheuber Ditch, a backwater wetland complex at the outlet of Scheuber Ditch into the Chehalis River that is connected year-round.

The floodplain along Scheuber Road would also provide storage of flood flows when flows on the Chehalis River at RM 77 exceed the annual flood magnitude. Flood flows bypassing through the SR-6 overflow site to the floodplain would not return to the river until the flows reach the north end of the floodplain bypass and storage area. Returning flows would discharge first through the existing Scheuber drainage ditch and then over the low-lying overbank area between RM 71.6 and RM 72.4 of the Chehalis River. This bypass flow is beneficial to both flood control and environmental restoration aspects of this project. Modifications to the banks of the Chehalis River in the area where the bypass flows re-enter the river channel may be required. These modifications could include armoring of the banks on both sides of the river to protect from possible head cutting or erosion opposite the bank from the cross flows. Reshaping of the Scheuber ditch side of the river to allow for smooth transition flow back into the river is another possible modification.

The design consists of using pre-cast concrete box culverts to bridge the SR-6 opening. The design would consist of supporting the roadway on concrete piles, which suit the site considering the opening width and the likelihood of poor soils. The structure would consist of a relatively thin pre-cast concrete slab supported on pile bents at 20- to 30-foot spacing.

6. CONSTRUCTION CONSIDERATIONS

6.1 HAUL ROADS

Temporary construction haul roads will be a minimum of 12 feet wide for one-way traffic and 24 feet wide for two-way traffic. Filter fabric and a minimum of 1.5 feet of pit run gravel will be placed over the fabric. Existing commercial quarries will be used as a source of gravel. Depending on the quality of excavation material, it may also be used for these roads. Costs are included to remove all the fill material used to build the temporary haul road and transport it to a disposal area. Silt fencing would be provided as necessary.

Existing roads used for haul roads will be surveyed before and after the project and restored to pre-project existing conditions. The local sponsor will select routes for the truck haul. Hours of operation will be specified to minimize traffic and noise problems.

The top of levee or the footprint of the levee will be used as much as possible during construction to minimize road construction impacts and costs.

Temporary or permanent access ramps will be made at all road crossings and driveways. In addition, work will be coordinated with the railroads for high traffic crossing areas.

Safety precautions will also be coordinated with WSDOT for construction immediately adjacent to I-5.

6.2 MATERIALS

Levee Fill: Materials for the levee will consist of compactable-engineered fill, meeting standard Corps of Engineers specifications, as discussed in the Geotechnical Investigations section.

Gravel: All gravel materials will be from existing commercial quarries. Clean gravels will be used when in or near the water to reduce siltation in the rivers. A gradation specification will describe what percentage of fine material is allowable.

Rip Rap: Rock source for the riprap bank protection will be approved during the bid process. This requires the contractor to demonstrate that the quality of the rock meets Corps standards, including a freeze thaw test and specific gravity. Rock will be quantified in units of tons in the cost estimate. But the drawings will indicate the number of cubic yards of rock. A conversion of 1.65 tons per cubic yards will be used. The dimensions of the rock will also be specified and field-checked during construction. The length shall not exceed 3 times its width. All riprap will be placed or keyed into the bank protection by a hydraulic excavator with a thumb, rather than end dumped by a truck.

6.3 Disposal

Recycling or using as much of the excavated material as possible will minimize disposal of unsuitable or excess material. Excavated material will be sorted to usable topsoil, levee fill material and unsatisfactory material, including any contaminated soil encountered. Any wet material will require dewatering before transporting on the highway. The topsoil will be placed on the slopes of the levee prior to hydroseeding. The suitable fill material will be mixed with imported engineered filled material and will be used as levee fill material. All unsatisfactory material will be removed from the project and all contaminated soil will be disposed of properly, meeting State requirements.

6.4 Fish Windows

In-water construction will occur only during the fish windows, which will be clearly specified for each river or tributary. In general this will be coordinated with the appropriate agencies to consider the latest changes in the endangered species list or other regulation changes.

Very little in-water work will be necessary and will be scheduled during appropriate fish windows. Current water-construction period closure is from February 15 to July 15. This should not present a scheduling problem since a very small percentage of work will be in-water construction.

7. OPERATION, MAINTENANCE, REPAIR & REHABILITATION (OMR&R)

The local sponsor, who is responsible for maintenance of the entire project, will be provided with an Operation, Maintenance, Repair and Rehabilitation Manual (OMR&R) at the time that the project is accepted and turned over to the local sponsor. The manual will specify what maintenance and estimated rehabilitation is required to meet federal standards. A cost estimate and time schedule will be included for budgeting and planning purposes. It also specifies the consequences of not doing the prescribed maintenance. If the federal government feels the project is in jeopardy of not functioning due to lack of maintenance, the government will do the work and bill the local sponsor for the effort.

For the levee system, a minimum of an annual inspection, preferably an inspection after each major flood event, by locals will be performed and results submitted to the Corps documenting levee conditions and any repairs or maintenance required or completed. Periodic government inspections will also be done to check that basic federal standards are being maintained, including:

- no trees over 4-inch diameter;
- grassed side slopes;
- drainage features operate correctly;
- annual mowing to allow for ease of inspection,
- maintained level gravel access road on top of the levee; and
- riprap rock sections will be monitored to assure bank protection, erosion control. Annually the local sponsor must submit a levee survey to verify the condition of the levee to maintain eligibility for Federal assistance after a major disaster.

For cost estimating purposes the OMR&R costs for levees are approximately $5,000 per year, per mile of levee. In addition, it is assumed that 50 percent of the rock will be replaced at year 25.

The government will identify any deficiencies in the maintenance or condition of the levee. A specific checklist of work items will be given to the local sponsor spelling out what is required to bring the project back into compliance, thus making the flood control structure eligible for federal assistance when major rehabilitation is needed or in the event that flood damage occurs. This includes eligibility for federal funds thru FEMA after a catastrophic disaster.

The OMR&R will also include a Flood Fight Plan. Since flood fight efforts are an integral part of the levee system, it becomes critical that the necessary equipment, materials and personnel are available. In addition the plan must specify where flood fight actions need to take place, when to take these actions, and who will be responsible for flood fighting.

This flood fight plan will need to be updated annually with points of contact, material and equipment inventory changes. Problem areas need to be identified and monitored. These documented problem areas should then be incorporated into the next year's maintenance plan. This will allow for the in-water work to be done at low-flow conditions, which is not only safer and cheaper, but a more environmentally friendly way to accomplish the work.

8. DESIGN AND CONSTRUCTION SCHEDULE

8.1 DESIGN

The design for the levee plan is at the 35 percent level. Plans and specifications will be continued in PED, which will be completed in December 2003. During the process, additional ITRs will be conducted at 65 percent and 90 percent. Design of the environmental mitigation and restoration features were done at a concept level. They will be brought up to an equal design level at the 65 percent review. At that point a government cost estimate will also be done.

Design work by WSDOT will also be done in the next phase as part of this project. A major design effort will be for required for the unique solution to flood problems at the I-5 bridges over Salzer Creek. Because WSDOT will be working on other related projects within the study area, close coordination between projects will be necessary. For example widening of all interchange areas and water runoff treatment designs can be directly incorporated into this project's flood control and mitigation designs.

Design coordination with the cities of Centralia and Chehalis to develop a plan for utilities will be refined with more specifics in the next phase. Special design features may include vaults or tunnels where the proposed levee crosses over the new sewer mains under construction to avoid any differential settlement problems.

Plans and specification writers will be added to the team at the 65 percent level to expedite the design completion and improve quality of the bid package.

Additional detailed coordination on environmental issues, such as avoiding wetlands, will be studied in more detail as the design progresses.

Geotechnical and HTRW investigations will provide more data input to the design as the information becomes available.

A 25 percent quantity contingency was used at this level of design. This contingency will be reduced as this additional information becomes available, particularly information from the property owners involved.

8.2 CONSTRUCTION SCHEDULE

The construction schedule for the levee plan is shown below. It is assumed that any construction necessary for mitigation or restoration features would also be completed in this time frame. The construction schedule for the recommended plan may include a separate contract for work on Skookumchuck Dam. That schedule may differ from the construction below for the levee plan.

Description	**Dates**
Chief's Report	Dec 02
All Permits Received	Aug 03
Project Cooperation Agreement Signed With Sponsor	Aug 03
Corps Receives Construction Funding	Dec 03
Sponsor Completes Real Estate Acquisition	Jan 04
Corps Advertises Construction Contract	Feb 04
Construction Contract Award (First Contract)	Apr 04
Contract Notice To Proceed	May 04
Approve Contractors Plans (Safety, Health and Environmental Protection)	Jun 04
Construction Contract Physically Complete (Last Contract)	Sep 06
Project Construction Physically Complete	Jul 07
Project Fiscally Complete	Sep 07
Final Acceptance & Transfer to Local Sponsor	Sep 07

9. COST ESTIMATE

Preliminary cost estimates have been developed for the alternatives modeled. All costs are presented in 2002 dollars and exclude interest during construction. The estimates include contractor’s overhead and profit, sales tax, engineering and planning, and a cost contingency appropriate to this phase of studies. The quantities also included a 25 percent contingency, mainly to cover possible changes to the levee alignment.

The estimated costs are preliminary only, and are contingent upon approval of the selected design by resource agencies and other interested parties. Mitigation and restoration costs are detailed elsewhere but would be included in the final project costs. The final project costs for the recommended plan would depend on final design details and price factors, and could vary from the estimates presented here.

Quantity estimates were made from work items and materials for the main components of the recommended design. Approximate unit prices were developed by the local sponsor’s contracted cost estimator and compared with previous cost estimates by the Corps, bid prices from similar projects, and quotes from manufacturers and contractors. Construction work was assumed to be limited to 8 hours a day, 5 days a week

Mitigation costs have not been included in the estimated construction costs. The level of mitigation, or the exact nature of habitat improvements required will be developed and refined as the design progresses. The preliminary estimated costs for mitigation or habitat improvements, and their associated annual maintenance costs have been developed. During the next phase these cost estimates will be refined along with the mitigation design costs. Mitigation costs would include additional land acquisition, as well as permitting, engineering, and construction costs.

The project construction period would take about 2 years total calendar time. The production is based on working 8 months a year, April through November, for two working seasons.

Preliminary cost estimates have been developed for the various Skookumchuck Dam Modification alternatives. All costs are presented in 2002 dollars and exclude interest during construction. The estimates include contractor’s overhead and profit, sales tax, and a construction contingency appropriate to this phase of studies.

It should be noted that the estimated costs are preliminary only, and are for comparison so that a cost-effective design alternative can be selected. The final project costs for the proposed design would depend on final design details and price factors, and could vary from the estimates presented here.

Quantity estimates were made from work items and materials for the main components of the proposed design. Approximate unit prices were developed from previous cost estimates by the Corps and WSDOT, bid prices from similar projects, quotes from manufacturers and contractors, and from current R.S. Means construction cost guides. Construction work was assumed to be limited to 8 hours a day, 5 days a week.

For the cost estimates, it was assumed that carefully controlled blasting would be used for all rock excavation. It is not known at this time whether there would be concerns with blasting adjacent to the dam. If mechanical excavation methods are required, excavation costs could increase significantly.

Mobilization and demobilization costs were taken as 5 percent of the direct cost subtotal. Sales tax was applied only to materials and equipment rental and not to labor costs. Contractor overhead and profit was taken as 25 percent of the direct cost with mobilization and sales tax added. A 25 percent construction contingency was then added to come up with a total direct cost.

Total project costs would include any costs associated with land acquisition, easements, mitigation, planning, permitting, engineering, and construction management. These costs have been developed by the local sponsor and checked by the Corps and are presented in the Cost Engineering Appendix D.

Annual operation and maintenance costs were also estimated for each of the alternatives. A 50-year project life was used with a discount rate of 6 percent and an inflation rate of 2.5 percent. Labor rates, including all overhead costs, were assumed to be $75 per hour. Maintenance costs were estimated to range from approximately $9,000 to $11,000 per year for each of the alternatives. Operation costs were estimated to be approximately $108,000 per year for each of the alternatives.

State Route 6 Floodplain Reconnection consists of the excavation of approximately 65,000 cubic yards to construct a 400-foot wide excavation of SR-6. Material to be excavated would be primarily river silts and clays. The silts and clay would likely be saturated when excavated, and could be very hard to transport and place in a disposal area. Consideration of on-site disposal to create habitat would be completed in the next study phase.

The excavation would probably be done with hydraulic excavators and on-highway haul units. Production would vary due to the material type, but would be about 125 bucket cubic yards per hour average per excavator. Three trucks per excavator would be required. No dewatering of the excavation was considered. A temporary bypass of SR-6 would be constructed using temporary fill material.

The structure would be a concrete elevated roadway, with a length of about 400 feet. The structure, a trestle, would consist of concrete piles with relatively short spans. This structure would support a roadway consistent with the existing SR-6.

The temporary road construction would be done with a stabilization fabric under-layment, and 1.5 to 4 feet of fill material. Costs are included to remove all the fill material and transport it to a disposal area. Silt fencing would be provided as necessary.

Costs to relocate the sewage treatment plant are not included since plans are underway to do this; nor are any costs associated with structure demolition or cleanup. Costs associated with minor land acquisition, easements, or mitigation is included under Real Estate Costs.

10. SPECIAL CONSIDERATIONS

10.1 WSDOT

Washington State Department of Transportation (WSDOT) has several projects proposed for the project study area. They have been mandated to improve all of their interchange areas by raising and widening, underpass clearance, bridge clearance. In addition to these structural considerations, there are new regulations that state they must not only consider the quality of the surface water drainage, but also quantity. In other words they may need more ponding areas adjacent to I-5, within the project area. Particularly at river, creek or existing culvert crossings.

These considerations are being coordinated as WSDOT's projects and this flood control project evolve. By working these projects together, costs and environmental impacts can be reduced.

Another major consideration is at the I-5 bridges over Salzer Creek. By WSDOT making modifications to the existing bridge, such as attaching floodwalls and closing the gap between the north and southbound lanes, the need to have a large pump and expensive station on Salzer creek is eliminated. In addition, long-term maintenance costs, which would be borne by the local sponsor, would also be eliminated.

10.2 SEWAGE TREATMENT

The existing sewage treatment plant project at Mellon Street is under construction. It will take several years to complete the plant modifications and associated sewer main plumbing project. The design accommodates this future and ongoing plans. Specific details of sewer main crossings by the flood control levees will be coordinated in the next phase.

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PLATES (66 SHEETS)

Plates are bound separately (attached).

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U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington

Final General Reevaluation Report

Appendix D:

Economics

June 2003

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TABLE OF CONTENTS

Section/Paragraph **Page No. D-**

1. INTRODUCTION ... 1

1.1 Purpose ... 1
1.2 Authority ... 1
1.3 Study Problem ... 1
1.4 Study Area ... 2
1.5 Study Reaches ... 2
1.6 Study Methodology ... 4

2. FLOODPLAIN LAND USE AND ASSOCIATED DATA COLLECTION ... 5

2.1 Land Use and Structure Value ... 5
2.2 Farm Budget and Crop Data ... 5
2.3 Content Value ... 6
2.4 Depth Percentage Damage Curves ... 6
2.5 Flood Damage Model ... 6
2.6 @RISK Variables ... 6

3. FLOODPLAIN INVENTORIES AND DAMAGES ... 8

3.1 Residential Inundation Damage ... 11
3.2 Residential Cleanup Costs ... 12
3.3 Emergency Costs ... 13
3.3.1 FEMA – Temporary Rental Assistance / Emergency Home Repairs ... 13
3.3.2 FEMA – Public Assistance Program ... 15
3.3.3 Summary of Emergency Costs ... 16
3.4 Commercial and Industrial Inundation Damage ... 17
3.5 Commercial and Industrial Cleanup Costs ... 17
3.6 Public Inundation Damage ... 18
3.7 Inundation Damage Summary ... 19

4. RESIDENTIAL, NONRESIDENTIAL, AND PUBLIC HEC-FDA MODEL RESULTS ... 21

5. AGRICULTURAL FLOOD DAMAGES ... 23

5.1 Agricultural Inventory ... 24
5.2 Typical Farm Budget Example ... 24
5.3 Restoration of Field Cropland after Flooding ... 26
5.4 Agricultural Flood Damages ... 26

6. TRANSPORTATION RELATED DAMAGES ... 28

6.1 I-5 Damages ... 28
6.2 Rail Freight Flood Impacts ... 29
6.3 Avoided Cost of I-5 Widening ... 30

7. EXPECTED ANNUAL DAMAGE RESULTS ... 32

8. WITH-PROJECT ECONOMIC ANALYSIS ... 33

8.1 Final Alternatives ... 33
8.2 Estimated Costs of Final Alternatives ... 34
8.3 Risk-Based Assessment and Evaluation of Final Alternatives ... 34
8.4 Residual Damages, Damages Reduced and Net Benefits ... 34

8.4.1 Chehalis River Measures....34
8.4.2 Skookumchuck Dam Modification....36
8.4.3 Skookumchuck Levee....36
8.5 Phase 2 - Screening Results, Preliminary NED Alternative....36

9. PHASE 3 – OPTIMIZATION AND IDENTIFICATION OF NED PLAN....37

TABLES

TABLE 1: MONTHLY PROBABILITY OF FLOOD OCCURRENCE....5
TABLE 2: RISK-BASED PARAMETERS....7
TABLE 3: RESIDENTIAL INVENTORY....8
TABLE 4: COMMERCIAL AND INDUSTRIAL INVENTORY....9
TABLE 5: PUBLIC INVENTORY....11
TABLE 6: CHEHALIS RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT....12
TABLE 7: SKOOKUMCHUCK RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT....12
TABLE 8: RESIDENTIAL CLEANUP COSTS CHEHALIS RIVER BY EVENT....12
TABLE 9: RESIDENTIAL CLEANUP COSTS SKOOKUMCHUCK RIVER BY EVENT....12
TABLE 10: FEMA DISASTER RELIEF....14
TABLE 11: TRA AVERAGE EXPENDITURE....14
TABLE 12: PUBLIC ASSISTANCE EXPENDITURES TO TRA EXPENDITURES....16
TABLE 13: EMERGENCY COSTS – CHEHALIS RIVER....16
TABLE 14: EMERGENCY COSTS – SKOOKUMCHUCK RIVER....16
TABLE 15: CHEHALIS COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE BY EVENT....17
TABLE 16: SKOOKUMCHUCK COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE BY EVENT....17
TABLE 17: CHEHALIS COMMERCIAL & INDUSTRIAL CLEANUP COSTS BY EVENT....17
TABLE 18: SKOOKUMCHUCK COMMERCIAL & INDUSTRIAL CLEANUP COSTS BY EVENT....18
TABLE 19: CHEHALIS PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT....18
TABLE 20: SKOOKUMCHUCK PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT....18
TABLE 21: CHEHALIS PUBLIC STRUCTURE CLEANUP COSTS BY EVENT....18
TABLE 22: SKOOKUMCHUCK PUBLIC STRUCTURE CLEANUP COSTS BY EVENT....19
TABLE 23: CHEHALIS RIVER STRUCTURAL DAMAGE SUMMARY....20
TABLE 24: SKOOKUMCHUCK RIVER STRUCTURAL DAMAGE SUMMARY....20
TABLE 25: EXPECTED ANNUAL DAMAGE BY CATEGORY....21
TABLE 26: HEC-FDA DAMAGES BY REACH....22
TABLE 27: STUDY AREA CROP HARVESTS – 1996....24
TABLE 28: MONTHLY FLOOD PROBABILITIES....24
TABLE 29: FARM BUDGET SWEET CORN....25
TABLE 30: SWEET CORN WEIGHTED LOSS CALCULATION....25
TABLE 31: PER ACRE CROP DAMAGE....26
TABLE 32: PER ACRE FIELD CROPLAND RESTORATION COSTS....26
TABLE 33: AGRICULTURAL DAMAGES BY FLOOD EVENT....26
TABLE 34: EXPECTED ANNUAL AGRICULTURAL DAMAGE....27
TABLE 35: I-5 FLOOD RELATED DAMAGES....29
TABLE 36: I-5 DAMAGES BY FLOOD EVENT....29
TABLE 37: RAILROAD DAMAGES BY FLOOD EVENT....30
TABLE 38: EXPECTED ANNUAL DAMAGE SUMMARY....32
TABLE 39: FINAL ALTERNATIVES....33
TABLE 40: PHASE 1 WITH-PROJECT ECONOMIC ANALYSIS....35
TABLE 41: PHASE III PRELIMINARY ALTERNATIVES....38
TABLE 42: PHASE III ALTERNATIVES NED BENEFITS....40
TABLE 43: COMPONENT COSTS....41

TABLE 44: TOTAL ANNUAL COSTS AND NED NET BENEFITS PHASE II ALTERNATIVES................................42
TABLE 45: NED PLAN RESIDUAL DAMAGES 45

FIGURES

FIGURE 1: CHEHALIS RIVER BASIN 3

APPENDICES

APPENDIX A – HEC-FDA MODEL DATA

APPENDIX B – STAGE-DAMAGE FUNCTIONS

APPENDIX C – AGRICULTURAL DATA

APPENDIX D – WSDOT DATA/CORRESPONDENCE

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1. Introduction

1.1 PURPOSE

The purpose of this report is to document the economic evaluation of the Centralia Flood Damage Reduction Project, including flood inundation damages for the Chehalis and Skookumchuck rivers in and around the vicinity of the cities of Chehalis and Centralia and the town of Bucoda in Lewis and Thurston Counties, Washington.

1.2 AUTHORITY

Corps work in the Chehalis River Basin is specifically supported by the following Congressional actions:

Skookumchuck Dam Modification Project: Section 401(a) of 1986 Flood Control Act (PL 99-662) authorized construction of "works of improvement" substantially in accordance with the Report of the Chief of Engineers, dated 20 June 1984. The report was an interim report submitted (third in a series) under the Chehalis River and Tributaries Feasibility Study authority, originally authorized by a 19 April 1946 House of Representatives Flood Control Committee Resolution. The project recommended in that report envisioned modification of the existing, private, water supply dam on the Skookumchuck River to provide a maximum of 28,500 acre-feet (ac-ft) of flood storage, reducing flood damages in the Skookumchuck valley, the town of Bucoda, and the city of Centralia.

Chehalis River & Tributaries Study: On 9 October 1998, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted Resolution 2581, requesting a review of past Corps report recommendations with a view to determining if the recommendations should be modified "with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification." This provides authority for the Corps to conduct a Flood Damage Reduction and Ecosystem Restoration Study for the Chehalis River Basin.

1.3 STUDY PROBLEM

The cities of Centralia and Chehalis have been subject to repeated flooding for many years. This flooding has caused extensive damage to private and public property and periodic closure of critical transportation routes resulting in significant economic losses. In closing transportation routes, the flooding also significantly disrupts emergency response by local governments, impacting public safety adversely. Without implementation of flood hazard reduction measures, actions, or projects, the area will continue to suffer from damaging floods. The local economy will continue to experience depressing economic effects due to the damages and uncertainty associated with future floods. In addition, stream habitat functions of the Chehalis River and its tributaries have been damaged in the past due to development throughout much of the Chehalis Basin. This has resulted in the diminishment of the remaining habitat resources to adequately support sustainable fish and wildlife resources. Loss of wetlands, riparian areas, and back channels has also contributed to some increased flooding in the area. The improvement of degraded areas along the Chehalis River or its tributaries can be a significant factor in sustaining and improving existing fish and wildlife resources in the Chehalis basin.

1.4 Study Area

The Chehalis River Basin lies between the Deschutes River Basin on the east and the Cowlitz River Basin on the south, the Willapa Hills on the west, and the Olympic Range on the north (Figure 1). The basin includes parts of Lewis, Thurston, Cowlitz, Pacific, Grays Harbor, Mason, Jefferson, and Wahkiakum counties.

The Chehalis River Basin is the second largest river basin in the state of Washington outside the Columbia River Basin. The total drainage area of the Chehalis River Basin is 2,660 square miles of which approximately 85 percent is forestlands. Approximately 257 square miles (164,000 acres), or 9.7 percent of the basin is agricultural land.

The Chehalis River system is largely rain-fed with precipitation levels that range from 45 inches per year in the eastern Chehalis River valley to over 200 inches in the Olympic Mountains. Estimated average annual discharge of the entire basin is 11,208 cubic feet per second (cfs)[1].

The four major population centers, Chehalis, Centralia, Aberdeen, and Hoquiam, depend on surface waters of the basin for the largest portion of their municipal and industrial supplies. The principal industrial use of water is in the manufacturing of wood, pulp and paper products. Aberdeen's industrial water system supplies most of this water from the Wynoochee River, with the remainder from Lake Aberdeen.

Land within the basin is mostly forest cover with interspersed agricultural and residential areas. Forestlands are generally located on the upland areas with scattered amounts on bottomlands and constitute approximately 77 percent of the Upper Chehalis Basin (upstream of Porter) and 91 percent of the lower basin (downstream of Porter). Most forested acres are corporation-owned with the remainder being privately or government-owned (Capitol State Forest, Mount Baker-Snoqualmie National Forest and Olympic National Forest). Intensive agriculture and irrigation occur mostly in the low-lying valleys along the Chehalis River and its tributaries. Commercial farms in the basin are following national trends of increased acreage and reduced numbers. Primary use of agricultural land is for crop production (133,000 acres). Pasture comprises 1.8 percent, or 31,000 acres, of the basin (USDA 1975).

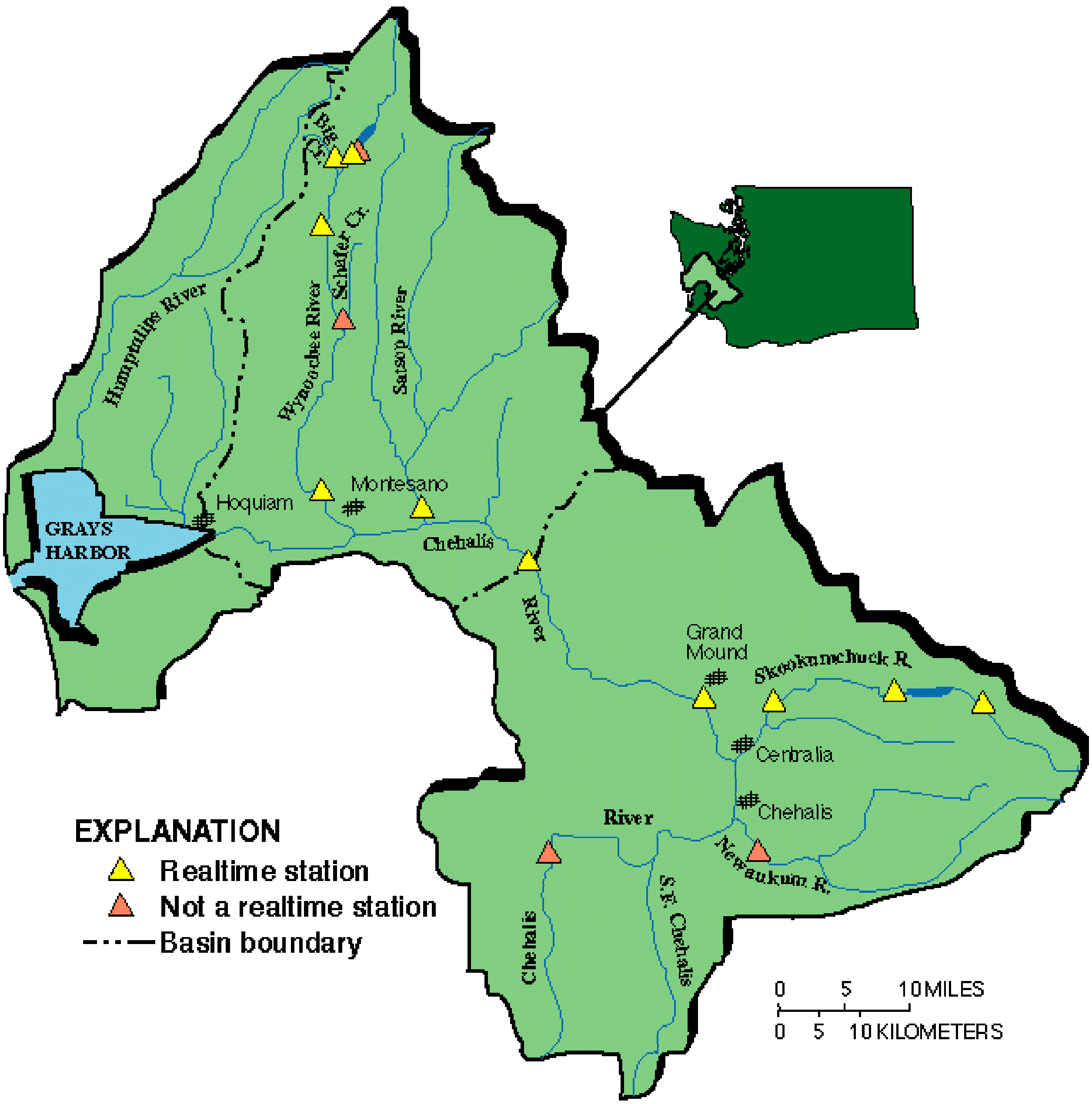
The anadromous fish resources of the basin are of national significance to sport, tribal, and commercial fishing and are important to the economy of the Chehalis Basin.

1.5 Study Reaches

The floodplain of the Chehalis and Skookumchuck rivers was broken into 12 reaches and 17 storage areas (see Plate 5 in the plates to the GRR; the plate does not include the town of Bucoda on the Skookumchuck or Skookumchuck River Reach 1). In addition to these areas, at the request of the local sponsor, a separable reach to cover China Creek has been included (Storage Area 610). At the present time, the analysis of potential damages in the China Creek area (Storage Area 610) has not been completed. As China Creek is separable from Chehalis and Skookumchuck rivers, omitting its potential inundation damages does not affect plan formulation for Chehalis or Skookumchuck, nor does it affect the general level of damages presented in this report.

[1] Chehalis River Council – http://www.crcwater.org/actplan/apbasovw.html

Figure 1: Chehalis River Basin



1.6 Study Methodology

The principal controlling guidance of the analysis comes from the U. S. Army Corps of Engineer's (the Corps, USACE) "Planning Guidance Notebook", ER 1105-2-100, with specific guidance from Appendix D – Economic and Social Considerations. Additional guidance on the risk-based analyses has been obtained from USACE's EM 1110-2-1619, dated 1 August 1996, "Engineering and Design - Risk-based Analysis for Flood Damage Reduction Studies." Guidance on agricultural damages has been derived from USACE Water Resources Support Center's "National Economic Development Procedures Manual – Agricultural Flood Damage," IWR Report 87-R-10, dated October 1987.

Procedurally, the damage assessment was conducted by employing HEC-FDA and HEC-EAD models. Structure and content data were first processed through an @RISK Excel spreadsheet to generate the appropriate stage/damage references with uncertainty for entry into the HEC-FDA model. This preliminary step was necessary due to the dependent relationships between structure damage and the damage categories of temporary relocation assistance, cleanup costs, and public assistance that cannot be modeled under HEC-FDA. The effects of this construction are that individual risk-based damage assessments are performed for each damage category external to the HEC-FDA model in a process that mimics the HEC-FDA methodology. Only the cumulative damage function is directly entered into the HEC-FDA model.

Without-project damages and with-project benefits are evaluated in the categories of: residential, commercial, and industrial inundation damages and flood cleanup costs; emergency costs; agricultural damages; and auto and rail transportation delays. The specific methodology employed in evaluating each category is explained including a description of key assumptions in the text provided for each category.

The Federal discount rate employed for this analysis is 6.125 percent with a price level of June 2002. The amortization period of the study is set at 50 years for all alternatives.

2. Floodplain Land Use and Associated Data Collection

2.1 LAND USE AND STRUCTURE VALUE

Land use was inventoried for the study area likely to be inundated by the 500-year flood event. A complete field survey of all commercial and industrial structures of the floodplain was undertaken. Residential structures were surveyed through a random sample of over 500 structures in the floodplain. Data collected included structure use, type of construction, structure size, condition, and first-floor elevation. A hand level was used to estimate elevations above ground level. The data was collected during the first half of FY01. Structure values are based on depreciated replacement value. Structure condition, use, type, and size were used in conjunction with the Marshall and Swift Valuation Service to develop estimates of depreciated replacement costs. First-floor elevation error and standard deviation for risk-based analyses are based on Table 6-5 of EM 1110-2-1619. Risk-based errors and standard deviations for residential depreciated replacement values are based on a triangular distribution with the upper and lower limits set at Marshall Valuation Service quality of construction grades at one grade above and one grade below, as discussed in Chapter 6-2 of EM 1110-2-1619.

2.2 FARM BUDGET AND CROP DATA

Agricultural crop acreage was developed with the assistance of the Cooperative Extension Office of Lewis County. Aerial mapping of agriculture allowed for the overlaying of floodplains to identify flooded agricultural acreage. Various crop budgets were obtained from the Cooperative Extension, Washington State University for northwest Washington. Historical crop yields and values for various floodplain crops were obtained from the U.S. Department of Agriculture, National Agricultural Statistics Service for Lewis County. Agricultural land restoration costs are based on previous USACE studies and farm budget reports. Monthly flood probabilities were derived based on the percentage of historical annual peak discharges occurring in each month at the U.S. Geological Survey's gauging station 12025000 Newaukum River near Chehalis. The probability of flood occurrence is shown in Table 1.

TABLE 1: MONTHLY PROBABILITY OF FLOOD OCCURRENCE

Month	Probability (%)
January	25.00
February	18.33
March	6.67
April	3.33
May	0.00
June	0.00
July	0.00
August	0.00
September	0.00
October	0.00
November	15.00
December	31.67

2.3 CONTENT VALUE

The risk-based content damage valuation and variation for each residential structure is based on the Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships of 4 December 2000. As specified by the EGM, damage to content is a direct function of structure value, which no longer requires the specific determination of content value. Therefore, residential content value determinations were not calculated for the study. Further, the use of the generic depth-damage relationships waves the survey requirement as prescribed by ER 1105-2-100 Appendix E section E-19q (1). Non-residential content values were developed from the Lake Pontchartrain Hurricane Protection Plan Report of CH2M Hill, Inc., prepared for the New Orleans District of the USACE.

2.4 DEPTH PERCENTAGE DAMAGE CURVES

Residential structure and content damage functions employed for this study are contained in Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships of 4 December 2000. The non-residential structural and content inundation damage curves utilized for the analysis are the Federal Emergency Management Agency (FEMA) National Flood Insurance Program's flood insurance rate review depth percent damage curves of 1998 for non-velocity zones. Agricultural damages have been assumed to be 100 percent based on conversations with County Agricultural Advisors for reasons of actual loss of crops and the non-marketability of the potentially surviving crops, except where noted in the analysis.

2.5 FLOOD DAMAGE MODEL

The flood damage analysis utilized the HEC-FDA model for the determination of expected annual flood damages. This model incorporates the principles of risk and uncertainty and evaluates project performance within the analysis. Economic damage inputs by category by reach and storage area to the HEC-FDA model were initially analyzed using Excel with @RISK at each floodplain hydraulic determination (2-, 5-, 10-, 25-, 50-, 100-, 200-, 500- and 1000-year as a general rule) to develop an overall "stage-damage" function by category by reach and storage area with error for the HEC-FDA model. An example of the @RISK spreadsheet is shown in Appendix A along with the hydrologic and hydraulic information employed in the HEC-FDA model. Appendix B lists the stage-damage functions without error and property inventories for the various reaches and storage areas developed for the study.

2.6 @RISK VARIABLES

The risk-based variables employed in the economic assessment of damages and their sources are listed in Table 2. Hydrologic and hydraulic uncertainty for the analysis is determined by the risk-based subroutines of the HEC-FDA model. Each different risk based parameter for each variable in Table 2 corresponds to a probability distributional function as defined in the at risk program.

TABLE 2: RISK-BASED PARAMETERS

Variable	Source	Risk-based Parameter
FFE - Residential	Survey	RiskTrigen (0.5,1.0, 4.5, 21.05, 95.00)
FFE - Nonresidential	Survey & EM 1110-2-1619	RiskNormal (0,0.1)
Residential Structure Size	Survey	RiskTnormal (1524, 524, 600, 4500)
Depreciated Replacement Value Structure	Survey & Marshall & Swift	RiskTriang (grade below, survey, grade above)
Temporary Relocation Assistance	FEMA	RiskTnormal (1537, 411, 0, 10000)
Public Assistance	FEMA	RiskTnormal (3.01, 2.36, 0, 20)
Cleanup Costs	Los Angeles Corps	RiskTnormal (3.65, 0.9375, 0, 10)

3. Floodplain Inventories and Damages

In the study area there were 3,926 residential units counted from base maps prepared by USACE. Marshall and Swift was used to determine the aggregate nominal depreciated structural value of approximately $383,517,000[2] that yields an average residential unit cost of $97,700. The average residential structure is approximately 1,550 square feet in size, which yields a depreciated square foot cost of approximately $63. The content value of these structures was not calculated, as the use of Economic Guidance Memorandum (EGM) 01-03 provides for the calculation of content damages directly from depreciated structural values. Residential structure count and value by location is shown in Table 3.

TABLE 3: RESIDENTIAL INVENTORY

CHEHALIS RIVER			SKOOKUMCHUCK RIVER		
Location	**Number**	**Structure Value**	**Location**	**Number**	**Structure Value**
Reach 1	208	20,319,000	Reach 1	35	3,419,000
Reach 2	52	5,080,000	Reach 2	26	2,540,000
Reach 3	98	9,574,000	Reach 3	383	37,415,000
Reach 4	365	35,656,000	Reach 4	619	60,469,000
Reach 5	123	12,016,000	Storage Area 701	4	391,000
Reach 6	272	26,571,000	Storage Area 702	76	7,424,000
Reach 7	40	3,908,000	Storage Area 703	118	11,527,000
Reach 7b	105	10,257,000	Storage Area 704	74	7,229,000
Storage Area 101	1	98,000	Storage Area 602	173	16,900,000
Storage Area 102	6	586,000	Storage Area 606	259	25,301,000
Storage Area 302	111	10,844,000	Storage Area 705	67	6,545,000
Storage Area 303	17	1,661,000	Storage Area 609	85	8,304,000
Storage Area 2	42	4,103,000			
Storage Area 3	38	3,712,000			
Storage Area 4	14	1,368,000			
Storage Area 5	251	24,520,000			
Storage Area 610B	264	25,790,000			
TOTAL	2007	196,063,000	TOTAL	1919	187,464,000

See Appendix A, Page A-7 for table showing linkages between storage areas and reaches.

As the hydrologic, hydraulic, and economic analyses are constructed on a risk-basis, determining the number of residential structures by flood event is not possible. However, by employing nominal frequencies and their associated nominal discharges and stages in relationship to the risk-based first floor of structures, mean flood inundated residential structure counts and the average level of inundation of the affected structures were derived as follows:

[2] All dollar values are expressed at an October 2002 price level.

Flood Event	Avg. Number of Residential Structures	Average Depth (ft)
1000-Yr	3324	3.3
500-Yr	2669	1.7
100-Yr	1561	0.8
50-Yr	1228	0.5
25-Yr	895	0.3
10-Yr	488	0.1

The survey of commercial and industrial structures indicates that within the study area there are 294 structures encompassing approximately 2,506,610 square feet with total depreciated valuations of $114,658,000 and $146,730,000 for structure and content, respectively. The location and valuations of these structures is given in Table 4.

TABLE 4: COMMERCIAL AND INDUSTRIAL INVENTORY

Location	Number	Structure Value	Content Value	Square Feet
CHEHALIS RIVER				
Reach 1	28	2,914,000	2,465,000	73,300
Reach 2	3	214,000	181,000	7,300
Reach 3	10	8,195,000	15,493,000	226,700
Reach 4	37	5,120,000	4,087,000	108,700
Reach 5	1	111,000	141,000	2,000
Reach 6	4	2,258,000	1,298,000	33,500
Reach 7	0	0	0	0
Reach 7b	2	332,000	322,000	5,200
Storage Area 101	0	0	0	0
Storage Area 102	0	0	0	0
Storage Area 302	7	2,788,000	3,165,000	57,700
Storage Area 303	0	0	0	0
Storage Area 2	31	16,640,000	25,337,000	384,800
Storage Area 3	30	12,297,000	13,005,000	262,200
Storage Area 4	52	28,277,000	42,101,000	657,200
Storage Area 5	6	3,016,000	4,715,000	40,900
Storage Area 610B	15	4,928,000	3,276,000	72,700
TOTAL	226	87,090,000	115,586,000	1,932,200
SKOOKUMCHUCK RIVER				
Reach 1	2	667,000	754,000	13,000
Reach 2	0	0	0	0
Reach 3	7	4,484,000	4,344,000	115,800
Reach 4	35	19,218,000	21,620,000	377,550
Storage Area 701	0	0	0	0
Storage Area 702	1	51,000	58,000	1,000
Storage Area 703	2	137,000	116,000	1,700
Storage Area 704	3	437,000	511,000	7,200
Storage Area 602	13	2,104,000	2,277,000	44,900
Storage Area 606	4	355,000	434,000	8,300
Storage Area 705	1	115,000	130,000	5,000
Storage Area 609	0	0	0	0
TOTAL	68	27,568,000	30,244,000	574,450

GRAND TOTAL	**294**	114,658,000	146,730,000	2,506,610

The location and valuation of public structures in the study area is presented in Table 5.

TABLE 5: PUBLIC INVENTORY

Location	Number	Structure Value	Content Value	Square Feet
CHEHALIS RIVER				
Reach 1	5	994,000	823,000	27,500
Reach 2	0	0	0	0
Reach 3	0	0	0	0
Reach 4	12	11,883,000	11,593,000	141,000
Reach 5	3	368,000	344,000	7,400
Reach 6	10	2,120,000	1,898,000	32,400
Reach 7	9	15,122,000	15,122,000	185,500
Reach 7b	1	196,000	47,000	2,500
Storage Area 101	0	0	0	0
Storage Area 102	0	0	0	0
Storage Area 302	0	0	0	0
Storage Area 303	0	0	0	0
Storage Area 2	13	1,472,000	1,657,000	60,900
Storage Area 3	55	6,716,000	3,705,000	193,400
Storage Area 4	0	0	0	0
Storage Area 5	1	263,000	263,000	3,000
Storage Area 610B	7	10,194,000	10,675,000	115,700
TOTAL	116	49,328,000	46,127,000	769,300
SKOOKUMCHUCK RIVER				
Reach 1	3	1,102,000	565,000	13,500
Reach 2	0	0	0	0
Reach 3	7	5,531,000	5,655,000	69,500
Reach 4	4	5,294,000	5,273,000	60,400
Storage Area 701	0	0	0	0
Storage Area 702	0	0	0	0
Storage Area 703	0	0	0	0
Storage Area 704	3	3,271,000	3,271,000	38,800
Storage Area 602	4	1,079,000	473,000	18,000
Storage Area 606	1	3,434,000	3,434,000	40,000
Storage Area 705	0	0	0	0
Storage Area 609	0	0	0	0
TOTAL	22	19,711,000	18,671,000	240,200
GRAND TOTAL	**138**	**69,039,000**	**64,798,000**	**1,009,500**

3.1 RESIDENTIAL INUNDATION DAMAGE

Residential flood inundation damages to structures referenced to the Chehalis River by event are shown in Table 6.

TABLE 6: CHEHALIS RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure	Content
25-year	8,487,000	4,949,000
50-year	14,072,000	8,117,000
100-year	19,552,000	11,187,000
500-year	50,953,000	28,297,000

Residential flood inundation damages to structures referenced to the Skookumchuck River by event are shown in Table 7.

TABLE 7: SKOOKUMCHUCK RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure	Content
34-year	4,709,000	2,826,000
50-year	6,362,000	3,785,000
88-year	9,086,000	5,349,000
143-year	12,753,000	7,479,000
320-year	18,783,000	10,853,000

3.2 RESIDENTIAL CLEANUP COSTS

Flooding not only causes damage to structures and contents but floodwaters present a significant cost in their aftermath clean up. Floodwaters leave debris, sediment and the dangers of diseases and mycotoxins throughout flooded structures. The cleaning of these structures is a necessary post-flood activity. Cleanup costs for the extraction of floodwaters, dry-out, and decontamination range from $1 to $4.75 per square foot, with a mean cost of $3.65 and standard deviation of $0.94 based on prior studies. Residential cleanup costs by location are shown in Table 8 and Table 9.

TABLE 8: RESIDENTIAL CLEANUP COSTS CHEHALIS RIVER BY EVENT

Flood Event	Cleanup Costs
25-year	2,976,000
50-year	4,377,000
100-year	5,510,000
500-year	9,481,000

TABLE 9: RESIDENTIAL CLEANUP COSTS SKOOKUMCHUCK RIVER BY EVENT

Flood Event	Cleanup Costs
34-year	2,139,000
50-year	2,672,000
88-year	3,454,000
143-year	4,657,000
320-year	5,853,000

3.3 EMERGENCY COSTS

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

3.3.1 FEMA – Temporary Rental Assistance / Emergency Home Repairs

FEMA provides grants to assist individuals and families to find suitable housing when they are displaced in cases of federally declared disasters. This assistance, being directly attributable to the disaster and being an expenditure that would not be undertaken except for the disaster, falls clearly under the emergency costs guidance of ER 1105-2-100. Therefore, funds expended by FEMA for Temporary Rental Assistance or Funds for Minor Emergency Home Repairs (TRA) in the event of flooding are NED flood damages.[3]

Complying with ER 1105-2-100, an Internet database search of FEMA disaster reports for flood and storm damage was performed. Table 10 shows a compilation of the various FEMA reports related to flood and storm.

Table 11 shows the average per claim expenditure by FEMA for TRA ranged from $583 to $2,034 with an overall average expenditure of $1,537 per claim. The standard deviation of the average per claim expenditures is $411.

For risk-based modeling purposes it is assumed that TRA per claim expenditure is normally distributed with a mean of $1,537 and a standard deviation of $411.

[3] The component of TRA funds for minor emergency home repairs does present a potential double counting of structural damage; however, this component is relatively minor in comparison to rental assistance and is deemed insignificant to the overall level of damage or project justification.

Table 10: FEMA Disaster Relief

Location	Date	Temporary Rental Assistance	Unemployment Assistance	Public Assistance	SBA Disaster Recovery Loans	Grants for Needs Unmet by Other Government or Voluntary Agencies
Andrew, Iron etc., MO	Apr-99	$328,233				$384,877
Madison County, MO	Apr-99				$374,000	
Kansas	Jan-99	$3,380,199		$1,196,242	$11,676,800	$2,459,248
Kansas & Missouri	Oct-98	$3,335,504			$1,806,700	$1,140,378
Kansas City, MO	Oct-98			$4,981,549		
Linn Co., MO	Oct-98			$116,762		
South, Central and Southeast Texas	Oct-98	$28,047,095	$427,324	$11,406,977	$88,443,500	$34,842,781
Washington	Oct-98			$1,600,000		
Southeast Texas	Sep-98	$4,190,165	$23,413	$5,267,342	$5,555,100	$2,209,979
Southwest Texas	Aug-98	$2,156,601	$65,817	$4,874,795	$6,450,000	$5,349,805
Wisconsin	Aug-98	$7,000,173			$3,508,400	$693,299
St. Louis City & County, MO	Jul-98	$1,300,000			$212,200	$440,491
Massachusetts	Jun-98	$5,400,000			$274,500	
Oregon	Jun-98	$215,294			$185,000	
North Carolina	Jan-98	$1,213,285		$7,187,159	$929,900	$306,987
North Dakota	Apr-97			$180,033,700		
California	1998	$22,000,000			$37,000,000	
Georgia	1998	$3,100,000		$29,300,000	$23,500,000	$1,800,000
Total		$81,666,549	$516,554	$245,964,526	$179,916,100	$49,627,845

Table 11: TRA Average Expenditure

Location	Date	TRA Funds	TRA Claims	$ per Claim
Andrew, Iron etc., MO	Apr-99	$328,233	341	963
Kansas	Jan-99	$3,380,199	2,388	1,415
Kansas & Missouri	Oct-98	$3,335,504	3,762	887
South, Central and Southeast Texas	Oct-98	$28,047,095	13,786	2,034
Southeast Texas	Sep-98	$4,190,165	2,159	1,941
Southwest Texas	Aug-98	$2,156,601	1,445	1,492
Wisconsin	Aug-98	$7,000,173	5,221	1,341
St. Louis City & County, MO	Jul-98	$1,300,000	2,231	583
Massachusetts	Jun-98	$5,400,000	3,527	1,531
Oregon	Jun-98	$215,294	132	1,631
North Carolina	Jan-98	$1,213,285	703	1,726
California	1998	$22,000,000	15,000	1,467
Georgia	1998	$3,100,000	2,455	1,263
Total		$81,666,549	53,150	$1,537

3.3.2 FEMA – Public Assistance Program

FEMA will reimburse local and state governments and certain nonprofits up to 75 percent of eligible disaster response costs through the public assistance program. It includes all or parts of the following:

- Debris removal
- Emergency protective measures
- Road systems and bridges
- Water control facilities
- Public buildings and contents
- Public utilities
- Parks, recreational and other activities of a governmental nature

These costs, as well as the 25 percent contribution by local and state governments and the nonprofits, are eligible NED emergency costs under ER 1105-2-100. Again, care must be taken to make sure double counting does not occur between public assistance expenditures and structural or other damage categories.

Table 12 presents FEMA expenditures on Public Assistance (PA) to TRA expenditures. The HEC-FDA model is structured in such a fashion that, if a risk-based analysis of PA expenditures is to be made without an external direct input of a PA/stage damage function, PA expenditures must be converted to an individual structure basis. Total Public Assistance expenditures are, as shown in Table 12, 3.01 times the expenditures on TRA. On an individual disaster basis, PA expenditures range from zero to an unknown factor based on the FEMA reports, with the highest reported factor of 9.45. Applying the four standard deviation rule, common to other HEC-FDA variance protocols, the risked-based function of PA is a mean damage of 3.01 times the individual TRA expenditure with a normal deviate of a multiple of 2.36 bounded by zero damage.

TABLE 12: PUBLIC ASSISTANCE EXPENDITURES TO TRA EXPENDITURES

Location	Date	Public Assistance, $	TRA, $	TRA Claims	PA/TRA
Andrew, Iron etc., MO	Apr-99		328,233	341	0.00
Kansas	Jan-99	1,196,242	3,380,199	2,388	0.35
Kansas & Missouri	Oct-98		3,335,504	3,762	0.00
Kansas City, MO	Oct-98	4,981,549			-
Linn Co., MO	Oct-98	116,762			-
South, Central and Southeast Texas	Oct-98	11,406,977	28,047,095	13,786	0.41
Washington	Oct-98	1,600,000			-
Southeast Texas	Sep-98	5,267,342	4,190,165	2,159	1.26
Southwest Texas	Aug-98	4,874,795	2,156,601	1,445	2.26
Wisconsin	Aug-98		7,000,173	5,221	0.00
St. Louis City & County, MO	Jul-98		1,300,000	2,231	0.00
Massachusetts	Jun-98		5,400,000	3,527	0.00
Oregon	Jun-98		215,294	132	0.00
North Carolina	Jan-98	7,187,159	1,213,285	703	5.92
North Dakota	Apr-97	180,033,700			-
California	1998		22,000,000	15,000	0.00
Georgia	1998	29,300,000	3,100,000	2,455	9.45
Total		245,964,526	81,666,549		3.01

3.3.3 Summary of Emergency Costs

Emergency costs (temporary relocation and public assistance expenditures) by flood event and river are shown in Table 13 and Table 14.

TABLE 13: EMERGENCY COSTS – CHEHALIS RIVER

Flood Event	Temporary Relocation Assistance	Public Assistance
25-year	419,000	1,456,000
50-year	675,000	2,345,000
100-year	924,000	3,212,000
500-year	2,109,000	7,327,000

TABLE 14: EMERGENCY COSTS – SKOOKUMCHUCK RIVER

Flood Event	Temporary Relocation Assistance	Public Assistance
34-year	249,000	864,000
50-year	335,000	1,161,000
88-year	472,000	1,641,000
143-year	654,000	2,274,000
320-year	943,000	3,276,000

3.4 COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE

Within the study area there are 294 commercial and industrial properties with a total floor space of 2,506,610 square feet. The total nominal depreciated structure value of these properties is $114,658,000 with a total content value of $146,730,000. The average square footage cost of these structures is $46. Overall content-to-structure value ratio for these structures is 128 percent. Commercial and Industrial structure and content values by location are shown in Table 4: Commercial and Industrial Inventory.

Flood inundation damages to these structures by river and event are shown in Table 15 and Table 16.

TABLE 15: CHEHALIS COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
25-year	1,685,000	1,709,000
50-year	11,495,000	14,620,000
100-year	14,735,000	20,116,000
500-year	25,153,000	39,367,000

TABLE 16: SKOOKUMCHUCK COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
34-year	2,481,000	2,122,000
50-year	2,927,000	2,602,000
88-year	4,317,000	4,020,000
143-year	5,007,000	5,345,000
320-year	6,114,000	7,204,000

3.5 COMMERCIAL AND INDUSTRIAL CLEANUP COSTS

Commercial and industrial cleanup costs are limited to commercial and retail structures normally expected to engage with the public, e.g., restaurants, retail stores, office structures and other such businesses. Cleanup costs are not anticipated to occur with light industrial or other non-public commercial enterprises. Cleanup costs for commercial and industrial structures are presented in Table 17 and Table 18.

TABLE 17: CHEHALIS COMMERCIAL & INDUSTRIAL CLEANUP COSTS BY EVENT

Flood Event	Cleanup Costs
25-year	310,000
50-year	2,905,000
100-year	3,768,000
500-year	5,609,000

TABLE 18: SKOOKUMCHUCK COMMERCIAL & INDUSTRIAL CLEANUP COSTS BY EVENT

Flood Event	Cleanup Costs
34-year	461,000
50-year	481,000
88-year	643,000
143-year	1,004,000
320-year	1,022,000

3.6 PUBLIC INUNDATION DAMAGE

The study area contains 138 public structures whose locations are shown in Table 5: Public Inventory. These structures cover an area of 1,009,500 square feet and have a depreciated structural value of $69,040,000 or approximately $68 per square foot. The content-to-structure ratio is approximately 94 percent, yielding a content valuation of $64,798,000.

Flood inundation damages to these structures by river and event are shown in Table 19 and Table 20.

TABLE 19: CHEHALIS PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
25-year	537,000	359,000
50-year	3,965,000	3,267,000
100-year	4,978,000	4,050,000
500-year	10,239,000	9,836,000

TABLE 20: SKOOKUMCHUCK PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
34-year	1,188,000	1,364,000
50-year	1,621,000	1,684,000
88-year	1,767,000	1,975,000
143-year	2,989,000	2,837,000
320-year	3,453,000	3,788,000

Cleanup costs for public structures are presented in Table 21 and Table 22.

TABLE 21: CHEHALIS PUBLIC STRUCTURE CLEANUP COSTS BY EVENT

Flood Event	Cleanup Costs
25-year	16,000
50-year	379,000
100-year	422,000
500-year	1,398,000

TABLE 22: SKOOKUMCHUCK PUBLIC STRUCTURE CLEANUP COSTS BY EVENT

Flood Event	Cleanup Costs
34-year	132,000
50-year	242,000
88-year	258,000
143-year	397,000
320-year	543,000

3.7 INUNDATION DAMAGE SUMMARY

The tables (Tables 23 and 24) on the following page present a summary of the previously discussed damages.

TABLE 23: CHEHALIS RIVER STRUCTURAL DAMAGE SUMMARY

Flood Event	Residential			Commercial			Public					
	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
25-year	8,487,000	4,949,000	2,976,000	1,685,000	1,709,000	310,000	537,000	359,000	16,000	419,000	1,456,000	22,903,000
50-year	14,072,000	8,117,000	4,377,000	11,495,000	14,620,000	2,905,000	3,965,000	3,267,000	379,000	675,000	2,345,000	66,217,000
100-year	19,552,000	11,187,000	5,510,000	14,735,000	20,116,000	3,768,000	4,978,000	4,050,000	422,000	924,000	3,212,000	88,454,000
500-year	50,953,000	28,297,000	9,481,000	25,153,000	39,367,000	5,609,000	10,239,000	9,836,000	1,398,000	2,109,000	7,327,000	189,769,000

TABLE 24: SKOOKUMCHUCK RIVER STRUCTURAL DAMAGE SUMMARY

Flood Event	Residential			Commercial			Public					
	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	Total
34-year	4,709,000	2,826,000	2,139,000	2,481,000	2,122,000	461,000	1,188,000	1,364,000	132,000	249,000	864,000	18,535,000
50-year	6,362,000	3,785,000	2,672,000	2,927,000	2,602,000	481,000	1,621,000	1,684,000	242,000	335,000	1,161,000	23,872,000
88-year	9,086,000	5,349,000	3,454,000	4,317,000	4,020,000	643,000	1,767,000	1,975,000	258,000	472,000	1,641,000	32,982,000
143-year	12,753,000	7,479,000	4,657,000	5,007,000	5,345,000	1,004,000	2,989,000	2,837,000	397,000	654,000	2,274,000	45,396,000
320-year	18,783,000	10,853,000	5,853,000	6,114,000	7,204,000	1,022,000	3,453,000	3,788,000	543,000	943,000	3,276,000	61,832,000

4. Residential, Nonresidential, and Public HEC-FDA Model Results

The stage-damage functions presented in Appendix B were combined with the hydrology and hydraulic information of Appendix A into the HEC-FDA model for computation of the expected annual damages with uncertainty. The results of the HEC-FDA model are shown in Table 26: HEC-FDA Damages by Reach. Total expected annual damage on the Chehalis River is $6,590,730 and $2,254,190 for the Skookumchuck River. The relative damage by category is shown below in Table 25: Expected Annual Damage by Category for each river.

TABLE 25: EXPECTED ANNUAL DAMAGE BY CATEGORY

Category	Chehalis River		Skookumchuck River	
	$ Damage	Percentage	$ Damage	Percentage
Residential				
Structure	1,789,290	27.15	663,700	29.44
Content	1,036,310	15.72	394,210	17.49
Cleanup	588,290	8.93	278,600	12.36
Nonresidential				
Structure	1,002,610	15.21	352,340	15.63
Content	1,119,860	16.99	311,300	13.81
Cleanup	239,120	3.63	62,240	2.76
Public				
Structure	229,080	3.48	22,800	1.01
Content	189,360	2.87	15,290	0.68
Cleanup	24,490	0.37	4,270	0.19
TRA	83,250	1.26	33,380	1.48
PA	289,070	4.39	116,060	5.15
TOTAL*	6,590,730	100.00	2,254,190	100.00

*Total may not add due to rounding

Analysis is based upon 6.125% discount rate, 2002 price level, and 50-year period of analysis

TABLE 26: HEC-FDA DAMAGES BY REACH

Expected Annual Damage for the Without-project Condition (Damage in $1,000's)													
Stream	Reach	Damage Categories (analysis is based upon 6.125% discount rate, 2002 price level, and 50-year period of analysis)											
		Com - Cleanup	Com - Cnt	Com - Str	PA	Res - Cleanup	Res - Cnt	Res - Str	TRA	Pub - Cleanup	Pub - Cnt	Pub - Str	Total
Chehalis	Reach 7b	0.02	10.05	11.27	64.22	92.98	240.04	427.35	18.50	2.07	2.11	9.12	877.73
	Reach 7	0.00	0.00	0.00	1.68	4.96	5.86	9.74	0.48	5.26	19.20	23.41	70.59
	Reach 6	1.54	6.57	8.14	21.40	53.10	73.95	124.28	6.13	1.22	6.30	7.95	310.58
	Reach 5	0.00	0.00	30.19	2.72	7.19	9.77	16.37	0.80	0.11	2.06	2.44	71.65
	S610B	13.45	36.81	64.72	27.25	60.32	98.64	169.26	7.82	5.58	59.19	59.67	602.71
	Reach 4	3.58	37.07	40.78	25.01	55.65	92.68	159.20	7.26	1.80	11.65	13.27	447.95
	S3	13.01	67.14	62.87	3.29	4.95	14.40	26.13	0.95	7.93	65.13	93.83	359.63
	S4	61.81	344.33	216.17	1.09	1.66	4.06	7.21	0.31	0.00	0.00	0.00	636.64
	S5	1.43	13.83	8.14	10.73	13.08	45.47	82.75	3.09	0.11	0.95	0.80	180.38
	Reach 3	5.94	28.80	16.96	14.34	27.62	50.72	87.86	4.11	0.00	0.00	0.00	236.35
	Reach 2	25.73	54.28	96.08	23.26	47.63	79.87	137.11	6.62	0.00	0.00	0.00	470.58
	S2	26.45	195.95	125.52	2.76	3.87	11.88	21.51	0.80	0.33	22.12	16.35	427.54
	Reach 1	1.71	19.84	31.67	74.64	176.26	250.69	421.91	21.60	0.07	0.65	2.23	1001.27
	S101	0.00	0.00	0.00	0.58	1.04	2.20	3.70	0.10	0.00	0.00	0.00	7.62
	S102	0.00	0.00	0.00	2.09	4.13	7.69	13.37	0.65	0.00	0.00	0.00	27.93
	S302	84.44	305.20	290.11	10.05	27.41	34.69	57.58	2.86	0.00	0.00	0.00	812.34
	S303	0.00	0.00	0.00	3.95	6.45	13.68	23.97	1.15	0.00	0.00	0.00	49.20
Total Chehalis		*239.12*	*1119.86*	*1002.61*	*289.07*	*588.29*	*1036.31*	*1789.29*	*83.25*	*24.49*	*189.36*	*229.08*	*6590.73*
Skookumchuck	Reach 4	39.36	150.35	219.73	22.24	54.90	83.13	141.74	6.40	1.80	7.62	9.11	736.38
	SK-609	0.00	0.00	0.00	10.67	20.97	38.10	66.08	3.09	0.00	0.00	0.00	138.91
	Reach 3	18.44	143.21	113.68	43.71	111.39	146.07	243.32	12.52	0.00	0.00	0.00	832.34
	SK-602	0.35	1.96	2.25	1.93	5.90	6.37	10.29	0.56	0.13	0.48	0.65	30.87
	SK-606	0.01	0.02	0.02	1.32	3.99	4.42	7.15	0.38	1.10	4.81	6.65	29.87
	SK-705	0.00	3.19	3.40	1.19	4.85	4.32	6.78	0.35	0.00	0.00	0.00	24.08
	Reach 2	0.00	0.00	0.00	8.34	17.39	25.88	43.59	2.38	0.00	0.00	0.00	97.58
	SK-701	0.00	0.00	0.00	0.74	1.75	2.12	3.48	0.20	0.00	0.00	0.00	8.29
	SK-702	0.00	0.00	0.00	14.33	28.25	45.98	78.45	4.16	0.00	0.00	0.00	171.17
	SK-703	0.17	1.42	2.15	3.37	14.32	12.56	19.58	1.01	0.00	0.00	0.00	54.58
	SK-704	0.00	0.00	0.00	0.44	1.69	1.50	2.33	0.09	0.00	0.00	0.01	6.06
	Reach 1	3.92	11.14	11.10	7.80	13.21	23.76	40.91	2.24	1.24	2.38	6.38	124.08
Total Skookumchuck		*62.24*	*311.30*	*352.34*	*116.06*	*278.60*	*394.21*	*663.70*	*33.38*	*4.27*	*15.29*	*22.80*	*2254.19*
TOTAL ALL STREAMS		**301.36**	**1431.16**	**1354.95**	**405.13**	**866.89**	**1430.52**	**2452.99**	**116.63**	**28.76**	**204.65**	**251.88**	**8844.92**

5. Agricultural Flood Damages

The Planning Guidance Notebook of the USACE (ER 1105-2-100) has specific rules on the treatment of agricultural crops. Agricultural crops are divided into two categories. The first is basic crops and the second is other crops. Appendix E, Section E-20 b. states:

> *"(2) Basic and Other Crops.*
>
> *(a) Basic crops (rice, cotton, corn, soybeans, wheat, milo, barley, oats, hay, and pasture) are crops that are grown throughout the United States in quantities such that no water resources project would affect the price and thus cause transfers of crop production from one area to another. The production of basic crops is limited primarily by the availability of suitable land.*
>
> *(b) On a national basis, production of crops other than basic crops is seldom limited by the availability of suitable land. Rather, production is generally limited by market demand, risk aversion, and supply factors other than suitable land. Thus, production from increased acreage of crops other than basic crops in the project area would be offset by a decrease in production elsewhere. In some parts of the Nation analysis of local conditions may indicate that the production of other crops is limited by the availability of suitable land. (Suitable land is land on which crops can be grown profitably under prevailing market conditions.) In this case, crops other than basic crops listed above may also be treated as basic crops when measuring intensification benefits by farm budget analysis."*

The guidance provided indicates that the loss in income is only applicable to basic crops and that damages to other crops is limited to the variable costs (the direct production investment of IWR Report 87-R-10) prior to damage. These conventions are the basis of the current agricultural analysis.

With no change in cropping patterns anticipated, following the guidance of E-20 b. (3), benefits are restricted to damage reduction benefits.

Damage reduction benefits are the increases in net income due to the plan, as measured by farm budget analysis. These income increases may result from increased crop yields and decreased production costs. ER 1105-2-100 requires risk-based analysis in all flood damage reduction studies. This includes studies where primary damages occur to agricultural crops. The ER identifies key variables that could be incorporated into the risk-based analysis. The ER suggests such variables as hydrologic/hydraulic variables, the discharge associated with exceedance frequency, conveyance roughness, and cross-section geometry, may apply to agricultural studies. In the area of economic damages, the ER does not identify key factors of uncertainty related to the stage-damage relationship in agricultural studies. The ER suggests that key variables in agricultural areas may be the timing of flooding and cropping patterns. USACE districts are under no requirement to use the economic variables identified in the ER (structure first floor elevation, content and structure values) for agricultural damages or to perform explicit risk-based analysis of agricultural structures if they do not affect the formulation of the project. It is believed that the incorporation of a risk-based analysis would not have an effect on future plan formulation; a risk-based analysis of agricultural damages has not been performed.

5.1 AGRICULTURAL INVENTORY

The study area contains approximately 2,200 acres of agricultural lands that lie west of the Chehalis River and are subject to flooding from the Chehalis River. Three crops are listed as the principal for the study area, as shown in Table 27. Specific county farm budget data does not exist for these three crops; therefore, nearby proxy county data has been employed (Appendix C).

TABLE 27: STUDY AREA CROP HARVESTS – 1996

Crop	Acres	Percentage
Hay	1,320	60
Green Peas – Process	550	15
Sweet Corn – Process	330	25
Total	2,200	100

Source: Cooperative Extension Office – Lewis County

Agricultural acreage for the study is treated as having a composite crop based on the above three crops. The use of a composite crop was required because no formal survey of agricultural production by location was conducted. Agricultural production acreage and locations were ascertained through the use of an overlay of floodplain boundaries on aerial photography of agricultural production acreage.

5.2 TYPICAL FARM BUDGET EXAMPLE

Farm budgets were obtained from the Cooperative Extension, Washington State University. The monthly probability of flood occurrence was based on the occurrence of annual peak flow as measured at the USGS gauge 12025000 on the Newaukum River near Chehalis. These flood occurrence probabilities are:

TABLE 28: MONTHLY FLOOD PROBABILITIES

Month	Probability
January	25.00
February	18.33
March	6.67
April	3.33
May	0.00
June	0.00
July	0.00
August	0.00
September	0.00
October	0.00
November	15.00
December	31.67

The typical farm budget analysis employed for this analysis is shown in Table 29 for sweet corn. The calculation of the potential damage inundation will cause to sweet corn is shown in Table 30. The estimated effect of flood inundation for sweet corn, as well as for all other crops, is a 100 percent crop loss for all floods. This damage potential is based on the duration of flooding, from 2 to 5 days for all floods, flood depths, and the seasonal time of flooding and its effects on post-flood ground saturation duration.

TABLE 29: FARM BUDGET SWEET CORN

EB 1587 Page 8

TABLE 1. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE
1990 SWEET CORN PRODUCTION COSTS
NORTHWEST WASHINGTON 50 ACRES ON 250 ACRE FARM

OPERATION	TOOLING	MTH	YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	VARIABLE COST: FUEL, LUBE, & REPAIRS	VARIABLE COST: MACH LABOR	VARIABLE COST: SERVICE	VARIABLE COST: MATER.	VARIABLE COST: INTER.	TOTAL VARIABLE COST	TOTAL COST
						$	$	$	$	$	$	$	$
DISK	130HP, 15' DISK	OCT	1989	.14	.17	6.02	3.68	1.50	.00	.00	.52	5.70	11.72
SUBSOIL	130HP, SUBSOILER	OCT	1989	.39	.48	15.10	7.14	4.28	.00	.00	1.04	11.46	26.56
DISK	130HP, 15' DISK 2X	MAR	1990	.28	.33	12.04	7.36	2.99	.00	.00	.52	10.87	22.92
LIMING	CUST LIMING, INCL. 1T LIME	MAR	1990	.00	.00	.00	.00	.00	23.00	.00	1.15	24.15	24.15
PLOW	130HP, 4-16 PLOW	MAR	1990	.39	.47	18.62	9.45	4.21	.00	.00	.68	14.34	32.97
FERTILIZE	CUSTOM FERT. APPLICATION[1]	APR	1990	.00	.00	.00	.00	.00	5.25	24.34	1.18	30.77	30.77
CULTIMULCH	130HP, 13' CULTIMULCHER	APR	1990	.16	.19	5.58	2.71	1.73	.00	.00	.18	4.62	10.20
WEED CONTROL	WEED CONTROL 60HP[2]	APR	1990	.38	.46	14.93	1.86	4.16	.00	23.63	1.19	30.84	45.77
PLANT	CUSTOM PLANTING[3]	APR	1990	.00	.00	.00	.00	.00	15.00	89.00	4.16	108.16	108.16
CULTIVATE	60HP,4R CULTIVATOR	MAY	1990	.18	.22	7.80	.90	2.00	.00	.00	.09	2.98	10.78
FERTILIZE	60HP,CULTVTR/FERT ATT.[4]	JUN	1990	.21	.25	10.41	1.28	2.29	.00	24.00	.55	28.12	38.53
HARVEST	BY PROCESSOR	AUG	1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PICKUP TRUCK	USED, THIS CROP	ANN	1990	.00	.00	.00	.00	.00	18.80	.00	1.13	19.93	19.93
LAND RENT	LAND RENT	ANN	1990	.00	.00	150.00	.00	.00	.00	.00	.00	.00	150.00
OVERHEAD	5% VARIABLE COST	ANN	1990	.00	.00	.00	.00	.00	14.60	.00	.00	14.60	14.60
TOTAL PER ACRE				2.13	2.57	240.50	33.38	23.16	76.65	160.98	12.38	306.55	547.05

[1] 220 LB/AC 0-0-60; 6 LB/AC ZINC.
[2] .5 GAL/AC SURPASS 6.7E; .375 GAL/AC ATRAZINE 4L.
[3] BAND APPLICATION OF 300 LB/AC 18-46-0.
[4] 200 LB/AC AMMONIUM NITRATE.

TABLE 30: SWEET CORN WEIGHTED LOSS CALCULATION

Sweet Corn												
Yield	6.5 tons											
Flood Probability	0.00	0.00	15.00	31.67	25.00	18.33	6.67	3.33	0.00	0.00	0.00	0.00
Month	9	10	11	12	1	2	3	4	5	6	7	8
Variable Cost	0.00	38.28	0.00	0.00	0.00	0.00	80.04	194.90	10.78	38.53	0.00	0.00
Cumulative Cost	0.00	38.28	38.28	38.28	38.28	38.28	118.32	313.22	324.00	362.53	362.53	362.53
Weighted Loss	0.00	0.00	5.74	12.12	9.57	7.02	7.89	10.43	0.00	0.00	0.00	0.00
TOTAL LOSS	$52.77											

Through similar farm budget analyses, the per-acre damage has been determined at the following values for the crops of the study area.

TABLE 31: PER ACRE CROP DAMAGE

Crop Type	Per Acre Damage	Weight	Weighted Loss
Hay	$220.48	60%	$132
Corn	$52.77	25%	$13
Peas	$61.60	15%	$9
Total per acre loss			$155

5.3 RESTORATION OF FIELD CROPLAND AFTER FLOODING

The requirement to restore agricultural land after having been inundated by flood will necessitate the reworking of fields at twice the level of normal land preparation and an the application of additional cycles of fertilizer, weed control, and pest control, based upon consultation with the Lewis County Farm Advisor. This level of requirement is consistent with the post-flood demands identified in other USACE studies. The estimated net cost for agricultural land restoration on a per acre basis is presented in Table 32.

TABLE 32: PER ACRE FIELD CROPLAND RESTORATION COSTS

Operation	$ Cost/per Acre
Disc (4 times)	60.00
Subsoil	9.00
Chisel Field (2 times)	15.00
Landplane (2 times)	24.00
Fertilize	64.00
Weed Control	45.00
Pest Control	26.00
Total	$243.00

In addition to restoration costs, it is assumed that post-flood cleanup of debris and other matter will cost $20 per acre for all agricultural land.

5.4 AGRICULTURAL FLOOD DAMAGES

Agricultural damages by flood event are shown in Table 33.

TABLE 33: AGRICULTURAL DAMAGES BY FLOOD EVENT

Flood Event	Crop Damage	Land Restoration	Cleanup	Total
6-year	52,000	82,000	6,000	140,000
10-year	227,000	356,000	29,000	612,000
100-year	341,000	534,000	44,000	919,000
500-year	341,000	534,000	44,000	919,000

Expected annual agricultural damages were calculated using HEC-EAD. The results of the HEC-EAD model for agricultural damages are shown in Table 34.

TABLE 34: EXPECTED ANNUAL AGRICULTURAL DAMAGE

Category	Expected Annual Damage
Crop Damage	42,930
Land Restoration Costs	67,420
Cleanup Costs	5,500
Total	115,850

6. Transportation Related Damages

Chehalis River flooding presents a serious threat to interstate commerce. Past floods have necessitated the closure of I-5 to vehicle traffic, as well as the closures of two major railroad lines (Burlington Northern Santa Fe and Union Pacific Railroads). The costs associated with travel delays, diversion costs, and cleanup costs are valid project concerns on a National Economic Development (NED) basis. The following sections explore these transportation related damages.

6.1 I-5 DAMAGES

Mapping of the floodplains indicates that flooding will make I-5 subject to closure between Centralia and Chehalis from floods. This mapping also indicates that a diversion around the floodplain will be required. However, this diversion will be quite lengthy, approximately 101 miles. The diversion, going southbound, involves leaving I-5 at the junction with SR-507 traveling northeast to Yelm, transitioning to SR-702 east and proceeding to SR-7; then proceeding southward on SR-7 for approximately 35 miles to Morton where a connection to U.S.-12 westbound is taken to return to I-5. Northbound traffic would reverse the route.

The estimate of the traffic count involved in the diversion is taken from the Washington State Department of Transportation's (WSDOT) Trips System for 2000. Average total daily through traffic between state route milepost 81.21 (before ramp SR 507) and milepost 68.94 (after ramp SR-12) Bow Hill Road is estimated at 51,000. In the immediate vicinity of the cities of Chehalis and Centralia average daily volume reaches approximately 62,000, but this added traffic is assumed to not leave the area. The affected daily traffic for the analysis is a base flow traffic rate of 51,000. Further, the analysis employs the Trips System indication that 12 percent of the traffic is truck, as measured by the Bow Hill Road indicator; the nearest indicator maintained by WSDOT that monitors vehicle mix.

The analysis of transportation delays and costs was carried forward by employing the procedure in ER 1105-2-100, Appendix D and as shown in Table D-4: Value of Time Saved by Trip Length and Purpose, in that appendix, with a measure of median household income for Lewis County of $32,557 (1997 U.S. Bureau of the Census). A per-vehicle passenger rate of 1.15 is assumed for the analysis. The diversion is estimated to take 3.16 hours, assuming a 32 mph diversion speed. Mileage rates are further assumed to be 34.5 and 48 cents for cars and truck, respectfully. The above factors yield a total daily cost of delay of $3,394,986 according to the guidelines of ER 1105-2-100, as shown in Table 35: I-5 Flood Related Damages.

Average Daily Total thru Traffic	51000		
Trucks	6120		
Cars	44880		
Median Family Income	$32,557		
Avg. Hourly Rate	15.65		
Value of Time (53.8%)	8.42		
Vehicle Operation Costs	Per Mile		
Truck	0.480		
Car	0.345		
	Miles	MPH	Time/hrs
Diversion	101	32	3.16

TABLE 35: I-5 FLOOD RELATED DAMAGES

	Value of Time $/hr	Occupancy Factor	Occ. Weighted VOT	Time Costs	Diversion Mileage Cost	Total Cost per Vehicle	Vehicle Units	Daily Costs Time	Daily Costs Mileage	Daily Costs Total
Cars	8.42	1.15	9.68	$30.57	$34.85	$65.41	44880	$1,371,783	$1,563,844	$2,935,627
Trucks	8.42	1	8.42	$26.58	$48.48	$75.06	6120	$162,662	$296,698	$459,360
TOTAL								$1,534,445	$1,860,541	$3,394,986

Transportation delay costs due to flood impacts are shown in Table 36: I-5 Damages by Flood Event based on estimated closure durations for flooding and cleanup for Chehalis-Centralia area.

TABLE 36: I-5 DAMAGES BY FLOOD EVENT

Flood Event	I-5 Closure in Days	Total Cost
25	0	$0
50	4	$13,579,945
100	4.5	$15,277,438
200	5	$16,974,931
500	6	$20,369,917

Applying these flood related values to the HEC-EAD model yields an estimate of equivalent annual damage of $476,300. Average annual damages in this category for the period until I-5 would be elevated in the without-project condition (2012) is $129,100.

6.2 RAIL FREIGHT FLOOD IMPACTS

The basis for the examination of NED costs from rail disruptions is the Pharos Corporation's "Chehalis River Flood Reduction Project" study of 2001, prepared for Lewis County. The study reports that the Burlington Northern Santa Fe Railway (BNSF) owns and operates the rail line running north and south within the Chehalis floodplain. This double main-line track parallels I-5 within the floodplain and continues south to Eugene, Oregon, where it connects with the Union Pacific Railroad (UPRR). BNSF traffic typically ranges from 30 to 40 trains per day, and is primarily composed of grain for export; forest products imported from Canada; and domestic shipments of metals and minerals, coal, chemicals, automobiles and consumer goods.

The second major rail service connected to the study area is the UPRR. Although UPRR lines do not run directly within the floodplain, UPRR, by way of trackage rights, operates trains over BNSF track in the Chehalis corridor to access and route shipments to many of their western Washington rail customers. The number of UPRR trains utilizing the Chehalis corridor is 18 to 20 trains per day.

Based on annual reports published by BNSF and UPRR and assuming a per rail car carrying weight of 268,000 pounds, the estimated daily rail car transit rate is 1,230 in the Chehalis corridor. In the event of a prolonged rail outage, these rail lines may be forced to reroute traffic via routes in either Pasco or Spokane, Washington. The shortest alternate route bypassing the Chehalis floodplain would increase trip mileage by 350 miles. BNSF estimates that the average mileage payout for equipment rent/car ownership at approximately $0.40 per mile. Given the mileage increase of the shortest alternate route, the additional cost per railcar diverted equals $140.00 or $172,200 per day for all railcars being diverted.

Furthermore, depending on the alternate line's available capacity, the rerouted cars would likely be subject to a minimum of 48 hours of extended transit time for the additional 350-mile trip. Estimating from the 1999 primary carriers annual reports, the approximate average daily equipment expense per railcar is $23.30. On an estimated daily volume of 1,230 railcars the rail lines would incur additional daily equipment expenses totaling $28,659.

Potential flood related operation and equipment expenses to the rail lines by flood event are shown below in Table 37: Railroad Damages by Flood Event.

TABLE 37: RAILROAD DAMAGES BY FLOOD EVENT

Flood Event	Duration	Railcars Effected	Reroute Expenses	Equipment Expenses	Total
50-year	4	4920	688,800	229,272	918,072
100-year	4.5	5535	774,900	257,931	1,032,831
200-year	5	6150	861,000	286,590	1,147,590
500-year	6	7380	1,033,200	343,908	1,377,108

Railroad damages were modeled in HEC-EAD to estimate expected annual damages. Applying a 25-year non-damaging event to the HEC-EAD model yields expected annual damage for railroads of $32,200.

6.3 AVOIDED COST OF I-5 WIDENING

The project purpose of the Centralia, Washington, Flood Damage Reduction PED Study is to reduce flood hazards and flood damage costs in the project area to the maximum extent practicable. In addition to providing flood protection to thousands of homes and hundreds of businesses, the project will also reduce inundation to I-5 in the Chehalis-Centralia area. This highway has been particularly susceptible to inundation in the project area historically, and has been shut down twice in the last 10 years with floodwater up to 8 feet in depth over the roadway (closed for 4 days in 1996, and 1 day in 1990).

Due to safety issues and the tremendous economic impacts associated with I-5 closures, WSDOT is on record as stating that I-5 will require raising to above the 100-year flood elevation at the same time as other federally mandated widening and upgrading is accomplished. The incremental costs of raising the freeway under the without-project condition has been estimated by WSDOT at $44 million. Their detailed engineering cost estimates are presented in Appendix D to this appendix. If the Recommended Plan turns out to provide at least 100-year protection to this section of I-5, the incremental costs of raising the freeway would not need to be expended. Under this scenario, the avoided cost can be included as an NED benefit. The construction timing used in the economic analysis was based on correspondence received from WSDOT.

Construction sequencing and timing assumptions were based on expected legislative funding streams that run from 2006 to 2012. The Corps conservatively chose to discount all construction costs from year 2012. A copy of WSDOT's letter that addresses construction timing can also be found in Appendix D to this appendix.

7. Expected Annual Damage Results

Table 38 summarizes the expected annual damages from flooding along the Chehalis and Skookumchuck rivers developed by the preceding analyses.

TABLE 38: EXPECTED ANNUAL DAMAGE SUMMARY

Damage Category	Expected Annual Damage
Structures	4,059,810
Contents	3,066,330
Cleanup	1,197,010
Temporary Relocation Assistance	116,630
Public Assistance	405,130
Agriculture	115,850
I-5 Delays	129,100
Railroad Delays	32,200
Total	**$9,122,060$**

8. With-project Economic Analysis

A risk-based analysis as previously described was performed for each alternative measure of the final preliminary array to determine residual damages and project performance. The with-project HEC-FDA conditions for each measure were modeled by modifying the existing hydraulic condition input data according to the results of the UNET modeling results. For example, if a particular discharge-frequency or stage-discharge function was altered as a result of a particular measure (levee, bypass, or reservoir), the appropriate without-project data set was modified and HEC-FDA re-run to calculate residual damages, damage reductions, and the performance of the alternative. Data on hydraulic performance is found in the body of the GRR.

8.1 Final Alternatives

An initial array of alternatives was formulated and screened by preliminary screening criteria. The resultant set of final alternatives was evaluated using the HEC-FDA risk-based economic model. The full array of preliminary final alternatives is presented below.

Table 39: Final Alternatives

ALTERNATIVE	CONFIGURATION	DESCRIPTION
Alternative 1		**No Action Alternative**
Alternative 2		**Skookumchuck Dam Modifications Alternative**
	SKDam1	Dam modification alternative 2.b.2 without pool raise
	SKDam2	Dam modification alternative 2.b.2
	SKDam	Existing dam
Alternative 3		**Overbank Excavation and Flowway Bypass Alternative**
	Bypass-SkDam2	Bypass 3.a with dam modification alternative 2.b.2
	Bypass-SkDam1	Bypass 3.a with dam modification alternative 2.b.2 without pool raise
	Hybrid-SkDam1	Modified bypass with levee alternative with dam modification alternative 2.b.2 without pool raise
	Hybrid-SkDam2	Modified bypass with levee alternative with dam modification alternative 2.b.2 with pool raise
Alternative 4		**Levee System Alternative**
	CheLev2-SkDam	Chehalis River, Salzer Creek, Dillenbaugh Creek modified levee design to 100-yr performance level with existing Dam
	CheLev2-SKDam1	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100- yr performance level with SKDam1
	CheLev2-SKDam2	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with SKDam2
	CheLev2-ExSkDam/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with existing dam and Skookumchuck levees
	CheLev2-SkDam1/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with SKDam1 and Skookumchuck Levees
	CheLev2-SkDam2/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with SKDam2 and Skookumchuck Levees

ALTERNATIVE	CONFIGURATION	DESCRIPTION
Alternative 7		**Interagency Alternative**
	Alternative 7-existing Dam	All structural features without I-5 raise and with levees with existing dam
	Alternative 7-SkDam1	All structural features without I-5 raise and with levees with low pool dam
	Alternative 7-SkDam1	All structural features without I-5 raise and with levees with high pool dam

8.2 Estimated Costs of Final Alternatives

Preliminary cost estimates developed during Phase 1 were refined for all final Phase 2 alternatives. The cost estimates were developed to include: 1) Construction Costs, 2) Real Estate Costs, 3) Operation and Maintenance Costs, and 4) Mitigation Costs. These cost estimates (in average annual figures) are presented in Table 40.

8.3 Risk-Based Assessment and Evaluation of Final Alternatives

The following paragraphs describe the RBA results for both damages reduced and project performance for each measure and combination of alternatives. The analysis results are presented in Table 40, and described in the following paragraphs.

8.4 Residual Damages, Damages Reduced and Net Benefits

8.4.1 Chehalis River Measures

The Chehalis River Levee measures, as the first alternative element, were evaluated using the existing Skookumchuck Dam operation. The HEC-FDA results for residual damages are presented in Table 40. Table 40's Other Damages Reduced includes transportation delays, agricultural damages, and the avoided cost savings from not raising I-5 during its scheduled modification as described in Section 6.3. Table 40 indicates only three of the five general alternative plans presented have a likelihood of meeting NED criteria. These three general plans are: (1) CheLev2, (2) Hybrid Plan, and (3) CheLev2–SKLev (in Table 40 nomenclature). Each of these general plans may or may not contain a Skookumchuck Dam modification. The two general plan types that can be ruled out as potentially producing a NED candidate are Bypass and Alternative 7. These two general plan types are ruled out for further analyses by their negative net NED benefits showing at this level of plan formulation. The Hybrid Plan general plan type is also eliminated from further analyses at this time given the disparity in net NED benefits in comparison to the other two general plan types. Although the Hybrid Plan type shows positive net NED benefits, it is unlikely that this plan type could close the annual benefit difference of $324, given the level of feature overlap between the general plan types.

The general plan type with the highest net benefit is ChevLev2 with a net annual benefit range of $1,677 to $2,699. With the difference between the two remaining general plan types only being levees on the Skookumchuck River and the general plan type with these levees (ChevLev2–SKLev) showing incremental justification, the remaining analyses focuses on this general plan type.

TABLE 40: PHASE 1 WITH-PROJECT ECONOMIC ANALYSIS

Alternative	Expected Annual Damages					Flood Damages Reduced	Other Damages[1]	Other Damages Reduced	Total Damages Reduced	Cost	Net Benefit	B/C
	Chehalis		Skook		Total							
	Res/Comm	Public	Res/Comm	Public								
No Action	6147.81	442.93	2211.84	42.36	8844.94	0.00	2239.10	0.00	0.00	0.00	0.00	0.00
CheLev2 - Existing SkDam	2347.19	82.95	2392.52	46.94	4869.60	3975.34	2239.10	2239.10	6214.44	4537.06	1677.38	1.37
CheLev2 - SkDam 1	2081.67	70.05	595.59	15.34	2762.65	6082.29	2239.10	2239.10	8321.39	5622.75	2698.64	1.48
CheLev2 - SkDam 2	2057.19	68.37	504.68	10.57	2640.81	6204.13	2239.10	2239.10	8443.23	5839.89	2603.34	1.45
CheLev2SR6 - Ex SkDam	2186.09	58.63	2290.11	42.72	4577.55	4267.39	2239.10	2239.10	6506.49	4863.89	1642.60	1.34
CheLev2SR6 - SkDam 1	1893.35	45.85	694.59	14.09	2647.88	6197.06	2239.10	2239.10	8436.16	5949.58	2486.58	1.42
CheLev2SR6 - SkDam 2	1876.98	43.86	498.56	10.30	2429.70	6415.24	2239.10	2239.10	8654.34	6166.72	2487.62	1.40
Hybrid Plan - Existing Dam	2231.15	61.06	1363.55	38.16	3693.92	5151.02	2239.10	2239.10	7390.12	5098.44	2291.68	1.45
Hybrid Plan - SkDam 1	1901.64	47.66	562.03	14.14	2525.47	6319.47	2239.10	2239.10	8558.57	6184.14	2374.43	1.38
Hybrid Plan - SkDam 2	1900.60	45.02	464.71	8.85	2419.18	6425.76	2239.10	2239.10	8664.86	6401.28	2263.58	1.35
CheLev2 - Ex SkDam/SKLev	2217.91	60.56	1677.61	42.06	3998.14	4846.80	2239.10	2239.10	7085.90	4865.90	2220.00	1.46
CheLev2 - SkDam 1/SkLev	1932.99	50.86	453.78	11.19	2448.82	6396.12	2239.10	2239.10	8635.22	5951.60	2683.62	1.45
CheLev2 - SkDam 2/SkLev	1924.27	48.05	337.42	9.32	2319.06	6525.88	2239.10	2239.10	8764.98	6168.73	2596.25	1.42
Bypass - Existing Dam	3404.44	30.56	2225.90	38.25	5699.15	3145.79	2239.10	0.00	3145.79	6070.04	-2924.25	0.52
Bypass - SkDam 1	2996.60	98.17	542.00	9.28	3646.05	5198.89	2239.10	0.00	5198.89	6882.46	-1683.57	0.76
Bypass - SkDam 2	2977.01	94.28	458.70	6.60	3536.59	5308.35	2239.10	0.00	5308.35	7526.87	-2218.52	0.71
Alternative 7 - Existing Dam	3382.07	97.10	2288.89	41.94	5810.00	3034.94	2239.10	0.00	3034.94	5081.55	-2046.61	0.60
Alternative 7 - SkDam 1	2899.76	74.89	601.44	18.63	3594.72	5250.22	2239.10	0.00	5250.22	5718.95	-468.73	0.92
Alternative 7 - SkDam 2	2869.41	70.80	526.26	7.69	3474.16	5370.78	2239.10	0.00	5370.78	5869.87	-499.09	0.91

[1]I-5 avoided cost savings and traffic delay reductions

8.4.2 Skookumchuck Dam Modification

The Skookumchuck Dam was included in the evaluation as a first added element to determine the flood reduction effectiveness. There were two storage alternatives evaluated: an 11,000 acre-foot dam and a 20,000 acre-foot dam. Each storage component was evaluated for each of the Chehalis plans. The incremental benefit for the CheLev2 plan with the 11,000 dam is $2,107 with an incremental B/C of 1.94. The combined plan yields net benefit of $2,698.64 with a B/C of 1.48. This includes the impacts of the dam on the Chehalis since the effects are captured in the resultant hydraulic analysis. The incremental benefit for raising the CheLev2 plan from 11,000 to the 20,000 dam is $122 with an incremental cost of $217, an incremental B/C of 0.56. Increasing the dam size from 11,000 to 20,000 is not justified and for this reason the analysis assumes that the 11,000 dam is incrementally justified as the first added element.

8.4.3 Skookumchuck Levee

In an attempt to further reduce flooding on the Skookumchuck River, specifically in Reach 4, levees along the Skookumchuck River were analyzed. The incremental net benefit change from CheLev2 plan with the 11,000 dam to the CheLev2 plan with the 11,000 dam and Skookumchuck levees is -$6; and, given that the ChevLev2 with 11,000 dam alternative does not consider backwater effects on the Skookumchuck River at this stage, it is reasonable to assume that the CheLev2–SKDam and SKLev plan type would most likely generate the NED recommended plan.

8.5 Phase 2 - Screening Results, Preliminary NED Alternative

Based on economic performance and engineering performance evaluated in screening Phase 2, the most effective alternative for reducing flood damages was identified as a combination of the flood control features Chehalis Levee, Skookumchuck Dam, and Skookumchuck Levee. This alternative appears to produce the highest net benefits. The NED size of each measure and as a combined system will be determined in the next iteration of optimization, Phase 3. At this time, no plan satisfies FEMA's Conditional Non-Exceedance Probability criteria for both rivers. However, the Chehalis Levee 2 Plan alternative meets the 0.01 Conditional Non-Exceedance Probability for the Chehalis River along the protected areas. To achieve the same performance along the Skookumchuck River, it appears that additional levees will need to be included along with a dam measure. The optimization exercise to be performed in Phase 3 may yield a smaller Skookumchuck Levee that performs better than the one tested in Phase 2.

9. Phase 3 – Optimization and Identification of NED Plan

In the final phase of plan formulation, several different sizes of the preliminary NED plan were further evaluated for optimization of project size. This optimization resulted in identification of the NED plan.

The previous section identified and examined potential solution modes to flood-related problems in the study area. This examination indicated that a potential solution involving dam modification and levee improvements might be justified. In this phase, the analysis' focus is on this potential dam/levee solution mode. As with the previous analyses outlined in this report, the analysis of dam/levee alternatives employs the HEC-FDA model. The with-project HEC-FDA conditions for each alternative were modeled by modifying the existing hydraulic condition input data according to the results of the UNET modeling to derive residual damages and project performance measures. For example, if a particular discharge-frequency or stage-discharge function was altered as a result of a particular measure (levee, bypass, or reservoir), the appropriate without-project data set was modified and HEC-FDA recalculated residual damages and performance parameters. The array of alternatives analyzed in this phase consists of three basic features, as follows:

- Skookumchuck Dam Modification;
- Chehalis River Levee Improvements; and
- Skookumchuck River Levee Improvements.

Each of these basic features has an array of its own. For Skookumchuck Dam, two storage capacity level increases are under consideration with these capacity increases being,

- an 11,000 acre-foot increase
- a 20,000 acre-foot increase.

For the Chehalis and Skookumchuck rivers' five levee improvement levels are considered for each with these levels being,

- a levee height 2 feet below the 100-yr WSE[4];
- a levee height at the 100-yr WSE;
- a levee height that has a 75-yr level of flood protection;
- a levee height that has a 100-yr level of flood protection;
- a levee height of approximately 200-yr level of protection; and
- a backwater levee only option on the Skookumchuck River.

These basic modes in combination comprise 54 potential alternatives, as shown in Table 41, below.

[4] As the study is conducted under a risk-based approach, the "100-year" flood consists of a distribution of floods defined by risk-based parameters as presented in hydraulics and hydrology appendices. For the 100-year WSE, the mean values of the risk parameters associated with the 1 percent chance flood were utilized to develop the water surface elevation. To provide protection of a given frequency, and as a flood of a given frequency consists of many differing levels, the height of the levee must contain 95 percent of that level's distribution of floods.

TABLE 41: PHASE III PRELIMINARY ALTERNATIVES

Skookumchuck	Chehalis Levee	Skookumchuck Levee
Existing	100	Backwater
11,000	100	Backwater
11,000	WSE -1	WSE -1
11,000	WSE -1	WSE
11,000	WSE -1	200
11,000	WSE -1	100
11,000	WSE -1	75
11,000	WSE	WSE -1
11,000	WSE	WSE
11,000	WSE	200
11,000	WSE	100
11,000	WSE	75
11,000	75	WSE -1
11,000	75	WSE
11,000	75	200
11,000	75	100
11,000	75	75
11,000	100	WSE-3
11,000	100	WSE-2
11,000	100	WSE -1
11,000	100	WSE
11,000	100	200
11,000	100	100
11,000	100	75
11,000	200	WSE -1
11,000	200	WSE
11,000	200	200
11,000	200	100
11,000	200	75
20,000	WSE -1	WSE -1
20,000	WSE -1	WSE
20,000	WSE -1	200
20,000	WSE -1	100
20,000	WSE -1	75
20,000	WSE	WSE -1
20,000	WSE	WSE
20,000	WSE	200
20,000	WSE	100
20,000	WSE	75
20,000	75	WSE -1
20,000	75	WSE
20,000	75	200
20,000	75	100
20,000	75	75
20,000	100	WSE -1
20,000	100	WSE
20,000	100	200
20,000	100	100
20,000	100	75
20,000	200	WSE -1

Skookumchuck	Chehalis Levee	Skookumchuck Levee
20,000	200	WSE
20,000	200	200
20,000	200	100
20,000	200	75

The HEC-FDA model was employed to determine residual damages for all damages except for those damages related to agriculture and transportation. In the case of agricultural damages, the designs of the alternatives would not afford protection to the Chehalis River's west side in the area of agricultural production, and agricultural damage reductions would be minimal, if at all. Therefore, no agricultural damage reductions are claimed for any alternative. In the case of rail freight transportation damages, the proposed alternatives would not fully cover the potentially impacted rail lines and transportation delays would continue during flooding events; therefore, no damage reductions are claimed.

In the without-project condition, traffic on I-5 experiences delays during flood events. I-5 is scheduled to have major modifications made by 2012 to increase its capacity and to eliminate flood-related delays. The related cost to elevate I-5 to avoid flood delays is $44,000,000. The without-project analysis indicates that the annual damages associated with traffic delays on I-5 are $476,300. Full implementation of flood control operations for all alternatives is 2007. Applying a net present value approach to the expected annual traffic delay costs during the 2007 to 2012 timeframe yields an annual damage reduction (benefit) of $129,079, if implemented.

Currently there are plans to upgrade and modernize I-5 to increase its capacity and remove it from the threat of flooding. The current cost of this future modernization for elevating the roadway above the 100-year event is estimated at $44,000,000. The plan for I-5 indicates that implementation would take place after the base year of any of the alternatives and would be finished in 2012. If an alternative with at least a 100-year level of protection is implemented, modernization of I-5 would avoid the elevation expenditure of $44,000,000. As this expenditure would occur in the future after the construction of an alternative, discounting this future cost yields a current base year value of $32,686,200. Amortization of this avoided expenditure yields an annual savings of $2,110,000.

NED benefits for the alternatives are shown in Table 42, below.

TABLE 42: PHASE III ALTERNATIVES NED BENEFITS

(in $1,000s, 2002 price level, 6.125% discount rate, 50-year period of analysis)

Skookumchuck Dam	Chehalis Levee	Skookumchuck Levee	Residual Damages*	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits
No Action	100	Backwater	4577.55	4267.37	2110.00	129.10	6,506.47
11,000	100	Backwater	2647.88	6197.04	2110.00	129.10	8,436.14
11,000	WSE -1	WSE -1	4340.59	4504.33	0.00	0.00	4504.33
11,000	WSE -1	WSE	4320.37	4524.55	0.00	0.00	4524.55
11,000	WSE -1	75	4305.28	4539.64	0.00	0.00	4539.64
11,000	WSE -1	100	4256.03	4588.89	0.00	0.00	4588.89
11,000	WSE -1	200	4213.24	4631.68	0.00	0.00	4631.68
20,000	WSE -1	WSE -1	4179.64	4665.28	0.00	0.00	4665.28
20,000	WSE -1	WSE	4157.31	4687.61	0.00	0.00	4687.61
20,000	WSE -1	75	4142.48	4702.44	0.00	0.00	4702.44
20,000	WSE -1	100	4087.72	4757.2	0.00	0.00	4757.20
20,000	WSE -1	200	4060.17	4784.75	0.00	0.00	4784.75
11,000	WSE	WSE -1	3695.48	5149.44	0.00	0.00	5149.44
11,000	WSE	WSE	3675.26	5169.66	0.00	0.00	5169.66
11,000	WSE	75	3660.17	5184.75	0.00	0.00	5184.75
11,000	WSE	100	3610.93	5233.99	0.00	0.00	5233.99
11,000	WSE	200	3568.13	5276.79	0.00	0.00	5276.79
20,000	WSE	WSE -1	3540.11	5304.81	0.00	0.00	5304.81
20,000	WSE	WSE	3517.77	5327.15	0.00	0.00	5327.15
20,000	WSE	75	3502.94	5341.98	0.00	0.00	5341.98
20,000	WSE	100	3448.18	5396.74	0.00	0.00	5396.74
20,000	WSE	200	3420.63	5424.29	0.00	0.00	5424.29
11,000	75	WSE -1	2983.3	5861.62	0.00	0.00	5861.62
11,000	75	WSE	2963.1	5881.82	0.00	0.00	5881.82
11,000	75	75	2948	5896.92	0.00	0.00	5896.92
11,000	75	100	2898.76	5946.16	0.00	0.00	5946.16
11,000	75	200	2855.97	5988.95	0.00	0.00	5988.95
20,000	75	WSE -1	2846.42	5998.5	0.00	0.00	5998.50
20,000	75	WSE	2824.1	6020.82	0.00	0.00	6020.82
20,000	75	75	2809.27	6035.65	0.00	0.00	6035.65
20,000	75	100	2754.5	6090.42	0.00	0.00	6090.42
20,000	75	200	2726.94	6117.98	0.00	0.00	6117.98
11,000	100	WSE-3	2591.48	6253.44	2110.00	129.10	8492.54
11,000	100	WSE-2	2556.29	6288.63	2110.00	129.10	8527.73
11,000	100	WSE -1	2533.37	6311.55	2110.00	129.10	8,550.65
11,000	100	WSE	2513.16	6331.76	2110.00	129.10	8,570.86
11,000	100	75	2498.06	6346.86	2110.00	129.10	8,585.96
11,000	100	100	2448.83	6396.09	2110.00	129.10	8,635.19
20,000	100	WSE -1	2409.98	6434.94	2110.00	129.10	8,674.04
11,000	100	200	2406.04	6438.88	2110.00	129.10	8,677.98
20,000	100	WSE	2388.65	6456.27	2110.00	129.10	8,695.37
20,000	100	75	2373.82	6471.1	2110.00	129.10	8,710.20
11,000	200	WSE -1	2337.05	6507.87	2110.00	129.10	8,746.97
20,000	100	100	2319.05	6525.87	2110.00	129.10	8,764.97
11,000	200	WSE	2316.83	6528.09	2110.00	129.10	8,767.19
11,000	200	75	2301.74	6543.18	2110.00	129.10	8,782.28
20,000	100	200	2291.5	6553.42	2110.00	129.10	8,792.52
11,000	200	100	2252.5	6592.42	2110.00	129.10	8,831.52
20,000	200	WSE -1	2223	6621.92	2110.00	129.10	8,861.02
11,000	200	200	2209.71	6635.21	2110.00	129.10	8,874.31
20,000	200	WSE	2200.67	6644.25	2110.00	129.10	8,883.35
20,000	200	75	2185.85	6659.07	2110.00	129.10	8,898.17
20,000	200	100	2131.07	6713.85	2110.00	129.10	8,952.95
20,000	200	200	2103.52	6741.4	2110.00	129.10	8,980.50

***Residual damages in this table do not include agriculture damages and rail damages – both these categories are not affected by proposed alternatives. Residual annual damages in these categories are $115,850 for agriculture and $32,200 for rail.*

Construction and annual costs for the various components are shown below in Table 43.

TABLE 43: COMPONENT COSTS

ALTERNATIVE	Total Construction Cost*	IDC	Total Economic Cost	Annualized Cost	O&M	TOTAL ANNUAL COST
Skookumchuck Dam						
Skookumchuck Dam 11,000 ac-ft	$9,304.05	$569.87	$9,873.93	$637.40	$448.30	$1,085.70
Skookumchuck Dam 20,000 ac-ft	$11,507.02	$704.80	$12,211.82	$788.32	$514.51	$1,302.83
Skookumchuck Levee						
Backwater	$8,122.00	$497.47	$8,619.47	$556.00	$19.03	$575.03
100yr WSE -3	$9,006.00	$551.62	$9,557.62	$617.00	$19.03	$636.03
100yr WSE -2	$9,602.00	$588.12	$10,190.12	$623.00	$19.03	642.03
100yr WSE -1	$9,774.00	$598.66	$10,372.66	$669.00	$19.03	$688.03
100yr WSE	$10,410.00	$637.61	$11,047.61	$713.00	$19.03	$732.03
75yr Protection	$10,952.00	$670.81	$11,622.81	$750.30	$19.03	$769.32
100yr Protection	$13,162.00	$806.17	$13,968.17	$901.70	$19.03	$920.73
200yr Protection	$14,482.00	$887.02	$15,369.02	$992.13	$19.03	$1,011.16
Chehalis Levee						
100yr WSE -1	$48,155.46	$2,949.52	$51,104.98	$3,299.03	$99.49	$3,398.52
100yr WSE	$50,705.46	$3,105.71	$53,811.17	$3,473.73	$99.49	$3,573.22
75yr Protection	$53,675.46	$3,287.62	$56,963.08	$3,677.19	$99.49	$3,776.69
100yr Protection	$60,905.46	$3,730.46	$64,635.92	$4,172.51	$99.49	$4,272.00
200yr Protection	$64,975.46	$3,979.75	$68,955.21	$4,451.33	$99.49	$4,550.83

**includes Real Estate*
***interest during construction is calculated using a two-year midlife full expenditure pattern with a 6.125% discount rate.*

These components in combination form the alternatives and have total costs and net benefits as shown in Table 44, below.

TABLE 44: TOTAL ANNUAL COSTS AND NED NET BENEFITS PHASE II ALTERNATIVES

(in $1,000s, 2002 price level, 6.125% discount rate, 50-year period of analysis)

Dam Size	Chehalis Levee*	Skookumchuck Levee*	Residual Damages**	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits	Skook Dam Cost	Chehalis Levee Cost	Skook Levee Cost	Total Cost	Net Benefits
11	100	-2	$2,556.28	$6,288.65	$2,110.00	$129.10	$8,527.75	$1,085.70	$4,272.00	$642.03	$5,999.73	$2,528.00
11	100	-1	$2,533.37	$6,311.55	$2,110.00	$129.10	$8,550.65	$1,085.70	$4,272.00	$688.03	$6,045.73	$2,504.92
11	100	BW	$2,647.88	$6,197.04	$2,110.00	$129.10	$8,436.14	$1,085.70	$4,272.00	$575.03	$5,932.73	$2,503.41
11	100	-3	$2,591.48	$6,253.44	$2,110.00	$129.10	$8,492.54	$1,085.70	$4,272.00	$636.03	$5,993.73	$2,498.81
11	100	0	$2,513.16	$6,331.76	$2,110.00	$129.10	$8,570.86	$1,085.70	$4,272.00	$732.03	$6,089.73	$2,481.13
11	100	75	$2,498.06	$6,346.86	$2,110.00	$129.10	$8,585.96	$1,085.70	$4,272.00	$769.32	$6,127.02	$2,458.94
11	200	-1	$2,337.05	$6,507.87	$2,110.00	$129.10	$8,746.97	$1,085.70	$4,550.83	$663.14	$6,299.66	$2,447.31
20	100	-1	$2,409.98	$6,434.94	$2,110.00	$129.10	$8,674.04	$1,302.83	$4,272.00	$663.14	$6,237.97	$2,436.07
11	200	0	$2,316.83	$6,528.09	$2,110.00	$129.10	$8,767.19	$1,085.70	$4,550.83	$711.09	$6,347.62	$2,419.57
20	100	0	$2,388.65	$6,456.27	$2,110.00	$129.10	$8,695.37	$1,302.83	$4,272.00	$711.09	$6,285.92	$2,409.45
11	200	75	$2,301.74	$6,543.18	$2,110.00	$129.10	$8,782.28	$1,085.70	$4,550.83	$769.32	$6,405.85	$2,376.43
20	100	75	$2,373.82	$6,471.10	$2,110.00	$129.10	$8,710.20	$1,302.83	$4,272.00	$769.32	$6,344.16	$2,366.04
11	100	100	$2,448.83	$6,396.09	$2,110.00	$129.10	$8,635.19	$1,085.70	$4,272.00	$920.73	$6,278.42	$2,356.77
20	200	-1	$2,223.00	$6,621.92	$2,110.00	$129.10	$8,861.02	$1,302.83	$4,550.83	$663.14	$6,516.80	$2,344.22
20	200	0	$2,200.67	$6,644.25	$2,110.00	$129.10	$8,883.35	$1,302.83	$4,550.83	$711.09	$6,564.75	$2,318.60
11	100	200	$2,406.04	$6,438.88	$2,110.00	$129.10	$8,677.98	$1,085.70	$4,272.00	$1,011.16	$6,368.85	$2,309.13
20	200	75	$2,185.85	$6,659.07	$2,110.00	$129.10	$8,898.17	$1,302.83	$4,550.83	$769.32	$6,622.98	$2,275.19
11	200	100	$2,252.50	$6,592.42	$2,110.00	$129.10	$8,831.52	$1,085.70	$4,550.83	$920.73	$6,557.25	$2,274.27
20	100	100	$2,319.05	$6,525.87	$2,110.00	$129.10	$8,764.97	$1,302.83	$4,272.00	$920.73	$6,495.56	$2,269.41
11	200	200	$2,209.71	$6,635.21	$2,110.00	$129.10	$8,874.31	$1,085.70	$4,550.83	$1,011.16	$6,647.68	$2,226.63
20	100	200	$2,291.50	$6,553.42	$2,110.00	$129.10	$8,792.52	$1,302.83	$4,272.00	$1,011.16	$6,585.99	$2,206.53
20	200	100	$2,131.07	$6,713.85	$2,110.00	$129.10	$8,952.95	$1,302.83	$4,550.83	$920.73	$6,774.38	$2,178.57
20	200	200	$2,103.52	$6,741.40	$2,110.00	$129.10	$8,980.50	$1,302.83	$4,550.83	$1,011.16	$6,864.82	$2,115.68
Ext	100	BW	$4,577.55	$4,267.37	$2,110.00	$129.10	$6,506.47	$0.00	$4,272.00	$591.89	$4,863.89	$1,642.58
11	75	-1	$2,983.30	$5,861.62	$0.00	$0.00	$5,861.62	$1,085.70	$3,776.69	$663.14	$5,525.52	$336.10
11	75	0	$2,963.10	$5,881.82	$0.00	$0.00	$5,881.82	$1,085.70	$3,776.69	$711.09	$5,573.48	$308.34
11	75	75	$2,948.00	$5,896.92	$0.00	$0.00	$5,896.92	$1,085.70	$3,776.69	$769.32	$5,631.71	$265.21
20	75	-1	$2,846.42	$5,998.50	$0.00	$0.00	$5,998.50	$1,302.83	$3,776.69	$663.14	$5,742.66	$255.84
20	75	0	$2,824.10	$6,020.82	$0.00	$0.00	$6,020.82	$1,302.83	$3,776.69	$711.09	$5,790.61	$230.21

Dam Size	Chehalis Levee*	Skookumchuck Levee*	Residual Damages**	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits	Skook Dam Cost	Chehalis Levee Cost	Skook Levee Cost	Total Cost	Net Benefits
20	75	75	$2,809.27	$6,035.65	$0.00	$0.00	$6,035.65	$1,302.83	$3,776.69	$769.32	$5,848.84	$186.81
11	75	100	$2,898.76	$5,946.16	$0.00	$0.00	$5,946.16	$1,085.70	$3,776.69	$920.73	$5,783.11	$163.05
11	75	200	$2,855.97	$5,988.95	$0.00	$0.00	$5,988.95	$1,085.70	$3,776.69	$1,011.16	$5,873.54	$115.41
20	75	100	$2,754.50	$6,090.42	$0.00	$0.00	$6,090.42	$1,302.83	$3,776.69	$920.73	$6,000.25	$90.17
20	75	200	$2,726.94	$6,117.98	$0.00	$0.00	$6,117.98	$1,302.83	$3,776.69	$1,011.16	$6,090.68	$27.30
11	0	-1	$3,695.48	$5,149.44	$0.00	$0.00	$5,149.44	$1,085.70	$3,573.22	$663.14	$5,322.05	-$172.61
11	0	0	$3,675.26	$5,169.66	$0.00	$0.00	$5,169.66	$1,085.70	$3,573.22	$711.09	$5,370.01	-$200.35
20	0	-1	$3,540.11	$5,304.81	$0.00	$0.00	$5,304.81	$1,302.83	$3,573.22	$663.14	$5,539.19	-$234.38
11	0	75	$3,660.17	$5,184.75	$0.00	$0.00	$5,184.75	$1,085.70	$3,573.22	$769.32	$5,428.24	-$243.49
20	0	0	$3,517.77	$5,327.15	$0.00	$0.00	$5,327.15	$1,302.83	$3,573.22	$711.09	$5,587.14	-$259.99
20	0	75	$3,502.94	$5,341.98	$0.00	$0.00	$5,341.98	$1,302.83	$3,573.22	$769.32	$5,645.37	-$303.39
11	0	100	$3,610.93	$5,233.99	$0.00	$0.00	$5,233.99	$1,085.70	$3,573.22	$920.73	$5,579.64	-$345.65
11	0	200	$3,568.13	$5,276.79	$0.00	$0.00	$5,276.79	$1,085.70	$3,573.22	$1,011.16	$5,670.07	-$393.28
20	0	100	$3,448.18	$5,396.74	$0.00	$0.00	$5,396.74	$1,302.83	$3,573.22	$920.73	$5,796.78	-$400.04
20	0	200	$3,420.63	$5,424.29	$0.00	$0.00	$5,424.29	$1,302.83	$3,573.22	$1,011.16	$5,887.21	-$462.92
11	-1	-1	$4,340.59	$4,504.33	$0.00	$0.00	$4,504.33	$1,085.70	$3,398.52	$663.14	$5,147.36	-$643.03
11	-1	0	$4,320.37	$4,524.55	$0.00	$0.00	$4,524.55	$1,085.70	$3,398.52	$711.09	$5,195.31	-$670.76
20	-1	-1	$4,179.64	$4,665.28	$0.00	$0.00	$4,665.28	$1,302.83	$3,398.52	$663.14	$5,364.49	-$699.21
11	-1	75	$4,305.28	$4,539.64	$0.00	$0.00	$4,539.64	$1,085.70	$3,398.52	$769.32	$5,253.54	-$713.90
20	-1	0	$4,157.31	$4,687.61	$0.00	$0.00	$4,687.61	$1,302.83	$3,398.52	$711.09	$5,412.45	-$724.84
20	-1	75	$4,142.48	$4,702.44	$0.00	$0.00	$4,702.44	$1,302.83	$3,398.52	$769.32	$5,470.68	-$768.24
11	-1	100	$4,256.03	$4,588.89	$0.00	$0.00	$4,588.89	$1,085.70	$3,398.52	$920.73	$5,404.95	-$816.06
11	-1	200	$4,213.24	$4,631.68	$0.00	$0.00	$4,631.68	$1,085.70	$3,398.52	$1,011.16	$5,495.38	-$863.70
20	-1	100	$4,087.72	$4,757.20	$0.00	$0.00	$4,757.20	$1,302.83	$3,398.52	$920.73	$5,622.08	-$864.88
20	-1	200	$4,060.17	$4,784.75	$0.00	$0.00	$4,784.75	$1,302.83	$3,398.52	$1,011.16	$5,712.51	-$927.76

Table 44 provides the results of the maximization analysis that was used to determine that project scope, or investment, where the last increment of cost is equal to the incremental benefit. Based on the above analyses, the three-element plan that most reasonably maximizes net NED benefits, the NED Plan, consists of the following.

- an 11,000 acre-foot modification plan for the Skookumchuck Dam;
- levee construction of 100-year level protection on the Chehalis; and
- construction of a levee at 2-feet below the 100-year WSE on the Skookumchuck River.

Residual damages for the NED Plan are shown in Table 45, below.

TABLE 45: NED PLAN RESIDUAL DAMAGES

Expected Annual Flood Damage for the NED Plan* 11,000 ac/ft Skookumchuck Dam modification, 100-yr Protection Levee Chehalis River, & 100-yr WSE -2 Skookumchuck Levee (Damage in $1,000's, 6.125%, 50 -year analysis period)												
Alternative	Damage Categories											
	Com - Cleanup	Com -Cnt	Com - Str	PA	Res - Cleanu p	Res - Cnt	Res - Str	TRA	Pub - Cleanup	Pub – Cnt	Pub – Str	Total
Without-project Damages	301.36	1431.16	1354.95	405.13	866.89	1430.52	2453.00	116.63	28.76	204.65	251.88	8844.92
NED Plan	27.45	201.48	175..75	160.46	314.51	573.63	993.52	46.29	5.08	24.50	33.61	2556.28
Damage Reduction	**273.91**	**1229.68**	**1179.20**	**244.67**	**552.38**	**856.89**	**1459.48**	**70.34**	**23.68**	**180.15**	**218.27**	**6288.65**

**Damages in this table do not include agriculture damages and rail damages – both these categories are not affected by recommended project. Residual annual damages in these categories are $115,850 for agriculture and $32,200 for rail. Additional project benefits categories of NED plan include $2,110,000 in avoided cost of fill for elevating I-5 and $129,100 in reduced traffic delays. Incorporating these values results in the following:*
Without-project damages including agricultural damages, rail damages, and traffic delays and cost of elevating I-5: ***$11,232.06***
NED Plan residual damages including agricultural damages and rail damages: ***$2,681.42***
*NED Plan damage reduction including avoided cost of fill for elevating I-5 and reduced traffic delays: $****8,527.75***

Appendix A – HEC-FDA Model Data

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		Reach		Chehalis 1
		Index Cross-Section (RM)		74.02
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	150.00	0.00
2	0.500	21,637	173.68	0.49
5	0.200	29,146	175.54	0.52
10	0.100	33,592	176.37	0.51
25	0.040	43,313	177.79	0.47
50	0.020	50,891	178.58	0.42
100	0.010	56,851	179.16	0.40
200	0.005	66,681	179.92	0.40
500	0.002	79,143	180.96	0.56
N/A	N/A	100,000	**183.00**	0.56

		Reach		Chehalis 2
		Index Cross-Section (RM)		72.80
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.95	0.00
2	0.500	20,231	172.34	0.57
5	0.200	28,237	174.47	0.54
10	0.100	32,582	175.32	0.51
25	0.040	42,186	176.77	0.47
50	0.020	48,736	177.53	0.50
100	0.010	52,747	178.12	0.54
200	0.005	60,574	178.89	0.73
500	0.002	67,166	180.06	1.02
N/A	N/A	90,000	**182.50**	1.02

		Reach		Chehalis 3
		Index Cross-Section (RM)		70.30
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.90	0.00
2	0.500	18,648	168.22	0.59
5	0.200	27,623	170.45	0.58
10	0.100	32,011	171.62	0.67
25	0.040	41,029	173.58	0.93
50	0.020	46,116	174.81	1.07
100	0.010	49,638	175.86	1.14
200	0.005	54,031	177.05	1.18
500	0.002	60,445	178.58	1.10
N/A	N/A	80,000	**182.00**	1.10

		Reach		Chehalis 4
		Index Cross-Section (RM)		68.67
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.90	0.00
2	0.500	18,743	166.90	0.75
5	0.200	27,075	169.82	0.75
10	0.100	31,511	171.14	0.76

		Reach		Chehalis 4
		Index Cross-Section (RM)		68.67
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
25	0.040	40,364	173.22	0.78
50	0.020	47,113	174.50	0.81
100	0.010	52,678	175.59	0.84
200	0.005	59,865	176.81	0.87
500	0.002	69,541	178.36	0.90
N/A	N/A	90,000	**181.50**	0.90

		Reach		Chehalis 5
		Index Cross-Section (RM)		67.29
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	471	149.90	0.00
2	0.500	18,718	165.45	0.78
5	0.200	27,071	168.36	0.72
10	0.100	31,396	169.59	0.70
25	0.040	40,512	171.42	0.68
50	0.020	47,289	172.47	0.68
100	0.010	53,343	173.40	0.69
200	0.005	61,636	174.40	0.74
500	0.002	72,201	175.72	0.86
N/A	N/A	95,000	**178.50**	0.86

		Reach		Chehalis 6
		Index Cross-Section (RM)		66.30
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	599	149.80	0.00
2	0.500	24,251	161.89	0.60
5	0.200	34,728	164.10	0.68
10	0.100	41,029	165.28	0.71
25	0.040	52,740	167.03	0.72
50	0.020	61,363	167.96	0.71
100	0.010	70,006	168.81	0.70
200	0.005	80,817	169.81	0.70
500	0.002	96,788	171.06	0.77
N/A	N/A	120,000	**173.00**	0.77

		Reach		Chehalis 7
		Index Cross-Section (RM)		65.20
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	323	143.75	0.00
2	0.500	24,260	157.97	0.66
5	0.200	34,717	160.67	0.63
10	0.100	41,006	162.01	0.61
25	0.040	52,754	163.70	0.59
50	0.020	61,399	164.67	0.57
100	0.010	70,026	165.51	0.56
200	0.005	80,800	166.50	0.55
500	0.002	96,802	167.77	0.55
N/A	N/A	120,000	**169.50**	0.55

		Reach		Skookumchuck 1
		Index Cross-Section (RM)		10.56
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	1,263	234.59	0.39
3.1	0.323	4,129	238.59	0.39
6.1	0.164	5,750	239.82	0.40
12.7	0.079	7,147	240.68	0.40
34	0.029	9,238	241.74	0.41
50	0.020	10,258	242.17	0.42
88	0.011	11,428	242.60	0.43
143	0.007	12,500	242.97	0.44
320	0.0031	14,331	243.60	0.46
482	0.0021	15,750	244.04	0.49
N/A	N/A	25,000	**247.00**	0.49

		Reach		Skookumchuck 2
		Index Cross-Section (RM)		5.08
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	1,319	195.60	0.39
3.1	0.323	4,191	200.89	0.39
6.1	0.164	5,797	202.01	0.36
12.7	0.079	7,355	202.89	0.33
34	0.029	9,393	203.62	0.27
50	0.020	10,561	203.92	0.24
88	0.011	11,804	204.19	0.21
143	0.007	12,940	204.43	0.20
320	0.0031	14,867	204.81	0.20
482	0.0021	16,137	205.04	0.23
N/A	N/A	25,000	**206.70**	0.23

		Reach		Skookumchuck 3
		Index Cross-Section (RM)		2.415
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	2,039	180.55	0.40
3.1	0.323	5,369	184.00	0.40
6.1	0.164	7,423	185.19	0.37
12.7	0.079	9,322	185.89	0.35
34	0.029	12,147	186.65	0.32
50	0.020	13,792	187.06	0.30
88	0.011	16,183	187.56	0.28
143	0.007	17,885	187.79	0.26
320	0.0031	21,158	188.07	0.24
N/A	N/A	40,000	**189.50**	0.24

		Reach		Skookumchuck 4
		Index Cross-Section (RM)		0.98
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	2,141	165.82	0.68
3.1	0.323	5,508	171.31	0.68
6.1	0.164	7,623	173.77	0.48

		Reach		Skookumchuck 4
		Index Cross-Section (RM)		0.98
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
12.7	0.079	9,553	174.36	0.37
34	0.029	12,381	175.21	0.32
50	0.020	14,091	175.84	0.33
88	0.011	16,554	176.39	0.39
143	0.007	18,124	176.90	0.44
320	0.0031	21,195	177.69	0.56
N/A	N/A	40,000	**181.00**	0.56

Chehalis River

Reach Number	Extent of reach in terms of river miles (RM)	Index Cross-Section for Reach (RM) [1]	Description
Chehalis 1	RM 75.2 to RM 73	RM 74.02	Confluence of Chehalis/Newaukum rivers to south end of airport
Chehalis 2	RM 73 to RM 71.5	RM 72.80	South end of airport to north end of airport
Chehalis 3	RM 71.5 to RM 69.2	RM 70.30	North end of airport to confluence of Chehalis River/Salzer Creek
Chehalis 4	RM 69.2 to RM 67.45	RM 68.67	Confluence of Chehalis River/Salzer Creek to Mellen St. Bridge
Chehalis 5	RM 67.45 to RM 66.9	RM 67.29	Mellen St. Bridge to confluence of Chehalis/Skookumchuck rivers
Chehalis 6	RM 66.9 to RM 66.0	RM 66.30	Confluence of Chehalis/Skookumchuck rivers to downstream end of proposed floodway excavation
Chehalis 7	RM 66.0 to RM 61.8	RM 65.20	Downstream end of proposed floodway excavation to Chehalis/Lincoln Creek confluence

1 - Index cross-sections for Chehalis River reaches are referenced to Skookumchuck River river mile (RM)

Skookumchuck River

Reach Number	Description of reach	Index Cross-Section for Reach (RM) [2]	Description
Skookumchuck 1	Town of Bucoda	RM 10.56	Town of Bucoda
Skookumchuck 2	RM 5.08 to RM 3.85	RM 5.08	Skookumchuck river mile 5.08 to confluence of Skookumchuck River/Hanaford Creek
Skookumchuck 3	RM 3.84 to RM 1.57	RM 2.415	Confluence of Skookumchuck River/Hanaford Creek to confluence of Skookumchuck River/Coffee Creek
Skookumchuck 4	RM 1.57 to RM 0.22	RM 0.98	Confluence of Skookumchuck River/Coffee Creek to limit of backwater effect from Chehalis River on Skookumchuck River

2 - Index cross-sections for Skookumchuck River reaches are referenced to Skookumchuck River river mile (RM)

UNET storage areas in the Chehalis/Centralia area and links to index cross-sections for the HEC-FDA analysis			
Storage Area Number [1]	River cross-section that storage area is hydraulically linked to [2]	Associated Economics Reach [3]	Associated Index Cross-Section [3]
102	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
101	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
100	Chehalis RM 76.70	Chehalis Econ. Reach 1	Chehalis RM 74.02
301	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
302	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
303	Chehalis RM 74.57	Chehalis Econ. Reach 1	Chehalis RM 74.02
2	Chehalis RM 72.80	Chehalis Econ. Reach 2	Chehalis RM 72.80
3	Salzer RM 1.56	Chehalis Econ. Reach 4	Chehalis RM 68.67
4	Salzer RM 1.28	Chehalis Econ. Reach 4	Chehalis RM 68.67
5	Chehalis RM 68.05	Chehalis Econ. Reach 4	Chehalis RM 68.67
501	Chehalis RM 68.67	Chehalis Econ. Reach 4	Chehalis RM 68.67
601	Skookumchuck RM 2.99	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
602	Skookumchuck RM 2.415	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
603	China Creek - N/A [4]	Not included in stage-damage function	N/A
604	China Creek - N/A [4]	Not included in stage-damage function	N/A
605	China Creek - N/A [4]	Not included in stage-damage function	N/A
606	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
608	China Creek - N/A [4]	Not included in stage-damage function	N/A
609	Skookumchuck RM 0.49	Skookumchuck Econ. Reach 4	Skookumchuck RM 0.98
610	Chehalis RM 67.36	Chehalis Econ. Reach 5	Chehalis RM 67.29
701	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
702	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
703	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
704	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
705	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415

1 - Storage Area number as related to the Chehalis UNET model and as delineated on the 1"=400' scale maps.
2 - Stream and river mile most closely associated with overflow to storage area.
3 - Economics reach and associated index cross-section that should be used to link the storage area to hydrologic (discharge-probability) and hydraulic (stage-discharge) information.
4 - Storage area is mostly flooded from China Creek (China Creek is not modeled hydraulically in the UNET model).

Bank elevations are in feet (msl) as defined in PIE's UNET model
Estimated zero-damage stage at index cross-section (to be used for stage-damage evaluation)

Chehalis River Index Cross-Sections

Reach	**Index Cross-Section**	**Estimated zero-damage elevation at Index Cross-Section**
	(RM)	(feet - msl)
Chehalis 1	74.02	172.5
Chehalis 2	72.80	172.3
Chehalis 3	70.30	169.2
Chehalis 4	68.67	166.2
Chehalis 5	67.29	168.0
Chehalis 6	66.30	164.0
Chehalis 7	65.20	160.0

Skookumchuck River Index Cross-Sections

Reach	**Index Cross-Section**	**Estimated zero-damage elevation at Index Cross-Section**
	(RM)	(feet - msl)
Skookumchuck 1	10.56	240.6
Skookumchuck 2	5.08	201.5
Skookumchuck 3	2.415	184.5
Skookumchuck 4	0.98	173.0

The following information is to be used to characterize existing ("pre-project") conditions in the Chehalis River basin
Discharge-Probability Function Statistics to be input to HEC-FDA for Chehalis River Reaches
Use with "Graphical Type" Probability Function in HEC-FDA, Water Surface Profile Type is "Discharge-Probability"

Reach	Chehalis 1	Chehalis 2	Chehalis 3	Chehalis 4	Chehalis 5	Chehalis 6	Chehalis 7
Index Cross-Section (RM)	74.02	72.80	70.30	68.67	67.29	66.30	65.20
Equivalent Record Length (years)	70	70	70	70	70	70	70
Exceedance Probability	Discharge (cfs)	Discharge (cfs)	Discharge (cfs)	Discharge (cfs)	Discharge (cfs)	Discharge (cfs)	Discharge (cfs)
0.999	14,516	10,455	5,079	8,549	8,448	11,683	11,688
0.500	21,637	20,231	18,648	18,743	18,718	24,251	24,260
0.200	28,285	27,181	26,573	25,951	26,030	33,620	33,632
0.100	33,715	32,444	31,978	31,429	31,606	40,892	40,906
0.040	41,835	39,889	38,958	39,202	39,539	51,392	51,408
0.020	48,878	46,043	44,257	45,645	46,132	60,233	60,251
0.010	56,851	52,747	49,638	52,678	53,343	70,006	70,026
0.005	65,898	60,078	55,132	60,384	61,259	80,847	80,869
0.002	79,781	70,871	62,613	71,750	72,958	97,060	97,085
0.001	91,971	79,974	68,458	81,352	82,862	110,942	110,970

Discharge-Probability Function Statistics to be input to HEC-FDA for Skookumchuck River Reaches
Use with "Graphical Type" Probability Function in HEC-FDA, Water Surface Profile Type is "Discharge-Probability"

Reach	Skookumchuck 1	Skookumchuck 2	Skookumchuck 3	Skookumchuck 4
Index Cross-Section (RM)	10.56	5.08	2.42	0.98
Equivalent Record Length (years)	49	49	49	49
Exceedance Probability	Discharge (cfs)	Discharge (cfs)	Discharge (cfs)	Discharge (cfs)
0.999	573	549	976	1,029
0.500	3,200	3,200	4,050	4,200
0.200	5,109	5,170	6,508	6,713
0.100	6,525	6,645	8,471	8,712
0.040	8,470	8,683	11,358	11,642
0.020	10,025	10,321	13,819	14,133
0.010	11,666	12,057	16,562	16,903
0.005	13,402	13,900	19,620	19,987
0.002	15,856	16,515	24,212	24,606
0.001	17,841	18,638	28,152	28,561

Max. Water surface elevation in storage area for given flood event (ft)
Return Interval of event (probability of occurrence in parentheses)

Storage Area Number [1]	2-yr (0.50)	5-yr (0.20)	10-yr (0.10)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	River Cross-section that storage area is hydraulically linked to [2]	Associated Economics Reach [3]	Associated Index Cross-Section [3]
102	N/A	176.24	178.22	181.09	181.82	182.31	183.03	183.83	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
101	N/A	176.17	178.09	181.07	181.81	182.34	183.16	184.02	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
100	N/A	176.16	178.07	181.94	182.39	182.72	183.48	184.43	Chehalis RM 76.70	Chehalis Econ. Reach 1	Chehalis RM 74.02
301	175.55	177.85	178.92	180.67	181.55	182.06	182.87	183.68	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
302	175.34	177.55	178.86	180.65	181.53	182.04	182.82	183.61	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
303	N/A	N/A	175.25	179.08	180.32	181.21	181.35	182.01	Chehalis RM 74.57	Chehalis Econ. Reach 1	Chehalis RM 74.02
2	N/A	N/A	N/A	N/A	175.42	176.13	177.51	179.24	Chehalis RM 72.80	Chehalis Econ. Reach 2	Chehalis RM 72.80
3	N/A	N/A	N/A	N/A	174.88	176.01	177.26	178.91	Salzer RM 1.56	Chehalis Econ. Reach 4	Chehalis RM 68.67
4	N/A	N/A	N/A	N/A	174.85	175.99	177.29	178.95	Salzer RM 1.28	Chehalis Econ. Reach 4	Chehalis RM 68.67
5	N/A	N/A	N/A	N/A	N/A	N/A	176.51	177.88	Chehalis RM 68.05	Chehalis Econ. Reach 4	Chehalis RM 68.67
501	N/A	169.67	171.35	173.33	174.77	175.64	176.98	178.62	Chehalis RM 68.67	Chehalis Econ. Reach 4	Chehalis RM 68.67
603	N/A	188.06	188.14	188.32	188.46	188.61	188.78	189.31	China Creek - N/A [4]	Not included	N/A
604	N/A	N/A	N/A	N/A	N/A	N/A	N/A	184.31	China Creek - N/A [4]	Not included	N/A
605	N/A	182.54	182.64	183.73	184.49	185.37	185.86	186.46	China Creek - N/A [4]	Not included	N/A
608	N/A	N/A	N/A	N/A	N/A	N/A	N/A	179.00	China Creek - N/A [4]	Not included	N/A
610	N/A	169.11	170.28	171.97	173.09	174.07	175.40	177.45	Chehalis RM 67.36	Chehalis Econ. Reach 5	Chehalis RM 67.29

1 - Storage Area number as related to the Chehalis UNET model and as delineated on the 1"=400' scale maps.
2 - Stream and river mile most closely associated with overflow to storage area.
3 - Economics reach and associated index cross-section that should be used to link the storage area to hydrologic (discharge-probability) and hydraulic (stage-discharge) information.
4 - Storage area is mostly flooded from China Creek (China Creek is not modeled hydraulically in the UNET model).
N/A - Storage Area is dry for the given event.

Max. Water surface elevation in storage area for given flood event (ft)
Return Interval of event (probability of occurrence in parentheses)

Storage Area Number [1]	3.1-yr (0.323)	6.1-yr (0.164)	12.7-yr (0.079)	34-yr (0.029)	50-yr (0.02)	88-yr (0.011)	143-yr (0.007)	482-yr (0.0021)	River Cross-section that storage area is hydraulically linked to [2]	Associated Economics Reach [3]	Associated Index Cross-Section [3]
601	N/A	186.29	188.12	188.32	188.46	188.60	188.77	189.63	Skookumchuck RM 2.99	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
602	N/A	N/A	N/A	N/A	N/A	184.66	187.12	187.51	Skookumchuck RM 2.415	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
606	N/A	N/A	N/A	N/A	N/A	N/A	179.06	179.61	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
609	N/A	169.38	170.45	172.04	173.06	173.93	174.96	176.25	Skookumchuck RM 0.49	Skookumchuck Econ. Reach 4	Skookumchuck RM 0.98
701	N/A	N/A	200.61	201.19	201.49	201.76	202.00	202.62	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
702	N/A	N/A	198.14	199.46	200.03	200.66	200.98	201.74	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
703	N/A	N/A	194.10	194.80	195.14	195.53	195.79	196.37	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
704	N/A	187.22	187.38	188.60	189.06	189.56	189.88	190.61	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
705	N/A	183.70	184.33	185.70	185.98	186.32	186.51	187.12	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415

1 - Storage Area number as related to the Chehalis UNET model and as delineated on the 1"=400' scale maps.
2 - Stream and river mile most closely associated with overflow to storage area.
3 - Economics reach and associated index cross-section that should be used to link the storage area to hydrologic (discharge-probability) and hydraulic (stage-discharge) information.
N/A - Storage Area is dry for the given event.

Figure A.1 - Example of @RISK Spreadsheet

REACH 1														
1000				YR				0.50	21.05					
Reference X				74.02				1.00						
Reference X WS elev				183.00				4.50	95.00					

3.4.2.1.1.1.1.1.1 RESIDENTIAL STRUCTURES ON THE CHEHALIS

SHEET #	GRID	STRUCTURE #	SPOT ELEVATION	RIVER MILE	RIVER	REACH	STRUCTURE TYPE	SAMPLE ELEVATION ADJUSTMENT	TRUE ELEVATION	x-Section WS Elev	REFERENCE X ELEV	X ADJUSTMENT	R&U ELEVATION	INUNDATION DEPTH
L16	12	5	179.8	73.10	CH	1	R	1.80	181.60	182.27	183.00	0.73	182.33	0.67
M16	23	11	175.7	73.17	CH	1	R	1.80	177.50	182.29	183.00	0.71	178.21	4.79
M16	23	12	179.1	73.17	CH	1	R	1.80	180.90	182.29	183.00	0.71	181.61	1.39
M16	23	13	176.5	73.17	CH	1	R	1.80	178.30	182.29	183.00	0.71	179.01	3.99
M16	23	14	175.3	73.17	CH	1	R	1.80	177.10	182.29	183.00	0.71	177.81	5.19
M16	23	15	175.2	73.17	CH	1	R	1.80	177.00	182.29	183.00	0.71	177.71	5.29
M16	24	1	175.2	73.17	CH	1	R	1.80	177.00	182.29	183.00	0.71	177.71	5.29
M16	25	2	175.4	73.17	CH	1	R	1.80	177.20	182.29	183.00	0.71	177.91	5.09
L18	24	1	182.8	73.40	CH	1	R	1.80	184.60	182.44	183.00	0.56	185.16	-2.16
L18	24	2	183.4	73.40	CH	1	R	1.80	185.20	182.44	183.00	0.56	185.76	-2.76
M16	31	1	175.2	73.70	CH	1	R	1.80	177.00	182.64	183.00	0.36	177.36	5.64
M16	31	2	175.5	73.70	CH	1	R	1.80	177.30	182.64	183.00	0.36	177.66	5.34
M16	31	3	175.5	73.70	CH	1	R	1.80	177.30	182.64	183.00	0.36	177.66	5.34
M16	31	4	176.1	73.70	CH	1	R	1.80	177.90	182.64	183.00	0.36	178.26	4.74

Figure A.1 - Example of @RISK Spreadsheet

			LCM	1.11					
	MEAN:	1,524	CCM	1.04			3.65	1,537	3.01
	STD:	532	G	68.87	79.50		0.94	411	2.36
	MIN:	600	A	49.69	57.36		0.00	0	0.00
	MAX:	4,500	F	42.85	49.47		10.00	10,000	20.00
	SUM	327,147		20,319,262	8,163,972	4,460,322	1,136,720	276,680	960,628
STRUCTURE DAMAGE %	CONTENT DAMAGE %	SQUARE FOOTAGE	M&S VALUE	STRUCTURE VALUE	STRUCTURE DAMAGE	CONTENT DAMAGE	CLEAN UP COSTS	TRA COSTS	PUBLIC ASSISTANCE
0.1835	0.1070	1,573	62.11	97,689	17,926	10,453	5,741	1,537	5,337
0.5168	0.2803	1,573	62.11	97,689	50,481	27,377	5,741	1,537	5,337
0.2550	0.1445	1,573	62.11	97,689	24,911	14,116	5,741	1,537	5,337
0.4535	0.2478	1,573	62.11	97,689	44,302	24,202	5,741	1,537	5,337
0.5320	0.2880	1,573	62.11	97,689	51,970	28,134	5,741	1,537	5,337
0.5455	0.2948	1,573	62.11	97,689	53,289	28,794	5,741	1,537	5,337
0.5455	0.2948	1,573	62.11	97,689	53,289	28,794	5,741	1,537	5,337
0.5320	0.2880	1,573	62.11	97,689	51,970	28,134	5,741	1,537	5,337
0.0000	0.0000	1,573	62.11	97,689	0	0	0	0	0
0.0000	0.0000	1,573	62.11	97,689	0	0	0	0	0
0.5590	0.3015	1,573	62.11	97,689	54,608	29,453	5,741	1,537	5,337
0.5455	0.2948	1,573	62.11	97,689	53,289	28,794	5,741	1,537	5,337
0.5455	0.2948	1,573	62.11	97,689	53,289	28,794	5,741	1,537	5,337
0.5015	0.2725	1,573	62.11	97,689	48,991	26,620	5,741	1,537	5,337

APPENDIX B – STAGE-DAMAGE FUNCTIONS

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Chehalis Reach 1 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
172.50	0	0	0	0	0	0	0	0	0	0	0	0
173.68	83	55	80	0	0	0	0	0	0	4	12	234
175.54	562	351	339	50	23	0	0	0	0	29	102	1,456
176.37	1,070	646	497	84	46	6	0	0	0	59	203	2,611
177.79	2,245	1,302	715	163	112	6	11	2	0	122	423	5,101
178.58	3,029	1,729	807	228	166	21	44	9	0	155	538	6,726
179.16	3,591	2,039	861	243	197	26	54	17	4	175	609	7,816
179.92	4,428	2,482	926	286	251	27	62	24	4	201	697	9,388
180.96	5,467	3,034	990	485	378	49	78	33	4	227	787	11,532
183.00	8,112	4,424	1,108	713	650	105	92	48	4	274	952	16,482
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	208	20,319										
Commercial	28	2,914	2,465	73,300								
Public	5	994	823	27,500								

Chehalis Reach 2 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
172.30	0	0	0	0	0	0	0	0	0	0	0	0
172.34	38	24	26	0	0	0	0	0	0	2	7	97
174.47	7	1	0	7	1	0	0	0	0	10	36	62
175.32	347	205	136	10	2	0	0	0	0	18	64	782
176.77	698	399	188	28	12	0	0	0	0	36	123	1,484
177.53	925	521	210	43	24	9	0	0	0	44	152	1,928
178.12	1,122	627	224	44	34	9	0	0	0	50	173	2,283
178.89	1,381	764	237	53	42	9	0	0	0	56	195	2,737
180.06	1,756	960	248	65	55	9	0	0	0	63	217	3,373
182.50	2,408	1,295	263	81	79	9	0	0	0	68	236	4,439
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	52	5,080										
Commercial	3	214	181	7,300								
Public	0	0	0	0								

Chehalis Reach 3 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
169.20	0	0	0	0	0	0	0	0	0	0	0	0
170.45	74	48	52	0	0	0	0	0	0	4	14	192
171.62	190	114	88	0	0	0	0	0	0	11	39	442
173.58	528	305	160	34	39	13	0	0	0	27	93	1,199
174.81	844	477	203	99	95	24	0	0	0	39	137	1,918
175.86	1,161	649	239	198	205	66	0	0	0	50	173	2,741
177.05	1,566	868	289	530	664	66	0	0	0	60	210	4,253
178.58	2,168	1,191	346	1,491	2,866	796	0	0	0	77	267	9,202
182.00	3,592	1,931	422	2,492	5,731	803	0	0	0	104	361	15,436
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	98	9,574										
Commercial	10	8,195	15,493	226,700								
Public	0	0	0	0								

Chehalis Reach 4 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
166.20	0	0	0	0	0	0	0	0	0	0	0	0
166.90	13	8	7	0	0	0	0	0	0	1	3	32
169.82	69	41	26	46	32	0	2	2	0	3	10	231
171.17	141	84	65	66	75	0	5	5	0	6	21	468
173.22	550	337	311	174	146	16	8	9	0	25	85	1,661
174.50	1,304	788	626	293	263	26	8	11	0	65	226	3,610
175.59	2,477	1,461	954	572	485	82	337	211	4	128	445	7,156
176.81	4,395	2,531	1,312	903	830	156	499	463	106	223	774	12,192
178.36	7,657	4,302	1,676	1,210	1,284	228	729	698	120	349	1,214	19,467
181.50	15,182	8,266	2,025	1,795	2,102	255	2,623	2,412	506	511	1,777	37,454
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	365	35,656										
Commercial	37	5,120	4,087	108,700								
Public	12	11,883	11,593	141,000								

Chehalis Reach 5 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
168.00	0	0	0	0	0	0	0	0	0	0	0	0
168.36	0	0	1	141	0	0	0	0	0	0	0	142
169.59	5	4	8	141	0	0	4	3	0	0	0	165
171.42	52	34	40	141	0	0	9	10	0	3	9	298
172.47	133	82	79	141	0	0	26	15	0	7	25	508
173.40	261	158	126	141	0	0	59	40	0	14	49	848
174.40	492	291	196	141	0	0	74	66	11	26	90	1,387
175.72	973	561	298	141	0	0	100	97	11	49	169	2,399
178.50	2,444	1,357	450	141	0	0	127	147	11	101	351	5,129
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	123	12,016										
Commercial	1	211	141	2,000								
Public	3	368	344	7,400								
Chehalis Reach 6 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
164.00	0	0	0	0	0	0	0	0	0	0	0	0
164.10	15	12	29	0	0	0	0	0	0	0	1	57
165.28	103	71	111	18	12	0	0	0	0	4	15	334
167.03	660	410	393	39	44	15	25	17	7	36	125	1,771
167.96	1,354	816	619	54	62	15	59	52	7	74	255	3,367
168.81	2,302	1,351	834	59	75	15	207	129	12	123	427	5,534
169.81	3,616	2,078	1,040	313	160	15	379	283	76	185	643	8,788
171.06	5,624	3,162	1,224	430	281	117	488	437	84	262	910	13,019
173.00	8,992	4,937	1,348	655	432	117	627	650	84	339	1,178	19,359
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	272	26,571										
Commercial	4	2,258	1,298	33,500								
Public	10	2,120	1,898	32,400								

Chehalis Reach 7 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
160.00	0	0	0	0	0	0	0	0	0	0	0	0
160.67	0	0	1	0	0	0	0	0	0	0	0	1
162.01	4	3	7	0	0	0	0	0	0	0	0	14
163.70	39	25	31	0	0	0	0	0	0	2	7	104
164.67	91	56	56	0	0	0	0	0	0	5	17	225
165.51	166	101	86	0	0	0	0	0	0	9	31	393
166.50	306	182	128	0	0	0	1,963	1,180	493	16	57	4,325
166.77	574	332	176	0	0	0	2,250	2,213	520	30	104	6,199
169.50	1,069	598	216	0	0	0	3,823	3,896	677	49	169	10,497
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	40	3,908										
Commercial	0	0	0	0								
Public	9	15,122	15,122	185,500								

Chehalis Storage Area 101 (Reference Reach 1) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
172.50	0	0	0	0	0	0	0	0	0	0	0	0
173.68	0	0	0	0	0	0	0	0	0	0	0	0
175.54	1	1	1	0	0	0	0	0	0	0	0	3
176.37	8	5	4	0	0	0	0	0	0	0	2	19
177.79	30	17	6	0	0	0	0	0	0	1	5	59
178.58	36	20	6	0	0	0	0	0	0	1	5	68
179.16	40	22	6	0	0	0	0	0	0	2	5	75
179.92	45	24	6	0	0	0	0	0	0	2	5	82
180.96	50	27	6	0	0	0	0	0	0	2	5	90
183.00	60	32	6	0	0	0	0	0	0	2	5	105
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	1	98										
Commercial	0	0	0	0								
Public	0	0	0	0								

Chehalis Storage Area 102 (Reference Reach 1) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
172.50	0	0	0	0	0	0	0	0	0	0	0	0
173.68	0	0	0	0	0	0	0	0	0	0	0	0
175.54	3	2	4	0	0	0	0	0	0	0	0	9
176.37	26	16	14	0	0	0	0	0	0	2	5	63
177.79	117	67	29	0	0	0	0	0	0	6	20	239
178.58	148	83	31	0	0	0	0	0	0	7	24	293
179.16	170	95	32	0	0	0	0	0	0	7	26	330
179.92	201	111	34	0	0	0	0	0	0	8	28	382
180.96	236	129	34	0	0	0	0	0	0	9	30	438
183.00	313	169	35	0	0	0	0	0	0	9	32	558
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	6	586										
Commercial	0	0	0	0								
Public	0	0	0	0								

Chehalis Storage Area 302 (Reference Reach 1) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
172.50	0	0	0	0	0	0	0	0	0	0	0	0
173.68	5	3	3	357	243	146	0	0	0	0	1	758
175.54	21	13	11	507	550	146	0	0	0	1	4	1,253
176.37	59	38	49	648	796	157	0	0	0	2	7	1,756
177.79	313	197	202	793	1,080	165	0	0	0	15	54	2,819
178.58	621	377	309	956	1,206	165	0	0	0	33	116	3,783
179.16	864	517	372	993	1,283	165	0	0	0	48	166	4,408
179.92	1,337	781	458	1,062	1,413	165	0	0	0	73	254	5,543
180.96	1,911	1,095	530	1,094	1,567	176	0	0	0	100	347	6,820
183.00	3,599	1,993	622	1,215	1,745	176	0	0	0	151	525	10,026
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	111	10,844										
Commercial	7	2,788	3,165	57,700								
Public	0	0	0	0								

Chehalis Storage Area 303 (Reference Reach 1) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
172.50	0	0	0	0	0	0	0	0	0	0	0	0
173.68	0	0	0	0	0	0	0	0	0	0	0	0
175.54	0	0	0	0	0	0	0	0	0	0	0	0
176.37	13	9	12	0	0	0	0	0	0	1	2	37
177.79	216	125	68	0	0	0	0	0	0	11	40	460
178.58	352	199	82	0	0	0	0	0	0	17	59	709
179.16	456	254	88	0	0	0	0	0	0	20	70	888
179.92	474	263	89	0	0	0	0	0	0	21	71	918
180.96	554	306	91	0	0	0	0	0	0	22	77	1,050
183.00	780	423	96	0	0	0	0	0	0	25	87	1,411
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	17	1,661										
Commercial	0	0	0	0								
Public	0	0	0	0								

Chehalis Storage Area 2 (Reference Reach 2) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
172.30	0	0	0	0	0	0	0	0	0	0	0	0
172.34	0	0	0	0	0	0	0	0	0	0	0	0
174.47	0	0	0	0	0	0	0	0	0	0	0	0
175.32	0	0	0	0	0	0	0	0	0	0	0	0
176.77	0	0	0	0	0	0	0	0	0	0	0	0
177.53	465	258	89	3,088	4,346	621	444	594	9	19	65	9,998
178.12	549	305	104	3,712	5,494	912	488	643	9	21	71	12,308
178.89	755	418	143	4,217	7,245	924	562	763	9	26	92	15,154
180.06	1,111	612	194	5,542	9,576	1,089	613	881	17	40	137	19,812
182.50	1,739	942	235	6,713	12,540	1,089	662	940	17	58	200	25,135
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	42	4,103										
Commercial	31	16,640	25,337	384,800								
Public	13	1,472	1,657	60,900								

Chehalis Storage Area 3 (Reference Reach 4) - Damages in $1,000

	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
166.20	0	0	0	0	0	0	0	0	0	0	0	0
166.90	0	0	0	0	0	0	0	0	0	0	0	0
169.82	0	0	0	0	0	0	0	0	0	0	0	0
171.17	0	0	0	0	0	0	0	0	0	0	0	0
173.22	0	0	0	0	0	0	0	0	0	0	0	0
174.50	507	283	115	1,178	1,035	176	2,663	1,843	226	19	65	8,110
175.59	696	388	152	1,713	1,838	502	2,834	1,980	249	27	93	10,472
176.81	972	537	186	2,483	2,701	508	2,959	2,078	249	38	132	12,843
178.36	1,381	752	210	3,359	4,009	769	3,100	2,150	249	50	175	16,204
181.50	2,088	1,113	218	4,750	6,123	772	3,277	2,198	249	58	202	21,048
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	38	3,712										
Commercial	30	12,297	13,005	262,200								
Public	55	6,716	3,705	193,400								

Chehalis Storage Area 4 (Reference Reach 4) - Damages in $1,000

	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
166.20	0	0	0	0	0	0	0	0	0	0	0	0
166.90	0	0	0	0	0	0	0	0	0	0	0	0
169.82	0	0	0	0	0	0	0	0	0	0	0	0
171.17	0	0	0	0	0	0	0	0	0	0	0	0
173.22	0	0	0	0	0	0	0	0	0	0	0	0
174.50	112	65	37	4,922	7,003	1,739	0	0	0	6	21	13,905
175.59	182	104	50	6,405	9,933	1,874	0	0	0	9	30	18,587
176.81	284	160	64	7,829	13,049	1,957	0	0	0	12	43	23,398
178.36	440	243	75	9,337	16,785	2,096	0	0	0	17	61	29,054
181.50	722	389	80	11,973	22,813	2,105	0	0	0	21	74	38,177
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	14	1,368										
Commercial	52	28,277	42,101	657,200								
Public	0	0	0	0								

Chehalis Storage Area 5 (Reference Reach 4) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
166.20	0	0	0	0	0	0	0	0	0	0	0	0
166.90	0	0	0	0	0	0	0	0	0	0	0	0
169.82	0	0	0	0	0	0	0	0	0	0	0	0
171.17	0	0	0	0	0	0	0	0	0	0	0	0
173.22	0	0	0	0	0	0	0	0	0	0	0	0
174.50	0	0	0	0	0	0	0	0	0	0	0	0
175.59	0	0	0	0	0	0	0	0	0	0	0	0
176.81	6,533	3,650	1,307	712	1,110	149	74	82	11	286	992	14,906
178.36	8,996	4,948	1,407	853	1,518	149	80	102	11	345	1,198	19,607
181.50	13,835	7,425	1,441	1,216	2,236	149	114	141	11	385	1,339	28,292
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	251	24,520										
Commercial	6	3,016	4,715	40,900								
Public	1	263	263	3,000								

Chehalis Storage Area 610B (Reference Reach 5) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
168.00	0	0	0	0	0	0	0	0	0	0	0	0
168.36	66	44	63	106	32	0	0	0	0	3	10	324
169.59	218	138	149	212	96	73	10	7	0	11	39	953
171.42	795	481	388	401	225	96	436	310	0	42	146	3,320
172.47	1,574	933	639	580	363	112	668	729	128	81	283	6,090
173.40	2,622	1,528	892	742	513	118	945	1,016	135	132	459	9,102
174.40	4,607	2,623	1,192	949	704	131	1,926	1,858	154	222	772	15,138
175.72	8,393	4,643	1,445	1,214	978	131	2,740	3,208	373	343	1,190	24,658
178.50	13,209	7,133	1,510	1,743	1,427	218	3,609	4,777	373	400	1,391	35,790
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	264	25,790										
Commercial	15	4,928	3,276	72,700								
Public	7	10,194	10,675	115,700								

Skookumchuck Reach 1 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
240.60	0	0	0	0	0	0	0	0	0	0	0	0
240.68	231	143	127	116	79	47	41	8	11	14	47	864
241.74	466	273	164	116	133	47	50	12	11	28	99	1,399
242.17	575	333	175	140	156	47	93	34	11	33	116	1,713
242.60	691	395	185	165	179	47	131	56	27	38	131	2,045
242.97	794	450	190	170	190	47	132	64	27	41	143	2,248
243.60	973	545	198	185	222	47	177	94	27	46	161	2,675
247.00	1,802	974	201	275	358	47	351	210	49	54	187	4,508
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	35	3,419										
Commercial	2	667	754	13,000								
Public	3	1,102	565	13,500								
Skookumchuck Reach 2 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
201.50	0	0	0	0	0	0	0	0	0	0	0	0
202.01	112	71	71	0	0	0	0	0	0	6	21	281
202.89	212	128	97	0	0	0	0	0	0	12	43	492
203.62	324	190	115	0	0	0	0	0	0	19	65	713
203.92	376	218	121	0	0	0	0	0	0	21	75	811
204.19	456	262	130	0	0	0	0	0	0	25	87	960
204.43	529	301	135	0	0	0	0	0	0	28	97	1,090
204.81	670	377	143	0	0	0	0	0	0	32	112	1,334
206.70	1,044	572	149	0	0	0	0	0	0	39	135	1,939
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	26	2,540										
Commercial	0	0	0	0								
Public	0	0	0	0								

Skookumchuck Reach 4 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
173.00	0	0	0	0	0	0	0	0	0	0	0	0
173.77	285	165	101	688	226	0	5	1	1	13	45	1,530
174.36	382	224	155	916	398	256	6	1	1	16	56	2,411
175.21	806	483	388	1,507	964	304	8	2	1	34	118	4,615
175.84	1,095	663	556	1,843	1,270	324	8	2	1	49	170	5,981
176.39	1,690	1,021	826	3,039	2,441	486	8	2	1	81	279	9,874
176.90	2,418	1,444	1,059	3,442	3,489	833	543	324	129	120	417	14,218
177.69	4,219	2,471	1,533	4,279	4,932	833	600	590	129	212	737	20,535
181.00	14,608	8,132	2,819	6,701	8,815	921	1,483	1,681	220	621	2,160	48,161
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	619	60,469										
Commercial	35	19,218	21,620	377,550								
Public	4	5,294	5,273	60,400								

Skookumchuck Storage Area 701 (Reference Reach 2) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
201.50	0	0	0	0	0	0	0	0	0	0	0	0
202.01	0	0	0	0	0	0	0	0	0	0	0	0
202.89	19	12	13	0	0	0	0	0	0	1	4	49
203.62	31	19	16	0	0	0	0	0	0	2	7	75
203.92	38	23	17	0	0	0	0	0	0	2	8	88
204.19	46	27	18	0	0	0	0	0	0	3	10	104
204.43	52	31	18	0	0	0	0	0	0	3	11	115
205.04	70	41	20	0	0	0	0	0	0	4	14	149
206.70	123	69	23	0	0	0	0	0	0	6	19	240
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	4	391										
Commercial	0	0	0	0								
Public	0	0	0	0								

Skookumchuck Storage Area 702 (Reference Reach 2) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
201.50	0	0	0	0	0	0	0	0	0	0	0	0
202.01	0	0	0	0	0	0	0	0	0	0	0	0
202.89	307	191	180	0	0	0	0	0	0	17	58	753
203.62	755	446	288	0	0	0	0	0	0	43	147	1,679
203.92	1,014	589	329	0	0	0	0	0	0	56	194	2,182
204.19	1,334	764	364	0	0	0	0	0	0	70	243	2,775
204.43	1,510	858	379	0	0	0	0	0	0	77	266	3,090
205.04	1,939	1,088	407	0	0	0	0	0	0	91	315	3,840
206.70	2,878	1,581	432	2	2	0	0	0	0	110	382	5,387
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	76	7,424										
Commercial	1	51	58	1,000								
Public	0	0	0	0								

Skookumchuck Storage Area 703 (Reference Reach 2) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
201.50	0	0	0	0	0	0	0	0	0	0	0	0
202.01	0	0	0	0	0	0	0	0	0	0	0	0
202.89	68	47	75	13	7	1	0	0	0	3	9	223
203.62	156	103	131	24	15	1	0	0	0	8	26	464
203.92	221	142	164	24	17	1	0	0	0	11	40	620
204.19	317	200	207	25	21	1	0	0	0	17	59	847
204.43	394	245	236	27	23	1	0	0	0	22	75	1,023
205.04	614	374	309	32	27	1	0	0	0	34	118	1,509
206.70	1,601	927	505	39	38	1	0	0	0	86	297	3,494
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	118	11,527										
Commercial	2	137	116	1,700								
Public	0	0	0	0								

Skookumchuck Storage Area 704 (Reference Reach 2) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
201.50	0	0	0	0	0	0	0	0	0	0	0	0
202.01	3	2	3	0	0	0	0	0	0	0	1	9
202.89	4	3	3	0	0	0	0	0	0	0	1	11
203.62	13	8	9	0	0	0	0	0	0	1	2	33
203.92	19	12	14	0	0	0	0	0	0	1	3	49
204.19	30	19	23	0	0	0	0	0	0	1	5	78
204.43	41	26	31	0	0	0	0	0	0	2	6	106
205.04	78	50	57	0	0	0	0	0	0	3	12	200
206.70	299	182	150	0	0	0	9	5	0	16	55	716
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	74	7,229										
Commercial	3	437	511	7,200								
Public	3	3,271	3,271	38,800								

Skookumchuck Storage Area 602 (Reference Reach 3) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
184.50	0	0	0	0	0	0	0	0	0	0	0	0
185.19	0	0	0	0	0	0	0	0	0	0	0	0
185.89	0	0	0	0	0	0	0	0	0	0	0	0
186.65	0	0	0	0	0	0	0	0	0	0	0	0
187.06	0	0	0	0	0	0	0	0	0	0	0	0
187.56	19	14	34	0	0	0	0	0	0	0	1	68
187.79	544	349	392	141	113	14	53	30	11	28	96	1,771
188.07	778	488	479	185	157	32	53	41	11	42	146	2,412
189.50	2,072	1,218	751	359	355	64	75	68	11	120	416	5,509
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	173	16,900										
Commercial	13	2,104	2,277	44,900								
Public	4	1,079	473	18,000								

Skookumchuck Storage Area 606 (Reference Reach 3) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
184.50	0	0	0	0	0	0	0	0	0	0	0	0
185.19	0	0	0	0	0	0	0	0	0	0	0	0
185.89	0	0	0	0	0	0	0	0	0	0	0	0
186.65	0	0	0	0	0	0	0	0	0	0	0	0
187.06	0	0	0	0	0	0	0	0	0	0	0	0
187.56	0	0	0	0	0	0	0	0	0	0	0	0
187.79	347	222	247	0	0	0	448	269	0	17	60	1,610
188.07	562	351	338	0	0	0	598	420	146	30	104	2,549
189.50	1,512	898	614	13	12	5	785	762	146	83	289	5,119
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	259	25,301										
Commercial	4	355	434	8,300								
Public	1	3,434	3,434	40,000								

Skookumchuck Storage Area 705 (Reference Reach 3) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
184.50	0	0	0	0	0	0	0	0	0	0	0	0
185.19	6	4	7	10	7	0	0	0	0	0	1	35
185.89	13	9	14	20	16	0	0	0	0	1	2	75
186.65	57	37	42	24	27	0	0	0	0	3	10	200
187.06	74	47	52	26	29	0	0	0	0	4	13	245
187.56	99	63	66	29	33	0	0	0	0	5	18	313
187.79	117	73	75	30	35	0	0	0	0	6	21	357
188.07	190	117	109	32	38	0	0	0	0	10	34	530
189.50	494	293	202	35	49	0	0	0	0	26	91	1,190
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	67	6,545										
Commercial	1	115	130	5,000								
Public	0	0	0	0								

Skookumchuck Storage Area 609 (Reference Reach 4) - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
173.00	0	0	0	0	0	0	0	0	0	0	0	0
173.77	75	47	46	0	0	0	0	0	0	4	13	185
174.36	168	101	83	0	0	0	0	0	0	9	30	391
175.21	431	253	161	0	0	0	0	0	0	22	78	945
175.84	705	408	227	0	0	0	0	0	0	35	120	1,495
176.39	1,016	582	287	0	0	0	0	0	0	48	168	2,101
176.90	1,472	832	355	0	0	0	0	0	0	67	232	2,958
177.69	2,157	1,202	421	0	0	0	0	0	0	90	314	4,184
181.00	4,006	2,168	485	0	0	0	0	0	0	126	438	7,223
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	85	8,304										
Commercial	0	0	0	0								
Public	0	0	0	0								

Skookumchuck Reach 3 - Damages in $1,000												
	Residential			Commercial			Public					
Stage	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
184.50	0	0	0	0	0	0	0	0	0	0	0	0
185.19	358	230	269	324	394	91	0	0	0	17	58	1,741
185.89	838	522	507	638	697	106	0	0	0	42	147	3,499
186.65	1,671	1,014	825	810	983	109	0	0	0	90	312	5,814
187.06	2,244	1,349	1,018	893	1,130	109	0	0	0	122	424	7,288
187.56	3,387	2,002	1,314	1,059	1,346	109	0	0	0	184	641	10,042
187.79	4,534	2,646	1,540	1,198	1,496	109	0	0	0	244	849	12,617
188.07	6,534	3,750	1,840	1,402	1,827	109	0	0	0	347	1,208	17,016
189.50	10,630	5,941	2,101	1,563	2,157	109	0	0	0	484	1,683	24,668
	Structure #	Value in $1,000		Square								
		Structure	Content	Feet								
Residential	383	37,415										
Commercial	7	4,484	4,344	115,800								
Public	7	5,531	5,655	69,500								

APPENDIX C – AGRICULTURAL DATA

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TABLE 1D. 1997 SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE FOR PRODUCTION OF ALFALFA HAY IN THE COLUMBIA BASIN; CENTER PIVOT IRRIGATION.

OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	VARIABLE COST: FUEL, LUBE, & REPAIRS	VARIABLE COST: LABOR	VARIABLE COST: SERVICE	VARIABLE COST: MATER.	VARIABLE COST: INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
FERTILIZE*	CUSTOM APPLICATION	NOV 1996	.00	.00	.00	.00	.00	3.33	30.73	3.12	37.19	37.19
WEED CONTROL	CUSTOM HERBICIDE APPLIC.	MAR 1997	.00	.00	.00	.00	.00	5.50	15.75	1.24	22.49	22.49
IRRIGATION	CENTER PIVOT, 42 AC. IN.	SEA 1997	.00	1.00	.00	12.00	12.00	105.50	.00	6.48	135.97	135.97
SWATH	70HP/14' WINDROWER	MAY 1997	.17	.20	5.21	4.43	2.40	.00	.00	.28	7.11	12.32
RAKE & TURN	85HP-WT, 18' TWO-ROW RAKE	MAY 1997	.06	.07	1.42	.90	.81	.00	.00	.07	1.77	3.19
BALE	150HP-WT, PTO BALER	MAY 1997	.20	.24	9.74	4.65	2.88	.00	3.36	.45	11.34	21.08
REMOVE & STACK	CUSTOM BALE WAGON	MAY 1997	.00	.00	.00	.00	.00	12.50	.00	.52	13.02	13.02
SWATH	70HP/14' WINDROWER	JUL 1997	.14	.17	4.47	3.80	2.06	.00	.00	.15	6.00	10.47
RAKE & TURN	85HP-WT, 18' TWO-ROW RAKE	JUL 1997	.06	.07	1.42	.90	.81	.00	.00	.04	1.75	3.16
REMOVE & STACK	CUSTOM BALE WAGON	JUL 1997	.00	.00	.00	.00	.00	10.00	.00	.25	10.25	10.25
BALE	150HP-WT, PTO BALER	JUL 1997	.17	.20	8.13	3.88	2.40	.00	2.69	.22	9.19	17.32
SWATH	70HP/14' WINDROWER	AUG 1997	.14	.17	4.47	3.80	2.06	.00	.00	.10	5.95	10.43
RAKE & TURN	85HP-WT, 18' TWO-ROW RAKE	AUG 1997	.06	.07	1.42	.90	.81	.00	.00	.03	1.73	3.15
REMOVE & STACK	CUSTOM BALE WAGON	AUG 1997	.00	.00	.00	.00	.00	10.00	.00	.17	10.17	10.17
BALE	150HP-WT, PTO BALER	AUG 1997	.17	.20	8.13	3.88	2.40	.00	2.69	.15	9.12	17.25
SWATH	70HP/14' WINDROWER	OCT 1997	.14	.17	4.47	3.80	2.06	.00	.00	.00	5.86	10.33
RAKE & TURN	85HP-WT, 18' TWO-ROW RAKE	OCT 1997	.06	.07	1.42	.90	.81	.00	.00	.00	1.70	3.12
REMOVE & STACK	CUSTOM BALE WAGON	OCT 1997	.00	.00	.00	.00	.00	7.50	.00	.00	7.50	7.50
BALE	150HP-WT, PTO BALER	OCT 1997	.14	.17	6.96	3.32	2.06	.00	2.02	.00	7.40	14.36
GOPHER CONTROL	COST OF ANNUAL GOPHER CONTROL	ANN 1997	.00	.00	.00	.00	.00	2.00	.00	.10	2.10	2.10
PICK-UP	3/4 TON	ANN 1997	1.00	.00	5.68	3.07	.00	.00	.00	.15	3.23	8.91
OVERHEAD	UTILITIES, LEGAL, ACCT., ETC.	ANN 1997	.00	.00	.00	.00	.00	23.31	.00	.00	23.31	23.31
LAND COST	NET RENT	ANN 1997	.00	.00	250.00	.00	.00	.00	.00	.00	.00	250.00
MANAGEMENT	7% OF EXPECTED GROSS RETURNS	ANN 1997	.00	.00	61.60	.00	.00	.00	.00	.00	.00	61.60
ESTABLISHMENT**	PRORATED ESTABLISHMENT COST	ANN 1997	.00	.00	94.32	.00	.00	.00	.00	.00	.00	94.32
TOTAL PER ACRE			2.50	2.80	468.84	50.22	33.54	179.65	57.24	13.53	334.17	803.01

*TWO-THIRDS OF APPLIED COST SINCE FERTILIZER NOT APPLIED FIRST YEAR OF PRODUCTION.

**$234.57 ESTABLISHMENT COST AMORTIZED OVER 3 YEARS AT 10% INTEREST.

TABLE 1C. 1997 SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE FOR ESTABLISHING ALFALFA HAY FOLLOWING WHEAT OR BARLEY IN THE COLUMBIA BASIN; CENTER PIVOT IRRIGATION.*

OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	VARIABLE COST: FUEL, LUBE, & REPAIRS	VARIABLE COST: LABOR	VARIABLE COST: SERVICE	VARIABLE COST: MATER.	VARIABLE COST: INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
FERTILIZE**	CUSTOM APPLICATION	AUG 1996	.00	.00	.00	.00	.00	5.00	50.40	.92	56.32	56.32
DISC & PACK	150HP-WT, 13' TANDUM DISC&PACK	AUG 1996	.20	.24	8.92	3.96	2.88	.00	.00	.11	6.95	15.87
CHISEL	200HP-WT, 13' CHISEL	AUG 1996	.20	.24	10.26	4.80	2.88	.00	.00	.13	7.81	18.07
DISC & PACK	150HP-WT, 13' TANDUM DISK&PACK	AUG 1996	.20	.24	8.92	3.96	2.88	.00	.00	.11	6.95	15.87
HARROW	150HP-WT, 36' HARROW	AUG 1996	.07	.08	2.53	1.07	.96	.00	.00	.03	2.07	4.59
PLANT	150HP-WT, RENTED AIR SEEDER	AUG 1996	.17	.25	5.35	2.35	3.00	6.00	61.60	1.22	74.16	79.52
IRRIGATE	CENTER PIVOT; 6 AC. IN.	SEP 1996	.00	.17	.00	2.00	2.04	16.80	.00	.17	21.01	21.01
PICK-UP	3/4 TON	ANN 1996	.40	.48	2.27	1.23	5.76	.00	.00	.35	7.34	9.61
OVERHEAD	UTILITIES,LEGAL,ACCT.,ETC.	ANN 1996	.00	.00	.00	.00	.00	13.70	.00	.00	13.70	13.70
TOTAL PER ACRE			1.23	1.70	38.24	19.37	20.40	41.50	112.00	3.05	196.32	234.57

*ALL FIXED COSTS ASSOCIATED WITH LAND & MANAGEMENT ARE ALLOCATED TO THE PRECEDING CROP.

**ASSUMES THAT THE STRAW HAS BEEN REMOVED FIRST.

TABLE 1. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE
1990 GREEN PEA PRODUCTION COSTS
NORTHWEST WASHINGTON, 100 ACRES ON A 250-ACRE FARM

OPERATION	TOOLING	MTH	YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	VARIABLE COST: FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
						$	$	$	$	$	$	$	$
DISK	130 HP, 15' DISK	SEP	1989	.14	.17	6.02	3.68	1.50	.00	.00	.57	5.75	11.77
CHISEL	130 HP, 10' CHISEL	SEP	1989	.21	.25	7.21	3.15	2.25	.00	.00	.59	5.98	13.20
LIMING	CUSTOM INCLUDES .75 TON L	MAR	1990	.00	.00	.00	.00	.00	17.25	.00	.86	18.11	18.11
FERTILIZE	CUSTOM BROADCAST[1]	APR	1990	.00	.00	.00	.00	.00	5.25	91.20	3.86	100.31	100.31
PLOW	130HP;MB 4-16 2WY	APR	1990	.39	.47	18.62	9.45	4.21	.00	.00	.55	14.21	32.83
CULTIVATE	130 HP, 15' CULTIVATOR	APR	1990	.23	.28	6.80	4.00	2.50	.00	.00	.26	6.76	13.56
CULTIMULCH	130 HP, 13' CULTIMULCHER	APR	1990	.16	.19	5.58	2.71	1.73	.00	.00	.18	4.62	10.20
WEED CONTROL	CUSTOM SPRAY[2]	APR	1990	.00	.00	.00	.00	.00	7.25	8.48	.63	16.36	16.36
WEED CONTROL	CUSTOM SPRAY[3]	MAY	1990	.00	.00	.00	.00	.00	7.25	19.00	.79	27.04	27.04
CULTIVATE	130HP; 15'CULTIVATOR	MAY	1990	.11	.14	3.40	2.00	1.25	.00	.00	.10	3.35	6.75
CULTIMULCH	130HP;13' CULTIMULCHER 2X	MAY	1990	.32	.38	11.15	5.43	3.46	.00	.00	.27	9.15	20.30
PLANT	60 HP, 10' DRILL DISK	MAY	1990	.28	.33	11.46	2.76	2.99	.00	71.10	2.31	79.16	90.62
INSECT CONT	CUSTOM 2X11[4]	MAY	1990	.00	.00	.00	.00	.00	7.25	2.48	.29	10.02	10.02
HARVEST	BY PROCESSOR	JUL	1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CULTIVATE	130 HP,15' CULTIVATOR	AUG	1990	.11	.14	3.40	2.00	1.25	.00	.00	.00	3.25	6.65
DISK	130HP,15'DISK 2X	AUG	1990	.28	.33	12.04	7.36	2.99	.00	.00	.00	10.36	22.40
LAND RENT	LAND RENT	ANN	1990	.00	.00	140.00	.00	.00	.00	.00	.00	.00	140.00
OVERHEAD	5% VARIABLE COSTS	ANN	1990	.00	.00	.00	.00	.00	16.72	.00	.00	16.72	16.72
PICK-UP TRUCK	USED, THIS CROP	ANN	1990	.00	.00	.00	.00	.00	18.80	.00	1.13	19.93	19.93
TOTAL PER ACRE				2.22	2.68	225.69	42.54	24.12	79.77	192.26	12.37	351.07	576.76

[1] 570 LB/AC 4-24-21.
[2] .33 LB/AC SENCOR 75%DF.
[3] .25 GAL/AC BASAGRAN 4EC.
[4] .5 PT/AC AQUA8 PARATHION; TWO APPLICATIONS: 10% BLOOM AND 100% BLOOM; 1/2 PAID BY PROCESSOR.

TABLE 1. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE
1990 SWEET CORN PRODUCTION COSTS
NORTHWEST WASHINGTON 50 ACRES ON 250 ACRE FARM

						VARIABLE COST							
OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
DISK	130HP, 15' DISK	OCT 1989	.14	.17	6.02	3.68	1.50	.00	.00	.52	5.70	11.72
SUBSOIL	130HP, SUBSOILER	OCT 1989	.39	.48	15.10	7.14	4.28	.00	.00	1.04	11.46	26.56
DISK	130HP, 15' DISK 2X	MAR 1990	.28	.33	12.04	7.36	2.99	.00	.00	.52	10.87	22.92
LIMING	CUST LIMING, INCL. 1T LIME	MAR 1990	.00	.00	.00	.00	.00	23.00	.00	1.15	24.15	24.15
PLOW	130HP, 4-16 PLOW	MAR 1990	.39	.47	18.62	9.45	4.21	.00	.00	.68	14.34	32.97
FERTILIZE	CUSTOM FERT. APPLICATION[1]	APR 1990	.00	.00	.00	.00	.00	5.25	24.34	1.18	30.77	30.77
CULTIMULCH	130HP, 13' CULTIMULCHER	APR 1990	.16	.19	5.58	2.71	1.73	.00	.00	.18	4.62	10.20
WEED CONTROL	WEED CONTROL 60HP[2]	APR 1990	.38	.46	14.93	1.86	4.16	.00	23.63	1.19	30.84	45.77
PLANT	CUSTOM PLANTING[3]	APR 1990	.00	.00	.00	.00	.00	15.00	89.00	4.16	108.16	108.16
CULTIVATE	60HP,4R CULTIVATOR	MAY 1990	.18	.22	7.80	.90	2.00	.00	.00	.09	2.98	10.78
FERTILIZE	60HP,CULTVTR/FERT ATT.[4]	JUN 1990	.21	.25	10.41	1.28	2.29	.00	24.00	.55	28.12	38.53
HARVEST	BY PROCESSOR	AUG 1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PICKUP TRUCK	USED, THIS CROP	ANN 1990	.00	.00	.00	.00	.00	18.80	.00	1.13	19.93	19.93
LAND RENT	LAND RENT	ANN 1990	.00	.00	150.00	.00	.00	.00	.00	.00	.00	150.00
OVERHEAD	5% VARIABLE COST	ANN 1990	.00	.00	.00	.00	.00	14.60	.00	.00	14.60	14.60
TOTAL PER ACRE			2.13	2.57	240.50	33.38	23.16	76.65	160.98	12.38	306.55	547.05

[1] 220 LB/AC 0-0-60; 6 LB/AC ZINC.
[2] .5 GAL/AC SURPASS 6.7E; .375 GAL/AC ATRAZINE 4L.
[3] BAND APPLICATION OF 300 LB/AC 18-46-0.
[4] 200 LB/AC AMMONIUM NITRATE.

HAY		First Cycle							Second Cycle						
	NPV	Est.	1	2	3	4	5	6	Est.	1	2	3	4	5	6
NO FLOOD	$246.18	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	-263.55	86.91	86.91	86.91	86.91	86.91	86.91
FLOOD DURING															
ESTABLISH	($50.72)	-263.55	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	-263.55	86.91	86.91	86.91	86.91	86.91
1st	($50.72)	-263.55	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	-263.55	86.91	86.91	86.91	86.91	86.91
2nd	($20.12)	-263.55	86.91	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	-263.55	86.91	86.91	86.91	86.91
3rd	$8.65	-263.55	86.91	86.91	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	-263.55	86.91	86.91	86.91
4th	$35.70	-263.55	86.91	86.91	86.91	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	-263.55	86.91	86.91
5th	$61.12	-263.55	86.91	86.91	86.91	86.91	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	-263.55	86.91
6th	$195.97	-263.55	86.91	86.91	86.91	86.91	86.91	-263.55	86.91	86.91	86.91	86.91	86.91	86.91	0.00
Average NPV	$25.70														
Loss per Acre	$220.48														

Sweet Corn												
Yield	6.5	tons										
Flood Probability	0.00%	0.00%	15.00%	31.67%	25.00%	18.33%	6.67%	3.33%	0.00%	0.00%	0.00%	0.00%
Month	9	10	11	12	1	2	3	4	5	6	7	8
Variable Cost	0.00	38.28	0.00	0.00	0.00	0.00	80.04	194.90	10.78	38.53	0.00	0.00
Cumulative Cost	0.00	38.28	38.28	38.28	38.28	38.28	118.32	313.22	324.00	362.53	362.53	362.53
Weighted Loss	0.00	0.00	5.74	12.12	9.57	7.02	7.89	10.43	0.00	0.00	0.00	0.00
TOTAL WEIGHTED LOSS	$52.77											

Green Pea												
Yield	2.5	tons										
Flood Probability	0.00%	0.00%	0.00%	15.00%	31.67%	25.00%	18.33%	6.67%	3.33%	0.00%	0.00%	0.00%
Month	8	9	10	11	12	1	2	3	4	5	6	7
Variable Cost	29.05	24.97	0.00	0.00	0.00	0.00	0.00	18.11	173.26	154.73	0.00	0.00
Cumulative Cost	29.05	54.02	54.02	54.02	54.02	54.02	54.02	72.13	245.39	400.12	400.12	400.12
Weighted Loss	0.00	0.00	0.00	8.10	17.11	13.51	9.90	4.81	8.17	0.00	0.00	0.00
TOTAL WEIGHTED LOSS	$61.60											

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Appendix D – WSDOT Data/Correspondence

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Location Project Design Estimate

			MP 76.7 to MP 81.6 (2' Freeboard)			
			NO-RAISE OPTION		RAISE OPTION	
ITEM	**UNIT**	**UNIT COST**	**QUANTITY**	**COST**	**QUANTITY**	**COST**
Earthwork						
GRAVEL BORROW INCL. HAUL	TON	$6	1,032,277	$6,193,660	2,152,540	$12,915,239
EMBANKMENT COMPACTION	CY	$1	557,987	$557,987	1,163,535	$1,163,535
Surfacing						
CRUSHED SURFACING BASE COURSE	TON	$15	109,612	$1,644,176	200720	$3,010,804
ASPHALT CONC. PAVEMENT CL. A	TON	$35	58,067	$2,032,336	86274	$3,019,607
ASPHALT CONC. PAVEMENT CL. E	TON	$30	75,585	$2,267,556	150247	$4,507,402
Structure						
REMOVE EXISTING BRIDGES	SF	$25	94296	$2,357,400	94,296	$2,357,400
WIDENING OF RR BRIDGE (MP 77.12)	SF	$100	9552	$955,200	9,552	$955,200
RR BRIDGE (MP77.51)	SF	$100	60600	$6,060,000	62,040	$6,204,000
13TH STREET BRIDGE	SF	$100	5648	$564,800	6,032	$603,200
DILLENBAUGH CREEK BRIDGE	S.F.	$100	19440	$1,944,000	20,880	$2,088,000
DILLENBAUGH CREEK - NB OFF RAMP BRIDGE	S.F.	$100	7072	$707,200	7,696	$769,600
DILLENBAUGH CREEK - SB ON RAMP BRIDGE	S.F.	$100	7072	$707,200	7,696	$769,600
SR 6 BRIDGE	S.F.	$100	13054	$1,305,400	15,372	$1,537,200
WEST STREET BRIDGE	S.F.	$100	5248	$524,800	6,400	$640,000
NATIONAL AVENUE BRIDGE	S.F.	$100	5904	$590,400	6,288	$628,800
SALZER CREEK BRIDGE	S.F.	$100	16800	$1,680,000	18,240	$1,824,000
MSE WALLS	S.Y.	$250	8,754	$2,188,399	15,172	$3,792,986
GRAVEL BACKFILL FOR WALLS	CY	$20	9,915	$198,298	24,811	$496,218
TEMPORARY WALLS	S.Y.	$100	0	$0	10,733	$1,073,333
Drainage						
SCHEDULE A STORM SEWER PIPE 36 IN. DIAM	LF	$35	26,000	$910,000	26,000	$910,000
SCHEDULE A STORM SEWER PIPE 24 IN. DIAM	LF	$25	39,000	$975,000	39,000	$975,000
SCHEDULE A STORM SEWER PIPE 18 IN. DIAM	LF	$20	6,933	$138,667	6,933	$138,667
CATCH BASIN TYPE 1	EACH	$900	173	$156,000	173	$156,000
DITCH SYSTEM	LF	$5	52,000	$260,000	52,000	$260,000
STORMWATER TREATMENT FACILITIES	LS	$1	500,000	$500,000	500,000	$500,000
Traffic						
ILLUMINATION, SIGNING, AND IT	LS	$1	1,150,000	$1,150,000	1,150,000	$1,150,000
TRAFFIC SIGNALS	LS	$1	1,850,000	$1,850,000	1,850,000	$1,850,000
SINGLE SLOPE CONCRETE BARRIER	LF	$45	26,000	$1,170,000	26,000	$1,170,000
TEMPORARY BARRIER	LF	$12	52,000	$624,000	156,000	$1,872,000
REMOVING AND RESTTING BARRIER	LF	$4	208,000	$832,000	624,000	$2,496,000
GUARDRAIL	L.S.	$1	115,000	$115,000	155,000	$155,000
MEDIAN BARRIER	LF	$25	9,500	$237,500	35,000	$875,000
TRAFFIC CONTROL	L.S.	$1	2,467,600	$2,467,600	3,457,600	$3,457,600
Other						
WETLAND MITIGATION	ACRE	$100,000	72	$7,177,410	100	$10,027,548
MISCELLANEOUS (25%)	L.S.	$1	12,760,498	$12,760,498	18,587,235	$18,587,235

TOTAL 1	**$ 63,802,489**	**$ 92,936,174**
MOBILIZATION (10%)	$ 6,380,249	$ 9,293,617
TOTAL 2	**$ 70,182,737**	**$ 102,229,792**
SALES TAX (7.6%)	$ 5,333,888	$ 7,769,464
ENGINEERING AND CONTINGENCIES (15%)	$ 10,527,411	$ 15,334,469
RIGHT OF WAY	$ 2,000,000	$ 3,000,000
TOTAL 3	**$ 88,044,036**	**$ 128,333,724**
PRELIMINARY ENGINEERING (10%)	$ 8,804,404	$ 12,833,372
FINAL TOTAL	**$ 96,848,440**	**$ 141,167,097**

COST ∆ (raise vs. no raise)= $44,318,657

Letter from Washington State Department of Transportation

Washington State
Department of Transportation
Douglas B. MacDonald
Secretary of Transportation

Southwest Region
11018 Northeast 51st Circle
P.O. Box 1709
Vancouver, WA 98668-1709

360-905-2000
Fax 360-905-2222
TTY: 1-800-833-6388
www.wsdot.wa.gov

December 5, 2001

Beth Coffey, P.E.
Seattle District Corps of Engineers
Planning Branch
PO Box 3755
Seattle, WA 98124

Dear Ms. Coffey:

The purpose of this letter is to communicate the Washington State Department of Transportation's (WSDOT) intentions of addressing safety and capacity needs on Interstate 5 in the Corps Centralia Washington Flood Damage Reduction Study Area. WSDOT intends to address the flooding of the Interstate before we go forward with a major capacity or safety project. This direction is in accordance with Federal and State laws and rules.

The WSDOT has prepared a New Law Budget (NLB) for the 2002 State Legislative session. We have included the widening of Interstate 5 from Rush Road to Ground Mound Interchange (milepost 72 to 88) in this budget. This includes funds to address the safety, capacity and flooding problems on this section of the Interstate. This is a ten-year budget proposal.

The Record of Decision (ROD) for the Environmental Impact Statement for the I-5 corridor including the action within your study area has not yet been issued. The Federal Highway Administration is consulting with the Environmental Protection Agencies on a few outstanding items. Once the ROD is issued, the WSDOT can begin project level environmental work.

If NLB funding for this project is approved next spring, we plan to begin right of way acquisition by 2005. We plan to begin construction on the first project by 2006 and complete construction on the last project by 2012.

I hope his letter adequately clarifies WSDOT's intentions on this issue.

Sincerely,

Bart S. Gernhart

Bart S. Gernhart, P.E.
Project Development Manager

BSG:kd
Gernhart/Coffey I-5 @ MP 72 to 88

U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington
Final General Reevaluation Report

Appendix E:
Real Estate Plan

June 2003

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TABLE OF CONTENTS

Section/Paragraph **Page No. E-**

1. INTRODUCTION 1
1.1 Real Estate Plan Purpose 1
1.2 General Project Description 1
1.3 Specific General Reevaluation Study Objectives 2
1.4 Feasibility Report 2
2. PROJECT LOCATION 2
3. ACCESS TO PROJECT SITES 2
4. DESCRIPTION OF LANDS, EASEMENTS AND RIGHTS-OF-WAY (LER) 3
4.1 Chehalis River Levees 3
4.1.1 Fords Prairie Levees 3
4.1.2 Mellen Street to Salzer Creek levees 4
4.1.3 Airport Levees 4
4.1.4 Salzer Creek Levees East of I-5 Freeway 4
4.2 Dillenbaugh Creek Levees 5
4.3 Skookumchuck River Levees - 100-year protection areas 6
4.4 Skookumchuck River Levees - Betterment Areas 6
4.5 Skookumchuck Dam 7
4.6 Mitigation Sites 7
4.6.1 Mainstem SR-6 Oxbow, SR-6 Bypass and Scheuber Ditch Sites 1 & 2 8
4.6.2 Mainstem Oxbow, Site 3a 8
4.6.3 Mainstem Oxbow at Golf Course, Site 3b 8
4.6.4 Salzer Creek-Chehalis Confluence, Site 15 8
4.6.5 Newaukum River at Stan Hedwall Park, Site 10 8
4.6.6 MF Newaukum River, Tauscher Road, Site 13 9
4.6.7 NF Newaukum River, Tauscher Road, Site 14 9
5. ESTATES 9
5.1 Standard Estates 9
5.1.1 Fee Simple 9
5.1.2 Flood Protection Levee Easement 9
5.1.3 Temporary Work Area Easement 9
5.1.4 Restrictive Easement 10
5.2 Non-Standard Estates 10
5.2.1 Perpetual Access Road Easement 10
5.2.2 Estate to be Used Where a Road is Utilized as a Levee 10
6. NAVIGATIONAL SERVITUDE 11
7. INDUCED FLOODING 11
8. PUBLIC LAW 91-646 AND LER ACQUISITION 12
9. RELOCATION ASSISTANCE BENEFITS 12
10. MINERALS 12
11. ZONING 12
12. FACILITY AND UTILITY RELOCATIONS 13
13. HTRW 13
14. LANDOWNER'S VIEWS AND PUBLIC OPPOSITION 13
15. OUTSTANDING THIRD PARTY INTERESTS 13
16. RISKS ASSOCIATED WITH ADVANCED LAND ACQUISITION 13
17. COST ESTIMATE FOR LANDS, EASEMENTS & RIGHTS-OF-WAY 14
17.1 Baseline Cost Estimate 14
17.2 LERRD Acquisition by Construction Phase 16
EXHIBIT "A" REAL ESTATE DRAWINGS 17

EXHIBIT "B" NON-FEDERAL SPONSOR'S REAL ESTATE ACQUISITION CAPABILITY ASSESSMENT....29
EXHIBIT "C" CERTIFICATION OF LANDS AND ATTORNEY'S CERTIFICATE....35

TABLES

TABLE F-1. BASELINE COST ESTIMATE FOR REAL ESTATE (BCERE)....15
TABLE F-2. PHASED LERRD ACQUISITION SCHEDULE 16

1. INTRODUCTION

1.1 Real Estate Plan Purpose

This Real Estate Plan (REP) is presented in support of the Centralia Flood Damage Reduction Project, Chehalis River, Washington, and describes the real estate required to implement the project. The purpose of the Real Estate Plan is to:

- identify the lands, easements, rights-of-way, relocations and disposal sites (LERRD) necessary to support construction, operation and maintenance of the proposed project elements described in the body of this General Reevaluation Report (GRR);
- outline the costs and real estate considerations associated with project implementation; and
- assess the Non-Federal Sponsor's (NFS) capability for LERRD acquisition.

For purposes of this plan, Lewis County, Washington is the Non-Federal Sponsor.

1.2 General Project Description

The U.S. House of Representatives Committee on Transportation and Infrastructure adopted Resolution 2581 on 9 October 1998, requesting a review of past Corps report recommendations with a view to determining if the recommendations should be modified "with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification." Resolution 2581 provided the authority and directive for the Corps to conduct this Flood Damage Reduction Study for the Chehalis River Basin.

The proposed project footprint encompasses approximately 1,365 acres, which includes approximately 107 acres of setback levees and/or floodwalls along the Chehalis and Skookumchuck rivers, 871 acres at the Skookumchuck Dam and Skookumchuck Lake water impoundment area behind the dam, and 95 acres to support environmental mitigation elements at seven sites located throughout the general project area. The proposed setback levee alignments will protect existing residential and commercial structures, highway and other transportation infrastructure from flooding while allowing floodplain and channel connectivity for environmental purposes. Since the proposed setback levees are designed to protect current development and preserve as many of the current floodplain functions as possible, development within the unprotected areas of floodplain would, therefore, be discouraged.

Setback levees will extend along the Chehalis River from approximately River Mile (RM) 64 near the city of Centralia, to RM 75 near the city of Chehalis, as well as along most of the lower two miles of both Dillenbaugh Creek and Salzer Creek. In addition, levee protection will be provided on the Skookumchuck River for backwater effects of the Chehalis River and flooding from the Skookumchuck Dam. The effected reach on the Skookumchuck River extends approximately 1 mile upstream from the confluence with the Chehalis River.

1.3 Specific General Reevaluation Study Objectives

The objective of the GRR is to develop flood damage reduction alternatives that minimize environmental impacts and that incorporate environmental features to mitigate any adverse impacts to fish and wildlife communities and habitats.

The objective of this REP is to identify and fully describe the LERRD that is necessary to implement the proposed project, and provide an estimate of land values and describe the real estate interests required to support construction and subsequent operation and maintenance of the proposed project. In addition, the REP identifies real estate-related issues that have been addressed as well as issues that will need to be addressed in the next project phase during refinement of the project design.

1.4 Feasibility Report

The feasibility report for this project is dated December 1982. The Board of Engineers for Rivers and Harbors approved the report 22 December 1988. The Engineering After Feasibility Studies report (EAFS), dated 7 December 1988, was submitted on 22 December 1988 for review and approval. The EAFS was subsequently approved.

2. PROJECT LOCATION

The project area is located in the upper Chehalis River Basin in and near the cities of Centralia and Chehalis in Lewis County, Washington, about 80 miles south of Seattle. Proposed levee and floodwall elements, and environmental mitigation elements are located on the Chehalis, Skookumchuck and Newaukum rivers, as well as Salzer and Dillenbaugh creeks (see, REP Exhibit A, LERRD Maps, map 1-of-10 for project area overview). The Skookumchuck Dam and reservoir are located approximately 20 miles upstream from the confluence with the Chehalis River in Centralia. The Skookumchuck Dam and reservoir reside outside of the NFS's political boundaries in Thurston County, Washington.

3. ACCESS TO PROJECT SITES

Existing public rights-of-way will be utilized to access levee elements that tie into or cross public roads. A 25-foot wide Temporary Work Area easement will be acquired on both sides of the levee footprints to provide access for construction activities. A 12-foot wide road constructed on top of the levees will provide access for purposes of operation and maintenance. The locations of ramps to provide access from public rights-of-way to the roads on top of the levees, for operation and maintenance of the levees, will be identified in the next project phase during refinement of the project design.

Some of the floodwall structures on the Skookumchuck levee element will require perpetual access easements from public rights-of-way across private lands to insure future access to the proposed floodwall structures. The location and valuation of necessary access routes across private lands will be identified in the next project phase when the project design is refined. Additional land values, NFS administrative costs and Federal review and assistance costs associated with acquisition of such perpetual access easement are covered in the real estate cost estimate contingencies.

4. DESCRIPTION OF LANDS, EASEMENTS AND RIGHTS-OF-WAY (LER)

4.1 CHEHALIS RIVER LEVEES

The Chehalis River levees described below will require approximately 41 acres of perpetual levee easements and 50 acres of temporary work area easements. The proposed project will be implemented in three separate construction phases. LERRD acquisition is scheduled to provide 12 months from the date the PCA is signed for acquiring Phase 1 LERRD, 24 months from the PCA signing to complete acquisition of Phase 2 LERRD, and 36 months to acquire and certify the remaining Phase 3 LERRD. NFS will have 12 to 36 months to acquire and certify the necessary lands available (see, Table F-2, *Phased LERRD Acquisition Schedule).* The Chehalis levee elements will protect flood-prone areas on the west side of the I-5 freeway between the cities of Centralia and Chehalis along the main stem of the Chehalis River (see, Exhibit A, map 1-of-10). Approximately 22.9 acres of the subject levee footprint and 25.3 acres of the subject temporary work areas are owned by public entities other than the NFS that need to be acquired to implement the proposed project. The NFS shall acquire approximately 17 acres of levee footprint and 21 acres of temporary work area from private owners. Approximately 2.7 acres within the perpetual levee easement footprint and 2.1 acres within the temporary work area easement footprint are owned in fee by the NFS. Federal appraisal principles for determining fair market value for crediting purposes apply to lands owned by the NFS prior to the date of Congressional authorization.

4.1.1 Fords Prairie Levees

The Fords Prairie levees will protect a neighborhood at the far northwest end of the project area near the City of Centralia (see, Exhibit A, map 2-of-10). The current highest and best use of approximately half of the subject parcels within the Fords Prairie neighborhood is single-family residential with the remaining affected parcels split between public/quasi public and agricultural land use categories. Although single-family residences in Fords Prairie are being affected by the proposed levee footprint, the majority of affects are limited to extremely small, narrow strips of land that will not amount to a displacement of any residences.

The Fords Prairie levees affect 19 private landowners and 4 public landowners (City of Centralia, Port of Centralia, Centralia School District #401, and the Washington Dept. of Game). Within the levee footprint there are about 8.1 acres in public ownership and 3.4 acres in private ownership. The temporary work area easements will cover about 10.8 acres of public lands and 5.2 acres of private lands. Access to the proposed levee footprint is available from public rights-of-way at six locations along the levee alignment. Specific locations for perpetual access to the levee for operation and maintenance will be identified in the next project phase during refinement of the project design.

4.1.2 Mellen Street to Salzer Creek levees

A set of three levees will protect the west side of the I-5 freeway between Centralia and Chehalis (see, Exhibit A, map 3-of-10). The north end of this levee alignment utilizes two small levees on a parcel of land owned by the City of Centralia, which is the location of the Centralia's old sewage treatment plant that is currently being replaced at another location. These two levees tie into I-5 and Mellen Street, respectively. The third levee in this group extends south from Mellen Street to Salzer Creek and is located predominately on Washington State Department of Transportation (WSDOT) land within the I-5 freeway right-of-way.

Highest and best use of lands within the proposed levee footprint is predominately agricultural. Other affected uses include three residential parcels, two undeveloped commercial parcels, one commercial-industrial and one public/quasi-public parcel. There are five private owners and one public owner (City of Centralia) that are affected by the subject levees. Approximately 0.22 acres of public lands and 1.1 acres of private lands are covered by the perpetual levee easement, and about 0.7 acres of public land and 2.5 acres of private land will be required for temporary work area easements. Access to this levee is available from public rights-of-way at Mellen Street and along Airport Road. The location of perpetual access points for future operation and maintenance activities will be identified in the next project phase during refinement of the project design.

4.1.3 Airport Levees

The Airport levees tie into the west embankment of the I-5 freeway at Salzer Creek and run south along Airport Road to the I-5/SR-6 junction south of the Chehalis-Centralia airport (see, Exhibit A, map 4-of-10). Highest and best of lands within this levee footprint include commercial/transportation on airport lands as well as two agricultural and one residential parcel. The Airport Road levees will protect the Chehalis-Centralia Airport and commercial-retail establishments located on the west side of the airport as well as the I-5 freeway from Salzer Creek south to the SR-6/I-5 junction. Access to the Airport Levees is available from public rights-of-way at Mellen Street and Airport Road.

There are three private owners and one public owner (Chehalis-Centralia Airport) affected by the proposed levees. The perpetual levee easement covers about 7.3 acres of land in public ownership and 3.6 acres privately owned. The temporary work area easements cover about 5.7 acres of public land and 3.1 acres of private land. The location of perpetual access points for future operation and maintenance activities will be identified in the next project phase during refinement of the project design.

4.1.4 Salzer Creek Levees East of I-5 Freeway

The Salzer Creek levees tie into the freeway embankment on the east side of the I-5 freeway at Salzer Creek. The levee on the north side of Salzer Creek (right bank) will provide protection to development in the south end of the city of Centralia (see, REP Exhibit A, map 3-of-10). The levee on the south side (left bank) will protect development at the north end of the city of Chehalis (see, REP Exhibit A, map 4-of-10). Highest and best use of lands affected by the Salzer Creek levees is predominately commercial with half of all affected commercial use parcels being undeveloped and/or vacant. Land use on other affected parcels includes residential, public/quasi-public and agricultural.

The Salzer Creek levees affect approximately 35 private ownerships, 2 public ownerships (City of Tacoma and City of Centralia), and 1 parcel owned in fee by the NFS. The total levee easement footprint for the Salzer Creek levees is approximately 18.4 acres and the approximate size of the temporary work area easements is 24.2 acres. Within the levee easement footprint, approximately 12.4 acres are in public ownership including about 0.03 acres owned in fee by the NFS, and about 6.0 acres are in private ownership. Lands affected by the temporary work area easement include approximately 16.0 acres in public ownership including about 2.6 acres owned in fee by the NFS and about 8.2 acres are privately owned. Federal appraisal principles for determining fair market value for crediting purposes apply to lands owned by the NFS prior to the date of Congressional authorization. The proposed levee footprint is accessible from several points where the levee alignment crosses public right-of-ways. The location of perpetual access points for future operation and maintenance activities will be identified in the next project phase during refinement of the project design. Appraised LER values by estate for the Chehalis levees is summarized in the table below.

Estates	Acres	Estimated Fair Market Value
Flood Control Levee Easement	41	$3,674,000
Temporary Work Area Easement (one-year term)	50	$ 286,000
TOTALS	**91**	**$3,960,000**

See Table F-1 for a cost estimate summary for the levees described above, including NFS administrative costs, Federal review and assistance costs and contingencies.

4.2 Dillenbaugh Creek Levees

Dillenbaugh Creek levees will be built adjacent to the west side of I-5, starting at the SR-6/I-5 junction and continuing south along the I-5 right-of-way (see, Exhibit A, map 5-of-10). The Dillenbaugh levee footprint is predominately located within the I-5 freeway right-of-way on lands owned by the WSDOT. The proposed levee will also affect two private owners. The NFS will need to acquire approximately 0.3 acres of perpetual levee easement and 0.8 acres of temporary work area easement outside of the I-5 freeway right-of-way. Access for construction is available from public rights-of-way. The location of perpetual access points for future operation and maintenance activities will be identified in the next project phase during refinement of the project design. Appraised LER values by estate type are summarized in the table below.

Estate	Acres	Estimated Fair Market Value
Perpetual Levee Easement	0.3	$ 26,000
Temporary Work Area Easement	0.8	$ 6,000
TOTALS	**1.1**	**$ 32,000**

See Table F-1 for a cost estimate summary for the above-described levees, including NFS administrative costs and Federal review and assistance costs.

4.3 SKOOKUMCHUCK RIVER LEVEES - 100-YEAR PROTECTION AREAS

The proposed Skookumchuck River levees will provide protection for approximately 2 river miles upstream from the Chehalis-Skookumchuck confluence on both sides of the Skookumchuck River (see, Exhibit A, Map 6-of-10). This element will utilize setback levees and floodwalls where the available area is not adequate to construct an earthen levee. The NFS will need to acquire approximately 5.5 acres for levees and floodwalls that are proposed for the Skookumchuck area and 9.5 acres for temporary work areas. Approximately 1.6 acres of public-owned lands are within the levee/floodwall footprint and about 1.7 acres of public-owned lands fall within the temporary work area footprint. Public landowners include the City of Centralia, City of Tacoma, and Washington Department of Game. Highest and best use for lands within the proposed footprint for Skookumchuck River levees includes residential, commercial-retail, vacant commercial and public/quasi public.

The majority of the Skookumchuck levees will be accessible from public rights-of-way that the levees cross or tie into. However, where access from a public right-of-way to levees or floodwalls is not available, a perpetual access easement will be required (see, REP, Section 5.2.1, Non-standard Estates, page 8-of-17). The identification, and valuation of necessary access routes will be determined in the next project phase during refinement of the project design. Appraised LER values by estate type are summarized in the table below.

Estate	Acres	Estimated Fair Market Value
Perpetual Levee Easement	5.5	$1,813,000
Temporary Work Area Easement (1 year)	9.5	$ 161,000
Totals	**15.0**	**$1,974,000**

See Table F-1 for a cost estimate summary for the above-described levees, including NFS administrative costs and Federal review and assistance costs.

4.4 SKOOKUMCHUCK RIVER LEVEES - BETTERMENT AREAS

The levees identified as Betterment Areas are not part of the Corps' proposed cost-share project. If the NFS proposes to include Betterment Areas within the scope of the construction contract, it must first demonstrate that it owns and controls a sufficient interest in the subject lands prior to the Corps advertising for construction. The NFS must also provide 100 percent of the estimated costs of construction associated with the Betterment Area portion of the levee alignment in advance of the Corps performing any work thereon.

The proposed Skookumchuck betterment areas include approximately 3.2 acres of perpetual levee easements and 0.14 acres of public-owned lands. Proposed temporary work area easements cover about 5.5 acres including approximately 0.4 acres of public-owned lands.

Estate	Acres	Estimated Fair Market Value
Perpetual Levee Easement	3.2	Not creditable
Temporary Work Area Easement (1 year)	5.5	Not creditable
Totals	**8.7**	**$ 0**

See Table F-1 for a cost estimate summary for the above-described levees, including NFS administrative costs and Federal review and assistance costs.

4.5 Skookumchuck Dam

The Skookumchuck Dam area, according to the NFS, is approximately 871 acres including the spillway and water impoundment area behind the dam. The dam is owned by PacifiCorp, a private corporation, and a consortium of eight public and private entities. Land values for the dam were provided by the NFS and represent the assessed value of the subject lands. The NFS has indicated that negotiations for purchase of the dam are ongoing between the NFS and dam owners. Assessed values for the dam and reservoir are provided in the table below.

Estate for Skookumchuck Dam & Reservoir	Acres	2001 assessed value
Fee Simple	871	$1,216,000

See Table F-1 for a cost estimate summary for the above-described levees, including NFS administrative costs and Federal review and assistance costs.

4.6 Mitigation Sites

Lands necessary for the seven proposed mitigation sites are located throughout the general project area and will be acquired in fee. See specific site descriptions below for more detailed information on each mitigation site. The highest and best use of most lands affected by the proposed mitigation elements is predominately agricultural. There are also a small number of parcels affected by the mitigation elements that have a highest and best use of single-residential, mining/forestry, undeveloped-vacant, public/quasi-public and commercial. Access is available from public rights-of-way to each of the proposed mitigation sites and the sites will be acquired in fee; therefore, no additional access rights will be necessary. The Washington State Department of Natural Resources (DNR) will be consulted in the next project phase to determine if state-owned aquatic lands under DNR jurisdiction and control will be affected by the proposed mitigation elements. See Table F-1 for a cost estimate summary for the mitigation elements described below, including NFS administrative costs and Federal review and assistance costs.

Estate for Mitigation Sites	Acres	Estimated Fair Market Value
Fee Simple	95	$2,720,000

4.6.1 Mainstem SR-6 Oxbow, SR-6 Bypass and Scheuber Ditch Sites 1 & 2

The southern portion of this mitigation element (Site 1) is located south of SR-6 near Scheuber Road and will reconnect an existing oxbow to the mainstem of the Chehalis River. The northern portion of this proposed element is a riparian corridor that will connect with the oxbow mentioned above at the SR-6 Bypass and extend north along the Scheuber ditch. At the north end of Site 2, directly east of the Chehalis-Centralia Airport, a confluence of Scheuber Ditch with the Chehalis River is proposed (see, Exhibit A, map 7-of-10).

This mitigation element covers approximately 201 acres and affects 17 landowners, including 0.16 acres of land owned by the NFS that falls within the boundary of the temporary work area easement along Scheuber Road. Federal appraisal principles for determining fair market value for crediting purposes apply to lands owned by the NFS prior to the date of Congressional authorization. This mitigation element may also affect DNR lands below ordinary high water on the Chehalis River.

4.6.2 Mainstem Oxbow, Site 3a

This mitigation element is located to the north of the airport and will reconnect an oxbow to the main stem of the Chehalis River. The oxbow will also provide a riparian corridor that connects the oxbow with Scheuber ditch to the west. This element affects five parcels with three owners and covers approximately 69 acres of land (see, Exhibit A, Map 8-of-10).

4.6.3 Mainstem Oxbow at Golf Course, Site 3b

This mitigation element is located predominately on a public golf course (Riverside Golf Club, Inc.) to the west of the Chehalis-Centralia Airport. The effect on fair market value of the golf course was estimated in the gross appraisal to be a total take. Efforts will be made in the next project phase during refinement of the project design to assess impacts to the golf course and determine if a total take can be avoided. This element will reconnect an existing oxbow to the mainstem of the Chehalis River utilizing riparian buffers along an excavated channel. This element affects six parcels with five landowners and covers approximately 12.5 acres (see, Exhibit A, Map 8-of-10).

4.6.4 Salzer Creek-Chehalis Confluence, Site 15

This mitigation element is located north of the airport at the confluence of Salzer Creek with the Chehalis River. This element affects five parcels with three landowners, the state of Washington, Wash. Dept. of Highways, and the city of Chehalis. Total acreage for this site is approximately 27.8 acres (see, Exhibit A, Map 8-of-10).

4.6.5 Newaukum River at Stan Hedwall Park, Site 10

This mitigation element is located on the Newaukum River southwest of Chehalis in and near Stan Hedwall Park. This element affects five parcels and five owners, and covers approximately 31 acres (see, Exhibit A, Map 9-of-10).

4.6.6 MF Newaukum River, Tauscher Road, Site 13

This mitigation element is located on the Middle Fork of the Newaukum River east of the city of Chehalis. This element affects six parcels and six owners including the State of Washington and covers approximately 41 acres (see, Exhibit A, Map 10-of-10).

4.6.7 NF Newaukum River, Tauscher Road, Site 14

This mitigation element is located on the North Fork of the Newaukum River east of the city of Chehalis. This element affects six parcels and five owners and covers approximately 5.4 acres (see, Exhibit A, Map 10-of-10).

5. ESTATES

5.1 STANDARD ESTATES

5.1.1 Fee Simple

The fee simple title to lands shown on Exhibit A, attached hereto, subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.

5.1.2 Flood Protection Levee Easement

A perpetual and assignable right and easement in the land described in Schedule A to construct, maintain, repair, operate, patrol, and replace a flood protection levee, including all appurtenances thereto; reserving, however, to the owners, their heirs and assigns, all such rights and privileges in the land as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.

5.1.3 Temporary Work Area Easement

A temporary easement and right-of-way in, on, over, and across the land described in Schedule A, for a period not to exceed ______________, beginning with date possession of the land is granted to the United States, for use by its representatives, agents, and contractors as a work area, including the right to move, store, and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of Centralia Flood Damage Reduction Project, together with the right to trim, cut, fell, and remove therefrom all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.

5.1.4 Restrictive Easement

A perpetual and assignable easement for the establishment, maintenance, operation, and use for a restricted area in, on, over, and across the land described in Schedule A, consisting of the right to prohibit human habitation; the right to remove buildings presently or hereafter being used for human habitation; the right to prohibit gatherings of more than 25 persons; the right to post signs indicating the nature and extent of the Government's control; and the right of ingress and egress over and across said land for the purpose of exercising the rights set forth herein; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines; reserving, however, to the landowners their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired.

5.2 NON-STANDARD ESTATES

All non-standard estates proposed for this project must be approved by CERE-AP prior to acquisition.

5.2.1 Perpetual Access Road Easement

A perpetual and assignable non-public easement and right-of-way in, on over and across the land described in Schedule A attached hereto for the sole and exclusive purposes of the location, construction, operation, maintenance, alteration and replacement of a non-public access way and appurtenances thereto; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures or obstacles within the limits of the right-of-way; reserving, however, strictly to the Grantor and its assigns, the right to cross over or under the right-of-way for any purpose whatsoever, which purpose shall not interfere with Grantee’s use of the easement; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

The Grantors and Grantee further agree that the Grantors, their heirs and assigns, shall be entitled to change the location of the easement area, and the road and appurtenances located thereon, to accommodate the future use or development of Grantor’s property so long as the new easement area, and the new roadway and appurtenances thereto, represent a reasonable substitute location and facility and so long as they are first provided by the Grantors at their sole expense. Nothing herein shall be construed to allow Grantee to create a public road, public access or public right-of-way on the easement herein granted or on any of Grantor’s other property. This access is being granted solely and exclusively for the limited purposes of construction, operation, maintenance, repair, replacement and rehabilitation of a floodwall and riprap to be located along the Skookumchuck River on the Grantor’s property as further described hereinafter in the Flood Protection Levee Easement. By accepting and recording this conveyance, the Grantee agrees to such limitation, which can only be modified by the express written consent of the Grantor.

5.2.2 Estate to be Used Where a Road is Utilized as a Levee

A perpetual and assignable easement and right of way in, on, over and across the land described in Exhibit A, for the location, construction, operation, maintenance, repair, alteration, replacement of a road and flood protection levee, including all appurtenances thereto; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures, or obstacles within the limits of the right-of-way; reserving however, to the owners, their heirs and assigns, the right to cross over the right of way as access to their adjoining land, the perpetual right, power, privilege, and easement to occasionally overflow, flood, and submerge the land together with all right, title and interest in and to the structures and improvements now situate on the land, except fencing (and also excepting _________) provided that no structures for human habitation shall be constructed or maintained on the land, that no other structures shall be constructed or maintained on the land except as may be approved in writing by Lewis County, Washington, and a representative of the U.S. Army Corps of Engineers, Seattle District, and that no excavation shall be conducted and no landfill placed on the land without such approval as to the location and method of excavation and/or placement of landfill; the above estate is taken subject to existing easements for public roads and highways, public utilities, railroads and pipelines; reserving, however, to the landowner, their heirs and assigns, all such rights and privileges as may be used and enjoyed without interfering with the use or abridging the rights and easement hereby acquired.

6. NAVIGATIONAL SERVITUDE

Based on information provided by the Regulatory Branch, Seattle District Corps of Engineers, Federal Navigational Servitude may only be exercised on the Chehalis River from the downstream limits to RM 68.5, near Centralia. There are no project elements proposed within the Chehalis River below RM 68.5; therefore, exercise of the navigational servitude is not anticipated for this project.

7. INDUCED FLOODING

The Corps has studied the possibility of induced flooding that may be caused by the Project. No induced flooding is predicted from Project features that will be constructed along the Skookumchuck River, including modifications to the dam, or Dillenbaugh Creek and Salzer Creek. The only induced flooding that could result from the Project is in the area along the Chehalis River upstream from the confluence with the Skookumchuck River where levees will be constructed to protect the City of Chehalis, public roads, and the municipal airport. All of the area that could be subject to induced flooding lies within an existing 100-year flood plain. The induced flooding area can best be described as the area within the flood plain starting about one mile south of the municipal airport, and proceeding north, bounded on the east by I-5, and on the west by Scheuber Road. The induced flooding area terminates just north of the airport. Within this area, the Corps has estimated the Project effects as follows:

a. Frequency: the Project will not impact the frequency of existing flooding.

b. Duration: the Project will not impact the duration of existing flooding.

c. Timing: the Project will not advance peak flood stage arrival.

d. Depth: The Project could result in a 4- to 6-inch maximum increase in depth during a 100-year flood. For smaller floods the depth declines, being 1.8 inches during a 50-year event and 1.2 inches during a 25-year event.

The Corps of Engineers should not have liability under federal law for a taking of property. The Project will not cause permanent or recurring flooding and damages from induced flooding would be speculative. Likewise, the non-federal sponsor should not be exposed to liability for a taking under state law because landowners will not be able to show a permanent and measurable reduction in value.

8. PUBLIC LAW 91-646 AND LER ACQUISITION

The NFS has been advised of Public Law 91-646, as amended. The NFS has land acquisition experience and is fully capable of acquiring any lands necessary for the project. Exhibit B provides a detailed assessment of the NFS' real estate acquisition capability.

All lands necessary for project implementation shall be made available by the NFS to the Corps by a Certification of Lands and Authorization for Entry and an Attorney's Certificate, a copy of which is presented as Exhibit C. Within 180 days after authorization of entry for construction is granted, the NFS shall provide to the Crops all supporting LERRD crediting documentation, including appraisals submitted for crediting purposes for NFS lands made available for project purposes.

9. RELOCATION ASSISTANCE BENEFITS

No relocation assistance benefits are anticipated for the proposed project. There are no families or businesses that will temporarily or permanently be displaced.

10. MINERALS

There are no known outstanding mineral interests or active mining operations in the project area that may affect implementation of the project.

11. ZONING

According to the NFS, there are no zoning ordinances currently proposed in lieu of or to facilitate acquisition in connection with this project. Nevertheless, Section 5.5.7 of the GRR states that the non-structural components of the selected plan "... are a critical part of the projects success. The local sponsor will implement these actions to the maximum extent practicable." The project area encompasses four political jurisdictions including Lewis County, Thurston County, and the cities of Centralia and Chehalis. The NFS, Lewis County, will sign the Project Cooperation Agreement (PCA), which will require compliance with the selected plan including non-structural requirements such as ordinances that restrict development within the 100-year floodplain. Although Section 5.5.7 of the GRR states that a revised floodplain management plan will be completed prior to the signing of the Project Cooperation Agreement (PCA), there is currently no mechanism in place to ensure future enforcement of such measures outside of the NFS's political jurisdiction.

12. FACILITY AND UTILITY RELOCATIONS

Some utility relocations are anticipated for this project. Many of the levee alignments tie into existing roads and some sections of roadbeds may be raised and utilized as levees. Utilities are typically located adjacent to roads on poles or in underground installations. Specific identification of necessary utility and facility relocations and determination of whether the subject utility owners have a compensable interest in the affected property will be conducted in the next project phase during refinement of the project design.

13. HTRW

The Corps has initiated an investigation to identify the presence and quantify the extent of hazardous, toxic and radiological wastes (HTRW) located in the project areas. A preliminary HTRW assessment was conducted via the Internet and through coordination with the Department of Ecology Toxics Cleanup Program, SW Regional Office, for occurrence of HTRW on lands, including structures and submerged land, in the study area. The assessment included a project review, review of site literature and project features, database search, review of available records and aerial photography, site inspections and interviews. It concluded that the levee would not affect any current contaminated facilities. Additional site investigations will be performed during the PED phase for the Skookumchuck levee alignment to confirm findings and survey for any additional contaminated sites. Further investigative work will be performed during PED phase of this project to determine the presence and extent of hazardous substances in the project area (see the body of the GRR, Section 2.9, HTRW Studies).

14. LANDOWNER'S VIEWS AND PUBLIC OPPOSITION

There is a limited number of landowners that have voiced concerns to the NFS regarding how their land may be affected by the presence of a levee on their property (aesthetic impacts as well as potential limitation of land use options). A few other landowners who are located on the river side of the proposed levee alignments are concerned that their property will not be protected. The local communities and residents, however, generally support the project.

15. OUTSTANDING THIRD PARTY INTERESTS

All property interests acquired in support of the proposed project must take priority over any third party interests that could defeat or impair the NFS' title to the property or interfere with construction, operation and maintenance of the project. All third party interests must be cleared from the title or subordinated to the interest being made available for the project.

16. RISKS ASSOCIATED WITH ADVANCED LAND ACQUISITION

The NFS has been advised of the risks associated with advance land acquisition activities. The District supports the NFS decision to begin LER acquisitions in anticipation of signing the

Project Cooperation Agreement (PCA), and will provide the NFS with Federal review and assistance.

Risks associated with advanced land acquisition that the NFS was advised of include, but are not limited to, the following:

1) Congress may not appropriate funds to construct the proposed project;
2) the proposed project may otherwise not be funded or approved for construction;
3) a PCA mutually agreeable to the NFS and the Government may not be executed and implemented;
4) the NFS may incur liability and expense by virtue of its ownership of contaminated lands, or interests therein, whether such liability should arise out of local, state, or Federal laws or regulations including liability arising out of CERCLA, as amended;
5) the NFS may acquire interests or estates that are later determined by the Government to be inappropriate, insufficient, or otherwise not required for the project;
6) the NFS may initially acquire insufficient or excessive real property acreage which may result in additional negotiations and/or benefit payments under P.L. 91-646 as well as the payment of additional fair market value to affected landowners which could have been avoided by delaying acquisition until after PCA execution and the Government's notice to commence acquisition and performance of LERRD; and
7) the NFS may incur costs or expenses in connection with its decision to acquire or perform LERRD in advance of the executed PCA and the Government's notice to proceed which may not be creditable under the provisions of P.L. 99-662 or the PCA.

17. COST ESTIMATE FOR LANDS, EASEMENTS & RIGHTS-OF-WAY

17.1 BASELINE COST ESTIMATE

The baseline cost estimate presented below in Table F-1 provides a breakdown of the estimated fair market value of project lands, NFS administrative costs associated with LERRD acquisition activities, and Federal review and assistance costs. NFS acquisition costs include incidental acquisition costs such as title, survey, appraisal, negotiation costs, recording fees and legal fees. Federal review and assistance costs include those costs associated with providing the NFS with LERRD requirements, review of acquisition and crediting appraisals, coordination meetings, review of right-of-way documents, legal support, and crediting activities. The total cost of LERRD activities including contingencies is estimated at approximately $ 14,270,000.

A 20 percent contingency is utilized to cover possible land value variations over time. A 35 percent contingency is utilized for NFS administrative costs and Federal review and assistance due to various issues that must be addressed in the next project phase when the proposed project design is refined.

TABLE F-1. BASELINE COST ESTIMATE FOR REAL ESTATE (BCERE)

Area Name	Estate	Acres	Est. Land Value	NFS costs	Fed costs	**Total**
Chehalis Levees	Perpetual Levee Eas.	41	$3,674,000			
	Temporary Work Area	50	$286,000			
		91	$3,960,000	$528,000	$214,000	**$4,702,000**
Dillenbaugh Creek	Perpetual Levee Eas.	0.27	$26,000			
	Temporary Work Area	0.77	$6,000			
		1.04	$32,000	$27,000	$24,000	**$83,000**
Skookum Levees (NED Plan)	Perpetual Levee Eas.	5.5	$1,813,000			
	Temporary Work Area	9.5	$161,000			
		15	$1,974,000	$330,000	$111,000	**$2,415,000**
Skookum Levees (Betterments)	Perpetual Levee Eas.	3.2	$0			
	Temporary Work Area	5.5	$0			
(no LER credit)		8.7	$0	$0	$67,000	**$67,000**
Mitigation Sites	Fee Simple	95	$2,720,000	$278,000	$110,000	**$3,108,000**
Skookumchuck Dam	Fee Simple	871	$1,216,000	$47,000	$32,000	**$1,295,000**
				$1,210,000		
					Sub-Total	**$11,670,000**
					20% contingency-lands only	**$1,981,000**
					35% admin costs only	**$619,000**
					TOTAL	**$14,270,000**

17.2 LERRD Acquisition by Construction Phase

It is anticipated that the proposed project will be constructed in three separate phases scheduled to begin in 2003 and end in 2007. The construction phases are summarized in Table F-2. LERRD acquisition for all construction phases is expected to begin in August 2003 – the anticipated date for execution of the Project Cooperation Agreement (PCA). See, Table F-2, Construction Phase Summary.

Phase 1 project areas include the Skookumchuck Dam, the I-5 levee north of Salzer Creek, and the levees that begin at Salzer Creek and follow Airport Road south to the SR-6/I-5 interchange. Phase 1 LERRD acquisitions are anticipated to begin in August 2003 and be completed by August 2004.

Phase 2 project areas include the Salzer Creek levees proposed for the east side of I-5 between the cities of Centralia and Chehalis, the Dillenbaugh Creek levees in the I-5 right-of-way south of SR-6. Phase 2 acquisition activities will begin with the signing of the PCA in August 2003 and will need to be completed by August 2005. The NFS will have 18 months to complete Phase 2 acquisitions.

Phase 3 project areas include the Ford's Prairie levee at the far north end of the project to the west of Centralia, the Skookumchuck levees and floodwalls located to the east of I-5 along the Skookumchuck River, and the seven proposed mitigation sites. Phase 3 acquisition activities will begin in August 2003 when the PCA is executed and should be completed by August 2006.

Table F-2. Phased LERRD Acquisition Schedule

Phase 1 construction is anticipated to begin in the summer of 2004. The NFS will require approximately 12 months from the date the PCA is executed to acquire and certify LERRD (Jun 03 – Jun 04). Phase 1 construction currently includes the following proposed project elements:

- Contract 1—Skookumchuck Dam
- Contract 2—I-5 levees from Mellon Street to Salzar Creek
- Contract 3—Airport levee from Salzer Creek to SR-6

Phase 2 construction is planned to commence in the summer of 2005. The NFS will have approximately 24 months to acquire and certify Phase 2 LERRD (Jun 03 – Jun 05). Phase 2 construction currently includes the following proposed project elements:

- Contracts 4, 5 & 6—Salzer Creek levees east of I-5
- Contract 2— Dillenbaugh Creek levees

Phase 3 construction is expected to begin in the summer of 2006. The NFS will have approximately 36 months to acquire and certify Phase 3 LERRD (Jun 03 – Jun 06) for the following project elements:

- Contract 4—Ford's Prairie levees
- Contract 4—Skookumchuck River levees
- Contracts 7&8—Project Mitigation Elements including SR-6 Bypass

EXHIBIT “A” REAL ESTATE DRAWINGS

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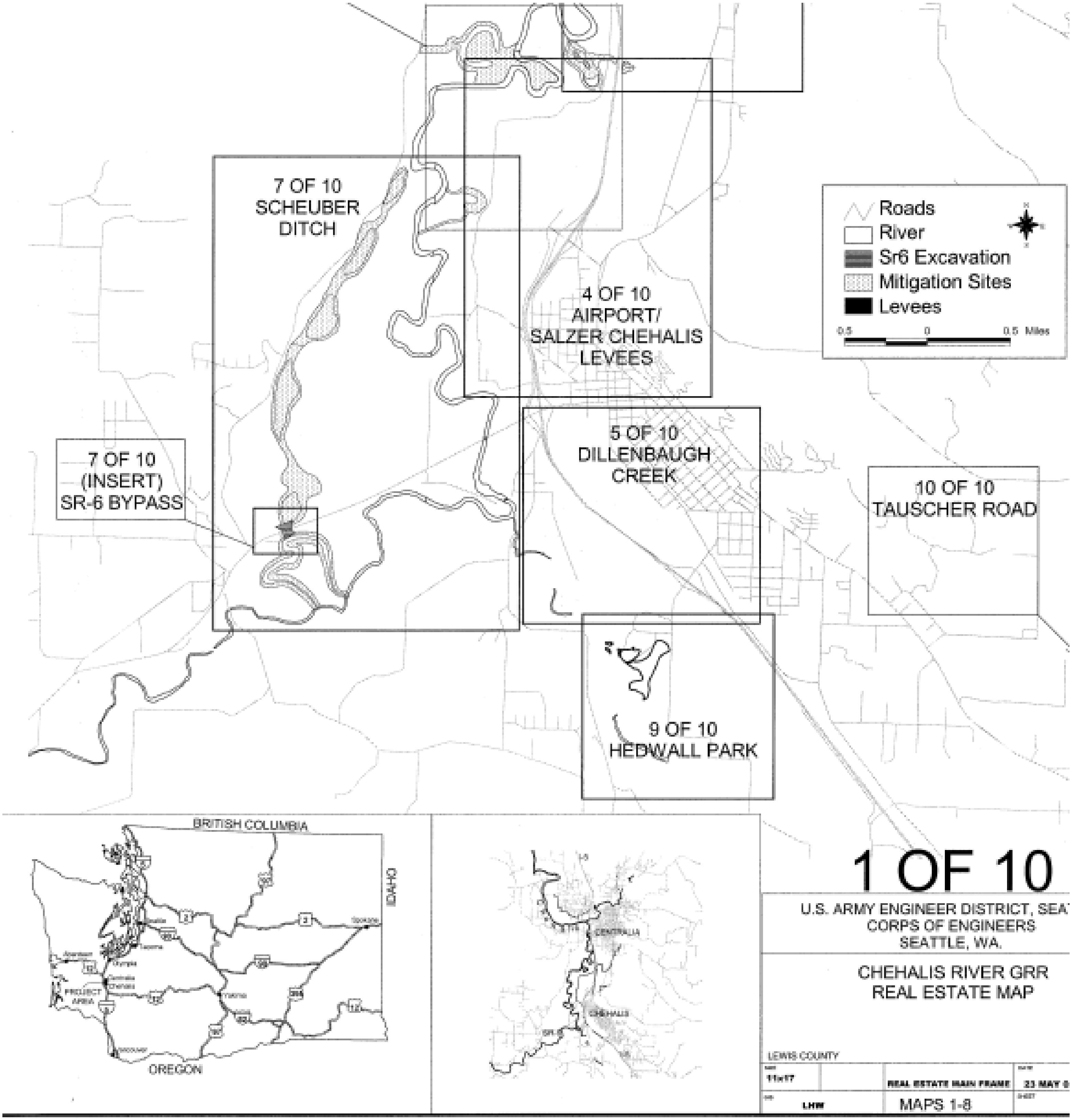
7 OF 10
SCHEUBER
DITCH
4 OF 10
AIRPORT/
SALZER CHEHALIS
LEVEES
Roads
River
Sr6 Excavation
Mitigation Sites
Levees
0.5
0
0.5 Miles
7 OF 10
(INSERT)
SR-6 BYPASS
5 OF 10
DILLENBAUGH
CREEK
10 OF 10
TAUSCHER ROAD
9 OF 10
HEDWALL PARK
BRITISH COLUMBIA
IDAHO
OREGON
CENTRALIA
CHEHALIS
1 OF 10
U.S. ARMY ENGINEER DISTRICT, SEAT
CORPS OF ENGINEERS
SEATTLE, WA.
CHEHALIS RIVER GRR
REAL ESTATE MAP
LEWIS COUNTY
11x17
REAL ESTATE MAIN FRAME
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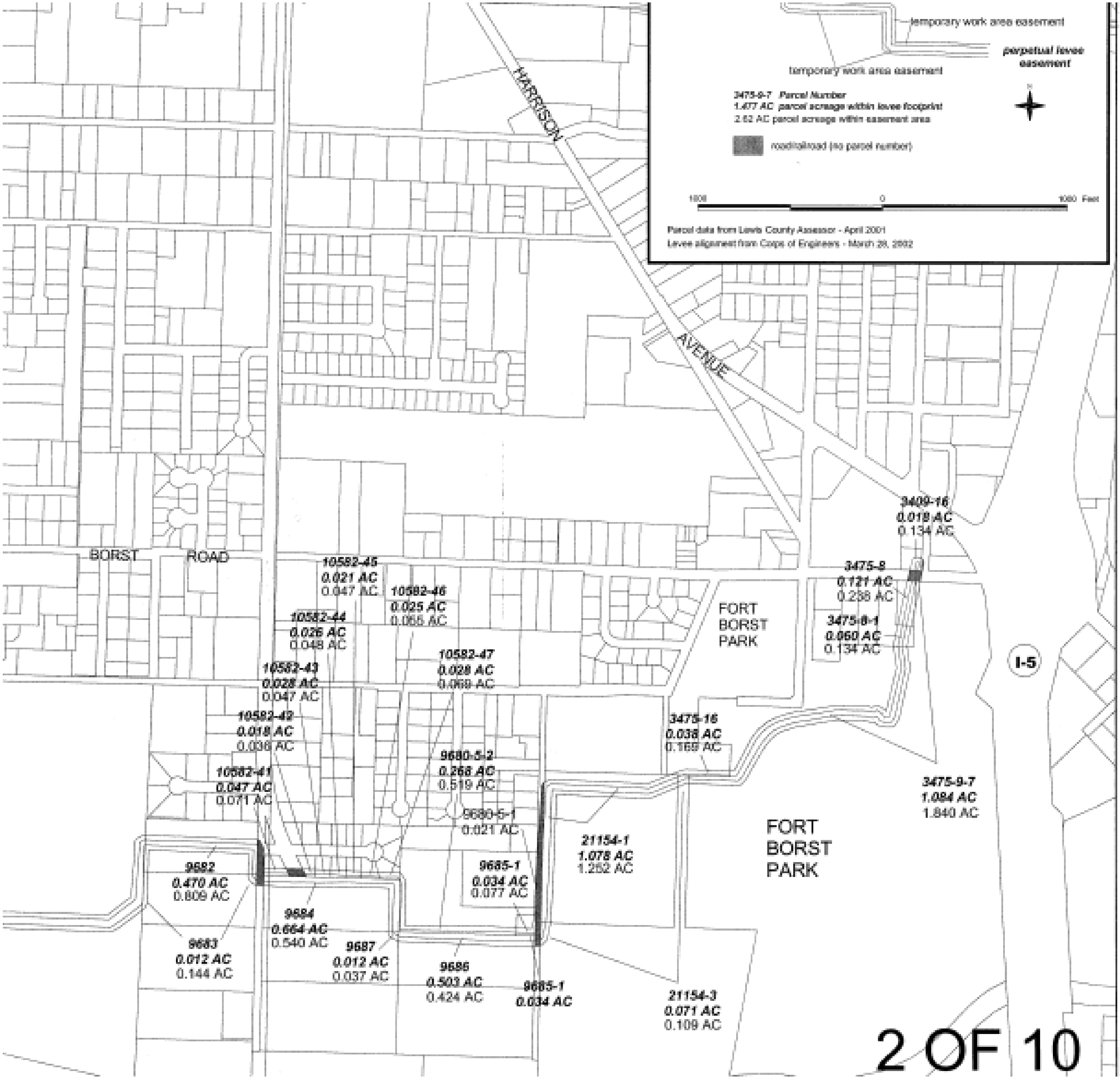
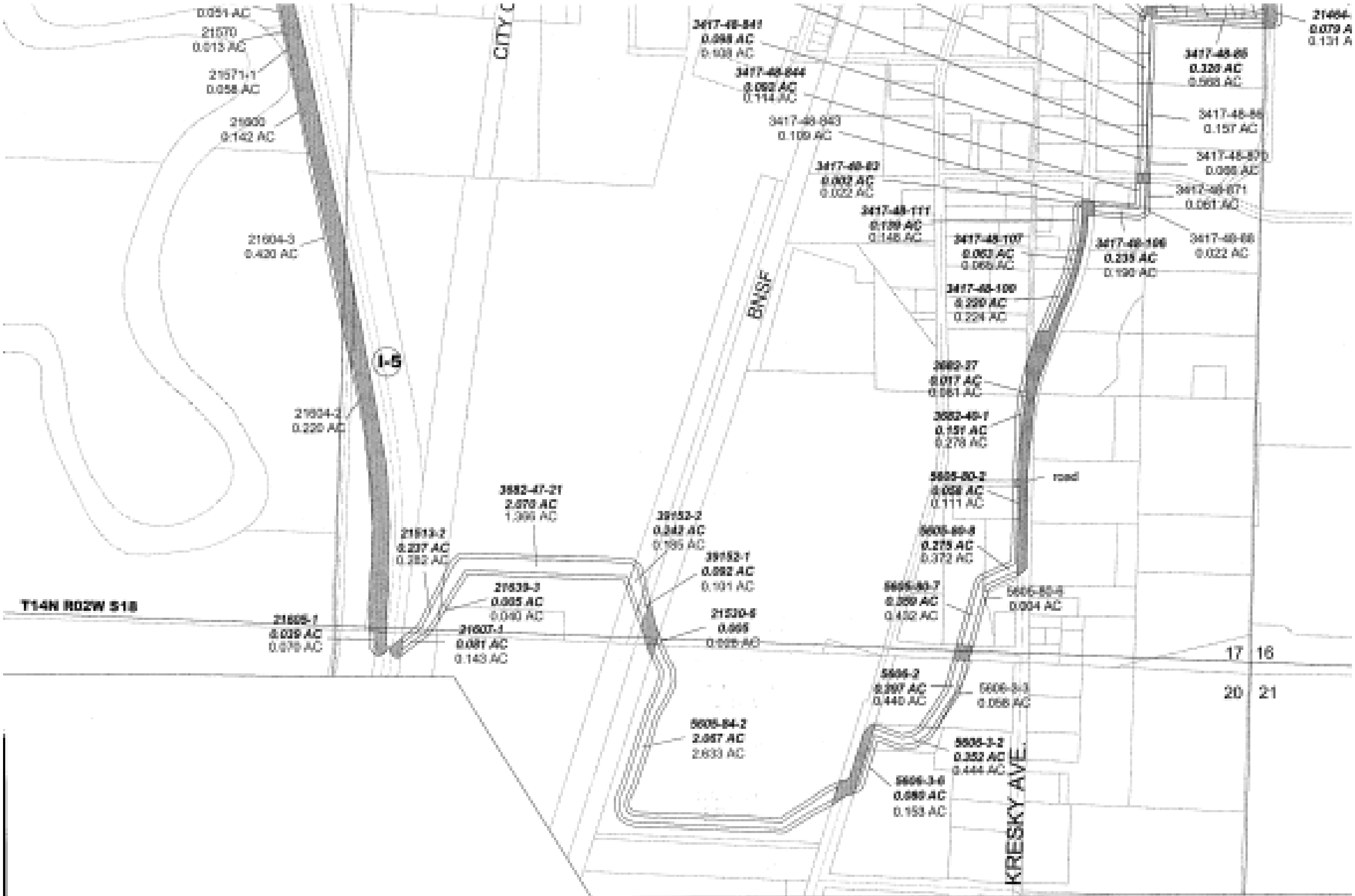
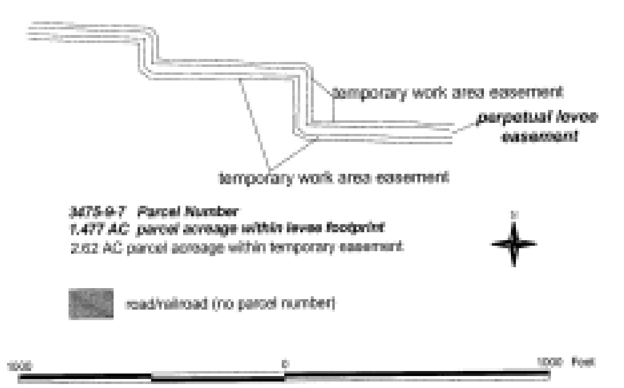
MAPS 1-8


temporary work area easement
perpetual levee easement
temporary work area easement
3475-9-7 Parcel Number
1.477 AC parcel acreage within levee footprint
2.62 AC parcel acreage within easement area
road/railroad (no parcel number)
1000 0 1000 Feet
Parcel data from Lewis County Assessor - April 2001
Levee alignment from Corps of Engineers - March 28, 2002
HARRISON AVENUE
BORST ROAD
FORT BORST PARK
I-5
3409-16 0.018 AC 0.134 AC
3475-8 0.121 AC 0.238 AC
3475-8-1 0.060 AC 0.134 AC
3475-16 0.038 AC 0.169 AC
3475-9-7 1.084 AC 1.840 AC
10582-45 0.021 AC 0.047 AC
10582-46 0.025 AC 0.055 AC
10582-44 0.026 AC 0.048 AC
10582-47 0.028 AC 0.069 AC
10582-43 0.028 AC 0.047 AC
10582-42 0.018 AC 0.038 AC
10582-41 0.047 AC 0.071 AC
9680-5-2 0.268 AC 0.519 AC
9680-5-1 0.021 AC
21154-1 1.078 AC 1.252 AC
9682 0.470 AC 0.809 AC
9685-1 0.034 AC 0.077 AC
9684 0.664 AC 0.540 AC
9683 0.012 AC 0.144 AC
9687 0.012 AC 0.037 AC
9686 0.503 AC 0.424 AC
9685-1 0.034 AC
21154-3 0.071 AC 0.109 AC



MATCH LINE TO PLATE 2 SHEET 3



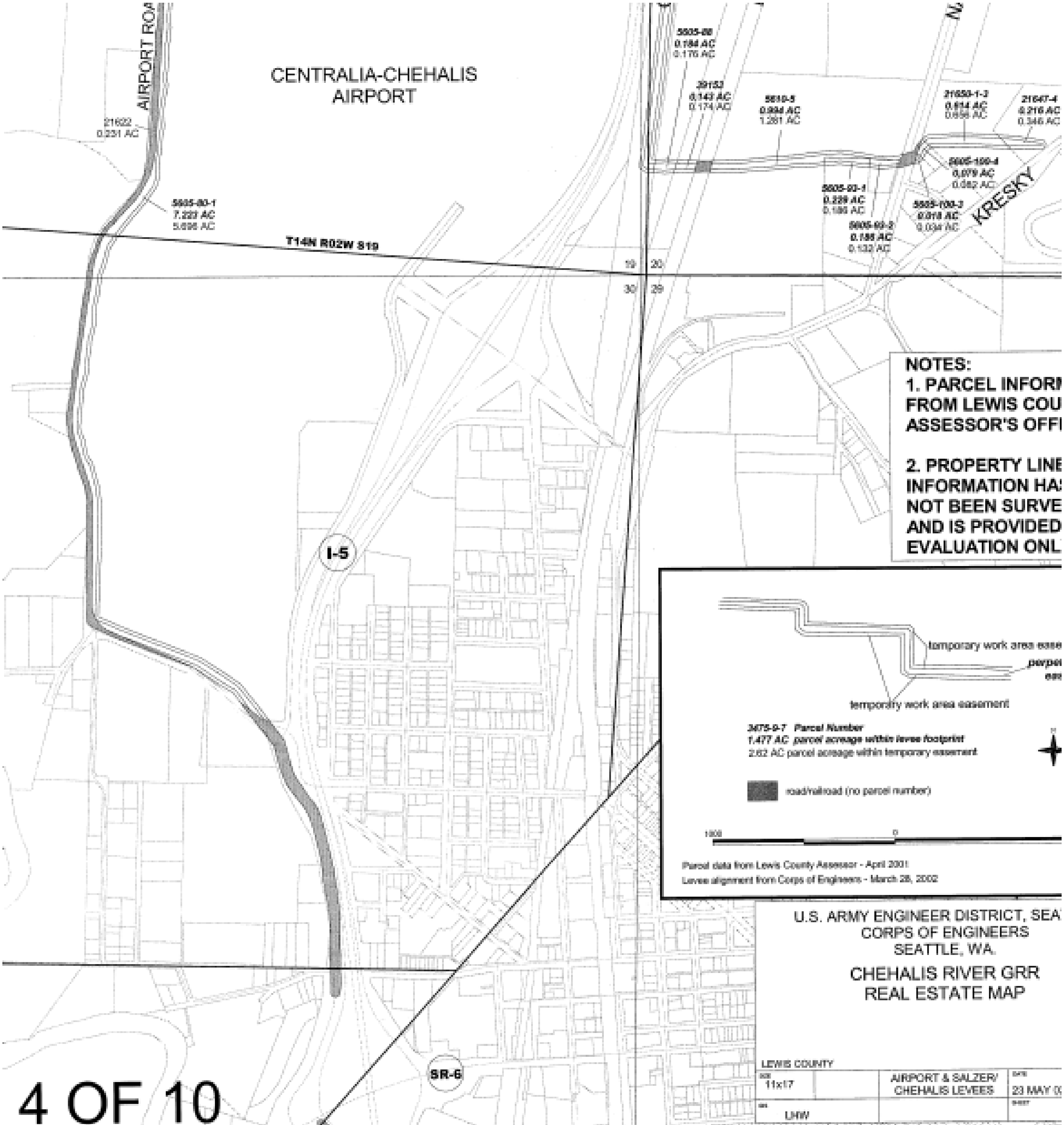
Parcel data from Lewis County Assessor - April 2001
Levee alignment from Corps of Engineers - March 28, 2002

3 OF 10

U.S. ARMY ENGINEER DISTRICT, SEAT
CORPS OF ENGINEERS
SEATTLE, WA.

CHEHALIS RIVER GRR
REAL ESTATE MAP

LEWIS COUNTY		
11x17	I-5 LEVEE SALZER CREEK CENTRALIA	23 MAY 0
LHW		



AIRPORT ROA
CENTRALIA-CHEHALIS AIRPORT
21622
0.231 AC
5605-80-1
7.222 AC
5.696 AC
T14N R02W S19
19
20
30
29
5605-88
0.184 AC
0.176 AC
29152
0.143 AC
0.174 AC
5610-5
0.994 AC
1.281 AC
21650-1-2
0.614 AC
0.656 AC
21647-4
0.216 AC
0.346 AC
5605-100-4
0.079 AC
0.082 AC
5605-93-1
0.229 AC
0.186 AC
5605-100-2
0.018 AC
0.034 AC
5605-93-2
0.186 AC
0.132 AC
KRESKY
I-5
SR-6
NOTES:
1. PARCEL INFORM
FROM LEWIS COU
ASSESSOR'S OFFI
2. PROPERTY LINE
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EVALUATION ONL
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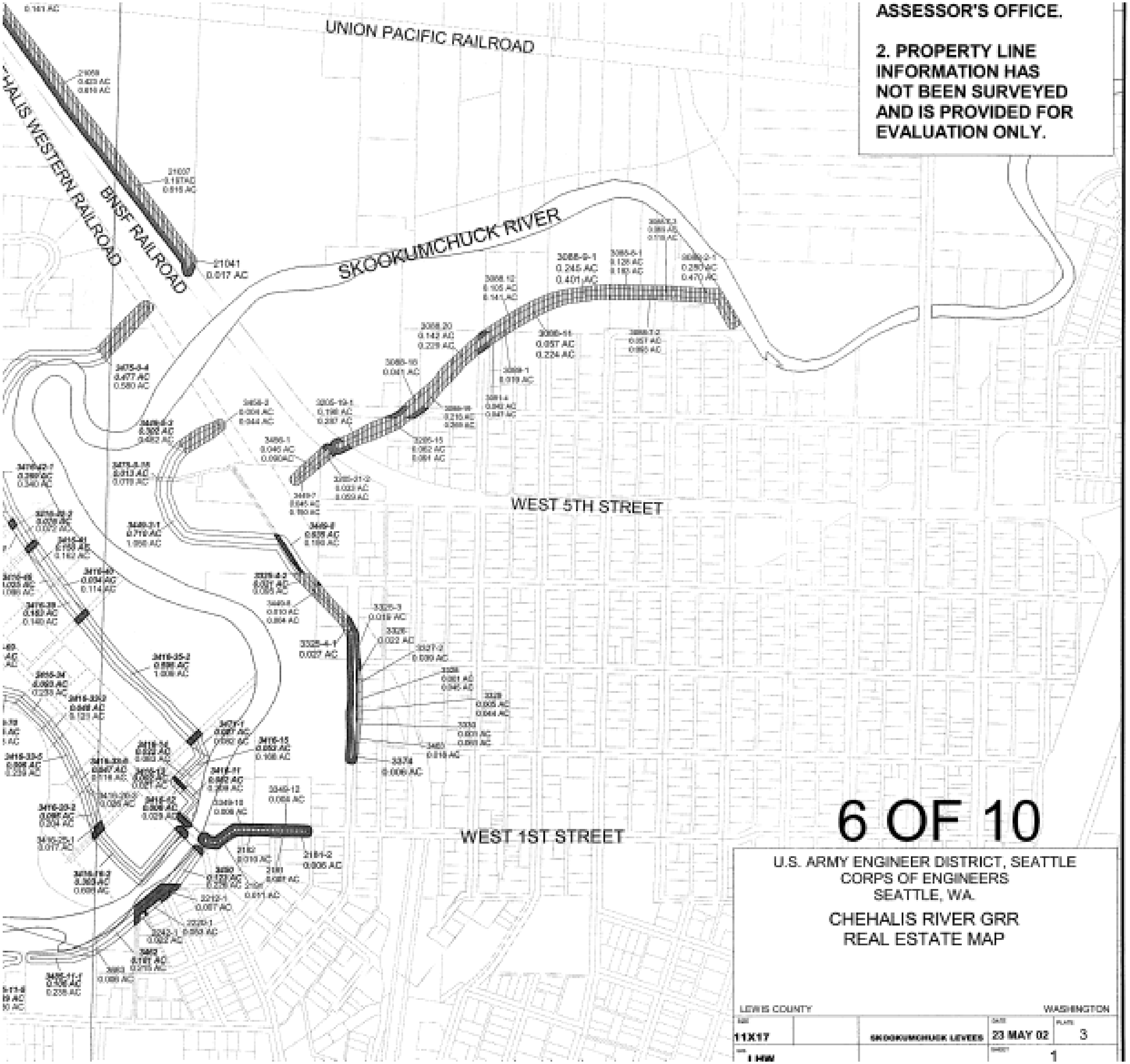
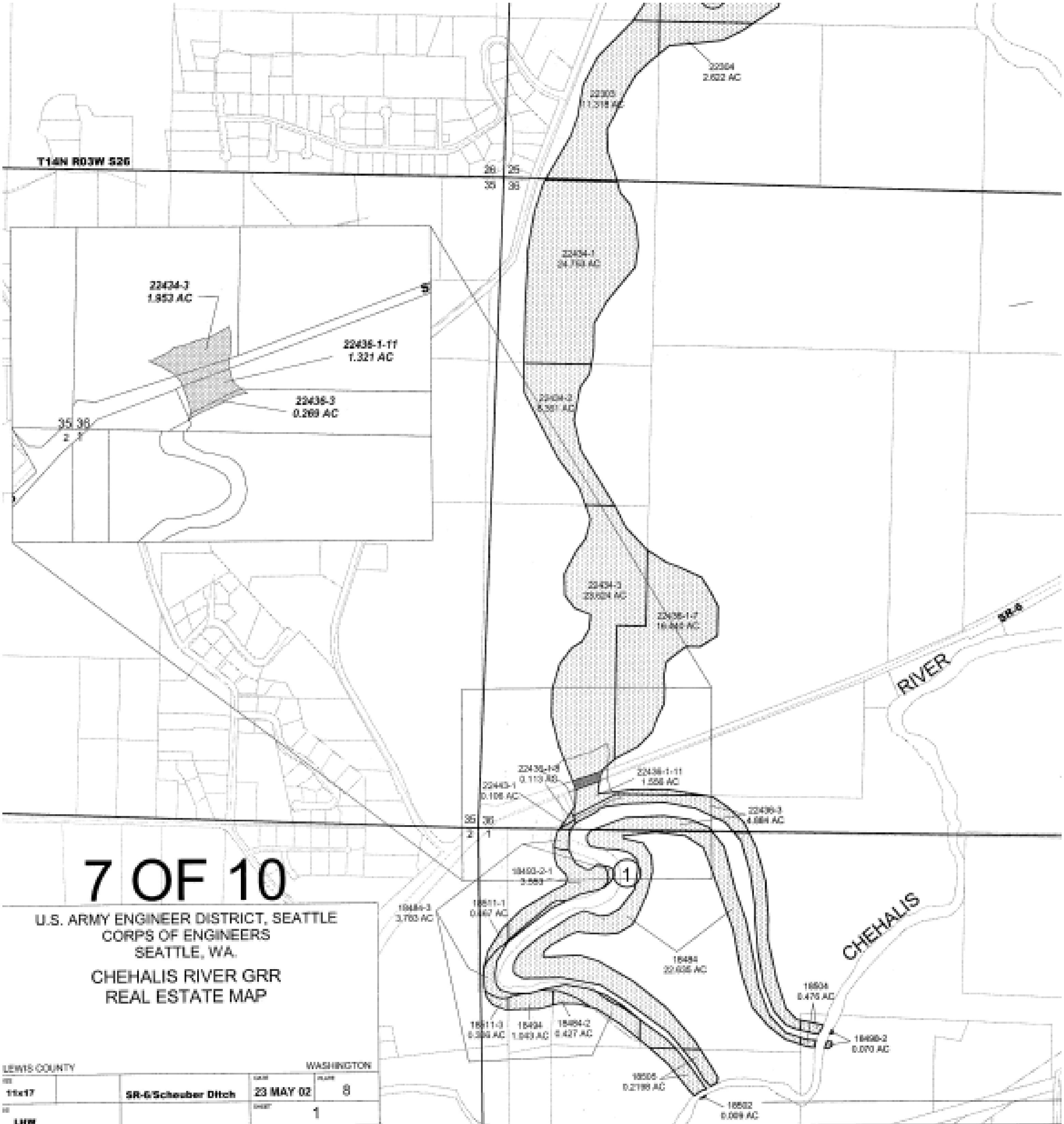
temporary work area easement
3475-9-7 Parcel Number
1.477 AC parcel acreage within levee footprint
2.62 AC parcel acreage within temporary easement
road/railroad (no parcel number)
1000
0
Parcel data from Lewis County Assessor - April 2001
Levee alignment from Corps of Engineers - March 28, 2002
U.S. ARMY ENGINEER DISTRICT, SEA
CORPS OF ENGINEERS
SEATTLE, WA.
CHEHALIS RIVER GRR
REAL ESTATE MAP
LEWIS COUNTY
11x17
AIRPORT & SALZER/
CHEHALIS LEVEES
23 MAY 0
LHW
4 OF 10

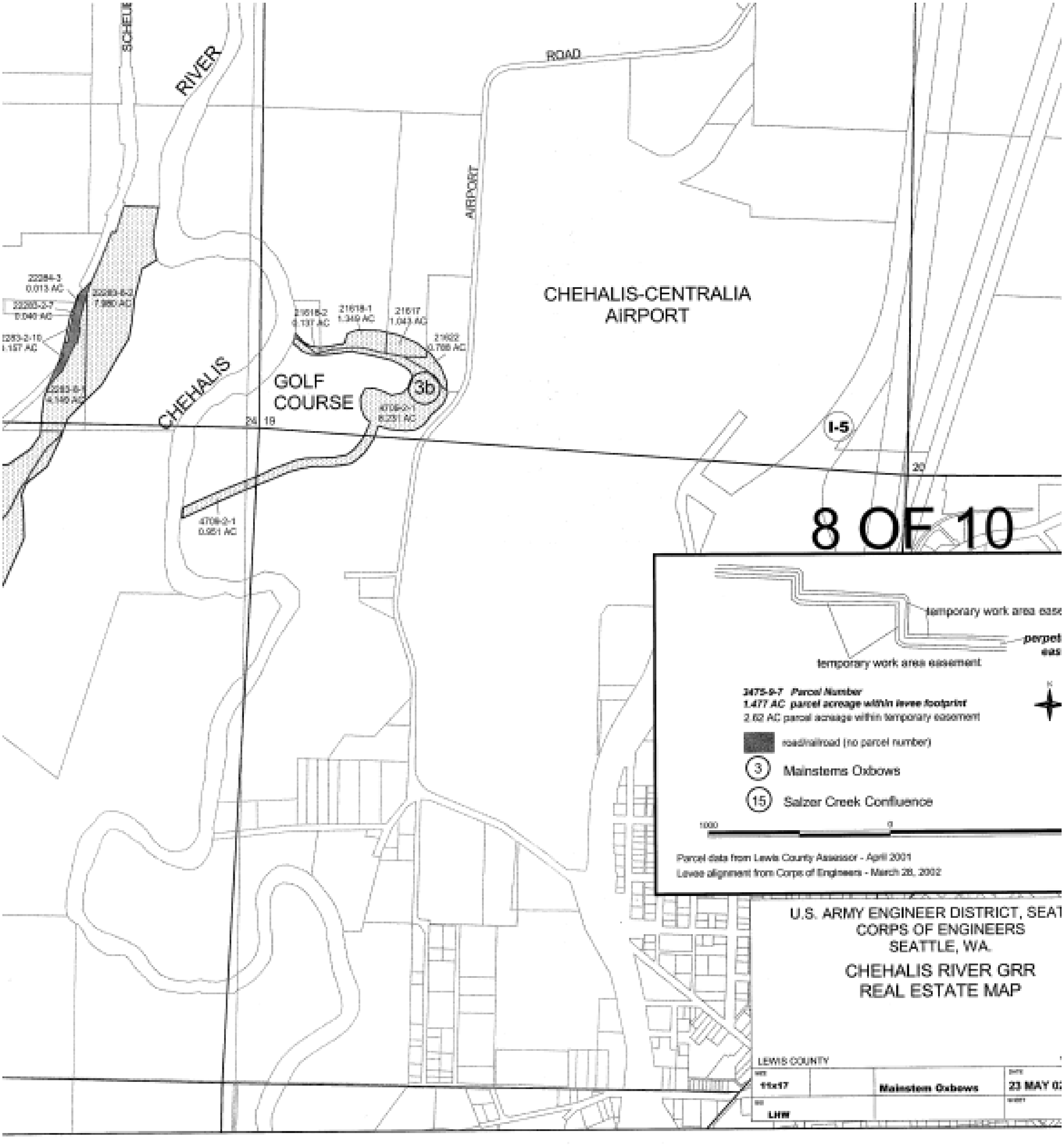
ASSESSOR'S OFFICE.
2. PROPERTY LINE INFORMATION HAS NOT BEEN SURVEYED AND IS PROVIDED FOR EVALUATION ONLY.
MARKET BOULEVARD
BNSF RAILROAD
5871-71-125
0.015 AC
31
32
6
5
5871-71-125
0.147 AC
0.380 AC
I-5
ISTRICT, SEATTLE
GINEERS
WA.
VER GRR
TE MAP
WASHINGTON
23 MAY 02
4
1
5 OF 10



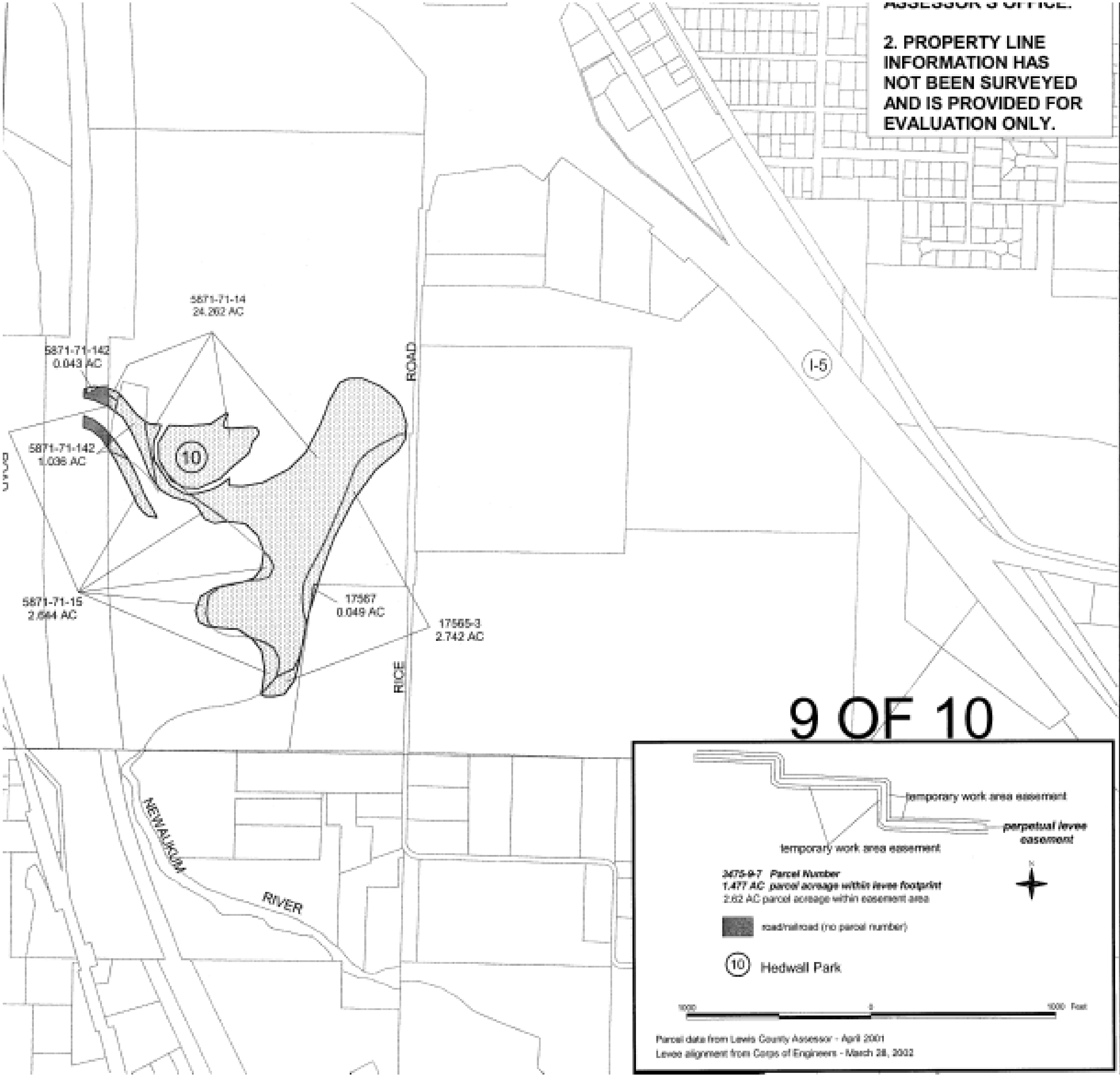
ASSESSOR'S OFFICE.
2. PROPERTY LINE INFORMATION HAS NOT BEEN SURVEYED AND IS PROVIDED FOR EVALUATION ONLY.
UNION PACIFIC RAILROAD
CHEHALIS WESTERN RAILROAD
BNSF RAILROAD
SKOOKUMCHUCK RIVER
WEST 5TH STREET
WEST 1ST STREET
21041
0.017 AC
3088-9-1
0.245 AC
0.401 AC
3088-11
0.057 AC
0.224 AC
3328-4-1
0.027 AC
3374
0.006 AC
2181-2
0.006 AC
6 OF 10
U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WA.
CHEHALIS RIVER GRR
REAL ESTATE MAP
LEWIS COUNTY
WASHINGTON
11X17
SKOOKUMCHUCK LEVEES
23 MAY 02
3
LHW
1



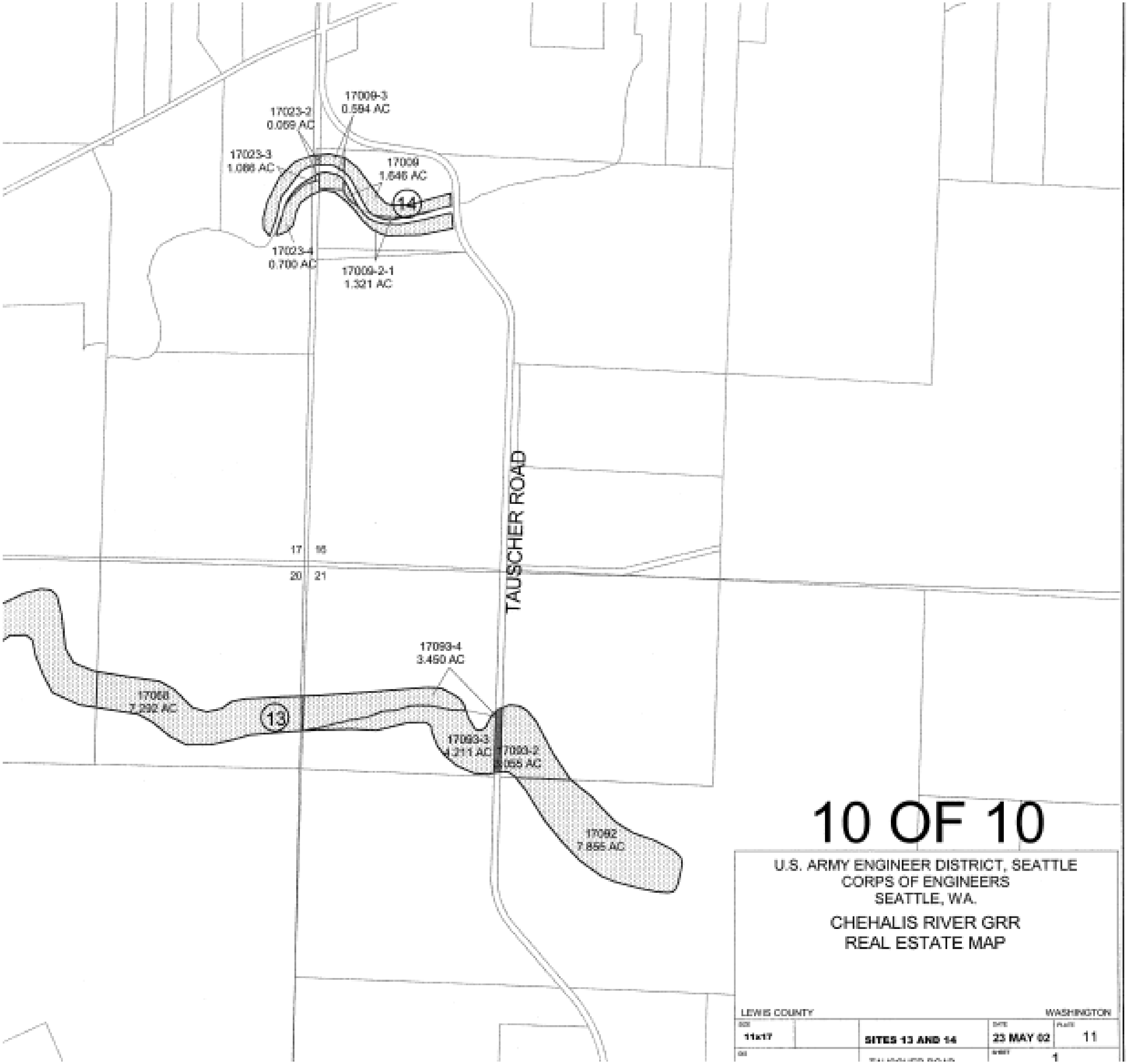
7 OF 10
U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WA.
CHEHALIS RIVER GRR
REAL ESTATE MAP
LEWIS COUNTY
WASHINGTON
11x17
SR-6/Scheuber Ditch
23 MAY 02
8
1
LHW
T14N R03W S26
CHEHALIS
RIVER
SR-6
22304
2.622 AC
22303
11.318 AC
22434-1
24.750 AC
22434-2
5.381 AC
22434-3
23.624 AC
22436-1-7
16.840 AC
22436-1-11
1.558 AC
22436-3
4.884 AC
22443-1
0.106 AC
18484
22.635 AC
18484-3
3.763 AC
18494
1.043 AC
18494-2
0.427 AC
18505
0.2198 AC
18502
0.009 AC
18504
0.476 AC
18498-2
0.070 AC
22434-3
1.953 AC
22436-1-11
1.321 AC
22436-3
0.269 AC



SCHEL
RIVER
CHEHALIS
ROAD
AIRPORT
CHEHALIS-CENTRALIA
AIRPORT
GOLF
COURSE
3b
I-5
24 19
20
22284-3
0.013 AC
22283-6-2
7.980 AC
22283-2-7
0.040 AC
2283-2-10
1.157 AC
2283-6-1
4.140 AC
21618-2
0.137 AC
21618-1
1.349 AC
21617
1.043 AC
21622
0.788 AC
4709-2-1
8.231 AC
4709-2-1
0.951 AC
8 OF 10
temporary work area ease
perpet
eas
temporary work area easement
3475-9-7 Parcel Number
1.477 AC parcel acreage within levee footprint
2.62 AC parcel acreage within temporary easement
road/railroad (no parcel number)
3 Mainstems Oxbows
15 Salzer Creek Confluence
1000
0
Parcel data from Lewis County Assessor - April 2001
Levee alignment from Corps of Engineers - March 28, 2002
U.S. ARMY ENGINEER DISTRICT, SEAT
CORPS OF ENGINEERS
SEATTLE, WA.
CHEHALIS RIVER GRR
REAL ESTATE MAP
LEWIS COUNTY
11x17
Mainstem Oxbows
23 MAY 02
LHW



2. PROPERTY LINE INFORMATION HAS NOT BEEN SURVEYED AND IS PROVIDED FOR EVALUATION ONLY.
5871-71-14
24.262 AC
5871-71-142
0.043 AC
5871-71-142
1.036 AC
10
5871-71-15
2.644 AC
17567
0.049 AC
17565-3
2.742 AC
RICE
ROAD
I-5
NEWAUKUM
RIVER
9 OF 10
temporary work area easement
perpetual levee easement
temporary work area easement
3475-9-7 Parcel Number
1.477 AC parcel acreage within levee footprint
2.62 AC parcel acreage within easement area
road/railroad (no parcel number)
Hedwall Park
Parcel data from Lewis County Assessor - April 2001
Levee alignment from Corps of Engineers - March 28, 2002



17009-3
0.594 AC
17023-2
0.059 AC
17023-3
1.086 AC
17009
1.646 AC
14
17023-4
0.700 AC
17009-2-1
1.321 AC
TAUSCHER ROAD
17
16
20
21
17093-4
3.450 AC
17068
7.292 AC
13
17093-3
1.211 AC
17093-2
2.055 AC
17092
7.855 AC
10 OF 10
U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WA.
CHEHALIS RIVER GRR
REAL ESTATE MAP
LEWIS COUNTY
WASHINGTON
11x17
SITES 13 AND 14
23 MAY 02
11
1

EXHIBIT "B" NON-FEDERAL SPONSOR'S REAL ESTATE ACQUISITION CAPABILITY ASSESSMENT

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CHEHALIS RIVER FLOOD DAMAGE REDUCTION PROJECT - GRR/EIS

ASSESSMENT OF NON-FEDERAL SPONSOR'S

REAL ESTATE ACQUISITION CAPABILITY

I. **Legal Authority:**

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? **(yes)**

b. Does the sponsor have the power of eminent domain for this project? **(yes) However, the sponsor's current condemnation authority may only be exercised over lands within Lewis County. (See, I, e., below regarding project lands outside sponsor's political boundaries)**

c. Does the sponsor have "quick-take" authority for this project? **(no) Note: The Non-Federal Sponsor has the authority to acquire immediate possession. However, title vests after just compensation is determined by agreement or judicial decision.**

d. Are any of the lands /interests in land required for the project located outside the sponsor's political boundary? **(yes) Skookumchuck Dam is located in Thurston County, Washington.**

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? **(yes) Skookumchuck Dam is located in Thurston County. The sponsor's current condemnation authority does not extend to lands outside Lewis County. However, if condemnation becomes necessary, the sponsor intends to establish a special flood control district at the dam, which would provide the sponsor with authority to condemn those lands in the event that a negotiated acquisition cannot be accomplished.**

II. **Human Resource Requirements:**

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P.L. 91-646, as amended? **(no) A right-of-way contractor with Federal project experience will be contracted to perform sponsor's LERRD duties.**

b. If the answer to II.a. is "yes," has a reasonable plan been developed to provide such training? **(N/A)**

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? **(no) An experienced right-of-way contractor will be contracted to perform sponsor's LERRD duties.**

d. Is the sponsor's projected in-house staff level sufficient considering its other work load, if any, and the project schedule? **(no) An experienced right-of-way contractor will be contracted to perform sponsor's LERRD duties.**

e. Can the sponsor obtain contractor support, if required, in a timely fashion? **(yes)**

f. Will the sponsor likely request USACE assistance in acquiring real estate? **(no)**

III. **Other Project Variables:**

a. Will the sponsor's staff be located within reasonable proximity to the project site? **(yes)**

b. Has the sponsor approved the project/real estate schedule/milestones? **(yes)**

IV. **Overall Assessment:**

a. Has the sponsor performed satisfactorily on other USACE projects? **(yes)**

b. With regard to this project, the sponsor is anticipated to be:

- ___ highly capable
- _X_ fully capable
- ___ moderately capable
- ___ marginally capable
- ___ insufficiently capable. (If sponsor is believed to be "insufficiently capable", provide an explanation).

V. **Coordination:**

a. Has this assessment been coordinated with the sponsor? **(yes)**

b. Does the sponsor concur with this assessment? **(yes)**
(If "no," provide explanation).

Prepared by:

KEVIN L. KANE
Realty Specialist

Reviewed and approved by:

MICHAEL J. COLBY
Acting Chief Real Estate Division
Seattle District
Corps of Engineers

CAPASSES.NFS [Chehalis River GRR—Real Estate Plan]
7/19/2002

EXHIBIT “C” CERTIFICATION OF LANDS AND ATTORNEY’S CERTIFICATE

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DATE

Department of the Army
Seattle District, Corps of Engineers
ATTN: Real Estate Division
Post Office Box 3755
Seattle, Washington 98124-3755

RE: Certification of Lands and Authorization for Entry for Centralia Flood Damage Reduction Project

Dear Sir:

By Project Cooperation Agreement dated the ____________ day of ___________________ 200__, Lewis County assumed full responsibility to fulfill the requirements of non-federal cooperation as specified therein and in accordance with the Water Resources Development Act of 1986, as amended.

This is to certify that Lewis County has sufficient title and interest in the lands hereinafter shown on Exhibit A, attached, in order to enable Lewis County to comply with the aforesaid requirements of non-federal cooperation.

Said lands and/or interest therein are owned or have been acquired by Lewis County, and are to be used for the construction, maintenance and operation of the above referenced project and include but are not limited to the following specifically enumerated rights and uses, except as hereinafter noted:

1. Fee: The fee simple title to the land shown Exhibit A attached.

2. Flood Protection Levee Easement

   A perpetual and assignable right and easement in (the land described in Schedule A) (Tracts Nos. ___, ____, and _____) to construct, maintain, repair, operate, patrol, and replace a flood protection levee, including all appurtenances thereto; reserving, however, to the owners, their heirs and assigns, all such rights and privileges in the land as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.

CERTLANDANDATTYCERT.DOC
05/05/03

3. Temporary Work Area Easement

A temporary easement and right-of-way in, on, over, and across (the land described in Schedule A) (Tracts Nos. ___, ___, and ___), for a period not to exceed ______________, beginning with date possession of the land is granted to the United States, for use by the (the land described in Schedule A) (Tracts Nos. ____, _____, and _____), its representatives, agents, and contractors as a (borrow area) (work area), including the right to (borrow and/or deposit fill, spoil, and waste material thereon) (move, store, and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the ___________________ Project, together with the right to trim, cut, fell, and remove therefrom all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.

4. Restrictive Easement

A perpetual and assignable easement for the establishment, maintenance, operation, and use for a restricted area in, on, over, and across the land described in Schedule A, consisting of the right to prohibit human habitation; the right to remove buildings presently or hereafter being used for human habitation; the right to prohibit gatherings of more than twenty-five (25) persons; the right to post signs indicating the nature and extent of the Government's control; and the right of ingress and egress over and across said land for the purpose of exercising the rights set forth herein; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines; reserving, however, to the landowners their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired.

5. Estate to be used when a road is being utilized as a levee

A perpetual and assignable easement and right of way in, on, over and across the land described above for the location, construction, operation, maintenance, repair, alteration, replacement of a road and flood protection levee, including all appurtenances thereto; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures, or obstacles within the limits of the right-of-way; reserving however, to the owners, their heirs and assigns, the right to cross over the right of way as access to their adjoining land, the perpetual right, power, privilege, and easement to occasionally overflow, flood, and submerge the land together with all right, title and interest in and to the structures and improvements now situate on the land, except fencing (and also excepting _________) provided that no structures for human habitation shall be constructed or maintained on the land, that no other structures shall be constructed or maintained on the land except as may be approved in writing by Lewis County, Washington, and a representative of the U.S. Army Corps of Engineers, Seattle District, and that no excavation shall be conducted and no landfill placed on the land without such approval as to the location and method of excavation and/or placement of landfill; the above estate is taken subject to existing easements for public roads and highways, public utilities, railroads and pipelines; reserving, however, to the landowner, their heirs and assigns, all such rights and privileges as may be used and enjoyed without interfering with the use or abridging the rights and easement hereby acquired.

6. Access Road Easement

A perpetual and assignable non-public easement and right-of-way in, on over and across the land described in Schedule "A" attached hereto for the sole and exclusive purposes of the location, construction, operation, maintenance, alteration and replacement of a non-public access way and appurtenances thereto; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures or obstacles within the limits of the right-of-way; reserving, however, strictly to the Grantor and its assigns, the right to cross over or under the right-of-way for any purpose whatsoever, which purpose shall not interfere with Grantee's use of the easement; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

The Grantors and Grantee further agree that the Grantors, their heirs and assigns, shall be entitled to change the location of the easement area, and the road and appurtenances located thereon, to accommodate the future use or development of Grantor's property so long as the new easement area, and the new roadway and appurtenances thereto, represent a reasonable substitute location and facility and so long as they are first provided by the Grantors at their sole expense. Nothing herein shall be construed to allow Grantee to create a public road, public access or public right-of-way on the easement herein granted or on any of Grantor's other property. This access is being granted solely and exclusively for the limited purposes of construction, operation, maintenance, repair, replacement and rehabilitation of a floodwall and rip-rap to be located in an environmentally sensitive area in and along Skookumchuck River on the Grantor's property as further described hereinafter in the Flood Protection Levee Easement. By accepting and recording this conveyance, the Grantee agrees to such limitation which can only be modified by the express written consent of the Grantor.

Lewis County does hereby grant to the United States of America, its representatives, agents and contractors, an irrevocable right, privilege and permission to enter upon the lands hereinbefore mentioned for project purposes.

Lewis County certifies to the United States of America that any lands acquired subsequent to the execution of the Project Cooperation Agreement that are necessary for this project have been accomplished in compliance with the provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, (Public Law 91-646) as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR, Part 24.

Lewis County, Washington

By: ______________________________

DATE: ____________________

*****

ATTORNEY'S CERTIFICATE

I, ______________________________, an attorney admitted to practice law in the State of Washington, certify that:

I am the attorney for the ____.

I have examined the title to ______________________________________[Parcel #] of land identified by the U.S. Army Corps of Engineers as needed for the Centralia Flood Damage Reduction Project and included in the Certification of Lands and Authorization For Entry document to which this Certificate is appended.

Lewis County is vested with sufficient title and interest in the described lands required by the United States of America to support the construction, operation, and maintenance of the Centralia Flood Damage Reduction Project.

There [ ] are (see attached risk analysis) [ ] are no outstanding third party interests of record that could defeat or impair the title and interests of Lewis County in and to the lands described, or interfere with construction, operation, and maintenance of the Project. Such interests include, but are not limited to, public roads and highways, public utilities, railroads, pipelines, other public and private rights of way, liens and judgments. To the extent such interests existed prior to acquisition of the described lands by Lewis County such interests have either been cleared or subordinated to the title and interests so acquired.

Lewis County has authority to grant the Certification of Lands and Authorization For Entry to which this Certificate is appended; that said Certification of Lands and authorization for entry is executed by the proper duly authorized authority; and that the authorization for entry is in sufficient form to grant the authorization therein stated.

DATED AND SIGNED at ____________________________, this ____ day of __________ 200__.

____
NAME
TITLE

5

U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington
General Reevaluation Report

Economic Revision Report

June 2003

Economic Revision Summary

Centralia Flood Damage Reduction Project
Chehalis River, Washington

The purpose of this report is to document the price level and discount rate updates and their impacts on the benefit cost analysis for both the Locally Preferred (LP) Plan and NED Plan described in the 2003 General Reevaluation Report for the Centralia Flood Damage Reduction Project. All benefits and costs were updated to October 2003 price levels and annualized over a 50-year period of analysis using the Fiscal Year 2003 Federal Discount Rate of 5 7/8 percent. The benefit cost analysis incorporates the revised mitigation costs as documented in the June 2003 Revised Mitigation Plan Addendum to the project's environmental impact statement.

Revised Damage Estimates

Expected annual damages under without project conditions were revised by applying appropriate indexes to varied categories. Data sources for these indexes included Marshall & Swift Valuation, US Department of Labor- Bureau of Labor Statistics, Engineering News Record, and US Department of Agriculture. These update factors increased the damage estimates from the June 2002 values found in the Economic Appendix to the current October 2003 price level and ranged from a low of 2.2 percent to a high of 4.6 percent. These factors (listed in Table 1) were applied to the individual stage damage curves in the HEC-FDA model by damage category. The revised expected annual damages are shown in Table 2 below (compare to Table 3-34 in the GRR main report and Table 38 in the economics appendix D).

TABLE 1: UPDATE FACTORS

DAMAGE CATEGORY	SOURCE	INDEX	FACTOR
Structure & Content	Marshall & Swift	Comparative Cost Multiplier –Seattle	Residential = 1.025 Non-res = 1.022
Clean-Up Costs	Bureau Of Labor Statistics	Producer Price Index-Building Cleaning And Maintenance Services	1.034
Temporary Relocation Assistance	Bureau Of Labor Statistics	Consumer Price Index - Shelter	1.046
Public Assistance	Bureau Of Labor Statistics	CPI- Services	1.045
Agricultural Damages	US Dept Agriculture	Prices Paid By Farmers	1.023
Avoided I-5 Cost	Engineering News Record	Weighted Average Of CCI And BCI	1.029
Traffic Delay	IRS	Mileage Rates	1.043

**TABLE 2: EXPECTED ANNUAL DAMAGE SUMMARY
WITHOUT PROJECT CONDITIONS
OCTOBER 2003 PRICES, 5 7/8% DISCOUNT RATE**

Damage Category	Expected Annual Damage
Structures	4,156,700
Contents	3,138,000
Cleanup	1,237,430
Temporary Relocation Assistance	121,920
Public Assistance	423,570
Agriculture	118,500
I-5 Delays	130,960
Railroad Delays	33,600
Total	**$9,360,680**

Benefits Revised

With project conditions were evaluated using these revised estimates. The HEC-FDA model was run for both the LP and NED Plans. Residual damages and flood damage reduction benefits for the NED plan is shown in Table 3 (compare to Table 45 in economics appendix D and Table 4-11 in the main report) and for the LP plan in Table 4.

TABLE 3: NED PLAN RESIDUAL DAMAGES

Expected Annual Flood Damage for the NED Plan* 11,000 ac/ft Skookumchuck Dam modification, 100-yr Protection Levee Chehalis River, & 100-yr WSE -2 Skookumchuck Levee (Damage in $1,000's, October 2003 Prices, 5.875%, 50 -year analysis period)												
Alternative	Damage Categories											
	Com - Cleanup	Com – Cnt	Com - Str	PA	Res - Cleanup	Res - Cnt	Res - Str	TRA	Pub - Cleanup	Pub - Str	Pub - Cnt	Total
Without-project Damages	312	1463	1385	424	896	1466	2514	122	30	257	209	9078
NED Plan	28	206	180	168	325	588	1018	48	5	34	25	2625
Damage Reduction	**284**	**1257**	**1205**	**256**	**571**	**878**	**1496**	**74**	**25**	**223**	**184**	**6453**

**Damages in this table do not include agriculture damages and rail damages – both these categories are not affected by recommended project. Residual annual damages in these categories are $119k for agriculture and $34k for rail. Additional project benefits categories of NED plan include $2,122k in avoided cost of fill for elevating I-5 and $131k in reduced traffic delays. Incorporating these values results in the following:*
Without-project damages including agricultural damages, rail damages, and traffic delays and cost of elevating I-5: ***$11,484***
NED Plan residual damages including agricultural damages and rail damages: ***$2,778***
*NED Plan damage reduction including avoided cost of fill for elevating I-5 and reduced traffic delays: $**8,706***

TABLE 4: LP PLAN RESIDUAL DAMAGES

Expected Annual Flood Damage for the Locally Preferred Plan* 20,000 ac/ft Skookumchuck Dam modification, 100-yr Protection Levee Chehalis River, & 100-yr Skookumchuck Levee (Damage in $1,000's, October 2003 Prices, 5.875%, 50 -year analysis period)												
Alternative	Damage Categories											
	Com - Cleanup	Com – Cnt	Com - Str	PA	Res - Cleanup	Res – Cnt	Res - Str	TRA	Pub - Cleanup	Pub - Str	Pub - Cnt	Total
Without-project Damages	312	1463	1385	424	896	1466	2514	122	30	257	209	9078
NED Plan	20	169	137	156	303	547	947	45	5	31	22	2382
Damage Reduction	**292**	**1294**	**1248**	**268**	**593**	**919**	**1567**	**77**	**25**	**226**	**187**	**6696**

**Damages in this table do not include agriculture damages and rail damages – both these categories are not affected by the selected project. Residual annual damages in these categories are $119k for agriculture and $34k for rail. Additional project benefits categories of LP plan include $2,122k in avoided cost of fill for elevating I-5 and $131k in reduced traffic delays. Incorporating these values results in the following:*
Without-project damages including agricultural damages, rail damages, and traffic delays and cost of elevating I-5: ***$11,484***
LP Plan residual damages including agricultural damages and rail damages: ***$2,535***
*LP Plan damage reduction including avoided cost of fill for elevating I-5 and reduced traffic delays: $**8,949***

Benefit-Cost Analysis

First costs for both the NED and LP plans were provided by the Seattle District. These MCACES project cost updates represent October 2003 price levels, 50-year period of analysis and a 5 7/8 percent discount rate. A summary of the annual cost estimation for both plans are displayed in Table 5.

TABLE 5
ESTIMATION OF ANNUAL COSTS
VALUES IN $1,000'S, OCTOBER 2003 PRICES,
50-YEAR PERIOD OF ANALYSIS AND 5.875% DISCOUNT RATE

	First Costs Code of Accounts	**NED Plan**	**LP Plan**
01	Lands & Damages	14,810	14,810
04	Dams	6,796	9,277
06	Fish & Wildlife Facilities	10,200	10,200
11	Levees & Floodwalls	43,625	47,414
30	Engineering & Design	5,929	6,536
31	Construction Management	5,929	6,536
Total First Costs		**$ 87,289**	**$ 94,773**
Interest During Construction		7,929	8,475
Total Investment Costs		95,218	103,248
Interest and Amortization		5,936	6,436
Operations and Maintenance		587	653
Annual Costs		**$ 6,523**	**$ 7,089**

With both annual benefits and annual costs revised to a common price level and interest rate, net benefits for both the NED and LP plans were determined. The following Table 6 compares the annual benefits and costs of these two alternatives.

TABLE 6
ANNUAL BENEFITS AND COSTS OF ALTERNATIVES
VALUES IN $1,000'S, OCTOBER 2003 PRICES,
50-YEAR PERIOD OF ANALYSIS AND 5.875% DISCOUNT RATE

	NED Plan	LP Plan
Annual Benefits		
Damage Reduction	$ 6,453	$ 6,696
Reduced Traffic Delays	$ 131	$ 131
Avoided Costs I-5	$ 2,122	$ 2,122
Total Annual Benefits	$ 8,706	$ 8,949
Annual Costs	$ 6,523	$ 7,089
Net Benefits	$ 2,183	$ 1,860
B/C Ratio	1.33	1.26

The selected plan provides estimated annual benefits of $8,949,000, including $6.7 million in flood related damages to structures and their contents, $2.1 million in annual avoided costs associated with the need to elevate I-5 without the project, and an annual reduction of $131,000 in traffic delays related to flooding. Residual annual damages in the study area amount to $2.5 million (including flood damages associated with structures and contents as well as residual agricultural damages and rail delay damages; neither of these latter two damage categories are affected by the NED or the selected Locally Preferred Plans).

Annual economic costs of the locally preferred plan are estimated at $ 7.1 million, resulting in annual net benefits of $ 1.9 million and a positive benefit-to-cost ratio of 1.26 to 1. The NED Plan will provide annual benefits of $ 8.7 million for an annual cost of $ 6.5 million, providing net benefits of $ 2.2 million and a benefit-to-cost ratio of 1.33 to 1.