US Army Corps of Engineers ®
Portland District

LIMITED REEVALUATION REPORT

Mount St. Helens Long-Term Sediment Management Plan Update

Sediment retention structure and upstream sediment plain on the North Fork Toutle River.

August 2014

EXECUTIVE SUMMARY

The purpose of this Limited Reevaluation Report (LRR) is to document updates to the long-term implementation plan for managing sediment from the Mount St. Helens (MSH) debris avalanche, in order to maintain authorized flood risk levels for over 50,000 people living in the communities of Longview, Kelso, Lexington and Castle Rock, Washington, through the year 2035. A review and update of the damage analysis in the 1985 MSH Decision Document (USACE 1985) showed that maintaining authorized flood risk levels results in over $29 million in flood damages prevented annually (the benefits of the MSH project were updated and verified in 2012). In addition, a planned approach to preventing sediment buildup in the lower Cowlitz River would reduce the overall flood fight costs by over $28 million annually. The original 1985 plan authorized construction of a sediment retention structure (SRS), levee improvements, and dredging. In addition, the original plan indicated that additional sediment management actions would be needed sometime after the year 2000, and also acknowledged that other actions besides dredging might be more appropriate in the future.

Current efforts focued on identifying remaining actions needed to complete the original MSH project. This LRR documents the investigation of other sediment management options and the identification of the most effective way to complete the project and maintain the authorized capacity in the Cowlitz River for flood risk management. The conditions in and around the Cowlitz River are different now from what they were in 1985.

Given the changes, this LRR describes what remaining actions would be required to complete the MSH project and maintain the congressionally authorized Cowlitz River capacity and flood risk management for the communities along the lower 20 miles of the Cowlitz River. The intent of the LRR was not to reformulate the MSH project, but rather to incorporate any changes and identify the least-cost approach to implement the remaining components of the project, while minimizing environmental and other negative impacts. The LRR documents the changes from the 1985 original plan and how best to manage the flood risk through 2035. Inputs that support the updated plan to complete the MSH project included:

- Changes in the physical conditions of the project area;
- Documentation of future expected deposition scenario under without project conditions and the continued need for flood risk protection;
- Assessment of flood risk management effectiveness for a range of measures including cost-effectiveness and environmental impacts; and
- Description of viable alternatives and determination of the recommended plan to finish the authorized project and comply with the National Environmental Policy Act and Endangered Species Act.

The existing SRS has been operating as run-of-river since 1998 and in recent years has become less efficient at trapping sediment. Consequently, sediment has been building up in the lower Cowlitz River, increasing the risk of flood damages to the communities along the river. Since 2007, several interim actions to maintain authorized flood reduction benefits were implemented. These actions included lower Cowlitz River dredging, minor levee work, and the placement of sediment trapping structures at the SRS and upstream of the SRS in the sediment plain.

To date, implementation of the initial and recent interim flood risk management construction actions have been successful in maintaining the congressionally authorized flood risk levels for the communities of Longview, Kelso, Lexington and Castle Rock. However, without completion of the MSH project, the trapping efficiency of the SRS would continue to decline and result in significantly increased flood risks each year in the lower Cowlitz River until exceeding the project's authorized flood risk levels by 2018.

The key components of the 1985 original plan that are still relevant and not evaluated or reassessed as part of the LRR include the following.

1. Project purpose and scope has not changed; therefore, the MSH project would not be reformulated. The benefits of the project were updated and verified in 2012. The purpose of the project remains to maintain, through year 2013, the flood risk levels authorized in 1985 and verified in 2012. This LRR effort documents the least-cost plan and environmentally sound approach to maintaining the authorized flood risk benefits.
2. Recommended approach to managing the sediment must be flexible given the acknowledged uncertainty about quantity and timing of sediment deposition in the lower Cowlitz River.
3. The MSH project can be completed based on the original authorizing language.
4. The MSH project can be completed based on the funding levels established in the 1985 Decision Document (adjusted for inflation).
5. The MSH project can be completed with existing non-federal cost share sponsor agreement established in 1986.

Current data indicated additional sediment management actions would be needed to prevent increased flood risks associated with sediment deposition in the lower 20 miles of the Cowlitz River. Recent assessments showed that unless further actions would be implemented, sediment buildup in the lower Cowlitz River would continue and increase the flood risk for over 50,000 people and their homes and businesses. The flood risk levels for the communities of Lexington, Kelso, Castle Rock and Longview would continue to deteriorate as the river channel fills with sediment. Without sediment management actions, the floodwaters could eventually overtop the levees and significantly impact the communities. Without completion and approval of this updated plan, the USACE would not be able to implement any additional sediment management actions. The likely future without project scenario would require emergency actions in response to increased flood risk conditions due to sediment buildup in the lower Cowlitz River.

The LRR evaluation of the alternatives demonstrated that the Phased Construction alternative (selected plan) would be the best approach to maintain the authorized flood risk levels to the communities of Kelso, Longview, Castle Rock and Lexington. The selected plan would be the least-cost plan, adaptable to uncertain sedimentation conditions through 2035 and beyond, can effectively handle extreme events, and would minimize impacts to fish and wildlife in the near term and over time. The selected plan includes:

- Two SRS spillway raises for a total raise of 23 feet above the existing spillway crest elevation;
- Grade building structures in the sediment plain above the SRS; and
- Cowlitz River dredging as needed to respond to unusual events.

Assuming a 3.5% discount rate and 18-year period of evaluation (2017-2035), the average annual cost for the two spillway raises and grade building structures would be $5.8 million. The potential need for dredging must also be accounted for. According to sediment modeling results, Cowlitz River dredging could be required to address unusual events and is included in the overall plan. It is uncertain when and

even if Cowlitz River dredging would be required; therefore, a range of costs was used to account for any dredging that could be required. If there was a requirement for dredging in the early years of the evaluation period (2018-2025), it would result in an average annual dredging cost of $9.97 million, whereas dredging in the 2028-2035 time frame would result in an average annual cost of $6.4 million. Therefore, the overall cost of this plan would range from an average annual cost of $5.8 million (no dredging required) to $15.8 million (dredging required early in evaluation period).

Environmental impacts for the three alternatives have been evaluated in the Supplemental Environmental Impact Statement (SEIS). The SEIS was prepared by the Portland District. Significant input into the SEIS was provided by the Washington Department of Fish and Wildlife which was a cooperating agency at the onset of the preparation of the SEIS but withdrew their cooperating agency status in a letter dated August 14, 2014 prior to the release of the SEIS. In addition, formal consultation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service was conducted for the selected plan. See Appendix B for more information.

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ACRONYMS AND ABBREVIATIONS

1-D/2-D	one dimensional/two dimensional
cfs	cubic feet per second
CVS	cross-valley structure
cy	cubic yard
DDR	Design Documentation Report
DWS	design water surface
ESA	Endangered Species Act
FCF	fish collection facility
FEDS	future expected deposition scenario
ft/s	feet (foot) per second
FY	fiscal year
GBS	grade-building structure
HEC	Hydrologic Engineering Center
HEC-FDA	Hydrologic Engineering Center Flood Damage Reduction Analysis
HMR	hydrometeorological report
IFS	island-forming structure
LiDAR	light detection and ranging
LOP	level(s) of protection
LRR	Limited Reevaluation Report
mcy	million cubic yard(s)
MSH	Mount St. Helens
NAVD88	North American Vertical Datum of 1988
NF	North Fork (Toutle River)
NGVD	National Geodetic Vertical Datum
NEPA	National Environmental Policy Act
NRCS	Natural Resource Conservation Service
OBM	operating basis mudflow
PMF	probable maximum flood
RCC	roller-compacted concrete
RM	river mile
SEIS	Supplemental Environmental Impact Statement
SF	South Fork (Toutle River)
SRS	sediment retention structure
TAGT	Technical Agency/Government Team
SWL	safe water level
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife
WY	water year

1. INTRODUCTION

1.1. OVERVIEW

The eruption of Mount St. Helens (MSH) in the spring of 1980 caused a large movement of sediment into surrounding watercourses, creating a threat of flooding in downstream communities and threat of navigation disruption in southwestern Washington. Following the eruption, the Portland District of the U.S. Army Corps of Engineers (USACE) implemented several strategies to mitigate the flood risk to downstream communities, as identified in the *Mount St. Helens, Washington, Decision Document, Toutle, Cowlitz and Columbia Rivers* (long-term sediment management plan; USACE 1985). A major component of the 1985 long-term sediment management plan was the construction of a sediment retention structure (SRS) at river mile (RM) 13 on the North Fork (NF) Toutle River in 1989. The purpose of the SRS was to retain sediment in the sediment plain upstream of the SRS, thereby reducing downstream transport and deposition of the sediment, which increases flood risk in the lower Cowlitz River. Other features of the 1985 long-term plan included levee improvements on the lower 20 miles of the Cowlitz River and as-needed dredging within the lower Cowlitz River.

The existing SRS has been operating as run-of-the-river[1] since 1998, reducing its sediment trapping efficiency and allowing more sediment to be transported downstream. This, in turn, has changed the rate of sediment accumulation in the lower Cowlitz River. The 1985 Decision Document identified dredging in the Cowlitz River as the recommended approach for managing sediment after the SRS became run-of-the-river. However, the conditions in and around the Cowlitz River are different now from what they were in 1985. Notably, the methods and constraints of dredging the lower Cowlitz River are considerably different than when analyzed in 1985. The scarcity of convenient disposal sites in the area, along with the listing of salmon species, eulachon and green sturgeon under the Endangered Species Act (ESA), have increased the complexity and cost of dredging, as well as the potential for adverse biological impacts.

The 1985 long-term sediment management plan recognized the likely need for a future reevaluation of the components of the plan based on changes in future conditions. Since 1998, increased sediment accumulation has been observed in the lower 20 miles of the Cowlitz River. Consequently, there is an increase in the risk of flood damages to the communities along the river. Since 2007, several interim actions to maintain authorized flood reduction benefits were implemented. These actions include lower Cowlitz dredging, minor levee work, and sediment trapping structures at the SRS and upstream of the SRS in the sediment plain.

To date, implementation of the initial and recent interim flood risk management features for the MSH project have been successful in maintaining the congressionally authorized flood risk levels for the communities of Longview, Kelso, Lexington and Castle Rock in Washington. However, without completion of the MSH project, the trapping efficiency of the SRS would continue to decline and result in significantly increased flood risks in the lower Cowlitz River by approximately 2018. The authorized levels of protection (LOP) for Lexington, Kelso, Castle Rock and Longview rely on continued management of the sedimentation in the lower Cowlitz River. Without completion of the MSH project, sediment would continue to deteriorate the LOP and put over 50,000 people and their property at significant risk.

[1] Run-of-the-river means that the dam essentially passes existing river flow without any storage of water upstream, as opposed to storage reservoirs that are designed to reduce peak flow by storing water, which has an accompanying large variation in reservoir pool elevations.

1.2. PURPOSE AND SCOPE

The purpose of this Limited Reevaluation Report (LRR) is to document updates to the long-term implementation plan for managing sediment from the MSH debris avalanche in order to maintain the authorized LOP for over 50,000 people living in the communities of Longview, Kelso, Lexington and Castle Rock, Washington, through year 2035. A review and update of the 1985 damage analysis (Decision Document, USACE 1985) shows that maintaining authorized LOP results in over $29 million in flood damages prevented annually (the benefits of the MSH project were updated and verified in 2012). In addition, a planned approach to preventing sediment buildup in the lower Cowlitz River, rather than relying on emergency flood fight actions such as dredging, would reduce the overall costs by over $28 million annually. The original plan in 1985 authorized construction of a sediment retention structure (SRS), levee improvements, and dredging. In addition, the original plan indicated that additional sediment management actions would be needed sometime after the year 2000, and also acknowledged that other actions besides dredging might be more appropriate in the future.

Current efforts focus on identifying remaining actions needed to complete the original MSH project. This LRR documents the investigation of other sediment management options and the identification of the most effective way to complete the project and maintain the authorized capacity in the Cowlitz River for flood risk management. The conditions in and around the Cowlitz River are different now from what they were in 1985. With the significant time lapse since the initial components of the MSH project were constructed, two significant issues–(1) changes to listed endangered species and (2) relative costs of various sediment management actions–are assessed in the LRR, as well as in an accompanying Supplemental Environmental Impact Statement (SEIS).

Environmental impacts for the three alternatives have been evaluated in the SEIS. The SEIS was prepared by the Portland District. Significant input into the SEIS was provided by the Washington Department of Fish and Wildlife which was a cooperating agency at the onset of the preparation of the SEIS but withdrew their cooperating agency status in a letter dated August 14, 2014 prior to the release of the SEIS. Formal consultation with the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) was conducted for the preferred plan. See Appendix B for more information.

Given the changes, this LRR describes what remaining actions are required to complete the MSH project and maintain the congressionally authorized Cowlitz River capacity and flood risk management for the communities along the lower 20 miles of the Cowlitz River. The intent of this LRR is not to reformulate the project but rather to incorporate any changes and identify the least-cost approach to complete the project, while minimizing environmental and other negative impacts. The scope of the LRR is to document the changes from the original plan and how best to manage the flood risk through 2035. Inputs that support the updated plan include:

- Changes in the physical conditions of the project area:
  - future sediment yield from the debris avalanche;
  - sediment budget from MSH to the mouth of the Cowlitz River;
  - current status/effectiveness of the MSH project features; and
  - design flood criteria for the SRS (design mudflow, probable maximum flood).
- Documentation of future expected deposition scenario (FEDS) under without project conditions and the continued need for flood risk protection.
- Assessment of flood risk management effectiveness for a range of measures including cost-effectiveness and environmental impacts.

- Description of viable alternatives and determination of the recommended plan to finish the authorized project and comply with the National Environmental Policy Act (NEPA) and Endangered Species Act (ESA).

1.3. ASSUMPTIONS

The key components of the 1985 original plan that are still relevant and were not evaluated or reassessed as part of the LRR include the following.

1. Project purpose and scope has not changed; therefore, the MSH project would not be reformulated. The benefits of the project were updated and verified in 2012. The purpose of the project remains to maintain, through year 2013, the authorized flood risk levels authorized in 1985 and verified in 2012. This LRR effort documents the least-cost plan and environmentally sound approach to maintaining the authorized flood risk benefits.
2. Recommended approach to managing the sediment must be flexible given the acknowledged uncertainty about quantity and timing of sediment deposition in the lower Cowlitz River.
3. The MSH project can be completed based on the original authorizing language.
4. The MSH project can be completed based on the funding levels established in the 1985 Decision Document (adjusted for inflation).
5. The MSH project can be completed with existing non-federal cost share sponsor agreement established in 1986.

1.4. PROJECT AUTHORIZATION

The MSH project remains an open construction project that was authorized by Congress under the Supplemental Appropriations Act of August 15, 1985 (Public Law 99-88). Under Public Law 99-88, the USACE was authorized to construct and operate a SRS, construct a fish collection facility (FCF), conduct dredging in both the Cowlitz and Toutle Rivers, and update and implement a long-term sediment management plan through the year 2035. The authorization acknowledged a large degree of uncertainty and need for flexibility in addressing the sediment load, as well as the possibility that future conditions may warrant raising the SRS. The State of Washington, as the non-federal sponsor of the Mount St. Helens project, has responsibility to provide real estate needs associated with project activities and to maintain dredge material disposal sites and mitigation in the form of assuming ownership, operation, and maintenance of the USACE-constructed FCF. These cost-sharing requirements are outlined in the 1986 Local Cooperation Agreement between the Department of the Army, the State of Washington, and the Cowlitz County diking districts. The Washington Department of Fish and Wildlife (WDFW) continues to operate and maintain the FCF on behalf of the State of Washington.

Although specified in the original 1985 plan, the precise LOP required to be maintained for the Longview, Kelso, Lexington, and Castle Rock levees were not clarified until 2000 under Section 339 of the Water Resources Development Act. Table 1-1 shows the authorized LOP for each of the Cowlitz River levees.

Table 1-1. Authorized LOPs for the Cowlitz River Levees

Levee Location	Levee Length (miles)	Percent Chance Exceedance Flood	Average Annual Recurrence Interval (years)
Kelso	5.7	0.70%	143
Longview	2.4	0.60%	167
Lexington	2.7	0.60%	167
Castle Rock	1.5	0.85%	118

1.5. AUTHORIZED PROJECT FUNDING SUMMARY

Table 1-2 summarizes the authorized funding for the MSH project to date, and the anticipated costs needed to complete the project.

Table 1-2. Summary of Authorized MSH Project Funding

Funding Summary[1]	Estimated Project Costs
Total Estimated Federal Project Cost (1985 dollars)	$304,566,000
Total Estimated Federal Project Cost (2013 dollars)	$512,695,000
Balance to Complete Project (2013 dollars)	$363,728,000

[1] Unadjusted actual expenditures through 2013 on MSH = $148,967,000.

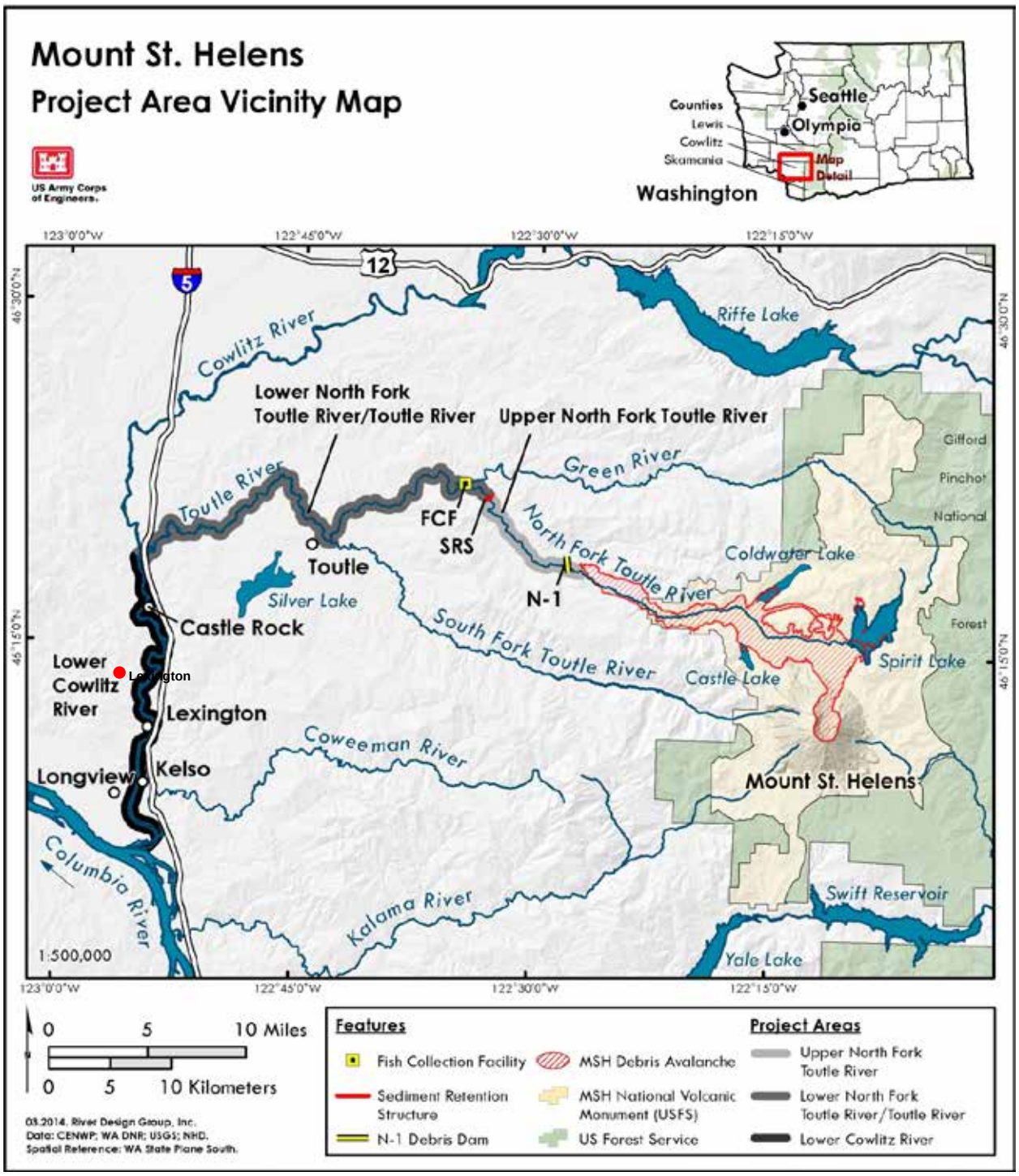
1.6. PROJECT LOCATION

The study area encompasses 1,200 square miles in southwest Washington, reaching north from the confluence of the Cowlitz River with the Columbia River to the headwaters of the North Fork Toutle River at MSH. A map of the study area is shown in Figure 1-1. The reach of primary interest for flood risk protection lies along the lower 20 miles of the Cowlitz River.

The Cowlitz River and its principal tributary, the Toutle River, are typical of rivers draining the west slopes of the Cascade Range. The terrain is mountainous and heavily forested except for clearcuts and areas devastated by the 1980 eruption. The Cowlitz River drains an area of 2,480 square miles including the Toutle River drainage area. Below its confluence with the Toutle, the lower 20 miles of the Cowlitz passes by the cities of Castle Rock, Lexington, Kelso, and Longview, Washington, before entering the Columbia River at RM 67.8.

The Toutle River basin primarily drains the northwest and southwest slopes of MSH and has a total drainage area of 512 square miles at its confluence with the Cowlitz River. The major tributaries of the Toutle River are its North Fork (NF) and South Fork (SF). The NF and SF Toutle rivers have their headwaters on the slopes of MSH and carry runoff and sediment westward to the Cowlitz River. The upper portion of the Toutle basin is managed as part of the Mount St. Helens National Volcanic Monument. The SF Toutle River drains 129 square miles and the NF Toutle drains 303 square miles, including 131 square miles from its tributary, the Green River. The NF Toutle basin includes three major lakes: Castle, Coldwater, and Spirit (see Figure 1-1). The lower Toutle River drains 80 square miles.

Figure 1-1. Mount St. Helens and Vicinity



The area affected by potential flooding varies from bottomland along the Cowlitz River to uplands at the base of the Cascade Mountains. Industrial riverfront and urbanized property lie adjacent to both the Columbia River and the downstream reaches of the Cowlitz River. Farther up the Cowlitz River, adjacent property generally changes from urban to agricultural land use. The upper portion of the Toutle River basin, except the volcanic and mudflow areas, is managed forestland.

1.7. HISTORY

1.7.1. Sediment Management Actions after 1980 Eruption

The May 18, 1980 eruption of MSH dramatically altered the hydraulic and hydrologic regimes of the Cowlitz and Toutle River valleys. Ash fall and the lateral blast from the eruption produced immediate and long-term effects on the hydrology of the Toutle watershed by changing its land cover and runoff characteristics. The excessive amount of sediment produced by the eruption and its aftermath was deposited downstream in the lower Toutle, Cowlitz, and Columbia rivers. The rapid influx of sediment reduced the channel capacities of the rivers affected. This left Castle Rock, Lexington, Kelso, and Longview in Washington with the potential for major flooding, even with normal runoff.

Emergency and interim measures were implemented by the USACE immediately after the eruption of Mount St. Helens. Temporary debris or check dam type structures were constructed across the NF Toutle River (N-1) and SF Toutle River (S-1) to immediately reduce the volume of sediment delivered to the Cowlitz River. Levees were raised along the lower Cowlitz River to prevent flooding and the Columbia River was dredged to eliminate the threat to navigation.

Figure 1-2. Post-eruption Dredging of the Cowlitz River

Eight sediment basins in the Cowlitz River drainage were operated from December 1980 to May 1981. Approximately 7.5 mcy of sediment was removed from the river course in this initial period. One of the larger sites, the Lower Toutle 1 (LT-1) dredge disposal upland site and sump, was located at river mile 1.5 on the Toutle River above the confluence with the Cowlitz River. The LT-1 site was re-opened during the winter of 1982-1983, and an additional 3 mcy was removed from the river. The LT-1 site was again operated during the winter of 1983-1984 with an estimated 4.5 mcy removed.

1.7.2. 1983 Comprehensive Plan

The 1983 Comprehensive Plan (USACE 1983) contained the first in-depth analysis by the USACE of the flooding and sedimentation problems resulting from the eruption of MSH. A sediment budget and a deposition analysis were developed as a basis for quantifying the size and duration of potential flooding and navigation blockage. A total of 1 billion cy was initially estimated to erode in the 50-year study period.

A least-cost analysis based on a 100-year benefits level was performed on five alternatives identified in the 1983 Comprehensive Plan for solving the sediment problem. A single SRS on the North Fork Toutle River upstream from the Green River was the most cost-efficient on the basis of the then predicted erosion rates and timing, and was selected as the most cost-efficient plan to achieve 100-year protection. A subsequent sensitivity analysis confirmed that the SRS remained the most cost-effective option, if the sediment budget was greater than approximately 54% of the predicted amount. This finding, as part of the Comprehensive Plan, was transmitted to the President in October 1983.

In a Memorandum to the Secretary of the Army, dated November 3, 1983, the Assistant Secretary of the Army for Civil Works requested that further analysis concentrate on one or more SRS structures at the lowest feasible site in the Toutle River basin. It was further directed that other stages or structures should be planned for construction, if and when needed. The rationale for proceeding with the feasibility stage of planning was founded in the unique nature of the problem created by the eruption. Consequently, the uncertainty of predicting erosion rates with field data from a very short post-eruption period necessitated a series of assumptions to predict the sediment budget. The Assistant Secretary stated that notwithstanding the best estimates of erosion rates, the actual stabilization of the basin by natural processes might occur more rapidly than anticipated. Thus, any programmed solution should provide flexibility to adjust to actual conditions.

1.7.3. 1984 Feasibility Study

A 1984 feasibility study was developed to recommend a permanent solution to the sedimentation and flooding problems for congressional authorization. The sediment budget was revised to indicate erosion of 650 million cubic yards (mcy) of material from the debris avalanche during the 50-year economic project life. A sensitivity analysis again concluded that the SRS was the best plan for handling erosion from the debris avalanche above 65% of the estimated sediment budget. After reviewing the feasibility report (USACE 1984), the Acting Assistant Secretary of the Army concluded that the concerns expressed in the November 3, 1983 Memorandum were still valid. As a result, three options – a SRS, a staged SRS and dredging – were to be evaluated during continuing planning and engineering.

1.7.4. 1985 Decision Document (Long-term Plan)

A Decision Document was completed in 1985 (USACE 1985). The 1985 report analyzed strategies for dealing with MSH-related sedimentation and resulting flooding in the Toutle/Cowlitz/Columbia river system. Measures considered included a single SRS constructed in one stage or multiple stages, dredging, and levee raises for communities along the lower Cowlitz River. The recommended plan identified a combination of a SRS (400-foot spillway) at the Green River site on the NF Toutle River, minimal levee improvements at Kelso, Washington, and dredging downstream from the SRS during its construction and in later years when the reservoir filled and allowed sediment to pass over the spillway.

The recommended plan was the National Economic Development plan, representing the alternative which produced the greatest net economic benefits among those considered. The approved plan also allowed flexibility to raise the spillway and/or crest of the structure if sediment monitoring showed more capacity was needed in the reservoir for either rare events (floods or mudflows) or unexpectedly high erosion from the avalanche. Social and environmental effects were considerably lower with this plan than any management strategy which depended principally on dredging. Mitigation for fish runs into the upper NF Toutle River was required in the form of construction of a fish collection facility.

2. IMPLEMENTATION OF THE 1985 DECISION DOCUMENT

This section provides a description and current status of the features implemented based on the authorized MSH project in the 1985 Decision Document (USACE 1985).

2.1. SEDIMENT RETENTION STRUCTURE

The SRS is located at RM 13.2 on the NF Toutle River, 30.5 miles above the mouth of the Toutle River. The SRS is a single-purpose structure designed to trap sediment eroding off the debris avalanche on MSH. The structure consists of an earth and rock fill embankment dam, an outlet works, and an ungated spillway excavated in rock. The SRS was constructed from 1987 to 1989 with a spillway crest at elevation 940 feet National Geodetic Vertical Datum (NGVD) and the top of dam at elevation 1,000 feet NGVD. The 60-foot differential between spillway crest and top of dam was required to safely pass the operating basis mudflow (OBM), defined as the maximum event for the North Toutle River valley during the effective lifetime of the project. The spillway width at the crest was constructed to be 400 feet. As sediment accumulated behind the SRS, the rows of outlet works pipes were buried and closed. The final, or top, row of pipes was closed in 1998. Since then, the NF Toutle passes down the spillway. During the time that NF Toutle flow passed through the SRS outlet works, the sediment trapping efficiency was approximately 92%. In 1998, the outlet works were buried by the sediment infill behind the dam. This resulted in permanently closing the outlets and forcing all river flow over the spillway and consequently more sediment flowing downstream of the SRS (SRS sediment trapping efficiency dropped to 31%).

The last periodic inspection of the SRS for the dam safety program occurred in 2013. The SRS and all its appurtenant features were found to be in safe operational condition and the project was deemed capable of fulfilling its design purpose. The SRS has currently trapped over 115 mcy of sediment.

Figure 2-1. Sediment Retention Structure after Construction (1989)

2.2. SPIRIT LAKE OUTLET TUNNEL

Spirit Lake is located about 5 miles north of MSH. The debris avalanche from the eruption blocked the natural outlet to Spirit Lake. By 1982, water in Spirit Lake was rising dangerously high behind debris dam left by the eruption. The debris dam was expected to eventually overtop which would likely result in breaching of the debris dam and severe downstream flooding. The USACE constructed and operated a temporary pumping station to relieve water pressure on the debris dam until a permanent solution could be implemented. The permanent solution was an 8,460-foot long by 12-foot wide by 12-foot high tunnel to carry water through Harry's Ridge into South Coldwater Creek to maintain a safe water elevation in Spirit Lake. Features of the permanent outlet included the tunnel, a vertical shaft, a gated intake structure, and an approach channel at the intake end. The tunnel was constructed by the USACE in May 1985 and the operation and maintenance of tunnel was turned over to the U.S. Forest Service. The last annual inspection of this tunnel, conducted by the USACE on behalf of the U.S. Forest Service, was conducted in 2013 and was found to be in safe operating condition.

2.3. FISH COLLECTION FACILITY

As the primary mitigation recommendation of federal and state fish and wildlife agencies during the initial evaluation of the SRS, a FCF was constructed in 1989 by the USACE, located 1.3 miles downstream of the SRS. The FCF serves as mitigation for adult coho salmon and winter steelhead fish passage impacts caused by the SRS (Figure 2-2 and Figure 2-3).

Figure 2-2. Fish Collection Facility during Construction

Figure 2-3. Fish Collection Facility

The authorization for the SRS was subject to the requirement that non-federal interests would operate and maintain the FCF. The agreement between the USACE and State of Washington was signed in 1986. As a result of the agreement, both parties engaged in a cooperative process to design the trap. The transfer of ownership to the State occurred in 1993. The WDFW, on behalf of the State of Washington, would continue to own, operate, and maintain the FCF indefinitely.

Fish trapped at the FCF are released into a transport tank on the FCF flatbed truck and hauled to one of two outplant sites on NF Toutle River tributaries located upstream from the SRS. The original outplant sites were located on Hoffstadt Creek and Alder Creek. However, the Hoffstadt Creek site was abandoned in mid-2000, as it was determined that a waterfall on Hoffstadt Creek was a complete fish passage barrier and limited the amount of spawning habitat accessible to outplanted fish. Outplant currently occurs on Bear Creek, a tributary to Hoffstadt Creek. Fall Chinook and summer steelhead trapped at the FCF are returned to the NF Toutle River downstream from the FCF.

2.4. BASE-PLUS DREDGING

"Base" refers to the base-level condition that corresponds to the nominal LOP available in November/December 1983 along the four levees on the lower Cowlitz River. These levees are the Castle Rock levee (left bank from RM 16.1 to 17.55), Lexington levee (right bank from RM 6.95 to 9.6), Kelso levee (left bank from RM 2.6 to 6.8), and the Longview levee (right bank from RM 3.1 to 5.5). Base-plus dredging was authorized in both the Toutle and Cowlitz rivers through the year 2035. This broad authorization was intended to encompass emergency measures. In 2008-2009, 2,662,000 cy of material were removed from the lower 3 miles of the Cowlitz River. This dredging was in response to a shoal that deposited in this area from a large sediment load delivered during a November 2006 event. No base-plus dredging has been performed on the Toutle River.

2.5. McCorkle Creek Pump Station Addition

McCorkle Creek enters the Cowlitz River at Lexington (Cowlitz RM 9.2) via a pumping facility. The eruption and emergency levee modifications impacted the capacity of the McCorkle Creek pumping facility in two ways. First, sediment and debris blocked the gravity flow outlet and raised the base level of the river. Second, the increased levee height resulted in additional head losses. Additional pumping capacity for the pump station was authorized to mitigate flooding along McCorkle Creek.

2.6. Levees

In the immediate years following the eruption of MSH, the levees in the lower Cowlitz River were raised and extended at Longview, Kelso, Lexington, and Castle Rock. These initial levee improvements, coupled with dredging the Cowlitz River channel to a greater capacity, were performed as an emergency reaction to the eruption and designed to provide protection to the population centers along the lower Cowlitz River. In order to make the emergency levee structures permanent, the 1985 plan included adding fill and revetment where necessary to provide additional stability. Figure 2-4 shows the location of the levees along the lower Cowlitz River.

2.7. Interim Actions

Since 2007, several interim actions were executed within the MSH project area to maintain authorized flood reduction benefits. These actions include lower Cowlitz dredging, minor levee work, and placing sediment trapping structures at the SRS and upstream of the SRS in the sediment plain.

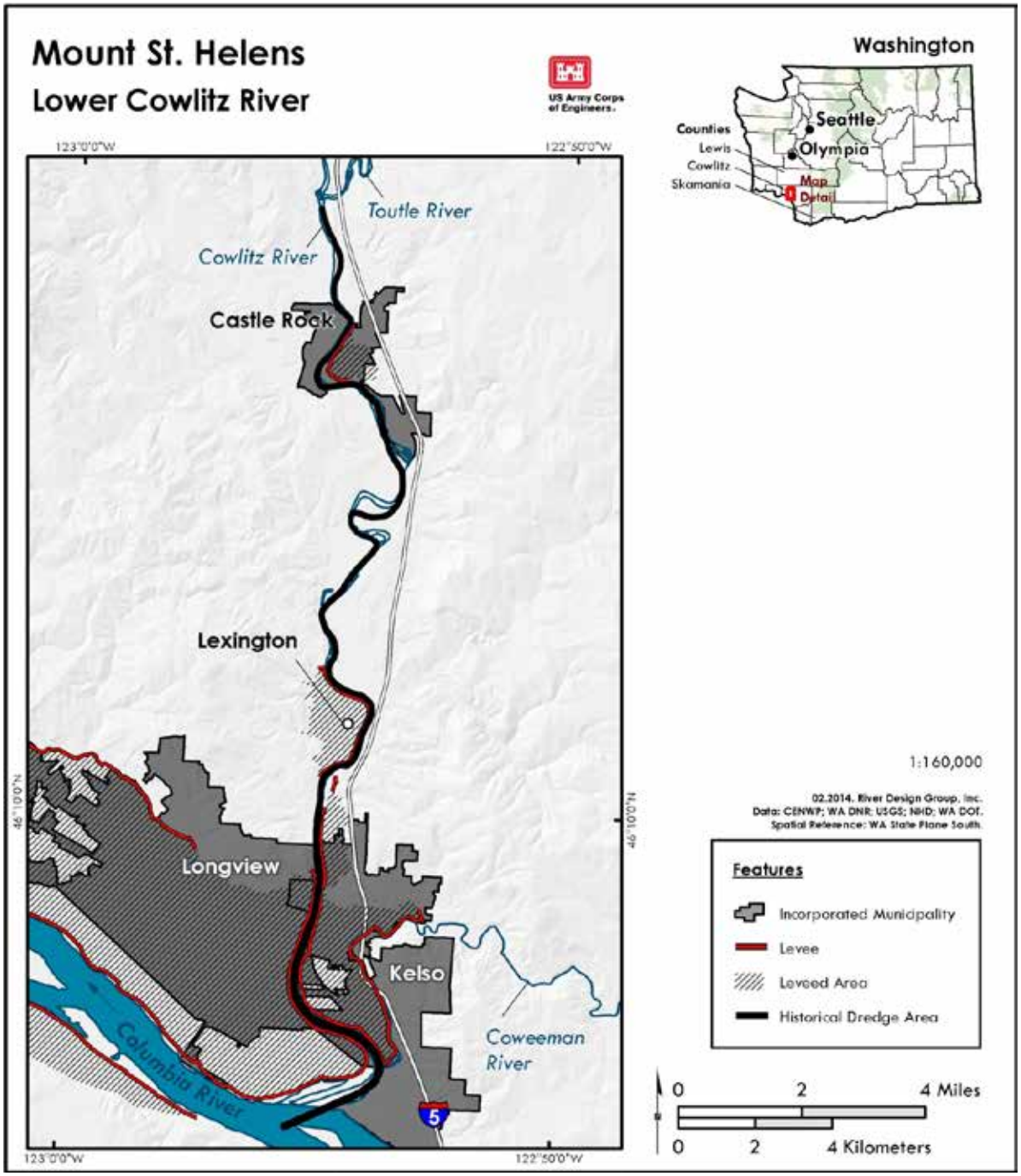
To date, implementation of the initial and recent interim flood risk management features for the MSH project have been successful in maintaining the congressionally authorized flood risk levels for the communities of Longview, Kelso, Lexington and Castle Rock. However, without the completion of the MSH project, trapping efficiency of the SRS would continue to decline and result in significantly increased flood risks in the lower Cowlitz River by 2018. In order to maintain authorized flood risk levels over the last few years, interim actions were implemented. The following subsections provide a summary of the interim actions completed since 2007.

2.7.1. Cowlitz River Dredging

In 2007 and 2008, the USACE dredged the lower 5.7 miles of the Cowlitz River (as measured from the centerline of the navigation channel in the Columbia River). This dredging was in response to the heavy sedimentation in the river during water year (WY) 2007 that resulted from a November 2006 event that delivered high sediment loads to the mouth of the Cowlitz River.

- From RM 0 to 0.6, about 2,188,000 cy of sediment was removed using a 30-inch pipeline dredge (*Oregon*) from November 2007 to February 2008.
- From RM 0.6 to 4.0, about 227,000 cy of sediment was removed using a 12-inch pipeline dredge (*Margeux*) from December 2007 to February 2008.
- From RM 4.0 to 5.7, about 246,000 cy of sediment was removed using a 16-inch pipeline dredge (Ross Island Dredge #10) from August to September 2008.
- In addition, 1,700,000 cy of material was dredged in November 2009 using the dredge *Oregon* from RM 0 to 0.6 on the lower Cowlitz River.

Figure 2-4. Location of Levees along the Lower Cowlitz River



Dredging the mouth of the Cowlitz benefits the lower part of the river to some upstream extent as the channel bed adjusts to the deepened sump created by dredging. At this point in time, the exact upstream extent of the benefit is unknown.

2.7.2. Castle Rock Levee Seepage Cutoff Wall

In 2008, the LOP for Castle Rock was estimated to be below 100 years, whereas the congressionally authorized LOP is 118 years. The USACE determined it would be prudent to improve the Castle Rock levee to return the LOP above the authorized level. In the fall of 2009, a 1,700-foot long segment of the Castle Rock levee upstream of the Arkansas Valley Road Bridge was improved. A seepage cutoff wall was constructed in part of the levee to achieve the improvement. This segment of levee was raised in 1980 after the eruption of MSH. The LOP was estimated to have dropped below 100 years due to increases in flood stages. Two factors caused the increased flood stages: (1) increased sediment deposition in the Cowlitz River, and (2) a preliminary hydrology update showing a change in the Cowlitz River's flow-frequency relationship. The result was a 2-foot increase in stage for the 100-year event. In addition to these changes in flood profiles, the confidence of the levee stability was influenced by the potential for under seepage. The failure fragility curve for the levee was influenced by this potential failure mode. To provide adequate factors of safety against seepage-related failure mechanisms, a 2.5-foot wide by 40-foot deep cement-bentonite seepage cutoff wall was constructed down the center of this segment of levee. The construction cost of this project was $1 million. The LOP for the Castle Rock levee upstream of the bridge is currently 406 years.

2.7.3. Grade Building Structures Pilot Project

In 2010, the USACE constructed a pilot project on the sediment plain above the SRS to test the constructability and performance of various grade building structure (GBS) concepts. The purpose of a GBS is to increase the amount of deposition within the sediment plain, effectively increasing the trapping efficiency of the SRS sediment plain system. The pilot project consisted of three main features: (1) a cross-valley structure (CVS); (2) 21 island-forming structures (IFS); and (3) a diversion berm. The initial construction cost for the pilot project was $3.5 million.

The performance of the pilot project was monitored closely in 2010-2011 over the wet season. LiDAR (light detection and ranging) data was obtained immediately after construction in 2010 and again in 2011 to evaluate the total volumes of deposition and erosion around the structures project. Sediment samples were taken twice over the monitoring period to determine the kinds of sediment trapped by the structures.

2.7.4. Sediment Retention Structure 7-foot Spillway Raise

An interim 7-foot SRS spillway raise at was constructed in 2012 to increase the sediment storage capacity of the SRS and reduce flood risk in the lower Cowlitz River. The main features of the 7-foot spillway raise included a roller-compacted concrete (RCC) structure founded on rock, and a plunge pool/low-flow channel excavated in rock from the new concrete structure to the existing spillway crest. Behind the SRS, a shallow pool of about 1 mcy over 200 acres resulted from the raise. The RCC section, plunge pool, and low-flow channel excavated in rock were designed to maintain downstream fish passage. The 7-foot spillway raise structure was set back from the existing spillway crest; if there would be future spillway raises, the downstream slope would be 7% or the slope of the existing spillway.

At the time of construction, it was expected that sediment would fill to the elevated spillway crest within 1 to 2 years. Observations has shown that within 2 years, the pool has nearly been filled in by sediment and a larger low flow channel has formed just upstream of the spillway where the crest shape shows a notch. During drier summer months, vegetation has grown in areas that are not inundated with summer flows. This vegetation growth is a significant change from previous characteristics of the sediment plain upstream of the SRS where no vegetation growth was observed. This change was likely due to the

change in the spillway-rating curve caused by the notched weir. During the winter months, this vegetation was inundated with flow and largely wiped out.

2.8. ONGOING SEDIMENT MONITORING

The *Mount St. Helens Sediment Control, Cowlitz and Toutle Rivers, Washington, Sediment Retention Structure Sediment Ranges, Design Memorandum No. 11* (December 1986) established a monitoring program to determine sediment deposition upstream and the resulting downstream impacts of the SRS. Downstream impacts include a determination of whether the designed LOP is being maintained along the lower Cowlitz River. The monitoring program also provides the data required for planning and designing of additional remedial actions if needed. Components of the system have evolved with changes in project conditions. Primary monitoring elements included continuous flow and sediment gages on the Toutle and lower Cowlitz Rivers, cross section and terrain data for the SRS, and cross-section data for the lower Cowlitz River that are reported in Annual Hydraulic Summary reports.

2.9. RELEVANT REPORTS/COLLECTED DATA

Provided below is a list of evaluations/studies that have been completed since the project was authorized. These reports provide important information/data that has been used to develop the updated long-term sediment management plan documented in this LRR:

U.S. Army Corps of Engineers Portland District, 1987. Mount St. Helens Sediment Control, Cowlitz, and Toutle Rivers, Washington. Design Memorandum No. 10, Sediment Retention Structure Fish Collection Facility. This design memorandum presented the description, criteria, and design of the fish collection facility constructed by the USACE as mitigation for the SRS. It also discussed interim fish collection.

U.S. Army Corps of Engineers Portland District, September 1997. Cowlitz River Flood Hazard Study, Cowlitz County, Washington. This study provided estimates of safe protection at authorized communities along the lower 20 miles of the Cowlitz River following the February 1996 flood event. Castle Rock levee was below authorized levels. Kelso, Longview and Lexington levees were above authorized levels. Flood frequency relationships were restudied using a longer period of record.

U.S. Army Corps of Engineers Portland District, April 2002. Mount St. Helens Engineering Reanalysis, Hydrologic, Hydraulics, Sedimentation, and Risk Analysis Design Documentation Report. This report reassessed the LOP for each Cowlitz River levee and determined the risk of flooding was high before the year 2035 at the damage reaches. The study showed when the LOP at Castle Rock, Lexington, Longview, and Kelso levees would drop below their authorized LOP. The report recalculated the 1996 LOP using new index points developed by the USACE. The hydraulic model used for the sediment and flood damage reduction analysis was a simplified version of the model developed in the 1997 report. It was noted that the water surface profile for the simplified model compared well to the original model for 1996. The LOP for all index points was greater than the 500-year level. In addition, basic physical and hydraulic data was developed to allow for further alternative analysis.

U.S. Army Corps of Engineers Portland District, December 2005. Cowlitz River Basin Hydrologic Summary, Water Years 2003-2004. This report summarized annual rainfall events and the largest instantaneous discharges at the Toutle River Tower Road station and at the Cowlitz River Castle Rock station. The report also showed the annual amount of sediment deposited upstream of the SRS and what is passed downstream.

U.S. Army Corps of Engineers Portland District, August 2006. Mount St. Helens Project, Cowlitz River Levee Projects—Level of Protection and Sedimentation Update. This report documented that the flood damage reduction benefits provided by the levees along the lower Cowlitz River had been degraded by current sedimentation processes. The observed trend of continued loss of channel capacity was expected to continue and spread upstream, further reducing the LOP. The analysis reports flood damage reduction values for 1996, 2003 and August 2006. The 1996 values vary from both the 1997 and 2002 reports. No explanation is provided in the 2006 report; however, discussions with USACE personnel who worked on the report indicated that an error was found in the Hydrologic Engineering Center Flood Damage Reduction Analysis (HEC-FDA) runs used in the 2002 report. The 1996 values reported in 2006 are reportedly corrected values from the 2002 analysis. The 2003 and August 2006 values utilized fragility curves developed in 2002, hydrology developed in 1997 and new hydraulic models to reflect deposition in the lower Cowlitz.

U.S. Army Corps of Engineers Portland District, July 2007. Mount St. Helens Ecosystem Restoration, General Reevaluation Study Reconnaissance Report. The purpose of this study was to determine if there was a federal interest in pursuing ecosystem restoration actions in the Toutle River watershed, while maintaining congressionally authorized levels of flood damage reduction for communities along the lower Cowlitz River. A range of potential ecosystem restoration measures and the associated costs and environmental benefits were identified and compared to existing conditions. From this report, the USACE decided that there was a federal interest in modifying the SRS spillway to allow for volitional upstream fish passage. Although work began on a design, it was put on hold until the long-term sediment management plan is established.

U.S. Army Corps of Engineers Portland District, February 2010a. Mount St. Helens Project, Cowlitz River Levees Safe Water Level Study. In 2009, the original levees on the Cowlitz River protecting Castle Rock, Lexington, Kelso, and Longview were reevaluated to update their safe water levels (SWL). The Coweeman levee on the east side of Kelso was also evaluated. Provided below are the findings from the report.

- For Castle Rock and Lexington levees, the SWL was at or above 1980 design water surface (DWS).
- For the Longview levee, the SWL was at the 1980 DWS. For several low sections, it was assumed that the Longview Diking District could reliably raise the levee temporarily to achieve a SWL equal to the 1980 DWS.
- For the Kelso levee, the SWL was the 1980 DWS except in two locations: (1) upstream of the sheet pile wall near the upstream end of the levee (North Kelso); and (2) the approximately 1,300 feet long section south of Olive Street and parallel to South River Road (South Kelso). The railroad grade was the SWL for a short distance just upstream of the sheet pile wall near the upstream end of the system. For the section south of Olive Street, with South River Road running along the interior toe of the levee, the SWL was approximately 3 feet below the levee top. The reason for the lower SWL here was the removal of dredge spoils adjacent to the riverward side of the levee, and the resulting harmful seepage through the levee predicted at elevated river stages.
- For the Coweeman levee, the SWL was the peak stage at the mouth of the Coweeman River in the 1996 flood event, which was above the 1962 DWS.

U.S. Army Corps of Engineers Portland District, February 2010b. Mount St. Helens Project Cowlitz River Levee Systems, 2009 Level of Flood Protection Update Summary. This report provided an updated estimate of the LOP at Kelso, Longview, Lexington and Castle Rock. New levee fragility curves,

hydrologic analysis, and hydraulic model were developed. The Castle Rock levee was below authorized levels. The Kelso, Longview and Lexington levees were above authorized levels.

Biedenharn Group, LLC, May 2010. Toutle/Cowlitz River Sediment Budget. In the onset of the current planning study for the sediment management plan, the Biedenharn Group, LLC was retained under contract with the Portland District to develop a comprehensive sediment budget for the Toutle basin. The purpose of the Biedenharn study was to present a sediment budget for the Toutle basin that identifies the existing watershed sediment sources, pathways of sediment transport and sinks of temporary storage of sediment based on all available data at the time as well as existing basin conditions. The results from this study were used to forecast sediment loads out to 2035.

U.S. Army Corps of Engineers Portland District, June 2010. Mount St. Helens Long-Term Sediment Management Plan for Flood Risk Reduction Progress Report. This report provided the progress made on the long-term sediment management plan alternatives analysis. The report summarized the updated sediment budget and the evaluation of the current conditions of the Mount St. Helens project features. Sixteen individual measures were identified and screened for continued analysis. An Agency Technical Review was performed on the Progress Report.

U.S. Army Corps of Engineers Portland District, April 2011. Mount St. Helens Future Expected Deposition Scenario (FEDS). This report introduced the hydraulic and sediment transport tools used to evaluate the performance of alternatives for the long-term sediment management plan. The tools were used to evaluate the future expected deposition in the Cowlitz River for the scenario in which no further measures are applied. In this scenario, the total deposition in the Cowlitz River between the Toutle and the Columbia was estimated to be 37.7 million tons (about 30 mcy); the LOP for Castle Rock, Lexington, Kelso, and Longview dropped significantly, with Castle Rock and Lexington almost certainly dropping below the authorized LOP.

U.S. Army Corps of Engineers Portland District, August 2011. Development of the PMF for the SRS. This report updated the probable maximum flood (PMF) for the SRS based on current data and methodologies. The new PMF inflow was 120,218 cubic feet per second (cfs) as compared to the original value of 213,000 cfs.

U.S. Geological Survey, 2011. Impact of Catastrophic Flood Events and Debris Flows on the Sediment Retention Structure, North Fork Toutle River, Washington (Open File Report 2011-1317). Roger Denlinger updated the mudflow scenarios and modeling for the SRS. Potential mudflows originating from the Mount St. Helens crater and from a failure of the debris avalanche blockage forming Castle Lake did not reach the SRS in the modeling.

U.S. Department of Agriculture, 2012. Analysis of Long-Term Sediment Loadings from the Upper North Fork Toutle River System, Mount St. Helens, Washington (NSL Technical Report Number 77). Andrew Simon, a researcher at the National Sedimentation Laboratory, was contracted to evaluate stability and erosion rates of the banks within the debris avalanche. The data presented a non-linear decay in predicted sediment load from 1980 out to 2035. Future load predictions were made of annual sediment loads based on a combination of field data and computer simulations. The study predicted a cumulative total from 1980 to 2035 of 430 mcy and potentially 510 mcy from 1980 to 2110.

U.S. Army Corps of Engineers, Portland District, June 2013. Mount St. Helens, Washington Design Documentation Report No. 16, Sediment Retention Structure 7-foot Spillway Raise. This Design Documentation Report (DDR) provided background information and documented the design for an

interim 7-foot spillway raise at the MSH SRS. The spillway raise was needed to increase the sediment storage capacity of the SRS and to reduce flood risk in the lower Cowlitz River.

U.S. Army Corps of Engineers, Portland District, 2012. Mount St. Helens Sediment Retention Structure Spillway Raise. A lessons-learned report about the construction of the SRS 7-foot spillway raise.

Colin Thorne, Josh Townsend and Todd Ashley, 2014. Geomorphic and Ecological Assessment and Evaluation of Grade Building Structures on the SRS Sediment Plain, North Fork Toutle River. The pilot project was installed in the sediment plain in 2010 to test various methods of trapping sediment. This study re-visited these structures and assessed their performance over the 3-year period. The aim of this project was to assess, evaluate and visualize the morphological, sediment and ecological performance of the fourteen engineered log jams constructed in the 2010 pilot project. The other elements of the pilot project listed above were excluded on instruction from the Portland District.

3. OVERVIEW OF THE LIMITED REEVALUATION STUDY

3.1. INTRODUCTION

The Limited Reevaluation study updates the 1985 long-term implementation plan for managing sediment from the MSH debris avalanche in order to maintain authorized LOPs for communities along the lower 20 miles of the Cowlitz River through the year 2035. The study evaluates the remaining actions that are required to complete the MSH project and to maintain the authorized LOPs. The intent of the study was not to reformulate the MSH project, but rather to incorporate any changes and identify the least-cost approach to complete the project, while minimizing environmental and other negative impacts. Inputs that support the updated plan include:

- Changes in the physical conditions of the project area:
  - future sediment yield from the debris avalanche;
  - sediment budget from MSH to the mouth of the Cowlitz River;
  - current status/effectiveness of the MSH project features; and
  - design flood criteria for the SRS (design mudflow, probable maximum flood).
- Documentation of FEDS under without project conditions and the continued need for flood risk protection.
- Assessment of flood risk reduction effectiveness for a range of measures including cost-effectiveness and environmental impacts.
- Description of viable alternatives within existing authority and determination of the recommended plan to finish the authorized project and comply with NEPA and ESA.

3.2. LEAST-COST EVALUATION APPROACH

In the Water Resources Development Act of 2000, Congress directed the USACE to maintain the authorized LOP through 2035 for the levees at Longview, Kelso, Lexington, and Castle Rock. The purpose of this analysis is to determine which alternative provides the specified LOP for the least cost. The analysis identifies the least-cost plan based on the life-cycle cost data provided by Portland District's Engineering Division. It should be noted that no new benefits analysis was undertaken for the purpose of project justification. The original benefits analysis was updated in 2012 and this verified the anticipated future benefits of the authorized project would be accrued with maintaining the LOP levels.

In order to compare the life-cycle costs of each of the long-term alternatives at a common point in time, the team laid out future actions associated with each alternative beginning in 2018. The team laid out anticipated future actions, and the timing associated with those actions, to continue to provide the specified levels from 2018 through 2035.

The least-cost approach allows for a comparison of the costs related to various measures, given the goal of maintaining the authorized LOP levels. For those measures that could not achieve the specified levels of protection as stand-alone measures/alternatives, the team identified which measures could be combined to provide an alternative that would meet the authorized LOP levels.

3.3. PUBLIC OUTREACH

3.3.1. Scoping Meetings

Scoping is the initial stage of the process to prepare a SEIS as part of the long-term sediment planning of alternatives. These meetings were used to identify issues, alternatives, and impacts to be addressed in the NEPA analysis. Public comments were accepted from the date of publication of the Notice of Intent on December 21, 2012 until April 6, 2013. Two public meetings were held in Kelso and Toutle, Washington on March 6 and 13, 2013, respectively. Forty-four people attended the public scoping meetings. Staff from the Portland District provided a brief presentation to provide participants with an understanding of the proposed alternatives and how the NEPA process would be used to select an alternative, with specific attention to how and when the public may provide input. Participants were engaged in a question/answer-session with USACE staff and were asked to submit written comments either at the meeting or at a later date through the mail or email.

Comments received from the public were generally concerned with fish and fish habitat; visual impacts; cultural resources; endangered species; wildlife and habitat including elk and the MSH Wildlife Area managed by the Washington Department of Fish and Wildlife (WDFW); flood-risk management; hydrology and water quality; placement of dredged sediments; effects analysis; alternatives; presentation of analysis results; and finances. The USACE reviewed and considered all these comments as part of the Limited Reevaluation study and SEIS process.

3.3.2. Cooperating Agency

The Council of Environmental Quality regulations implementing NEPA directs lead agencies to conduct NEPA analyses and prepare documentation in cooperation with agencies with jurisdiction by law or special expertise (40 CFR 1501.6 and 40 CFR 1508.5). The WDFW agreed to be a cooperating agency through this planning process. The USACE has coordinated extensively with WDFW during scoping and preparation of the SEIS and LRR, particularly regarding technical issues of fish and wildlife management.

The WDFW has provided the USACE with a draft statement of their vision and values with respect to its participation as a cooperating agency. The vision statement was generally consistent with the project's purpose and need: management of sediment from the NF Toutle River in manner that minimized flood risks and supported a healthy, functional ecosystem with minimal human intervention. Values supporting the vision statement included:

- Desire for a healthy functioning Toutle River system that is sustainable.
- Maintaining community safety and minimizing long-term impacts to the environment are not mutually exclusive goals, but can and should work in tandem.
- Common ground that supports healthy, sustainable fish and wildlife populations, while reducing flood risks associated with sediment resulting from the eruption is achievable.
- Creativity and innovation solutions are valued.
- Differences should be respected and mutually agreeable remedies should be sought whenever possible.

Prior to completion of the Draft SEIS, WDFW withdrew their cooperating agency status in a letter to USACE on August 14, 2014.

3.3.3. Technical Agency/Government Team

A Technical Agency/Government Team (TAGT) was formed in October 2012 as a panel of representatives from regional agencies and governmental and tribal entities. This panel has been coordinating the development of the updated MSH sediment management plan. The key purpose of the TAGT is to provide a forum for information exchange in order to assist the USACE and study sponsors in developing and implementing actions in the Toutle River basin that would address sediment management concerns and potentially contribute to the restoration of the ecosystem. The TAGT first met in October 2012 and has met multiple times, including a meeting at the FCF and site visit. These meetings provided a forum to keep sediment management plan stakeholders updated on available data regarding sediment movement, current LOP at the levees, and to present the results of fish and wetland monitoring efforts. The USACE proposes to continue facilitating the TAGT through the adoption and implementation of the updated sediment management plan.

3.3.4. Public Comment

The NEPA process incorporates public involvement in the decision-making process for the updated MSH sediment management plan. To satisfy this requirement, the USACE would solicit public comments on the draft SEIS and hold multiple public meetings to present details of the updated plan for additional public review and feedback. All comments received during the public review period would be evaluated and responses compiled in the document following the close of the comment period.

4. CHANGED PHYSICAL CONDITIONS IN THE PROJECT AREA

4.1. UPDATING SEDIMENT YIELDS

4.1.1. Introduction

Immediately after the 1980 eruption of MSH, it was determined that significantly increased sediment yields from the watercourses affected by the blast could produce excessive sediment loadings to the Toutle and lower Cowlitz rivers for an extended period of time. It was also recognized that future sediment yields would be the most significant factor in sizing any sediment management solution to maintain the authorized LOPs for the lower Cowlitz River levees. A significant effort was made to predict future sediment loadings.

4.1.2. Historical Sediment Estimates

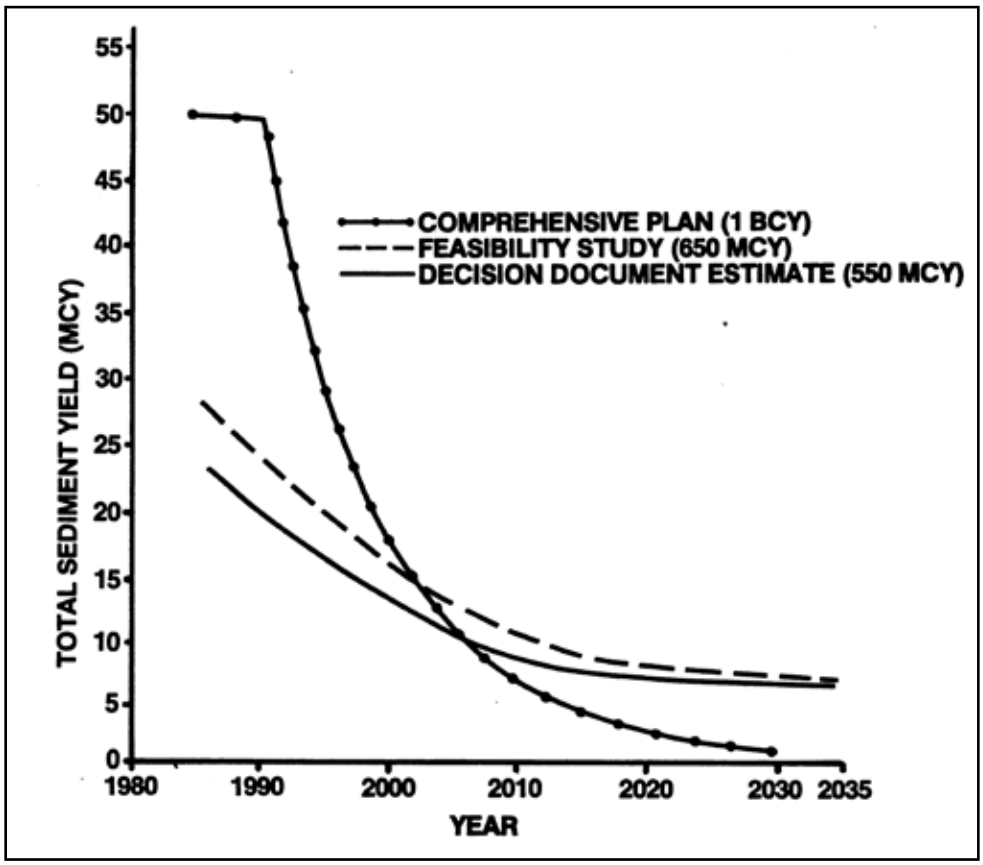
In the early planning years immediately post-eruption, estimates of total sediment yield from the debris avalanche varied greatly (Figure 4-1). As additional data was collected and analyses were performed, the total estimate of sediment yield decreased from 1 billion cy in the 1983 Comprehensive Plan (USACE 1983) to 550 mcy in the 1985 Decision Document (USACE 1985). The estimate and assumptions from the Decision Document were used to inform the selected plan and provided the basis for the SRS design and out-year dredging. All three early estimates assumed a decaying sediment yield through 2035. The Decision Document curve predicted the least decay in sediment yield in the final decades of the 2035 planning period. In the Decision Document, the USACE expands the discussion on these curves by mentioning variability in yield:

> "… it must be kept in mind that the sediment estimate reflects long-term average conditions. Part of the average is accounted for by low probability floods and mudflows, events in which substantial volumes of sediment are transported. Thus in a year with a low probability event, sedimentation can far exceed the average curves represented in the illustrations of the budget outputs. On the other hand, low flow periods would produce less sediment than shown on the average."

4.1.3. Studies Arguing for No or Minimal Decay in Sediment Yield

Major and others (2000) investigated the sediment yield from Mount St. Helens following the 1980 eruption to provide a two-decade perspective. Their paper looks at sediment loadings from watersheds draining Mount St. Helens that were affected by the eruption, including effects from the blast, lahar, and debris avalanche. The investigative process relied on suspended sediment data collected by the U.S. Geological Survey (USGS) in the Toutle River system and SRS deposition volumes calculated by USACE to estimate an annual sediment load to the USGS Kid Valley gage location below the SRS for WY 1982 to 1998.

Figure 4-1. Historic Estimates of Debris Avalanche Sediment Yield



Major and others (2000) concluded that, "Sediment yields in the aftermath of explosive volcanic eruptions typically decline nonlinearly as physical and vegetative controls diminish sediment supply. However, spatial and temporal perturbations resulting from hydrologic functions are likely to punctuate, or even temporarily reverse, long-term trends, which complicate projection of time to equilibrium." These reversals in the sediment supply can be seen in the 1996 and 2006 hydrologic events. High sediment yields are associated with each event and higher than average sediment yields persist for two or more years following each event.

Speaking specifically about long-term sediment yield from the basin, Major and others (2000) concluded that, "…yields from basins that experience dominantly channel disturbances will likely remain elevated for as much as several decades. Thus, measures designed to mitigate sediment transport in the aftermath of severe explosive eruptions must remain functional for decades." This is a fair and direct warning regarding the current sediment management effort. In Major (2004), this warning is reiterated, "Persistent extraordinary suspended sediment yields from severely disturbed channels indicate that mobile supplies of sediment remain accessible, and those supplies will not be exhausted for many more years or possibly decades."

Major and others (2000) identified the persistently high sediment yield basins as those that had valleys coated by lahar deposits. The mechanism for this persistent high yield was described as, "complex cycles of incision, aggradation and widening. …channel adjustments become discharge

dependent, and sediment entrainment relies primarily on bank collapse during trench widening, rather than bed scour. If bank stability persists, high sediment yield persists." Yields from basins affected primarily by blast pyroclastics reduced to background levels within 5 years of the eruption as evidenced in the Green River.

Recent work on long-term post-eruption sedimentation at Mount Pinatubo, Philippines has supported the findings of Major (2000, 2004). Gran and others (2011) looked at sediment yields and depositional rates in two streams draining the east flank of the volcano. Both basins were impacted by the 1991 eruption similarly, mass filling of the valleys with pumaceous pyroclastic-flow deposits and a hillslope blanket of air-fall tephra. An 18-year analysis of depositional rates indicates that, "Patterns of long-term sedimentation are similar to those of the North Fork Toutle River (Washington State, United States) at Mount St. Helens, with two phases of erosion and sediment export" (Gran et al. 2011). Gran and others (2011) go on to describe the two phases thusly:

> "… sedimentation yields declined exponentially at first, but an exponential decay model was insufficient to describe the long-term sedimentation in basins with significant channel disturbance. Although an exponential decay model appears to describe the first phase of erosion quite well, from hillslope tephra erosion and valley network development, continued fluvial instability is not captured by the exponential decay model. At Mount Pinatubo and Mount St. Helens, sediment export rates leveled off at rates one to two orders of magnitude higher than pre-eruption or background levels, remaining high for at least 20 years following the eruption."

4.1.4. Studies Arguing for Decay in Sediment Yield

Simon and Klimetz (2011), through funding from the USACE, investigated the potential for decay of future sediment yield from the debris avalanche. The approach taken was to investigate changes in the channel cross section surveys performed on the debris avalanche from 1980 through 2010. Thirty cross sections ranging from the SRS to nearly the crater that had been periodically surveyed were collected and cataloged. Changes in cross sectional area at each cross section were divided between bed and bank erosion for each time increment. Non-linear regressions of bed and bank erosion at each cross section over time were solved for a range of years and multiplied by the distance to the next downstream cross section to obtain erosion volumes. Cumulative erosion of sediment delivered to the N-1 structure was calculated by this method.

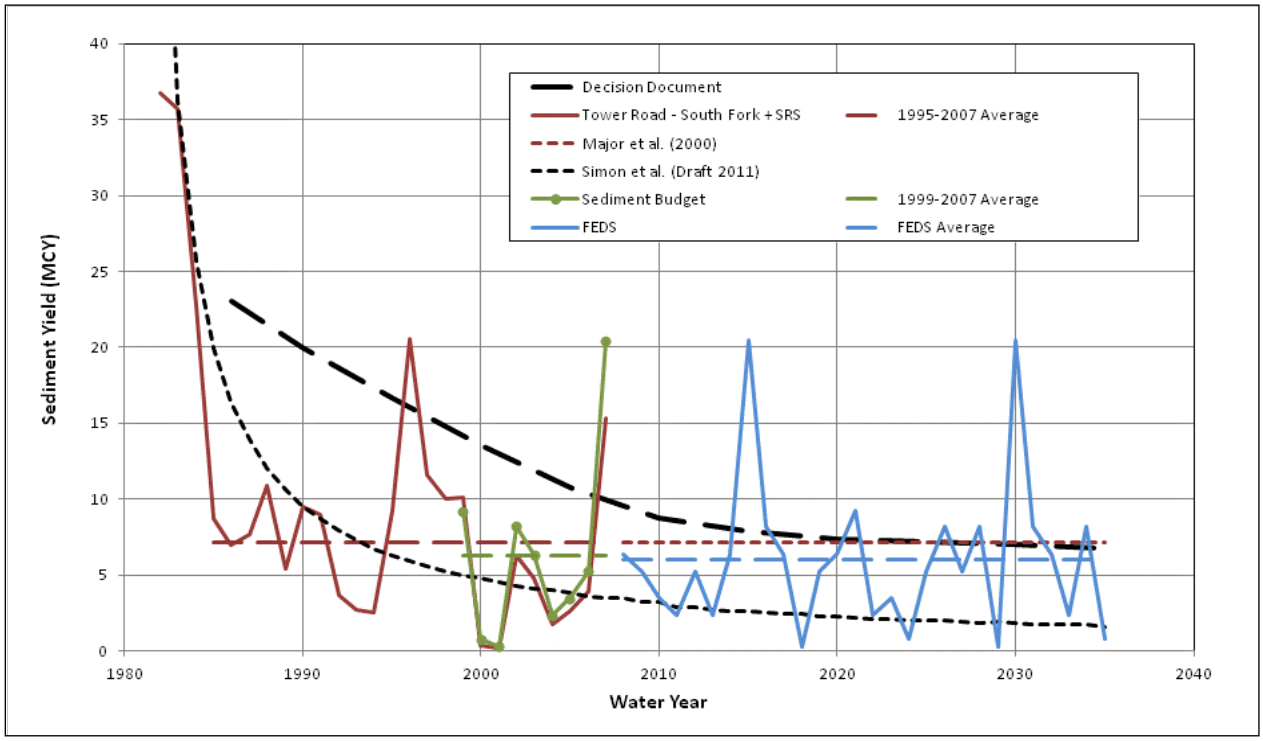
It was determined that a large portion of the observed incision occurred during three periods of variable length: (1) high flows in 1982, which included the Jackson Lake breakout and drawdown debris-jammed channel breakout. The study concluded that lateral erosion has become the pumping of Spirit Lake, (2) the February 1996 flow event, the largest recorded post eruption hydrologic event (near a 1% exceedance probability), and (3) the November 2006 event that combined a 100-year precipitation event on bare ground with a drainage area capture and possible dominant process and source of sediment in the system contributing approximately 80% of the material is eroded from the channels. The non-linear curves fit to observed data necessarily predicted a future with decaying sediment yields from the debris avalanche. While the study did not specifically address changes in variability, the conclusion was that long-term sediment yield was expected to decay for the foreseeable future barring another significant disturbance to the mountain.

4.1.5. Adopted Approach for Future Sediment Yield

The FEDS report (USACE April 2011) presents the adopted approach used to represent the debris avalanche sediment loads for the planning horizon of the long-term sediment management alternative analysis. This adopted approach attempts to apply a reasonable yet conservative estimate of future sediment yield along with an estimate of sediment load variability. Due to the high degree of variability in the daily flow-sediment load relationship observed in the basin, it was determined that relying on observed data to create the future conditions was superior to creating a synthetic flow-load series. The data used to the create the future series was taken from the sediment budget (USACE 2009), a document that attempted to integrate all sediment related data in the Cowlitz Basin to create the most accurate estimate of annual sediment sources and sinks since the SRS began operating as a run-of-river spillway in 1998.

To apply a measure of conservatism in the estimate of future sediment loading, the no-decay assumption based on Major and others (2000) was applied to create the data set. Years of coupled data (sediment and hydrologic) were randomly selected from the pool of data in the sediment budget. These years were compiled into a series starting in 2008 and extending through 2035. This was done thousands of times until and full statistics of random selection were known. A single series of years was selected that represented the median condition for both sediment and hydrologic metrics. That series of years was developed into daily flows and sediment loads using observed data and used as the future condition. Many series were available that met the median requirement; in selection a series was selected that showed a similar distribution of peak events to the observed series. This prevented selection of a series dominated by only very high and very low datasets. Since a median series was selected, no additional conservatism was added to the assumption of no decay in debris avalanche sediment yield. Figure 4-2 shows the historic and current estimates of sediment yield, as well as interpretations of yields predicted by relevant scientific studies.

Figure 4-2. Adopted Approach to Future Sediment Yield



4.1.6. Sediment Yield Uncertainty and Desire for Adaptability

A relatively high degree of uncertainty still exists regarding future sediment yield from the debris avalanche, both in terms of total yield and variability of yield. The best available scientific analyses of future yield have widely varying conclusions, a near future of persistent high load or one of continued decay. Data collection into the future would be the best (any maybe only) way to know with certainty how sediment yields from large volcanic debris avalanches mature. Variability of load also would be important in understanding depositional trends in the Cowlitz River. The mechanisms for variation are well understood and have been documented from the early years following the eruption. Unfortunately, these mechanisms cannot be controlled or even predicted. In addition, little information is available to predict if the magnitude of this variability would change in time. The fundamental tenets that Simon and Klimetz (2011) relied upon would suggest decay in the magnitude of variability; however, this would be highly uncertain.

In order to respond to this inherent uncertainty in the primary driver of sedimentation in the Cowlitz River (sediment yield from the debris avalanche), an adaptive approach would be desirable. Any feasible management strategy should be able to accommodate the conservative sediment input of the adopted approach, but would preferentially be scalable if significant decay would occur. It is expected that an adaptable approach would be less costly if decay occurs and later components are not constructed.

4.1.7. Sediment Yield Conclusion

The greatest degree of uncertainty regarding future deposition in the lower Cowlitz River involves the unknown future sediment loads that come from the debris avalanche. Initial estimates from the 1985 planning effort assumed some decay in the avalanche erosion; however, since the estimates were based only on limited data, reevaluation of this forecast was necessary in the current planning process. While there are some expert opinions that significant decay in avalanche erosion would be likely, other studies suggest that spikes in the sediment load delivered to downstream structures could punctuate any decay in average erosion.

To apply a measure of conservatism in the estimate of future sediment loading, the no-decay assumption was applied to the forecast of future sediment loads from the debris avalanche. However, to respond to this inherent uncertainty in the primary driver of sedimentation in the Cowlitz River (sediment yield from the debris avalanche), an adaptive approach would be desirable. Any feasible management strategy should be able to accommodate the conservative sediment input of the adopted approach, but would preferentially be scalable if significant decay would occur.

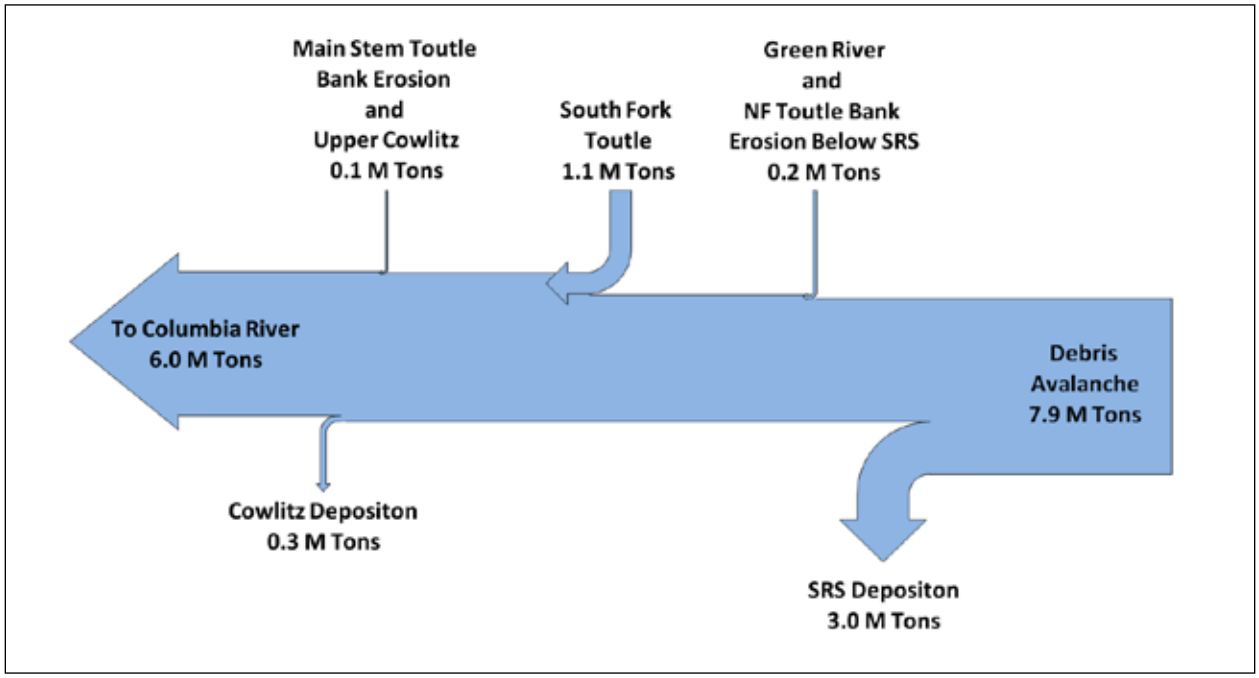
4.2. SEDIMENT BUDGET UPDATE

Sediment budgets from the original planning studies performed in 1985 estimated the sediment budget for the Toutle watershed based on the limited data available from the eruption in 1980 to 1985. Since these original estimates, the USACE Portland District authored numerous engineering reports pertaining to distribution of sediment within the Toutle River basin in relation to the various projects of MSH. This information was published in annual hydrologic summaries, available for most years, and several river sedimentation studies.

In the onset of the current planning study for the sediment management plan, the Biedenharn Group, LLC was retained under contract with the Portland District to develop a comprehensive sediment budget for the Toutle River basin. The purpose of the Biedenharn study was to present a sediment budget for the basin that identifies the existing watershed sediment sources, pathways of sediment transport and sinks of temporary storage of sediment based on all available data at the time as well as existing basin conditions. The results from this study were used to forecast sediment loads out to 2035.

The Biedenharn sediment budget relies heavily on USGS gages in the Cowlitz River and Toutle River basins, which provide a long-term estimate of the suspended sediment loads. An unbroken data records extends from the present to, in some cases, the early years immediately after the eruption. More recently, bathymetric surveys in the lower 20 miles of the Cowlitz channel have provided a record of sediment deposition since 2009. LiDAR has added to this information by providing sediment plain deposition data to characterize the persistent sediment loads coming from the debris avalanche. This information collected has been vital to the understanding of the sediment distribution of the basin, an understanding of the problem to be analyzed, and a basis for comparing benefits from the various measures under consideration. The importance of this data in the analysis of the alternatives cannot be understated. A synthesis of the available information up to 2009 can be found in the latest sediment budget (Biedenharn Group 2010), a summary of which can be found in Figure 4-3.

Figure 4-3. Average Annual Sediment Budget 1999-2007



Source: Biedenharn Group 2010

Sediment loads in the Toutle River are derived from localized bank/bed erosion from the debris avalanche, the North Fork below the debris avalanche, the Green River, the South Fork, or the Toutle River below all these tributaries. By and far the largest source of sediment loads are derived from the debris avalanche. Table 4-1 summarizes the relative contribution of sediment loads into the Toutle River from these various sources.

Table 4-1. Summary of Sediment Sources in Toutle River Basin

Sediment Source	Average Percent of Total
Bank Erosion North Fork - Elk Rock to SRS	5
Bank Erosion North Fork below SRS	3
Bank Erosion South Fork	2
Bank Erosion Toutle River	1
Green River Sediment Source	1
Mt St Helens Debris Avalanche North Fork	**80**
Mt St Helens Debris Avalanche South Fork	8

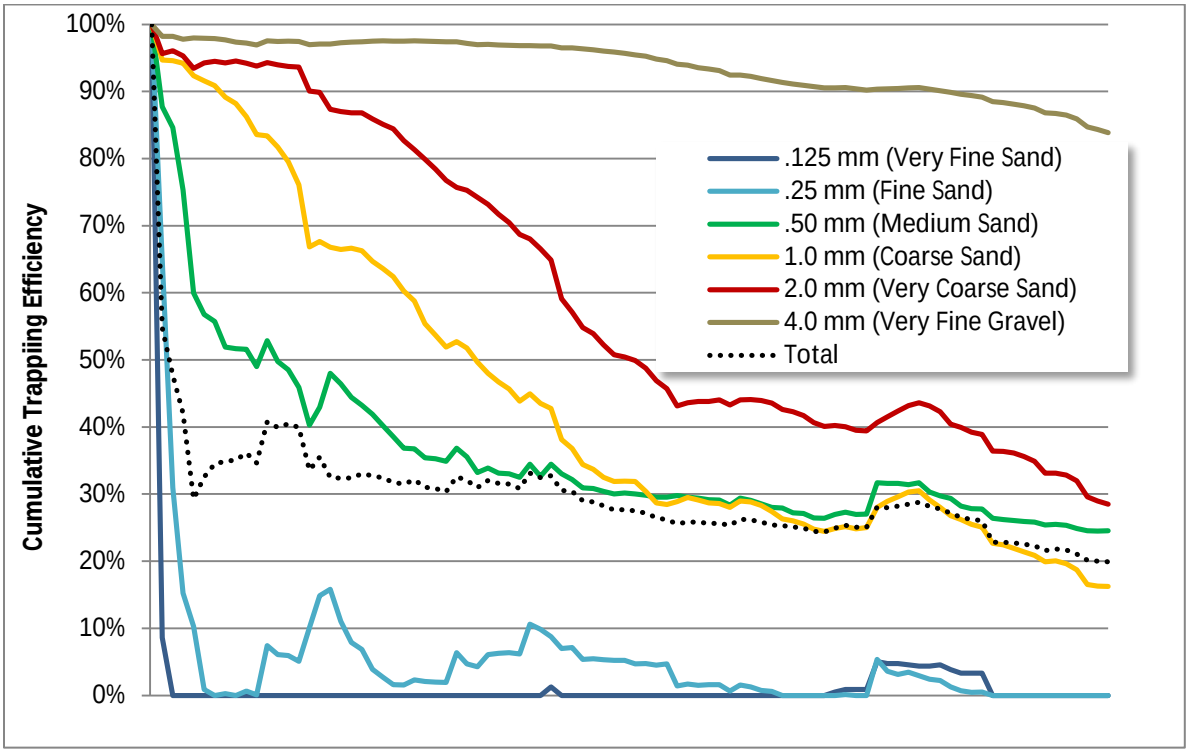
4.3. CURRENT STATUS AND FUTURE EFFECTIVENESS OF EXISTING PROJECT FEATURES

4.3.1. SRS Trap Efficiency

From its initial construction to 1998, when its last row of outlet pipes were closed, the SRS passed the flow of the North Fork primarily through its outlet structure. The trapping efficiency of the incoming sediment load during this period remained high because the attenuation of the outlet structure was efficient at dropping sediment out of the incoming NF Toutle River sediment load. Once the top row of pipes was closed, the NF Toutle River started flowing exclusively over the 400-foot spillway. Because there was much less flow attenuation for flow over the spillway than through the outlet structure, the trapping efficiency of the SRS precipitously dropped during this period. In order to estimate the trapping efficiency of the SRS, a two-dimensional (2-D) MIKE 21C model was developed for an approximately 9-mile reach of the NF Toutle upstream of the SRS.

Annual trap efficiency of the SRS through 2035 was highly variable; however, the cumulative trap efficiency showed a declining trend (Figure 4-4). The trapping efficiency computed by the sediment budget between 1999 and 2007 was estimated to be 37%. The total sediment output from the SRS for the 28-year simulation was computed to be 172 million tons and composed of 25% clay/silt, 72% sands, and 3% very fine gravels.

Figure 4-4. Predicted Trapping Efficiency of the SRS from 2007-2035



4.3.2. Cowlitz River Deposition

Depositional trends through the planning period in the lower 20 miles of the Cowlitz River below its confluence with the Toutle River was investigated by sediment transport modeling using one-dimensional (1-D) HEC-RAS software. This mobile-bed tool was developed from a hydraulically calibrated fixed-bed model utilized in the 2009 LOP analysis. The sediment transport function within the model was calibrated to observed depositional trends between 2003 and 2008. The model was then run with the 28-year long-term sequence of flows and sediment loads developed from upstream analysis. Total deposition in the Cowlitz River between the Toutle and the Columbia was estimated to be 37.7 million tons. Coarse and very coarse sands comprise nearly 80% of the deposited mass.

4.4. UPDATE OF DESIGN FLOOD CRITERIA FOR THE SRS

4.4.1. Probable Maximum Flood

As part of the updated long-term sediment management plan, the USACE recalculated the PMF for the SRS. This recalculation was documented in the report, *Development of the PMF for the SRS* (USACE August 2011). The primary reason for reinvestigation was to update the PMF to reflect the most recent hydrometeorological report (HMR). The HMR was used to calculate the probable maximum precipitation, which forms the basis of the PMF. At the time the SRS was designed, HMR-43 was the latest guidance from the National Weather Service on estimating the PMP.

Publication of the *Hydrometeorological Report Number 57* (HMR-57) in October 1994 provided new guidance that supersedes the previous guidance.

Once the reinvestigation began, all components of the analysis were checked against recent data and understanding. The modeled unit hydrograph originally used was determined to be excessively conservative when compared with observed data at the USGS gage #14140525, North Fork Toutle below SRS near Kidd Valley. A new composite unit hydrograph was developed based on observed data. Additionally, current understanding of sediment bulking during extreme events indicated that the assumed bulking factor was also excessively conservative. The bulking factor was reduced but some conservatism was retained as the science still has some uncertainty.

The 2011 PMF recalculation effectively reduced the design PMF from 213,000 cfs to 120,214 cfs, a 44% reduction in peak flow. District Quality Control and Agency Technical Review were both completed for the August 2011 report.

4.4.2. Operating Basis Mudflow

The mudflow scenarios for the SRS were reevaluated for the updated long-term sediment management analysis. For 1985 design of the SRS, the requirement to pass the OBM, as defined in Chapter 2, without overtopping the dam was the critical criterion for sizing the spillway, and resulted in a height difference between the spillway crest and the dam crest of 60 feet. Current estimations of the OBM event, as well as how it would spread out from the source before reaching the SRS, led the USACE to suspect that the full 60 feet of height difference may not be required.

The Portland District and the USGS Cascades Volcano Observatory now believe the most appropriate OBM would be an event similar to the event that occurred in March 1982, when a minor explosion from the 1980s lava dome sprayed the snow-covered crater walls with gas, hot ash, and hot rocks, melted the snow, formed a transient lake in the crater having a volume of about 4-5 mcy, and generated a flood and mudflow on the order of 13-20 mcy. This would be a considerably smaller-volume event than the original 75 mcy OBM.

The current understanding of conditions that could result in a mudflow within the lifetime of the SRS project indicates that the volume of the mudflow would be much less than, and only approximately 25% of, the volume assumed during original design of the SRS. In addition, even for mudflows occurring now with volumes comparable to the original OBM volume, the mudflows do not reach the SRS using current modeling tools for mudflow routing. As a result, the OBM was not the controlling criterion for determining the height of the dam above the spillway crest. With this new understanding of the OBM, the critical criterion for the SRS spillway becomes the ability to pass the PMF.

5. FUTURE EXPECTED DEPOSITION SCENARIO (FEDS)

5.1. TECHNICAL APPROACH

The FEDS analysis and report (USACE April 2011) introduced the hydraulic and sediment transport tools used to evaluate performance of alternatives for development of an updated long-term sediment management plan. The FEDS analysis would be the best deterministic estimation of future conditions through the authorization time frame if no actions are taken in the watershed and a continuation of the existing processes and dynamics occur.

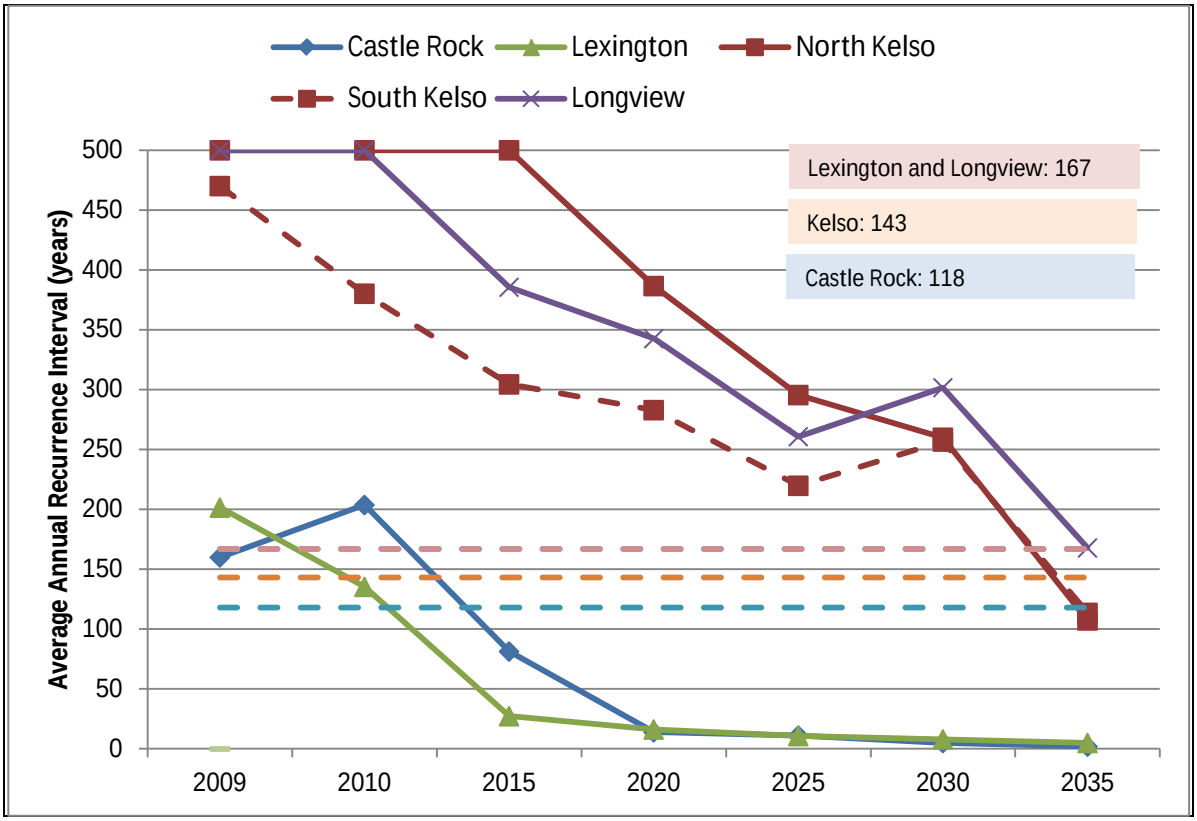
The selected technical approach utilized a set of deterministic hydraulic and sediment transport models arranged in series extending from the toe of the debris avalanche in the upper NF Toutle watershed downstream to the Columbia River. This set of models was driven by a time series of flows and sediment inputs extending from present time to the end of the authorization period (2035). This series of water and sediment discharges was based on 9 years of historic hydrologic record (WY 1999 to 2007). Data developed in the sediment budget (May 2010) for WY 1999 to 2007 were used as surrogates for future forecast years through 2035. Analysis of the surrogate hydrologic period compared to the historic flow record showed that the period is reasonably representative of the historic sediment yield record. Considerations of global climate change are not addressed in this analysis due to the relatively near 2035 end-of-project authorization. The total predicted load from the MSH debris avalanche to the SRS sediment plain for the period from 2008 to 2035 was estimated to be 215 million tons.

Sediment transport models using both 1-D HEC-RAS and 2-D MIKE 21C software were developed to determine future trends in sediment deposition and outflow from the SRS through 2035. The 1-D and 2-D model limits extend approximately 9 miles upstream from the SRS spillway to just upstream of N1. Both models were calibrated to historic observed deposition and run for a specific 28-year future sequence of surrogate years. Results from both long-term models generally agreed providing additional certainty in the analysis; however, sediment output from the 2-D model was considered most accurate due to the improved capability to analyze hydraulic conditions in a braided system by the 2-D model. Sediment loading output from the 2-D model was used in downstream models.

With the suite of models described in the FEDS analysis, it was possible to produce a probabilistic levee performance metric for future conditions with and without alternatives. The models were used to predict future condition stage-discharge rating curves for frequency flows. This was combined with the existing hydrologic and geotechnical data and analyzed in the HEC-FDA tool. This was done for the 28-year sequence to review the performance of the levees out to 2035. A plot of this analysis is shown in Figure 5-1.

In addition to the future performance of the levees from 2009 to 2035, authorized levels are shown as horizontal dashed lines. The future performance of the Longview levees showed downward trends but was maintained above authorization until the year 2035. Kelso levees maintain authorized LOP for nearly the entire planning horizon with the LOP dropping below authorization around 2034. The Lexington and Castle Rock levees were more problematic and showed performance that falled below authorization in the near future. Thus, the FEDS condition would not meet the congressional authorization.

Figure 5-1. Future Levee Performance in the Lower Cowlitz River



This probabilistic future performance metric was used to determine if a proposed action or suite of actions (alternatives) is viable in protecting the communities. Alternatives moving forward for consideration would need to reasonably meet the performance metric. The approach taken laid the foundation for determining alternative performance based on model results. The selected modeling approach provided adequate flexibility to accommodate the full range of proposed actions, while delivering the required high-quality results. Significant findings of the FEDS effort included:

- Analysis of SRS future performance indicated that there would be a significant reduction in trapping efficiency of coarse and very coarse sands in the current planning period. Downstream analysis showed that these materials compose the majority of deposition in the lower 20 miles of the Cowlitz in the same time frame.
- Uncontrolled deposition in the lower Cowlitz would affect upstream communities first. Sediment loads from the steeper Toutle River flow into the Cowlitz near RM 20. Once this load reaches the Cowlitz, the reduced transport potential resulted in deposition in the upper reaches. This effect was exacerbated by a natural pinch point in the Cowlitz near RM 7 that created a backwater profile and promoted deposition near Lexington. Communities higher in the system would experience a reduction in future flood damage reduction system performance more rapidly than those lower in the system due to this cumulative effect of deposition downstream of their levees.
- The do nothing, or FEDS condition, would not meet congressional authorization.

Sediment deposition boundaries upstream of the SRS for the FEDS condition were developed for two scenarios: (1) the deposition boundary out to the project horizon of 2035, and (2) the deposition boundary representing long-term development of a sediment plain grade that approaches dynamic equilibrium. The 2035 depositional boundary was developed from a hydraulic model of the sediment plain for the period from 2009 to 2035. This model used a 10 meter x 10 meter mesh to describe the sediment plain and an incoming sediment load consistent to what has been seen since 1998. Model results were spatially plotted to represent the impact area caused by sediment deposition to 2035. The long-term equilibrium impact areas were derived from a conceptual model of the sediment plain that suggests that as the sediment deposits upstream of the SRS, the valley slope would reach an ultimate slope of ½ the pre-SRS slope. This concept of ½ the pre-SRS valley slope (or S/2) was developed in the original design of the SRS (USACE September 1986).

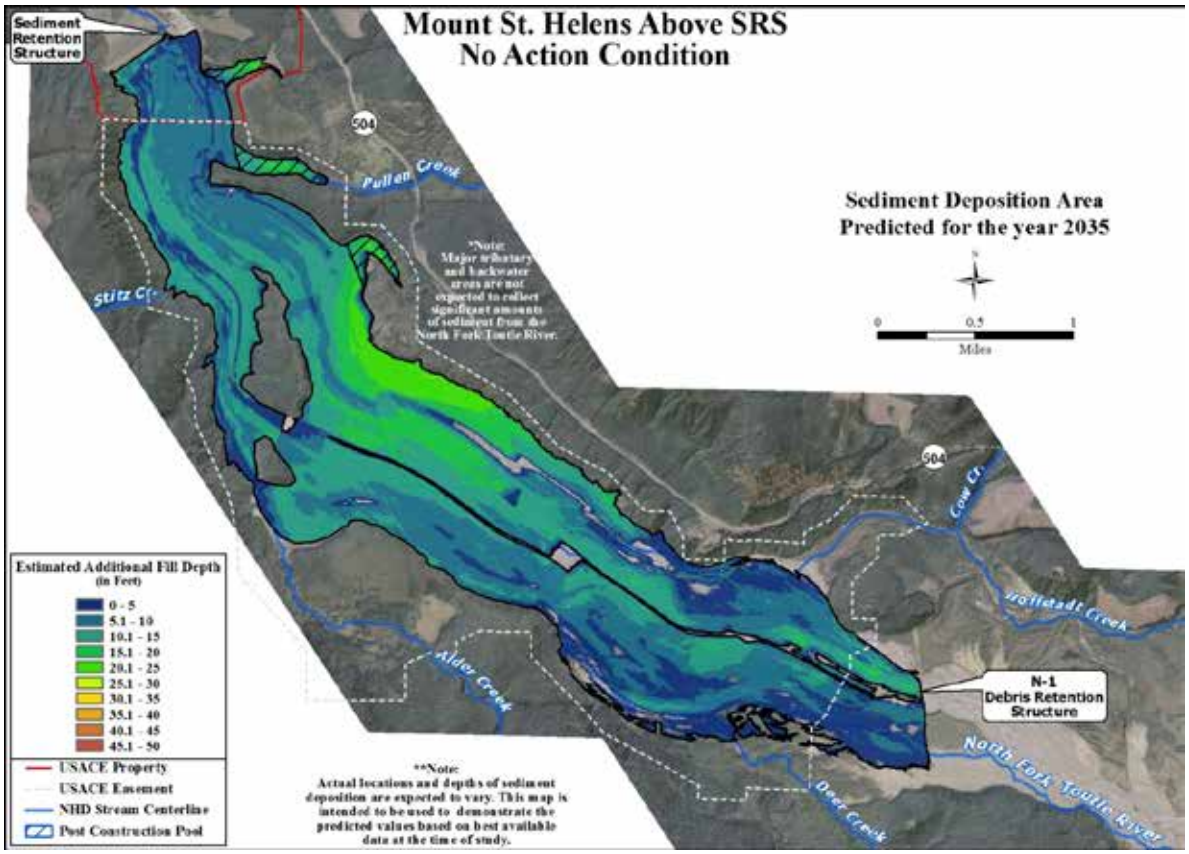
The long-term inundation boundaries were developed using the S/2 conceptual model which imposed a 0.006 ft/ft slope (based on the 1985 estimate of the valley slope of 0.012 ft/ft for the North Fork Toutle upstream of RM 13). A valley alignment was developed using both the general alignment of the North Fork Toutle and the valley banks. Then a 0.006 ft/ft slope was overlaid onto the sediment plain with a downstream control starting at the SRS spillway crest from the 2013 conditions as surveyed using LiDAR. A volume was computed from the S/2 profile line to the 2013 LiDAR bare earth surface. Approximately 100 mcy would be expected to deposit to reach the ultimate S/2 profile. Combined with the sediment that has deposited within the sediment plain from the SRS construction to 2013 (116 mcy), the total deposition estimated behind the SRS based on the S/2 profile model was estimated to be 216 mcy.

An estimate of the timeframe the S/2 would be expected to be reached was derived from the estimate of the volume that is necessary to reach the S/2 profile for the FEDS case, an estimate of the SRS trapping efficiency into the future, and an estimate of the incoming sediment load assuming no decay in avalanche erosion. From this information, it was estimated that the S/2 profile would be reached by the year 2100.

To develop the depositional boundary of the sediment plain for the FEDS case, a 2-D hydraulic model was developed from the SRS to just upstream of the N-1 structure. This hydraulic model uses a 10-meter by 10-meter grid with the SRS as the downstream boundary condition. The upstream boundary condition was made up of water and sediment loadings that match what has been observed from 1998 to 2009. The 2-D model included a mobile bed component to the hydraulic computations and a depth of deposition/erosion was estimated based on these computations. The sediment depositional boundary resulting from this iterated slope is shown in Figure 5-2.

These sediment depositional boundaries were developed to support concurrent investigation into the environmental impacts of the existing conditions and the proposed alternatives. The boundaries were overlain onto appropriate sensitive environmental areas to develop areas of potential impact under various scenarios. The Supplemental Environmental Impact Statement (SEIS), included as an appendix to this report, contains more information on the application of the sediment depositional boundary estimates.

Figure 5-2. FEDS Sediment Depositional Based on Volume Estimated in 2035



5.2. FLOOD PROBLEM

Additional sediment management actions are needed to prevent increased flood risks associated with sediment deposition in the lower 20 miles of the Cowlitz River. Recent assessments showed that unless further actions implemented, sediment buildup in the lower Cowlitz River would continue and put 50,000 people and their homes and businesses at increased flood risk. The LOP for the communities of Lexington, Kelso, Castle Rock and Longview would continue to deteriorate as the river channel fills with sediment. Without actions, the floodwaters would eventually overtop the levees and significantly impact the communities. The likely future without-project scenario assumes the communities would attempt to address the sediment buildup in the Cowlitz River and flood problems through as-needed dredging activities in the Cowlitz channel.

A review and update of the 1985 damage analysis showed that maintaining authorized flood risk levels results in over $29 million in flood damages prevented annually (the benefits of the MSH project were updated and verified in 2012). In addition, a planned approach to preventing sediment buildup in the lower Cowlitz River, rather than relying on emergency flood fight actions, resulted in an additional benefit of over $28 million annually.

5.3. POTENTIAL IMPACTS OF CLIMATE CHANGE

Climate change modeling suggested precipitation increases would come from rain instead of snow and result in flashier flows and elevated sediment delivery. Essentially, more rain-driven sediment transport could offset sediment reductions related to vegetation recovery and/or possible sediment load decay in the avalanche area.

Considerations of global climate change were not addressed in this analysis due to the relatively near 2035 end-of-project authorization. Climate change in the near term would be a relatively small uncertainty relative to the uncertainty of the total load from the debris avalanche, which involves natural system disturbance and recovery processes. Sea level rise due to climate change would not be expected to affect the project area.

6. SEDIMENT MANAGEMENT MEASURES

6.1. SEDIMENT MANAGEMENT MEASURES SCREENING PROCESS

The 2010 Progress Report (USACE 2010) documented the range of sediment management measures considered and evaluated to address the ongoing deposition in the lower Cowlitz River. The measures evaluation process consisted of three primary phases. The first phase involved a review of existing information and brainstorming workshops. A team composed of USACE and regional stakeholders assembled to develop potential sediment management measures. Based on those discussions and input from agency representatives and the general public, a total of 16 measures were identified for evaluation. Overall, the screening process assessed each measure on how well it performed. The range of variables considered at one or more of the screening levels include the following:

- Reduction in flood risk on the Cowlitz River per authorized project;
- Cost-effective;
- Minimization of impacts to the environment;
- Reliability of design;
- Adaptable to changing conditions;
- Protection to cultural resources; and
- Acceptable to the public.

Figure 6-1 shows the types of measures originally under consideration and their geographical locations.

The first level screening was completed based on preliminary cost information, updated sediment budget information and input from sediment experts. During the first level screening, it became clear that 7 of the 16 measures had major shortcomings related to one or several of the screening factors (typically issues related to reliability, cost effectiveness, and/or ability to significantly reduce flood risks). The following seven measures were dropped during the first screening.

- Debris avalanche stabilization.
- Elk Rock sediment dam.
- Sediment plain sump.
- Lower Toutle Sump (LT1).
- Expand floodplain on Toutle River.
- Horseshoe Bend sump/cutoff.
- Reconnect old channel at mouth.

Although multiple criteria were considered in evaluating measures, the primary rationale for dropping measures in the first screening level was that the flood risk management benefits relative to the costs were low compared to other options. These seven measures were dropped from further analysis. Details of this first level screening can be found in the Progress Report (USACE June 2010).

For the nine remaining measures, a second level screening was performed where conceptual designs and refined cost estimates were developed. Limited hydrologic, hydraulic, and sediment transport modeling was performed. This short list was carried forward for further analysis during development of the LRR. Appendix A explains the analysis that went into each of the measures for the second screening.

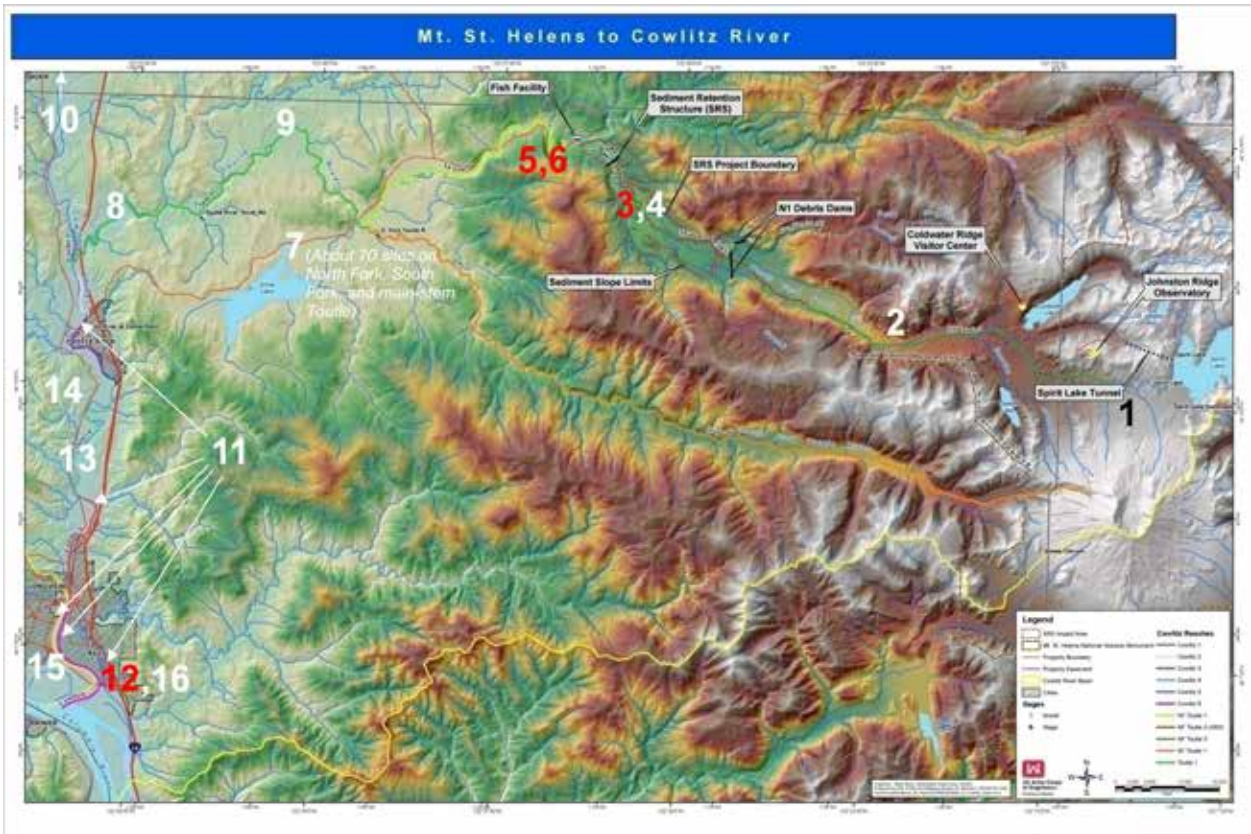
Table 6-1 summarizes how measures were screened through each level of evaluation.

Based on this evaluation, the remaining four measures (dredging, SRS raise, phased spillway raise, and GBS) were grouped to form three action alternatives carried forward for further evaluation:

- Cowlitz River dredging only;
- SRS dam raise only; and
- Phased-construction (SRS spillway crest raise and GBS with as-needed dredging).

These alternatives have been determined to meet the overall sediment management needs and are deemed relatively efficient, effective, complete, and allow for the management of the significant uncertainty in future sediment deposition. These alternatives are described in the next section.

Figure 6-1. Locations of Sediment Management Measures Analyzed in the 2010 Progress Report (USACE June 2010)



Numbering Key for Sediment Management Measures:

1. Debris avalanche stabilization.
2. Elk Rock sediment dam.
3. Grade-building structures
4. Sediment plain sump.
5. Raised SRS dam and spillway
6. Raised SRS spillway
7. Stabilization of banks
8. Lower Toutle Sump (LT1).
9. Expand floodplain on Toutle River.
10. Modify operation of Mossyrock Dam
11. Levee improvements
12. Cowlitz River dredging
13. Expand floodplain on Cowlitz River
14. Horseshoe Bend sump/cutoff.
15. Reconnect old channel at mouth.
16. Dikes to flush sediment at mouth

Table 6-1. Screening Results for Sediment Management Measures

Note: Viable measures used in alternative formulation shown in green.

Measures	Status after 1st Screening	Status after 2nd Screening	Status after LRR Screening
1. Debris Avalanche Stabilization	Not viable—treatment would be undermined by channel erosion	Not viable	Not viable
2. Elk Rock Sediment Dam	Not viable—Would store significant sediment but costly compared to SRS raise	Not viable	Not viable
3. Grade Building Structures	Viable—Moderate sediment control; low cost	Viable—Moderate sediment control; low cost	Viable component of an alternative
4. Sediment Plain Sump	Not viable—High Cost; limited sediment trapped	Not viable	Not viable—Further analysis completed but determined not effective and very costly
5. Raised SRS Dam/Spillway	Viable—Relatively high cost but significant sediment trapped	Viable—Relatively high cost but significant sediment trapped	Viable—Relatively high cost but significant sediment trapped
6. Raised SRS Spillway	Not viable—Moderate sediment control; low cost but concerned about impacts to SRS ability to manage mudflows	Not viable—Moderate sediment control; low cost but concerned about impacts to SRS ability to manage mudflows	Viable—Added back because mudflow analysis determined not a problem with SRS
7. Stabilization of Banks (LT-1 Bank Stabilization)	Not viable—not significant source of sediment; spot treatment considered	Not viable—not significant source of sediment	Not viable— quantity of sediment eroding from LT-1 bank would be very small as compared to the overall sediment budget.
8. Lower Toutle Sump(LT-1)	Viable—Further assessment of trapping efficiency suggested	Viable—Further assessment of trapping efficiency suggested	Not viable—Costly compared to ability to trap sediments impacting Cowlitz
9. Expand Floodplain on Toutle River	Not viable—limited opportunities to expand floodplain; limited impact	Not viable—limited opportunities to expand floodplain; limited impact	Not viable
10. Modify Operation of Mossyrock Dam	Viable—Recommended additional evaluation of benefits	Viable—Not reliable option but still good thing to consider	Not viable—Not reliable or limited effectiveness at moving sediment for flood protection
11. Levee Improvements	Not viable—would induce flooding in non-leveed reaches. Minor improvements still appropriate	Not viable—would induce flooding in non-leveed reaches. Minor improvements still appropriate	Not viable—would induce flooding in non-leveed reaches. Minor improvements still appropriate
12. Cowlitz River Dredging	Viable—effective but potentially costly	Viable—effective but potentially costly	Viable—effective but potentially costly
13. Expand Floodplain on Cowlitz River	Viable—Further consideration warranted	Not viable—Due to industrial & commercial infrastructure & associated contaminant removal expense	Not viable
14. Horseshoe Bend Sump/Cutoff	Not viable—limited benefit for major cost & potential contaminants	Not viable—limited benefit for major cost & potential contaminants	Not viable—limited benefit for major cost & potential contaminants
15. Reconnect Old Channel at Mouth	Not viable—limited benefit for major cost & potential contaminants	Not viable—limited benefit for major cost & potential contaminants	Not viable—limited benefit for major cost & potential contaminants
16. Dikes to Flush Sediment at Mouth	Viable—Further consideration warranted	Viable—Further consideration warranted	Not viable—some benefit but strongly rejected by fish agencies

6.2. MEASURES ADVANCED FOR ALTERNATIVE ANALYSIS

6.2.1. Sediment Plain Grade-building Structures

The GBS concept involves increasing the channel length of the NF Toutle River by meandering it alternatively across the valley upstream of the SRS. The increase channel length would effectively reduce the transport capacity of the channel for the purpose of increasing sediment deposition in the plain and decreasing the volume of sediment available for deposition in the Cowlitz River. The concept involves "building the grade" of the river profile to more adequately hold sediment in an area of the sediment plain approximately 3 miles upstream of the SRS. Figure 6-2 shows a conceptual layout of the GBS.

The structures would likely be composed of a backbone of 12-foot sheet pile cantilever walls made of an inert composite material, with rock placed along both the upstream and downstream sides of the walls for support and protection from impact and scour. At-grade openings would allow the NF Toutle to flow down valley in an alternating pattern from left side of the valley to the right. The opening width for these structures would need to be large, in the order of 300-600 feet to prevent excessive scour. The sheet pile walls would be faced with rock riprap to prevent localized scour.

Construction of the GBS would likely be constructed in two phases, centered on the in-water work period allowed by law. The first phase would begin with enough time to buildup and repair the access road, establish a construction office, and set up staging areas for construction of the in-water structures to begin. The second phase would involve the actual building of the structures during the in-water work period.

The river channel would have to be temporarily diverted for parts of the work. The temporary berm closing off portions of the valley would be in place for the duration of the project. Actual means and methods would be completed and maintained by the contractor; however, existing materials likely would be used to build a berm and dig a new diversion channel. This diversion work would be reversed upon completion. Figure 6-3 illustrates the conceptual schematic of the GBS system.

Some foreseeable issues or constraints on the project may include the following:

- Maintain viable fish passage during all phases of construction/operations including juvenile fish passage at the SRS and adult trap and haul operations.
- Maintain fish passage at all GBS.
- Maintain fish passage in current anadromous fish-bearing streams within the sediment plain deposition zone including North Fork Toutle River, Alder Creek, Deer Creek, Hoffstadt Creek, and Bear Creek. This action could potentially be dredging to reopen any fish passage constrictions or to maintain a migration channel. Periodic surveys and monitoring would determine if this action would be necessary.

As in the FEDS case, this portion of the Toutle River was modeled using MIKE21C to quantify sediment deposition above the SRS over the next 28 years. Details of the 2-D model used for testing this concept can be found in the 2011 FEDS report.

Figure 6-2. Conceptual Location of the GBS within a Depositional Zone in Sediment Plain

Figure 6-3. Conceptual Design of Grade Building Structures

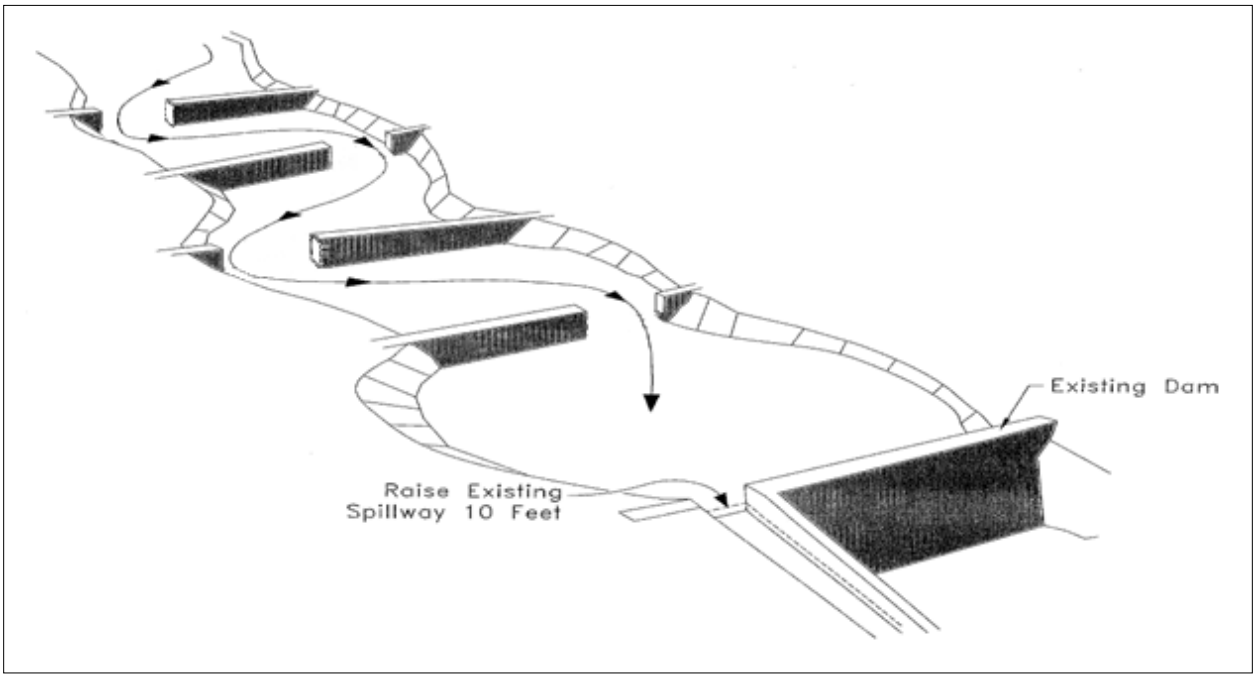
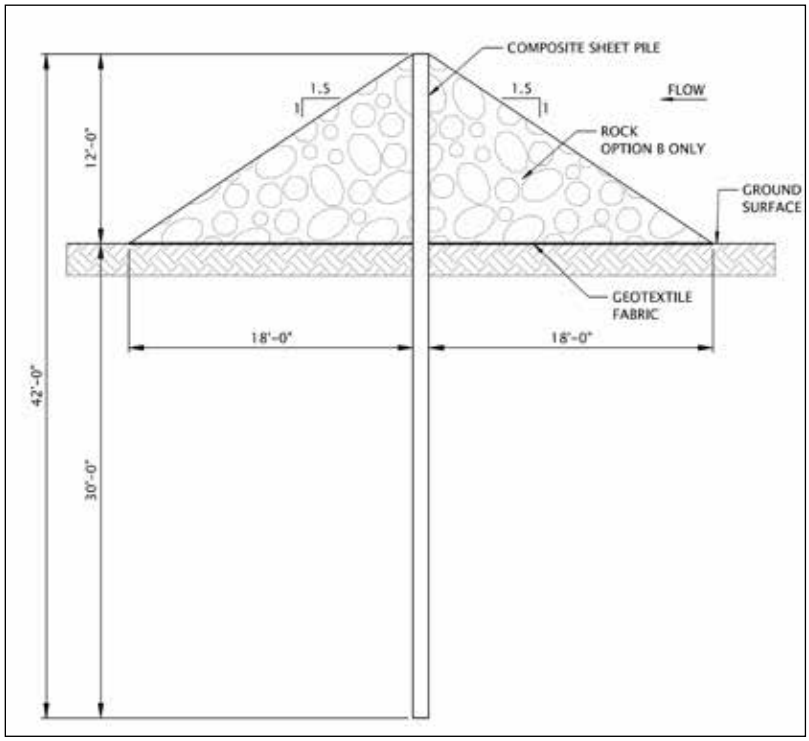


Figure 6-4. Cross sectional View of GBS Concept



Several alternatives were investigated to test the GBS concept upstream from the SRS. Results from a crest raise without the GBS was compared to the results from a crest raise with the GBS and it was found that there was a 20% increase in deposition within the sediment plain. Based on these findings, raising the existing SRS spillway by 10 feet or more, in conjunction with subsequent construction of GBS, was shown to be effective to induce additional deposition of the sediment plain upstream of the SRS. Details of the analysis of this measure can be found in Appendix A.

While the conceptual configuration was shown by the model to provide adequate flood management out to 2035, actual design and implementation of these structures could vary considerably. Unknown future sediment loads could drive a different configuration or magnitude of GBS. In addition, physical modelling being conducted for the GBS would inform the future design of the structures. Because the structure can be constructed in part or as a whole, depending on the changing conditions, this measure would be very adaptable to changing conditions.

6.2.2. 43-foot SRS Spillway Raise

This alternative involves raising the SRS as the primary sediment management measure. The alternative would raise the spillway by 43 feet and would raise the top of the SRS dam by 30 feet. The alternative would also involve the construction of new outlet works consisting of four rows with eight 4-foot diameter pipes in each row (32 pipes total), allowing the modified SRS to function as it did during Phase 1 of the 1985 long-term sediment management plan (see Section 1.2.2) with an overall sediment trapping efficiency of 80%. Construction of this alternative would take about 2 years. The following sections summarize this alternative (see Appendix A for more information).

6.2.2.1. 43-foot SRS Spillway Raise Description

The 2010 Progress Report (USACE 2010) included conceptual designs for raising the SRS dam. After the Progress Report was published, the USACE determined that the range for raising the SRS dam to manage sediment through 2035 would be from 30 to 70 feet. The USACE developed feasibility level designs and cost estimates for five SRS raises (30-foot, 40-foot, 50-foot, 50-foot adaptable to 70-foot, and 70-foot), and performed hydraulic and sediment modeling to evaluate the SRS dam raise concepts. This work resulted in proposing a spillway raise height of 43 feet and a proposed dam height raise of 23 feet for this alternative (USACE 2013).

The existing SRS spillway width is 400 feet. Under the SRS raise measure, the spillway would be widened to 500 feet. Widening the spillway substantially reduces the required elevation difference between the top of dam elevation and spillway crest elevation that would be needed to pass the PMF, resulting in significant savings in construction time and costs. The existing upstream and downstream slopes of the SRS would be maintained. The SRS raise would require some demolition of the existing roller-compacted, concrete-faced rockfill dam to tie the existing impervious core and drainage system to the new system. Figure 6-5 shows the plan and sections for a 43-foot SRS spillway raise. Figure 6-6 shows a cross section schematic of the SRS raise. In the figure, the cross section shows a 40-foot raise; however, it was recognized that a 43-foot raise would be needed. The configuration of the cross section would be very similar, but the details of the SRS cross section would be determined during the design phase of the project.

Figure 6-5. 43-foot SRS Spillway Raise Concept Plan

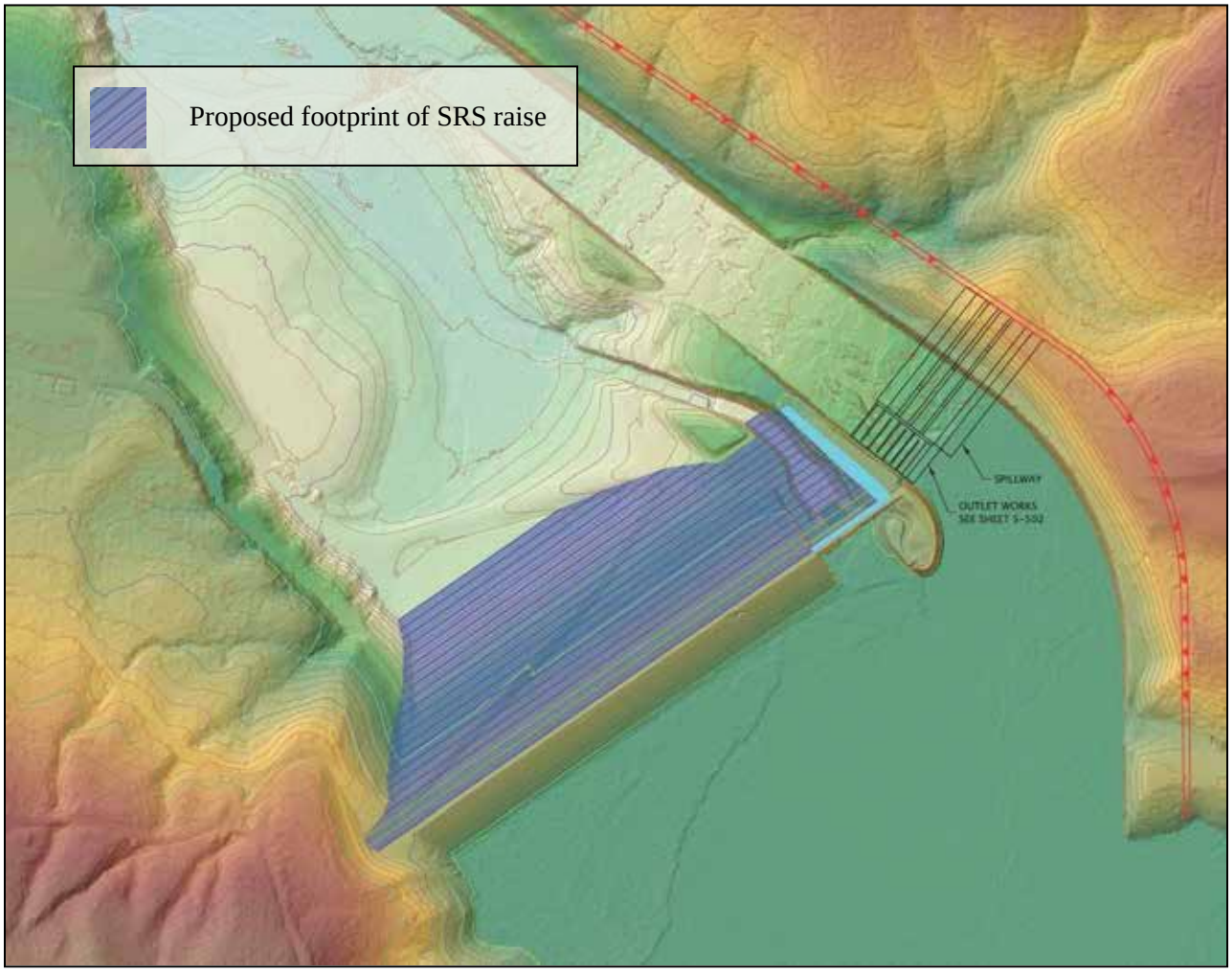
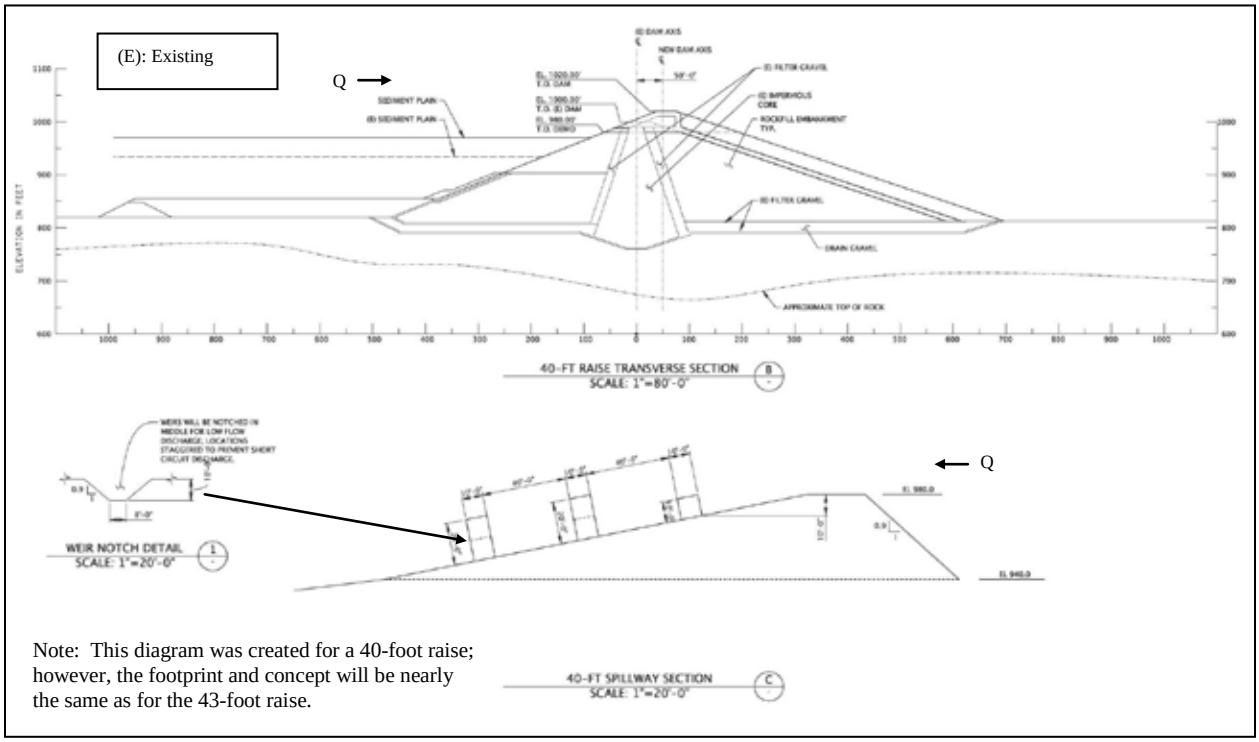


Figure 6-6. Cross-section for 43-foot SRS Spillway Raise

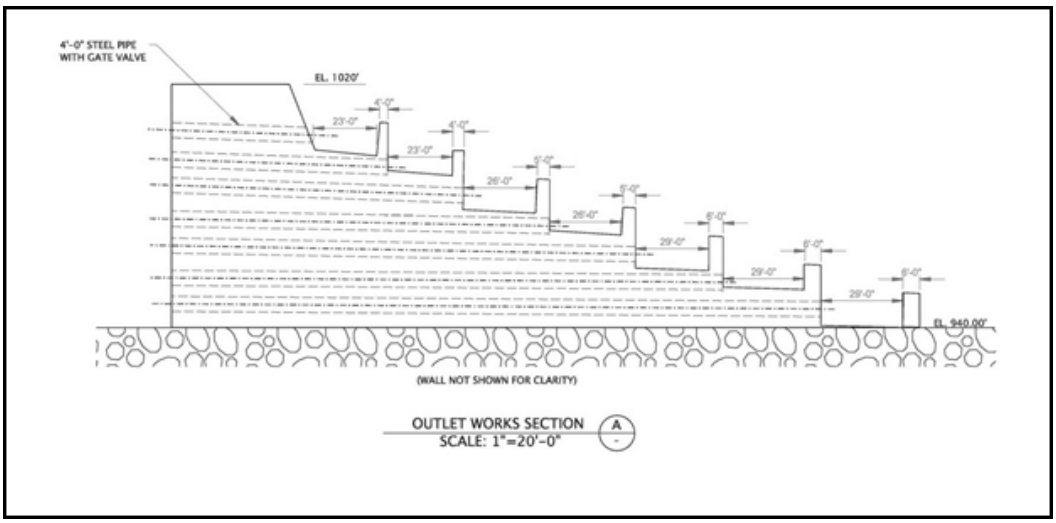


Note: This diagram was created for a 40-foot raise; however, the footprint and concept will be nearly the same as for the 43-foot raise.

Construction of the SRS raise would also include the construction of a new set of outlet works consisting of four rows of eight 4-foot diameter pipes for a total of 32 pipes. The pipes would be spaced 10 feet apart. The outlet works would discharge into an energy dissipating "pool" and flow over weirs spaced at 10-foot elevations and V-notched to augment passage of fish during periods of low flow (see Figure 6-7). At lower flow rates, all flow would stay within the channel that would crisscross back and forth between V-notches down the downstream face of the outlet works. At higher discharge rates, the flow would spill over weirs that separate the different tiers. The pipe inverts, channel invert, and weir crests are all sloped at 2% to support the movement of sediment from the outlet works.

Following construction, the SRS would function as it did during Phase 1 of the 1985 long-term sediment management plan with the creation of a pool of water extending upstream of the SRS as the downstream movement of water would be slowed by the SRS dam, spillway, and outlet works structures. The depth of the ponded water behind the SRS at the outlet works (i.e., the headwater depth) would vary both seasonally, due to winter storm runoff or snowmelt, and over time. Immediately following construction, the SRS would create a 20-foot deep pool (as measured at the outlet works) extending upstream from the SRS to the downstream edge of the large island. As sediment accumulates, water and fine sediment would pass through the outlet works while larger sand-sized sediment would remain trapped behind the SRS. As sediment settles, the headwater depth at the outlet works would decrease to between 10 and 15 feet and the ponded area would slowly decrease. This was predicted to occur in the first year following construction.

Figure 6-7. Outlet Works and Weirs in Section



Sediment settling and building up over time would eventually bury the first (i.e., lowest) row of outlet work pipes, triggering their closure. Closure of the first set of outlet works was predicted to occur 2 years following construction. Closure of the second, third and forth rows of pipes are predicted to occur less than 7 years, less than 12 years, and less than 16 years, respectively, following construction. The SRS would return to being a "run-of-the-river" project less than 17 years following construction. After the modified SRS becomes a run-of-the-river, the sediment load of the Toutle and Cowlitz rivers downstream on the SRS would be likely to increase and the trend in LOP would once again begin to decline.

For this alternative, the spillway would be raised 43 feet and the top of dam would be raised 23 feet. The elevations of these raises are based on engineering analysis that would provide for maintaining LOPs for the protected lower Cowlitz River communities. Deposition behind the raised SRS was predicted to result in run-of-the-river conditions in about 2035. The sediment loading condition from the debris avalanche would be a major source of uncertainty. The SRS raise would provide a fixed solution, and there would be little ability to adapt to changes in sediment loading conditions.

6.2.2.2. 43-foot SRS Spillway Raise Conclusions

The existing SRS proved successful in trapping sediment, limiting sediment deposition in the Toutle and Cowlitz rivers, and maintaining the authorized LOP for the Cowlitz levees. Since the SRS has become run-of-river, more sediment passes and the LOP for the levees decreases. Raising the SRS would be a reliable method of managing sediment in terms of flood damage reduction along the Cowlitz River. The selected spillway raise height is 43 feet. The raised SRS would be most effective while operating with all flow passing through the outlet works with a trapping efficiency of 80%, before the project again becomes run-of-river. Raising the SRS would provide a large sediment storage capacity. After implementation of the raise, no further major action would likely be required.

6.2.3. Phased SRS Spillway Raise

6.2.3.1. Phased SRS Spillway Raise Description

Spillway crest raise options for the existing SRS structure were identified as a potential viable sediment management measure in the 2010 Progress Report (USACE 2010). In contrast to the SRS raise, where the entire dam and spillway are raised 43 feet, the spillway crest raise includes only raising the spillway crest and not the dam embankment. Conceptually, the raised SRS, with outlet works, would maximize the outlet structure flow capacity with mechanical gates and pipes, while the crest raises would necessarily create a limited pool depth due to the small overall raise in spillway crest. Instead of shutting gates incrementally, the crest would be raised incrementally. Because the crest raise still would allow fine sands and silts past the SRS (as compared to a full SRS dam raise that would trap approximately 80% of the incoming load), the target trapping efficiency of the crest raises could be much lower than what would be necessary for an SRS raise.

During development of the Progress Report (USACE 2010), it was determined that two additional raises of the existing SRS spillway could be performed and result in significant additional sediment deposition upstream of the SRS. The Phased Construction alternative involves up to two incremental raises of the SRS spillway elevation (totaling up to 23 feet) without raising the top of dam elevation, building GBS in the sediment plain upstream of the SRS, and as needed dredging in the lower Cowlitz River. Each phase of this alternative would be implemented only if and when needed. To determine whether a next phase would need to be constructed, the USACE would monitor hydrologic and sediment conditions in both the sediment plain and the lower Cowlitz River and decide whether conditions trigger the need for action. The three phases of the Phased Construction alternative are sequential and are listed below in order of implementation:

- Phase 1: First SRS spillway crest raise.
- Phase 2: Second/final SRS spillway crest raise.
- Phase 3: Grade building structures.

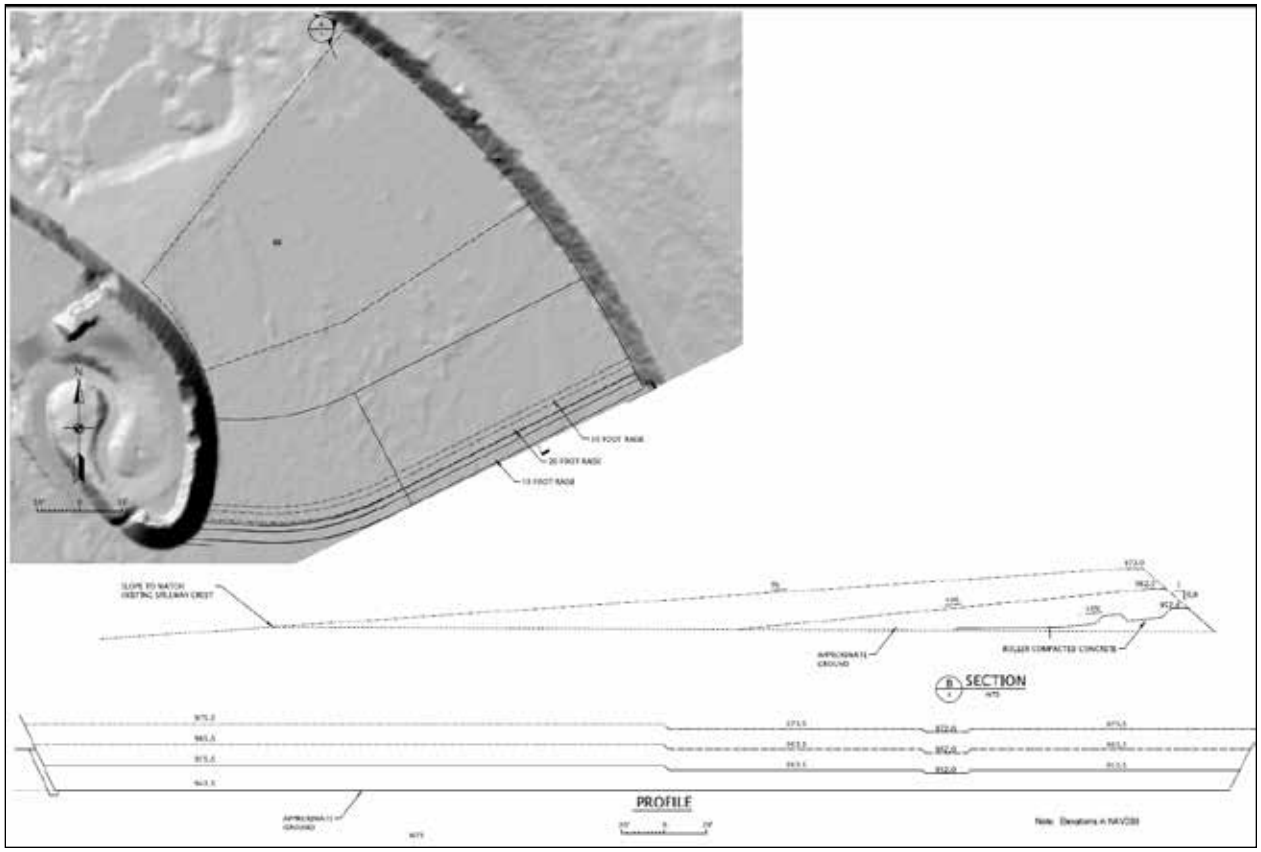
The implementation timing of the crest raises would depend on sediment conditions behind the SRS and in the Cowlitz River, which are monitored and evaluated annually. If the sediment load from the debris avalanche follows the conservative assumption used in the FEDS, the first crest raise likely would be needed in the first 2 years after approval of this plan, and the next crest raise would be needed approximately 4 to 8 years after that.

As done with the recent 7-foot spillway raise, each future crest raise would be constructed of RCC and would include a 200-foot wide by 3-foot deep “notch” for summer low flows to pass without disruption to the surrounding settled sediment. During construction at low flow, the river would continue to be routed over the spillway ensuring continuity of flow. Upstream volitional fish passage would not be feasible at this time over the spillway; however, this measure would not preclude future modifications to accommodate it.

After the construction of each spillway raise, a shallow pool would exist behind the SRS. The pools would trap sediment eroding from the debris avalanche. In the final configuration, the SRS would be a run-of-river project as it is now. The raised crest for each implementation would be constructed such that the final raised spillway slope would be 7% or less.

Each crest raise would utilize existing roads and staging areas that are within the boundaries of the existing USACE easement. Minor improvements to the existing roads at the SRS may be necessary to accommodate heavy construction traffic. Public access to the SRS would be restricted. After mobilization, river diversion would be accomplished in a similar way as the 2012 spillway crest raise; isolating one side of the spillway crest at a time before allowing the NF Toutle River to engage the entire width of the spillway. The two additional spillway crests would be placed directly on top of the existing spillway crest. Figure 6-8 shows a schematic of the spillway crest raise and how the new spillway crests would overlay the existing structure.

Figure 6-8. SRS Spillway Crest Raise Schematic



6.2.3.2. Phased SRS Spillway Raise Conclusion

The recent SRS spillway raise action proved successful in trapping sediment, limiting sediment deposition in the Toutle and Cowlitz rivers, and maintaining the authorized LOP for the Cowlitz levees. Measurements of annual deposition in the Lower Cowlitz in the year after construction of the spillway crest raise in 2012 showed that the Cowlitz scoured the channel bed, compared to the depositional trends that had been observed in years past. The capacity of these raises would be limited; therefore, although effective for some time, the predicted quantities over time suggest this measure would be viable only if combined with other measures. The raises could be constructed in a relatively short amount of time and in response to changing conditions, and remain viable and very adaptable to changing sediment conditions.

6.2.4. Cowlitz River Dredging

6.2.4.1. Dredging Description

The Cowlitz River dredging measure involves removing depositional material from the river through the year 2035 to maintain the authorized flood damage reduction levels in the Castle Rock, Lexington, Kelso and Longview protected areas. The three primary design elements for the dredging measure include: (1) estimating the amount of deposition in the Cowlitz River and subsequent determination of material removal volumes and associated dredge prisms required to maintain the authorized LOP through 2035; (2) the determination of material removal techniques and capability; and (3) dredge material storage area identification, including acquisition and site preparation requirements. Refer to the 2010 Progress Report and Appendix A for additional details.

Based on an evaluation of these three design elements and potential volume of sediment deposition in the lower Cowlitz River through 2035, a viable dredging plan was developed. Provided below are the dredging assumptions and constraints.

- Dredge material storage areas were identified adjacent to and along the entire length of the Cowlitz River from its confluence with the Toutle River (RM 20) to its confluence with the Columbia River. This was due to the predicted material removal requirement encompassing the entire 20-mile section of river to accommodate the authorized levels of protection.
- The majority of proposed dredge material storage areas are already owned by Cowlitz County or the State of Washington; however, this plan would require some acquisition by the State.
- The utilization of existing and available technology to remove material from the river was assumed to increase the certainty in cost estimation and feasibility. It is a relatively safe assumption that various sizes of hydraulic dredges could remove the materials.
- It is assumed that the dredging industry would be capable of providing the resources to accomplish the concept dredging operations.

6.2.4.2. Dredging Conclusion

Dredging in the lower Cowlitz River in 2007 and 2008 has proved successful in maintaining authorized LOP for the communities along the lower Cowlitz River. Although effective, the predicted sediment quantities over time suggested this measure would be viable only if implemented regularly. As a standalone alternative, dredging would be required on nearly an annual basis.

It was determined that dredging also could be integrated into the other measures. For the Phased Construction alternative, dredging was reserved as a reactionary measure to accommodate single, high-sediment load events in the system. Preliminary engineering analysis showed that for the Phased Construction alternative, the critical areas occur from Cowlitz RM 5 to 13. Pipeline dredging would be used to remove and place material in the upland disposal sites. The size of the pipeline dredge used may range from 12 to 30 inches depending on the location of dredging. Booster pumps could be used to facilitate longer pumping distances. Appendix A provides a preliminary design of the dredging component of the Phased Construction alternative. Dredging would be a viable measure and adaptable to changing sediment conditions and combinations of actions.

7. ALTERNATIVES EVALUATION

7.1. OVERVIEW

Based on the evaluation of the four viable measures described in the previous section, three alternatives were identified that maintain the authorized LOP for the communities along the lower Cowlitz River through 2035. These three alternatives include:

1. Cowlitz River dredging only.
2. SRS spillway and embankment raise.
3. A phased construction plan consisting of:
    a. SRS spillway crest raises,
    b. Grade-building structures, and
    c. As-needed dredging.

These alternatives were determined to be viable because they maintain the LOP through 2035. The costs, environmental, cultural and historical impacts, reliability, adaptability, and public acceptability of each alternative are summarized in the following sections.

7.2. ALTERNATIVE 1 – COWLITZ RIVER DREDGING ONLY

7.2.1. Overview

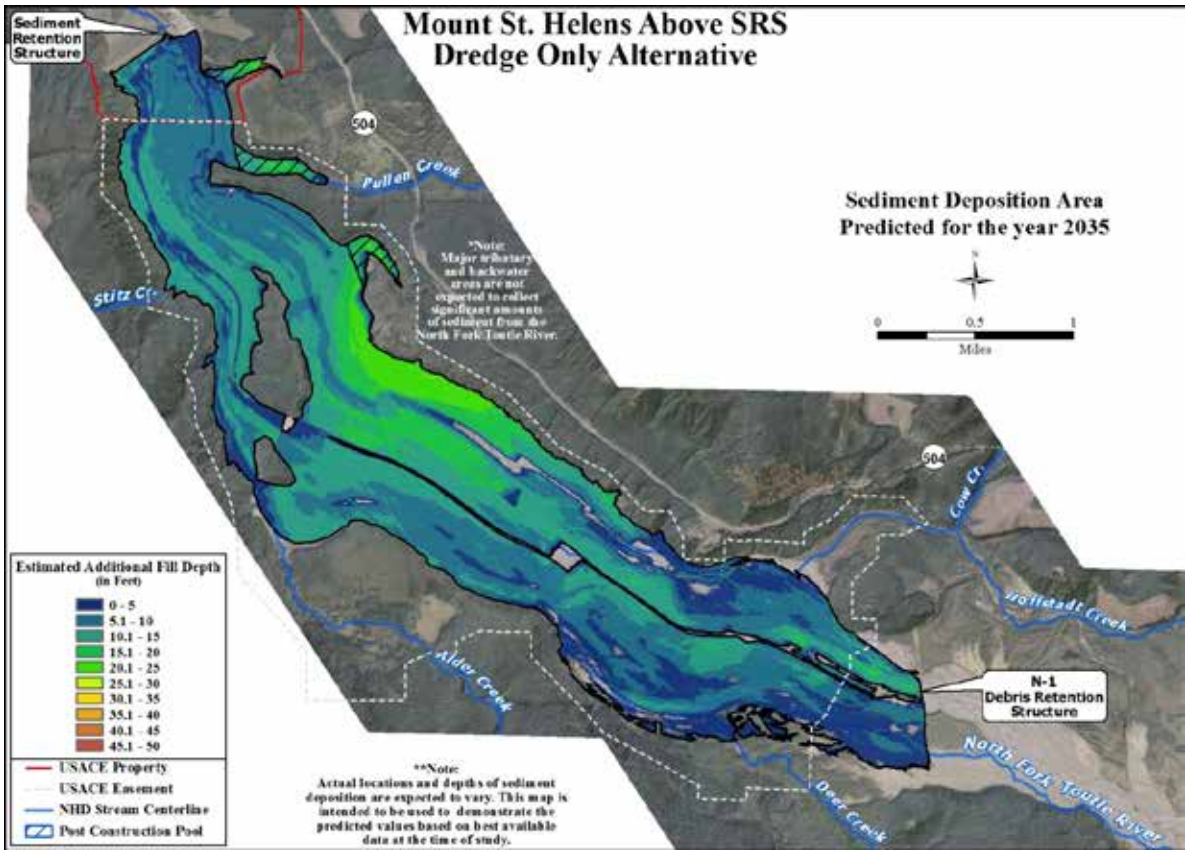
The 1985 Decision Document identified dredging in the lower Cowlitz River as a potential long-term sediment management action to be employed after all pipes on the SRS outlet structure closed and the spillway began operating as a run-of-river project. Design Memorandum No. 15 (USACE 1987), from the original analysis, identified the need to dredge beginning by the year 2000. The Dredging Only alternative does not include any improvements to the SRS. Therefore, the sediment depositional footprint for the Dredging Only alternative was the same as for baseline conditions. A description of how this depositional boundary was developed can be found in Chapter 5.

The depositional boundary represents the long-term estimate of total project impacts if no further construction was executed and a continuation of the existing processes and dynamics upstream of the SRS occur. Based on generalized assumptions of SRS trapping efficiency, incoming sediment load, and deposition geometry, the depositional scenario was estimated to occur by approximately 2100 if no decay in the avalanche erosion was realized. If decay in avalanche erosion resulted in lower sediment loads in the North Fork Toutle, it was possible that the S/2 profile would not be achieved until 2400. Assuming that the S/2 profile is reached by 2100, the long-term sediment depositional volume (100 mcy) was pro-rated to 2035. An additional depositional boundary based on this pro-rated estimated volume can be found in Figure 7-1. More information regarding the development of this depositional boundary can be found in Chapter 5.

For the life of the project, it was estimated that 27 mcy would be dredged in the lower 20 miles of the Cowlitz River. The original formulation of the alternative anticipated that dredged material would be disposed of in the overbank areas adjacent to the dredging locations. The Dredging Only alternative continues the assumption that the on-going deposition in the lower Cowlitz River can be removed by dredging material from the channel and placing it on the overbanks. This section summarizes the Dredging Only alternative.

Based on anticipated future sediment loads from the debris avalanche, similar to that which was experienced from 1998 to 2008, the dredge prism presented in Design Memorandum No. 15 (USACE 1987) was found to be inadequate for maintaining the authorized LOP for future expected sedimentation in the lower Cowlitz River. A new dredge prism, designed as described in Appendix A, provides the authorized LOP for the Cowlitz River levees through the end of the planning period.

Figure 7-1. Dredging Only Depositional Boundary for 2035



Due to the large estimated amounts of sediment that would need to be dredged, the Dredging Only alternative assumes a 3-month dredging activity with two to three hydraulic dredges operating every 1 to 2 years on average. The total estimated volume of sediment to be dredged would be 48 mcy out to 2035. While it was estimated that the entire 20-mile reach would be affected in the lower Cowlitz River, dredging from RM 7 to 20 would be needed on a more frequent basis than the lower reach. This was primarily due to bed load depositing as soon as flow from the Toutle River enters the Cowlitz River. A natural constriction in flow near river mile 7.0 on the Cowlitz also causes a backwater effect that promotes deposition. Fine material (fine sands and silts) move through the upper reach of the Cowlitz River into the lower 5 miles of the Cowlitz where some deposits but the majority would continue into the Columbia River. Modeling output summarized in Table 7-1 shows a potential timing of when the dredging events are needed. Annual monitoring of the lower Cowlitz River would be required to determine when to dredge and the amount of material to be dredged. See Appendix A for more information about dredging the Cowlitz River.

Table 7-1. Dredging Reaches and Timing and Quantities (mcy)

Year	Upper RM 7.4 to 19.55	Middle RM 5.2 to 7.4	Lower RM 1.6 to 5.2	Confluence Columbia to RM 1.6	Total
2018	3.1	0.7			**3.8**
2021	6.1	0.9	2.5		**9.6**
2024	2.1	0.3		2.5	**5.0**
2027	4.5				**4.6**
2030	4.6	0.7			**5.4**
2033	8.2	1.0			**9.2**
Total	**39**	**4.4**	**2.5**	**2.5**	**48**

The following subsections describe the LOP performance, estimated costs, adaptability, environmental impacts, cultural resources impacts, and public impacts of this alternative.

7.2.2. LOP Performance

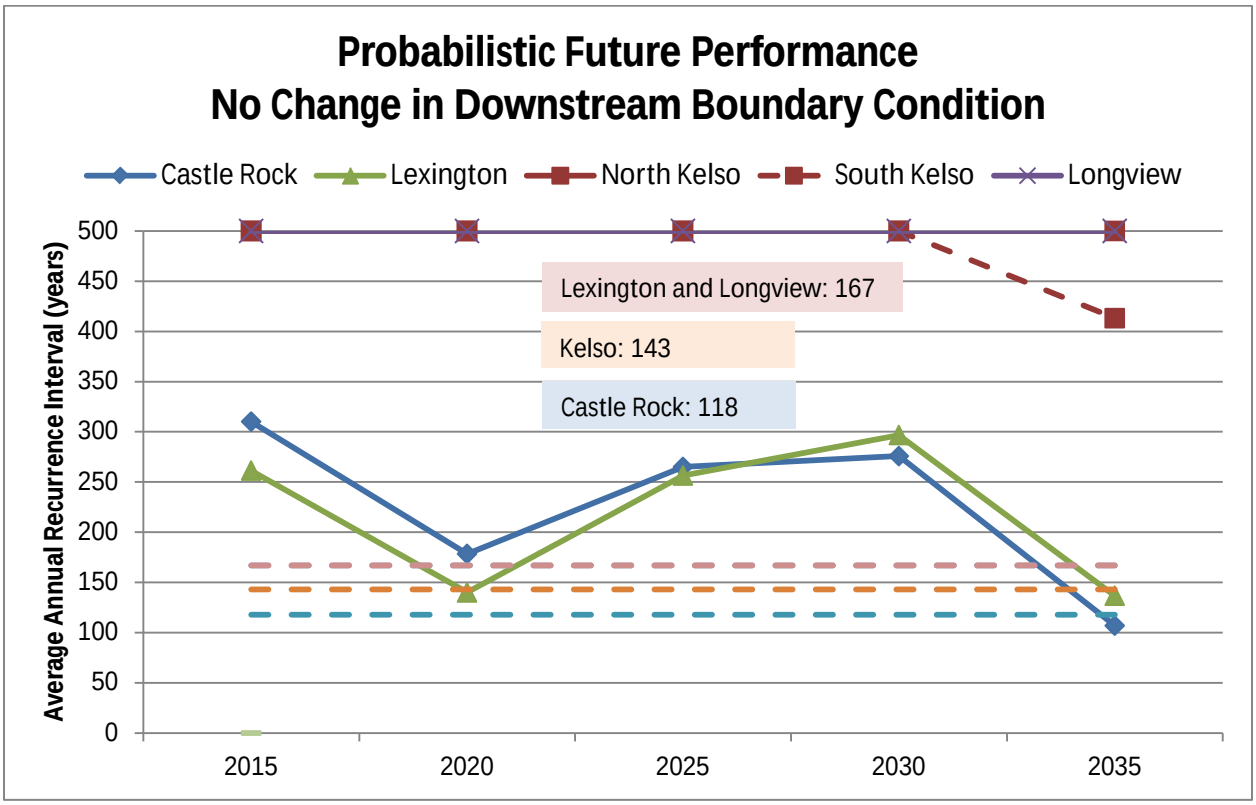
Using the tools, methodology and performance metric described in the 2011 FEDS report, a series of dredging events was determined that would plot a future performance trajectory for maintaining authorized LOP levels. Figure 7-2 shows projected performance of the alternative through the end of the planning period at 5-year increments for the dredging alternative. Since the shape of the dredging prism remains constant through time, the variability seen in the performance plot was a function of the variability in incoming sediment load/transport capacity. Following large events that result in significant deposition, performance was significantly reduced potentially to levels below authorization. Subsequent dredging would be required to remove the deposition and reestablish a comfortable margin for future deposition. This is similar in concept to maintenance depth dredging for navigation projects in that additional depth (or conveyance area in this case) would be necessary for the project to function between dredging events. The modeling demonstrates that this alternative could maintain LOP levels through 2035.

7.2.3. Costs

With an estimated total dredge volume of 48 mcy, the total cost for Cowlitz River dredging and upland placement would be over $1 billion. This estimate includes costs associated with the actual planning, engineering and design for dredging, ongoing sediment monitoring, environmental impacts monitoring and mitigation, real estate, and ongoing management of the existing SRS. Assuming a 3.5% discount rate and 18-year period of evaluation (2017-2035), the average annual cost for this dredging alternative would be $45.1 million. Refer to the Appendix C (Costs) and Appendix D (Economics) for additional information.

While there wuold be some existing dredge disposal sites available for use, it was assumed that some property along the river would need to be acquired for use as upland disposal sites, and that these sites would be obtained prior to the dredging actions. The USACE Portland District performed estimation of real estate values based on a gross appraisal on the potential dredge disposal sites in 2013. In total, the real estate acquisition necessary for the dredge disposal sites would be approximately $6.5 million. The valuation of real estate was included in this alternative plan as a non-federal cost share item.

Figure 7-2. Probabilistic Future Performance for Dredging Alternative



The streaked horned lark is a federally threatened and state endangered species associated with bare ground or sparsely vegetated habitats. Placement of dredge material on disposal sites along the lower Cowlitz River has the potential of attracting this bird. While no colonies are known to exist in the lower Cowlitz River, the placement of dredge fill would provide suitable habitat. Therefore, a site survey would be conducted prior to dredging activities.

Continued deposition of sediment upstream of the SRS would inundate the areas on the fringe of the sediment plain. Critical fish habitat would be impacted as a result of the sediment deposition upstream of the SRS. Some monitoring and mitigation for impacts to this critical habitat would be likely and was included in the overall cost estimate.

7.2.4. Environmental Considerations

Environmental impacts for this alternative have been evaluated in the SEIS. Identified impacts included sedimentation infill of wetlands and critical fish habitat as the sediment plain continues to aggrade; potential blockage of spawning habitat in tributaries at their confluences with the sediment plain leading to potential difficulty for downstream migration of salmonids; and loss of wildlife foraging (primarily elk) and loss of mature trees.

Wetlands present along the sediment plain fringe would be slowly and continuously buried as sediment deposits over time. However, the expected rate of sediment deposition under the dredge-only alternative is such that the wetlands would most likely continue with their presently observed

trend of larger individual plants surviving the burial with new plants becoming established in between. No permanent net loss of wetlands is expected from the Dredging Only alternative.

For ESA-listed salmonids, green sturgeon, Pacific eulachon, and bull trout in the lower Cowlitz River where dredging would be conducted, the USACE has determined that the proposed action "may affect and is not likely to adversely affect" these species or their designated critical habitat. The determination that these species and their critical habitat would not be adversely affected is based on all dredging activities being conducted during the in-water work window when these species are least likely to be present and on the continuous replenishment of sediment to the habitat. Monitoring of and mitigation for impacts to critical habitat are included in the overall cost estimate.

Placement of dredge material in the disposal sites along the lower Cowlitz River has the potential of attracting the streaked horned lark, federally threatened and state endangered species. While no colonies are known to exist in the lower Cowlitz River, the placement of dredge fill would provide suitable habitat. A site survey would be conducted prior to dredging activities.

The sediment plain is bordered by mature forest growing on mineral soils rather than the pure sand of the sediment plain, which is also seasonally saturated to the surface by water. Continued deposition of sediment upstream of the SRS would inundate these forested areas on the fringe of the sediment plain and result in the loss of those trees directly adjacent to the sediment plain as the mineral, upland soil becomes increasingly water saturated. The original EIS accounted for the loss of this forest acreage. The impacted area would be within the USACE-leased land for sediment storage. Additional information can be found in the SEIS.

7.2.5. Cultural and Historical Resources

Cultural resources impacts for the Dredging Only alternative were evaluated and are included in the SEIS. The National Historic Preservation Act of 1966 (NHPA) requires federal agencies take into account the effect of their actions on cultural resources, termed historic properties, listed on or eligible for listing to the National Register of Historic Places (NRHP). Historic properties are defined as any prehistoric or historic district, site, building, structure, or object that possess significance and integrity. The use of existing dredge disposal locations would result in no impacts to cultural resources. The existing disposal locations were inventoried for historic properties during the dredging response to the MSH eruption. Selection of new areas for additional disposal locations would require new cultural resources inventory to evaluate the areas for the presence of resources eligible for listing to the NRHP.

7.2.6. Public Use Considerations

The Dredging Only alternative would require regular work in and along the lower 20 miles of the Cowlitz River. Dredging would be anticipated to occur in the summer months on nearly an annual basis. The lower 20 miles of the Cowlitz River are heavily populated and include the communities of Kelso, Longview, Castle Rock and Lexington. Dredging on the river and moving dredging equipment in and out of this area could have the following negative impacts:

- Moving dredging equipment in and out on the roadways adjacent to the Cowlitz River could impact local community access at times.
- Dredging equipment would increase noise levels in areas where dredges are operating.

- Recreation areas and trails along the lower Cowlitz River may be temporarily closed to public use when dredging is occurring.
- Recreational boat use would be limited in the areas of active dredging.

Public use considerations were evaluated and are included in the SEIS.

7.2.7. Reliability

Dredging the Cowlitz River would be a reliable alternative as long as sediment monitoring is maintained and the regular stream of funding for dredging is maintained.

7.2.8. Adaptability

The Dredging Only alternative would be adaptable to varying and unpredictable volumes of sediment depositing in the lower river. Regular monitoring, including a hydrosurvey of the lower river, would need to be conducted annually to determine the amount and extent of sediment requiring removal. The extent of dredging would be directly related to the extent of sediment in the dredge prism. In this way, the alternative would be adaptable to future sedimentation trends.

7.2.9. Public Acceptability

The public review process would determine the extent of public acceptability. Lower Cowlitz River citizens and river users would experience regular but relatively minor noise impacts and periodic limitations to boat ramps and river trail access where dredging is taking place. Previous dredging work has not identified significant concerns from the public.

7.2.10. Summary of Cowlitz River Dredging Only Alternative

Provided below is a summary of the effects of the Dredging Only alternative and its viability as a standalone alternative to maintain authorized flood risk management to the communities along the lower 20 miles of the Cowlitz River (see Section 7.5 for a comparison of all three alternatives).

- Reduces flood risk and maintains LOP on the Cowlitz River. Results of the analysis indicated that dredging could be an effective long-term sediment management plan alternative.
- Cost effective. Based on results of the analysis and follow up assessment, it was determined this type of measure would be costly but effective.
- Requires regular dredging and placement of material in lower 20 miles of Cowlitz River corridor. Fish and wildlife impacts would be difficult to avoid, but monitoring could minimize impacts to the environment.
- Reliable. Historical dredging has demonstrated its reliability as long as sediment monitoring and a regular funding stream to dredge would be maintained.
- Adaptable to changing sediment deposition conditions;
- The action is within existing sediment deposition zone; therefore, it would not impact protected historical and cultural resources.
- Differing public opinions exist about dredging as a long-term sediment management strategy.

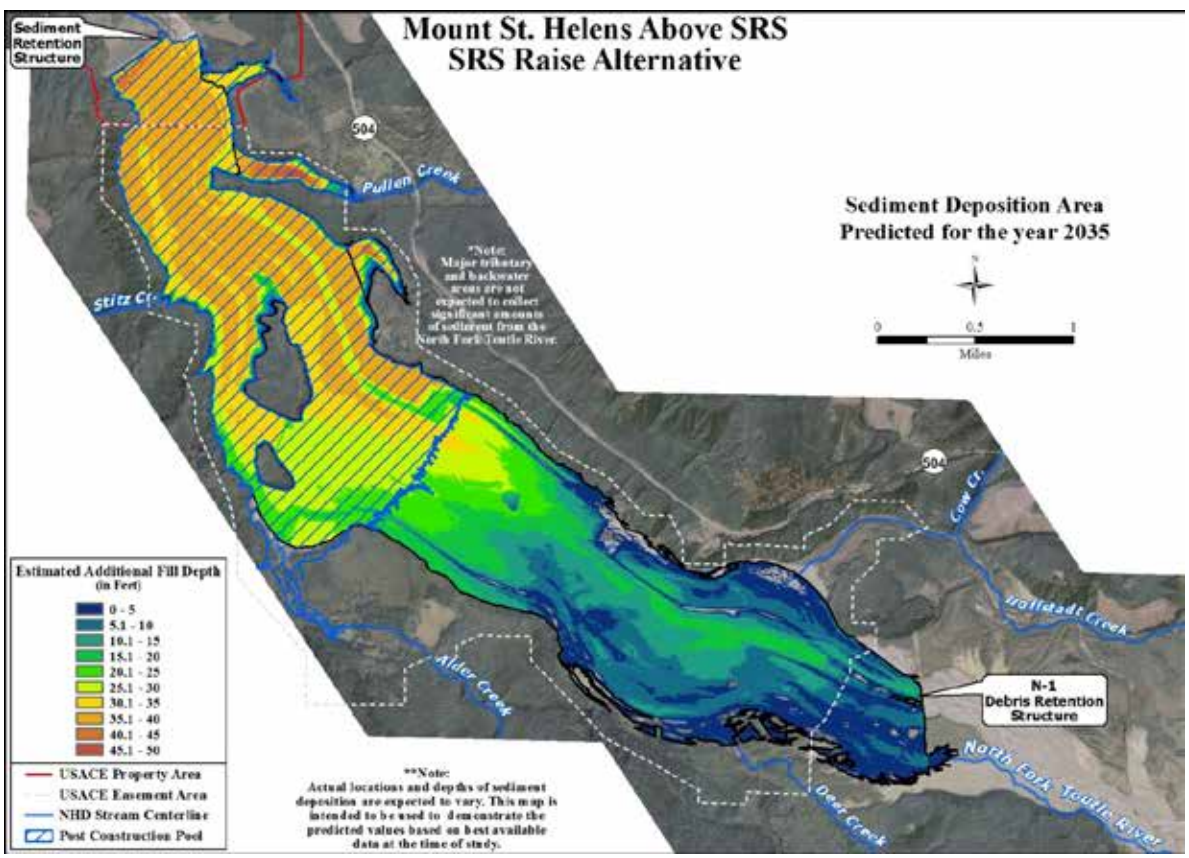
7.3. ALTERNATIVE 2 – SRS SPILLWAY AND EMBANKMENT RAISE

7.3.1. Overview

This alternative involved raising the SRS as the primary sediment management measure. The new outlet works of the raised SRS would have an overall sediment trapping efficiency of 80%. The spillway of the SRS would be raised 43 feet to elevation 990 feet NGVD29 and the top of dam would be raised 30 feet to elevation 1,030 feet NGVD29. The raise would be constructed over a 2-year period. The concept design for the raised SRS is described in more detail in Appendix A.

The long-term sediment and water depositional footprint behind the raised SRS with a sediment slope of "S/2" (0.006 ft/ft) would be one half the pre-eruption valley slope, which is the estimated long-term final valley slope behind the SRS. The total volume estimated to reach this S/2 profile would be approximately 324 mcy by the year 2300 if sediment loads from the debris avalanche remain persistently high. Assuming decay in sediment loads from the debris avalanche, it would be possible that the S/2 profile for the 43-foot raise would not be reached, even several hundred years in the future. Assuming that the decay in the avalanche erosion was not realized, an estimate was made on the volume expected for the 43-foot raise by 2035. A valley slope was developed by an iterative method that resulted in the estimated 2035 volume for the 43-foot raise. The depositional boundary that corresponds to this valley slope can be found in Figure 7-3.

Figure 7-3. Depositional boundary for the 43-foot Raise in 2035



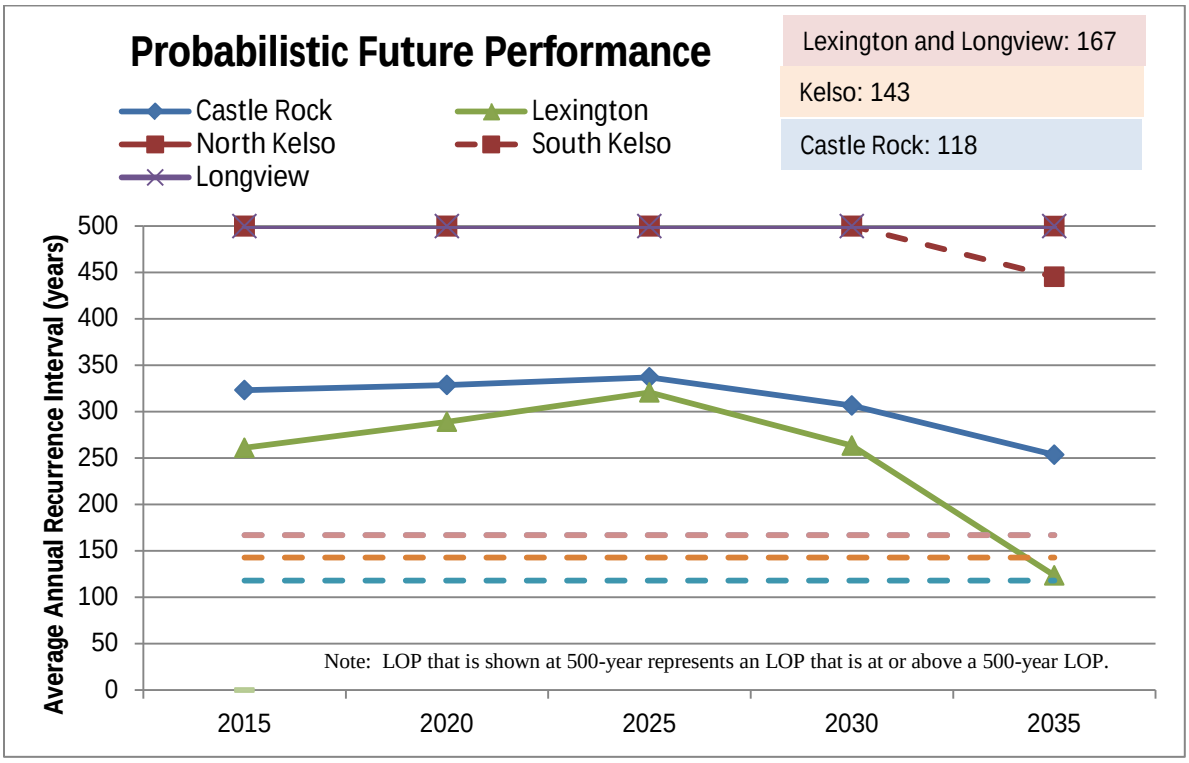
With the construction of the 43-foot SRS raise, there likelky would be a 10-foot deep seasonal pool with occasional spikes to 30-feet deep for the first 15 years. Within the first 2 years post construction, the first row of outlet pipes would be closed and a 20-foot deep seasonal pool would extend from the SRS upstream to the large island. Over the next 5 years, a 10-foot deep pool with seasonal spikes to 30-feet deep would occur. This pattern would continue for many years with eventually 40+ feet of sediment at the face of the dam. More shallow sediment deposition would occur upstream and into the Alder Creek confluence. The existing pilot project GBS would be completely buried 50+ years post SRS raise construction.

The following subsections describe the LOP performance, estimated costs, adaptability, environmental impacts, cultural resources impacts, and public impacts of this alternative.

7.3.2. LOP Performance

Using the tools, methodology and performance metric described in the 2011 FEDS report, a raised SRS alternative was analyzed to assure future performance of the Cowlitz levees. Figure 7-4 shows the projected performance through the end of the planning period at 5-year increments for the raised SRS alternative. Since the raised SRS alternative would be a highly effective preventative measure (prevents sediment from entering the lower Cowlitz River), the trajectory of future performance would be relatively smooth. In approximately 2030, when the raised SRS would fill with sediment to spillway crest height and begin passing significant load over the spillway, project performance would begin to fall toward authorized levels.

Figure 7-4. Probabilistic Future Performance for Raised SRS Alternative



7.3.3. Costs

The cost of the 43-foot SRS raise would be over $351 million. This cost estimate included costs associated with the actual planning, engineering and design for the SRS raise, ongoing sediment monitoring, environmental impacts monitoring and mitigation, real estate, and ongoing management of the existing SRS. The long-term footprint extends outside the existing USACE easement by approximately 128 acres. Assuming a 3.5% discount rate and 18-year period of evaluation (2017-2035), the average annual cost for the 43-foot SRS Raise alternative would be $21.3 million. While flow passes through the new SRS outlet works, there may be higher operation and maintenance costs than there are for the present run-of-river condition.

Sediment monitoring and level of protection evaluations would be required less frequent compared to the other alternatives. The intensity of monitoring would be reduced while the raised SRS is operating with flow through the new outlet works. Monitoring generally would consist of sediment loads from the debris avalanche, hydrosurvey in the lower Cowlitz River, and deposition surveys in the sediment plain. Additional monitoring of the outplant site productivity and connectivity to downstream channels would be necessary to assure productivity of the fish populations in the basin.

7.3.4. Environmental Considerations

Environmental impacts for this alternative have been evaluated in the SEIS. Impacts may include sedimentation infill of wetlands and some critical fish habitat as the sediment plain continues to aggrade; potential blockage of spawning habitat tributaries at their confluences with the sediment plain leading to potential difficulty for downstream migration of salmonids; limitations to future upstream volitional fish passage at the SRS spillway; loss of wildlife foraging (primarily elk); and loss of mature trees including old growth forest.

Wetlands present near the face of the SRS would be inundated by a large pool of standing water and those along the sediment plain fringe further upstream would be buried as sediment deposits. In upstream reaches of the sediment plain that experience a slower rate and depth of sediment deposition, existing wetlands would most likely continue with their presently observed trend of larger individual plants surviving the burial with new plants becoming established in between. Natural recruitment of wetlands over time in the sediment plain would be expected, but their future size and location cannot be estimated. A monitoring and mitigation plan for wetlands would be implemented and was included in the overall cost estimate.

For ESA-listed coho salmon and steelhead, the USACE has determined that the proposed action "may affect and is likely to adversely affect" these species or their designated critical habitat. The determination that these species and their critical habitat would be adversely affected is based on impacts to downstream-migrating juveniles as they are routed through outlet works pipes at the SRS and the downstream energy-dissipating weirs, as well as potential disconnection of the spawning and rearing tributaries to the NF Toutle River due to heavy, localized sedimentation. Monitoring of and mitigation for impacts to critical fish habitat was included in the overall cost estimate.

The elk comprising the MSH herd are a species of management concern for the WDFW. The SRS and spillway raise alternative would impact existing elk forage habitat, primarily in the form of lost wetlands. The WDFW indicated that availability of adequate winter forage was a limiting factor for the population health of the MSH herd.

The sediment plain is bordered by mature forest growing on upland, mineral soils rather than the pure sand of the sediment plain, which is also seasonally saturated to the surface by water. After construction of the raised SRS and spillway, the upstream extent of the large pool of water is expected to result in some impact to forest including old-growth forest trees. Continued deposition of sediment upstream of the SRS would inundate these forested areas on the fringe of the sediment plain and result in the loss of those trees directly adjacent to the sediment plain as the mineral, upland soil becomes increasingly water saturated. The original EIS accounted for the loss of this forest acreage. The impacted area would be within the USACE-leased land for sediment storage. Some additional acreage of forest would be impacted that was not included and mitigated for.

7.3.5. Cultural and Historical Resources

Cultural resources impacts for this alternative were evaluated and are included in the SEIS. Raising the height of the SRS 43 feet would result in potential adverse effects to historic properties listed on or eligible for listing to the NRHP. An area encompassing approximately 650 acres was identified as potentially impacted by the SRS raise and a cultural resource inventory was performed. This inventory work was completed by a cultural resources contractor that resulted in the identification of several historic-era resources. A determination of eligibility for these newly completed resources has yet to be finalized. In addition, the SRS itself was evaluated for NRHP and while it is less than 50 years old, it was determined eligible for the NRHP under Criterion G, significance obtained within the last 50 years. Potential adverse effects to cultural resources include the alteration of the SRS structure and spillway, and the potential depositional of several historic era archeological sites whose NRHP eligibility is yet to be determined. Adverse effects to any eligible or listed NRHP historic property would require mitigation efforts agreed upon in either a Memorandum of Agreement or a Programmatic Agreement between the USACE, Washington Department of Archaeology and Historic Preservation, potentially the Advisory Council on Historic Preservation, and any relevant Native American Tribe.

7.3.6. Public Use Considerations

Raising the height of the SRS is anticipated to occur over two seasons during the summer months. The area that construction would occur is rural in character. Therefore, impacts to the public should be minimal. The primary impact would likely be increased traffic on the highway leading up to the MSH tourist attractions. In addition, visitation to the existing SRS and trail to viewing platform would be impacted during construction. Refer to the SEIS for additional details.

7.3.7. Reliability

For the SRS raise, reliability refers to both the stability of the structure under loading and the ability of the structure to perform as expected (i.e., trapping sediment). During the design phase of this project, the SRS would be constructed to reliably withstand the PMF storm. Through periodic inspection and evaluations, the current SRS reliably handles this storm event. It is reasonable to assume that a future design of the SRS can accommodate these design criteria.

Initially the trapping efficiency of the raised SRS would be high (nearly 90%), but as the rows of pipes are closed and flow of the NF Toutle routed through the spillway, the trapping efficiency would diminishe. The plan incorporates this slow decline in trapping efficiency. Therefore, the 43-foot SRS raise would be a reliable alternative once constructed.

7.3.8. Adaptability

The 43-foot SRS raise would not be adaptable to varying and unpredictable volumes of sediment depositing in the lower river. For this alternative, the spillway and top of dam would be raised a pre-determined height of 43 feet. The raised spillway elevation was based on the following assumptions:

- The sediment loading condition from the debris avalanche through 2035 would be the same as it was from 1999-2007; that is, there would be *no decay in the sediment loading*.
- The overall trapping efficiency of the new outlet works would be 80%.
- Once the raised SRS becomes run-of-river again, there is at least a 5-year time period before sedimentation in the Cowlitz River threatens authorized LOPs.
- The authorized LOPs would be maintained through 2035.

The SRS raise was based on the above sediment loading and trapping efficiency assumptions. If it turns out there is decay in the future sediment loadings, a shorter SRS raise would have sufficed. Because the raised SRS would be built based on the above set of assumptions, there would be no ability to adapt to changes in sediment loading conditions.

7.3.9. Public Acceptability

The public review process would determine the extent of public acceptability. Public scoping meetings and input from agencies and other organizations indicated significant concerns with this option due to the limitations on future upstream volitional fish passage at the SRS and sediment plain infill impacts to other habitats.

7.3.10. Summary of 43-foot SRS Raise Alternative

Following is a summary of the effects of the 43-foot SRS raise and its viability as a standalone alternative to maintain authorized flood risk management to the communities along the lower 20 miles of the Cowlitz River (see Section 7.5 for a comparison of all three alternatives).

- Reduces flood risk and maintains LOP on the Cowlitz River. Results of the analysis indicated that this would be an effective long-term sediment management plan alternative.
- Cost effective. Based on results of the analysis and follow up assessment, it was determined this type of measure would be significantly less costly than dredging but does require all funding upfront.
- Impacts the tributary habitat above the SRS and would likely preclude future potential for volitional upstream fish passage at the SRS.
- Reliable. It is a reliable alternative to manage sediment through 2035.
- Is not adaptable to changing conditions. Would build and store whatever volume of sediment was transported from the MSH avalanche. There is some evidence actual loads may decline over time.
- The action may impact some protected historical and cultural resources.
- Differing public opinions about exist but strong opposition was indicated through scoping and other meetings.

7.4. ALTERNATIVE 3 – PHASED CONSTRUCTION PLAN

7.4.1. Overview

The Phased Construction alternative involves up to two incremental raises of the SRS spillway elevation (totaling up to 23 feet) without raising the top of dam elevation, building GBS in the sediment plain upstream of the SRS, and as needed dredging in the lower Cowlitz River. Each phase of this alternative would be implemented only if and when needed. To determine whether a next phase would need to be constructed, the USACE would monitor hydrologic and sediment conditions in both the sediment plain and the lower Cowlitz River and decide whether conditions trigger the need for action. The three phases of the Phased Construction alternative are sequential and are listed below in order of implementation:

- Phase 1: First SRS spillway crest raise.
- Phase 2: Second/final SRS spillway crest raise.
- Phase 3: Grade building structures.

For this alternative, the spillway would be raised in phased increments over time to a total raise height of 23 feet above the crest established in the 2012 spillway crest improvements. Each raise would increase the spillway crest by up to 13 feet in order to increase the sediment storage capacity behind the SRS. The timing and height of the incremental raises would not be prescribed up-front, but would be determined based on sediment infilling conditions behind the SRS, sediment conditions in the Cowlitz River, and the budgeting cycle for funding. Each increment includes maintaining existing downstream fish passage, and the final configuration maintains the existing spillway slope of 7%.

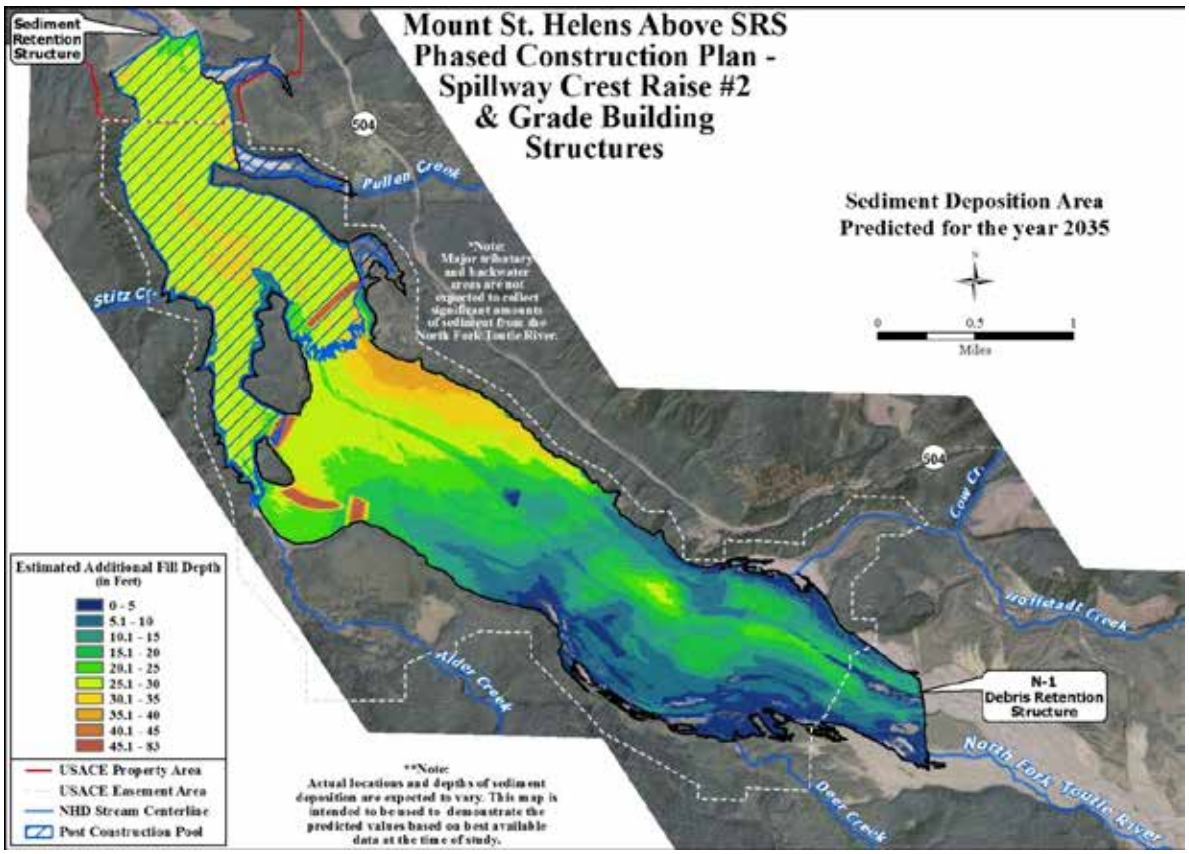
After the SRS spillway has been raised a total of 23 feet (two crest raises above the 2012 improvements) and sediment fills to the spillway crest, the next upstream measure would be to construct the GBS (consisting of strategically located dikes in the sediment plain). Figure 6-3 showed the preliminary configuration of the dikes, which would be constructed using sheet piling in the center extending into the foundation surrounded by rockfill. The openings between the dikes and the valley walls would be at existing grade at the time of construction, and protected from scour using rock and possibly at-grade sheet piling. During high flow events, temporary pools would form behind the dikes allowing sediment to settle out.

Some sediment deposition in the Cowlitz River is still expected and in the event of an unusually large sediment load, dredging in the river is reserved for these unusual sediment deposition events. The footprint of this dredging effort would be much less than the Dredging Only alternative and would only be performed when needed to continue to maintain level of protection for the lower Cowlitz levees.

In order to maintain level of protection for the communities in the Lower Cowlitz River, it was estimated that two crest raises and the GBS would be needed prior to the end of the project horizon (year 2035). An depositional map was developed for these 2035 conditions for the phased plan by using the volume estimated for the long-term S/2 depositional estimate assuming no change in the incoming load or trapping efficiency of the SRS. For the two crest raises and the GBS structures, the long-term sediment deposition was estimated to be 195 mcy which would occur in approximately 2220. If decay in the sediment load from the debris avalanche is realized, then the estimate of achieving the S/2 profile would likely be after the year 2900. Assuming that the S/2

profile would be realized by 2220, the estimated volume was pro-rated for the 2035 horizon and a profile matching this pro-rated volume was developed. Figure 7-5 shows the 2035 depositional boundary for the Phased Construction alternative. This depositional boundary was used to inform the environmental impacts detailed in the SEIS.

Figure 7-5. Depositional Boundary for Phased Construction Alternative by 2035



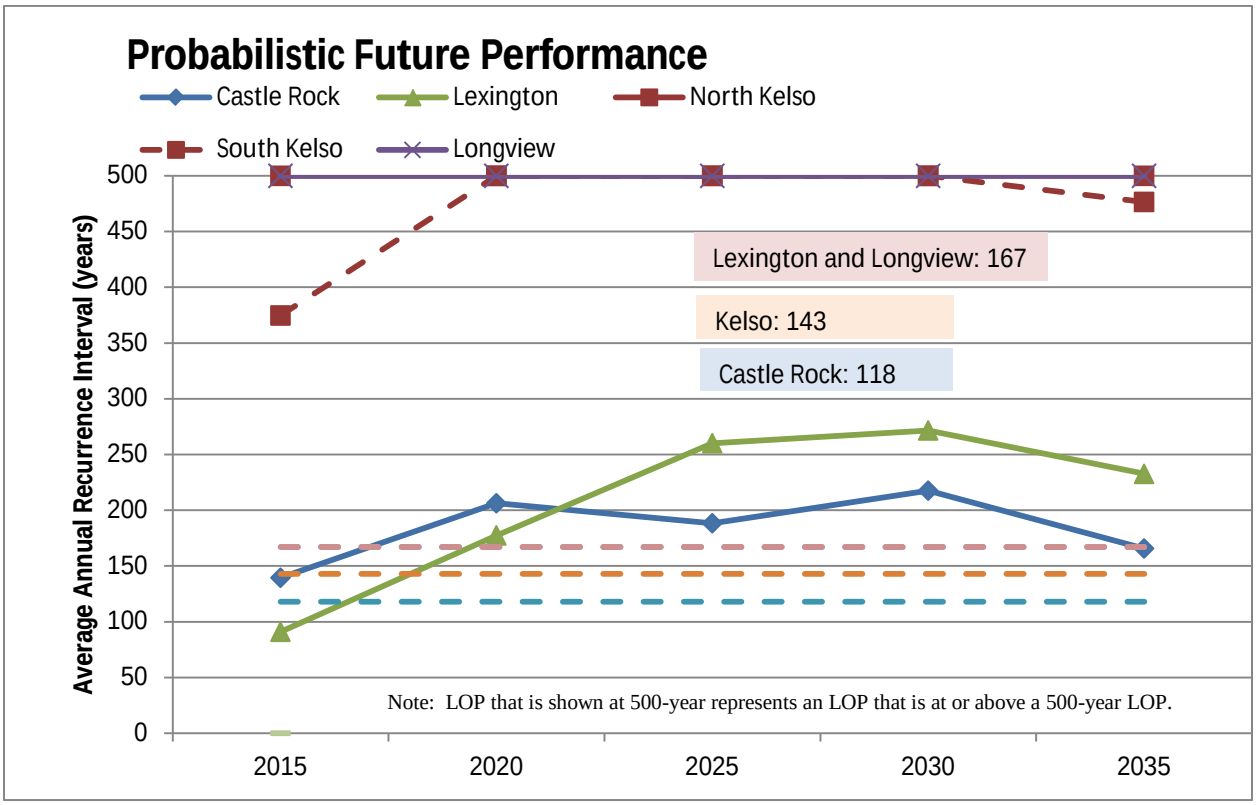
The following subsections describe the LOP performance, estimated costs, adaptability, environmental impacts, cultural resources impacts, and public impacts of this alternative.

7.4.2. LOP Performance

Using the tools, methodology and performance metric described in the 2011 FEDS report, a series of SRS spillway crest raises, GBS, and Cowlitz dredging events were determined that would plot a future performance trajectory maintaining authorized levels. This combination of measures are both preventative (crest raises and GBS reduce sediment load to lower Cowlitz River) and reactionary (Cowlitz dredging removes deposited material). Figure 7-6 shows the projected performance of the alternative at 5-year intervals through the end of the planning period. Since the preventative measures are not overwhelmingly sized (like the raised SRS alternative), large events are still capable of depositing significant volumes of sediment in the lower Cowlitz. It is after these large and rare events that dredging may be required in the lower Cowlitz. Variability in future performance is related to variability in the incoming load/transport capacity. Following large events that result in significant deposition, performance can be significantly reduced potentially to levels

below authorization. Subsequent dredging is required to remove the deposition and reestablish a comfortable margin for future deposition.

Figure 7-6. Probabilistic Future Performance for Phased Construction Alternative



7.4.3. Costs

The cost of the phased construction plan would be $281 million with the majority of these costs attributed to potential unusual event dredging. This estimate includes costs associated with the actual planning, engineering and design for the SRS raise, ongoing sediment monitoring, environmental impacts monitoring and mitigation, real estate, and ongoing management of the existing SRS.

Assuming a 3.5% discount rate and 18-year period of evaluation (2017-2035), the average annual cost for the two spillway raises and grade building structures would be $5.8 million. The potential need for dredging also is included. According to sediment modeling results, Cowlitz River dredging could be required to address unusual events and is included in the overall plan. It is uncertain when and even if Cowlitz River dredging would be required; therefore, a range of costs was used to account for any dredging that could be required. If there were a requirement for early-year dredging (2018-2025), it would result in an average annual dredging cost of $9.97 million, whereas late-year dredging (2028-2035) would result in an average annual cost of $6.4 million. Therefore, the overall cost of this plan would range from an average annual cost of $5.8 million (no dredging required) to $15.8 million (dredging required early in evaluation period). Refer to Appendix C (Costs) and Appendix D (Economics) for additional information.

7.4.4. Environmental Considerations

Environmental impacts for this alternative have been evaluated in the SEIS. Impacts identified include sedimentation infill of wetlands and some critical fish habitat as the sediment plain continues to aggrade, potential blockage of spawning habitat tributaries at their confluences with the sediment plain leading to potential difficulty for downstream migration of salmonids, loss of wildlife foraging (primarily elk), and loss of mature trees.

Wetlands present along the sediment plain fringe would be slowly and continuously buried as sediment deposits over time. However, the expected rate of sediment deposition under the phased construction alternative is such that the wetlands would most likely continue with their presently observed trend of larger individual plants surviving the burial with new plants becoming established in between. To ensure no net loss, monitoring would be performed.

The sediment plain is bordered by mature forest growing on mineral soils rather than the pure sand of the sediment plain, which is also seasonally saturated to the surface by water. Continued deposition of sediment upstream of the SRS would inundate these forested areas on the fringe of the sediment plain and result in the loss of those trees directly adjacent to the sediment plain as the mineral, upland soil becomes increasingly water saturated. The original EIS accounted for the loss of this forest acreage. The impacted area would be within the USACE-leased land for sediment storage.

For ESA-listed coho salmon and steelhead, the USACE has determined that the proposed action "may affect and is likely to adversely affect" these species or their designated critical habitat. The determination that these species and their critical habitat would be adversely affected is based on impacts to downstream-migrating juveniles should they encounter a disconnection of their spawning and rearing tributaries to the NF Toutle River due to heavy, localized sedimentation. Monitoring of and mitigation for impacts to critical habitat were included in the overall cost estimate.

In the event that dredging becomes necessary, ESA-listed salmonids, green sturgeon, Pacific eulachon, and bull trout and their designated critical habitat in the lower Cowlitz River "may be affected and are not likely to adversely affected." The determination that these species and their critical habitat would not be adversely affected is based on all dredging activities being conducted during the in-water work window when these species are least likely to be present and on the continuous replenishment of sediment to the habitat. Monitoring of and mitigation for impacts to critical habitat were included in the overall cost estimate.

The streaked horned lark is a federally threatened and state endangered species that is associated with bare ground or sparsely vegetated habitats found in the lower Columbia River basin. Placement of dredge material on the dredge sites in the lower Cowlitz River has the potential of attracting streaked horned lark. While no colonies are known to exist in the lower Cowlitz River, the placement of dredge fill provides suitable habitat. Therefore, a site survey would be conducted prior to dredging activities.

7.4.5. Cultural and Historical Resources

Cultural resources impacts for this alternative were evaluated and are included in the SEIS. Modifications to the SRS spillway height could potentially result in adverse effects to historic properties listed on or eligible for listing to the NRHP. An area was identified as potentially impacted by the SRS spillway raises and a cultural resource inventory was performed. This

inventory work was completed by a cultural resources contractor that resulted in the identification of several historic-era resources. A determination of eligibility for these newly identified resources has yet to be finalized. If these resources are determined not eligible for the NRHP and the Washington Department of Archaeology and Historic Preservation concurs, then no further work is necessary for these archeological sites.

In addition, the SRS itself was evaluated for NRHP. While it is less than 50 years old, it was determined eligible for the NRHP under Criterion G, properties exhibiting significance obtained within the last 50 years. Potential adverse effects to cultural resources include the alteration of the SRS spillway structure itself. However, the selection of this alternative would involve only the alteration of the SRS spillway and likely result in a determination of "no adverse effect." Any other adverse effects determination to any eligible or listed NRHP historic property would require mitigation efforts agreed upon in either a Memorandum of Agreement or a Programmatic Agreement between the USACE, Washington Department of Archaeology and Historic Preservation, potentially the Advisory Council on Historic Preservation, and any relevant Native American tribe.

7.4.6. Public Use Considerations

This alternative may have some impacts to public uses. Raising the height of the SRS spillway is anticipated to occur in the summer months. The area that construction would occur is rural in character. Therefore, impacts to public uses would be minimal. The primary impact would likely be increased traffic on the highway leading up to the MSH tourist attractions. In addition, there is some visitation to the existing SRS and the trail leading to a viewing platform that would be impacted during construction.

Construction of the small GBS upstream of the SRS would temporarily impact some recreation use. Hunting in the area would be prohibited during construction windows. In addition, there is a private resort adjacent to the sediment plain. Visitors to this facility often walk or ride horses in the sediment plain. These activities would not be permitted during summer construction windows.

Occasional dredging in and along the lower 20 miles of the Cowlitz River would have temporary impacts to the public. The lower 20 miles of the Cowlitz River is heavily populated (includes the communities of Kelso, Longview, Castle Rock and Lexington). Any dredging is anticipated to occur in the summer months. Dredging on the river and moving dredging equipment in and out of this area may have the following negative impacts:

- Moving dredging equipment in and out on the roadways adjacent to the Cowlitz River may impact local community access at times.
- Dredging equipment would increase noise levels in areas where dredges are operating.
- Recreation areas and trails along the lower Cowlitz River may be temporarily closed to public use when dredging is occurring.
- Recreational boat use would be limited in the areas of active dredging.

7.4.7. Reliability

The components of this alternative have been tested and applied in the past; the combination provides a reliable approach to managing sediment. Field assessment of the GBS pilot project and the 7-foot spillway raise demonstrate these types of measures work. Our proposed ongoing

monitoring is an important component of the plan and helps to reduce uncertainty in the effectiveness of the plan. The ongoing sediment monitoring must be maintained in order to plan for the implementation timing of the components of the plan in order to realize the sediment management benefits.

7.4.8. Adaptability

This alternative consists of a phased approach—two spillway raises and GBS—that would be built incrementally as needed. The decision to build the next increment would be based on sediment depositional trends and trends in the level of protection of the Cowlitz River levees and the budgeting cycle for funding. Decay in the annual debris avalanche sediment loads could eliminate the need for construction of the alternative elements, thereby reducing overall project costs and preventing overbuilding.

Recent studies conducted by the Portland District indicated a significant potential for a diminished annual sediment load from the debris avalanche into the future. Decay trends were based on both empirical evidence from annual sediment load estimates back to 1980, as well as projected computer model simulations. Degrees of uncertainty in the delivery of the annual sediment loads would make the adaptability of this plan a key advantage over a single structure built at one time.

Using this phased approach would prevent overbuilding a long-term sediment management plan. An unusually large sediment event could result in some sedimentation to bypass the spillway raise/GBS structures and deposit problematic sediment in the Cowlitz River. The dredging component is included as a feature of this plan in order to dredge the lower Cowlitz River sediment as a result of an unusual event.

7.4.9. Public Acceptability

The public review process would determine the extent of public acceptability. Raising the SRS spillway and construction of GBS would occur periodically over many years during the summer months. The area that construction would occur is rural in character. Therefore, impacts to the public should be minimal. The primary impact would likely be increased traffic on the highway leading up to the MSH tourist attractions. In addition, visitation to the existing SRS and trail to viewing platform would be impacted during construction. Public scoping meetings and other meetings have identified concern about fish passage and stream connectivity issues.

If the dredging component of this plan was required, lower Cowlitz River citizens and river users would experience relatively minor noise impacts and limitations to boat ramps and river trail access where dredging is taking place (see the SEIS for additional information).

7.4.10. Phased Construction Alternative Summary

Provided below is a summary of the effects of the phased construction alternative to maintain authorized flood risk management to the communities along the lower 20 miles of the Cowlitz River (see Section 7.5 for a comparison of all three alternatives).

- Reduced flood risk on the Cowlitz River. Results of the pilot project indicated that GBS could be an effective component of the long-term sediment management plan. Results of the analysis and construction of a 7-foot spillway raise in 2012 showed this to be an

effective component of the long-term sediment management plan. The combination of these actions along with dredging (as needed) would make this a solid alternative in order to maintain authorized LOP in the lower Cowlitz River.

- Cost effective. Based on results of the analysis and follow up assessment, it was determined that this type of measure would be significantly less costly than other options.
- Minimizes impacts to the environment; monitoring of tributary connectivity would be necessary for some time after the last raise; does not preclude upstream volitional fish passage at some time in the future.
- Reliable. It is a reliable measure to manage sediment through 2035.
- Adaptable to changing conditions, would only build what is needed.
- The action may impact protected historical and cultural resources.
- Differing public opinions exist about this alternative. Public scoping meetings and other meetings identified concern about fish passage and stream connectivity issues.

7.5. COMPARISON OF ALTERNATIVE PLANS

7.5.1. Comparison of Average Annual Costs

The following life-cycle cost comparisons are based on the stream of expenditures for each alternative from 2018 through 2035 and applying a 3.5% discount rate. Table 7-2 summarizes the present value and average annual costs by alternative.

Table 7-2. Average Annual Costs by Alternative

Alternative	Present Value Cost ($)	Average Annual Cost ($)
Cowlitz River Dredging Only	594,967,771,000	45,10,8939,000
43-foot SRS Raise	269,32,9061,000	21,26,7283,000
Phased Construction Plan:		
Phased Construction	60,67,6928,000	5,83,9721,000
As-needed Dredging	131,49,5291,000	9,969,000
Total Plan Costs	192,16,9219,000	15,800,000

The life-cycle cost comparisons showed that the least-cost approach for maintaining the authorized LOP to the communities of Kelso, Longview, Castle Rock and Lexington through 2035 is the phased construction alternative (spillway raise + GBS + as-needed dredging).

7.5.2. Overall Comparison of Alternatives

The evaluation of the alternatives demonstrated that the Phased Construction alternative would be the best approach to maintain the authorized LOP to the communities of Kelso, Longview, Castle Rock and Lexington. Table 7-3 summarizes the overall rationale used to screen the alternatives. Based on this rationale and the least-cost analysis, the Phased Construction alternative is identified as the selected plan. The Phased Construction alternative was found to be the least-cost plan, adaptable to uncertain sedimentation conditions through 2035 and beyond, effective in handling extreme events, and minimizes impacts to fish and wildlife in the near term and over time.

Table 7-3. Comparison of Alternatives

Criteria	Alternatives		
	Cowlitz River Dredging Only	**Spillway Raise at SRS**	**Phased Construction (spillway raise + GBS + dredging as needed)**
Effective at maintaining flood damage reduction benefits	Meets need	Meets need	Meets need
Economics - Average Annual Cost (18 years)	Highest cost. About $45 million/year with annual costs.	$21.3 million/year with majority of funding required upfront.	Least-cost plan. $5.8 million/year for structures and $10 million/year included for as-needed dredging. Structure funding needs distributed over time; dredging funds only needed for unusual sediment deposition conditions & may not ever be required.
Environmental Considerations	Regular impacts to the lower Cowlitz.	Upstream tributary habitat impacts; future upstream fish passage at the SRS not likely an option.	Upstream tributary habitat impacts & intermittent impacts to lower Cowlitz due to dredging; future upstream fish passage at SRS remains an option.
Reliability	Yes - as long as monitoring and dredging action is maintained.	Yes - some monitoring still required.	Yes - as long as monitoring and plan implementation is maintained.
Adaptability	Yes - dredge as needed.	No - requires full funding and construction upfront (some of which may be unnecessarily conservative).	Yes - implement components of plan over time as needed.
Public Acceptability	Lower Cowlitz River users have noise and access impacts during dredging, but generally acceptable.	Opposition to this option likely.	To be determined.

8. SELECTED RECOMMENDED PLAN

8.1. RECOMMENDED PLAN

The evaluation of the alternatives provided in the previous section demonstrated that the Phased Construction Plan would be the best approach to maintain the authorized LOP levels to the communities of Kelso, Longview, Castle Rock and Lexington. This plan was found to be cost effective, adaptable to uncertain sedimentation conditions through 2035 and beyond, effective in handling extreme events, and minimizes impacts fish and wildlife in the near term and over time. The Phased Construction Plan is a phased plan involving the following three sediment management measures:

- SRS spillway raises,
- Grade-building structures, and
- As-needed dredging in the Cowlitz River.

The sediment modeling and additional analyses provided a planning level timeline for when different sediment management actions may be needed. Table 8-1 summarizes the planning level timeline. As-needed dredging has been accounted for in this plan by incorporating extreme sediment load events in the forecasted years. When these events occur, dredging may be required. The extreme sediment events occur within the forecast years 2015 and 2021. The dredging events shown in Table 8-1 are in response to the large sediment loads from the particular events. The design of the crest raises was not intended to handle the loads from the avalanche that result from large events upstream in the basin. These large sediment loads would be largely carried over the spillway crest and flush through the system. The actual need for dredging and the timing could occur through 2035.

Appenidx A contains a detailed analysis of each component of the Phased Construction Plan. The next section summarizes the implementation strategy of the plan.

8.2. IMPLEMENTATION STRATEGY

The benefit of the Phased Construction Plan lies in the uncertainty associated with future conditions in the MSH basin. The authorization language prescribed a LOP for the communities along the lower Cowlitz River. As such, implementation of any construction action would need to accommodate an ever-changing environment and on-going assessment of the LOP. This would be in contrast to an authorization where a project was designed for a relatively static set of hydrologic conditions.

The Phased Construction Plan has been designed to respond to changes in the MSH basin by only implementing actions necessary for maintaining the LOP in the lower Cowlitz River. Execution of the Phased Construction Plan would require on-going assessments in three distinct phases: (1) annual monitoring, (2) assessing the need for construction action, and (3) determining what construction actions are needed. Within this process, an implementation strategy would be defined to guide when and what actions would be needed. While this implementation strategy was meant to guide the process, it also was necessary to ensure that adaptability and best professional judgment would be used to ensure that actions are correctly applied in a timely way. The following section describes the implementation strategy for the Phased Construction Plan in more detail.

Table 8-1. Planning Timeline for Phased Construction Plan

Year	Construction Activity
2017	DDR/plans and specifications for 1st crest raise; real estate acquisition; lark monitoring; flow & sediment monitoring; LOP; annual report
2018	Construct 1st crest raise; wetland & wildlife habitat rehabilitation; flow & sediment monitoring; LOP; annual report
2019	Dredge 2 mcy in Cowlitz; flow & sediment monitoring; LOP; annual report
2020	Dredge 2.4 mcy in Cowlitz; flow & sediment monitoring; LOP; annual report
2021	Wetland & wildlife monitoring; lark monitoring; flow & sediment monitoring; LOP; annual report
2022	Dredge 3.5 mcy in Cowlitz; diversion berm maintenance; flow & sediment monitoring; LOP; annual report
2023	DDR/plans & specifications for 2nd crest raise; wetland & wildlife monitoring; flow & sediment monitoring; LOP; annual report
2024	Construct 2nd raise; wetland & wildlife habitat rehabilitation; flow & sediment monitoring; LOP; annual report
2025	Flow & sediment monitoring; LOP; annual report
2026	Flow & sediment monitoring; LOP; annual report
2027	Wetland & wildlife monitoring; flow & sediment monitoring; LOP; annual report
2028	Flow & sediment monitoring; LOP; annual report
2029	Wetland & wildlife monitoring; flow & sediment monitoring; LOP; annual report
2030	Wetland & wildlife habitat rehabilitation; additional outplant site construction; flow & sediment monitoring; LOP; annual report
2031	Follow-on GBS work; flow & sediment monitoring; LOP; annual report
2032	Flow & sediment monitoring; LOP; annual report
2033	Wetland & wildlife monitoring; flow & sediment monitoring; LOP; annual report
2034	Flow & sediment monitoring; LOP; annual report
2035	Wetland & wildlife monitoring; lark monitoring; flow & sediment monitoring; LOP; annual report

8.2.1. Annual Monitoring

Authorization based on providing specific LOP levels for lower Cowlitz River communities would require annual monitoring to assess the performance trends of the existing levees. Correct application of a Phased Construction Plan also would emphasize the need for annual monitoring. Knowing the quantity and distribution of the annual water volumes and sediment loads within the basin would be essential in correctly applying the components of the plan. Figure 8-1 provides a flowchart that describes the annual monitoring portion of the decision-making framework for the Phased Construction Plan.

Data must be gathered annually to describe basin conditions in order to effectively implement the Phased Construction Plan. Uncertainty in the response of the sediment loads to hydrologic events also would require quantification of the annual loads and the deposition within the Toutle/Cowlitz River systems. Figure 8-2 shows the locations of data collection locations that are part of an annual monitoring effort necessary to support the Phased Construction Plan.

Figure 8-1. Phased Construction Plan (Part 1), Annual Monitoring

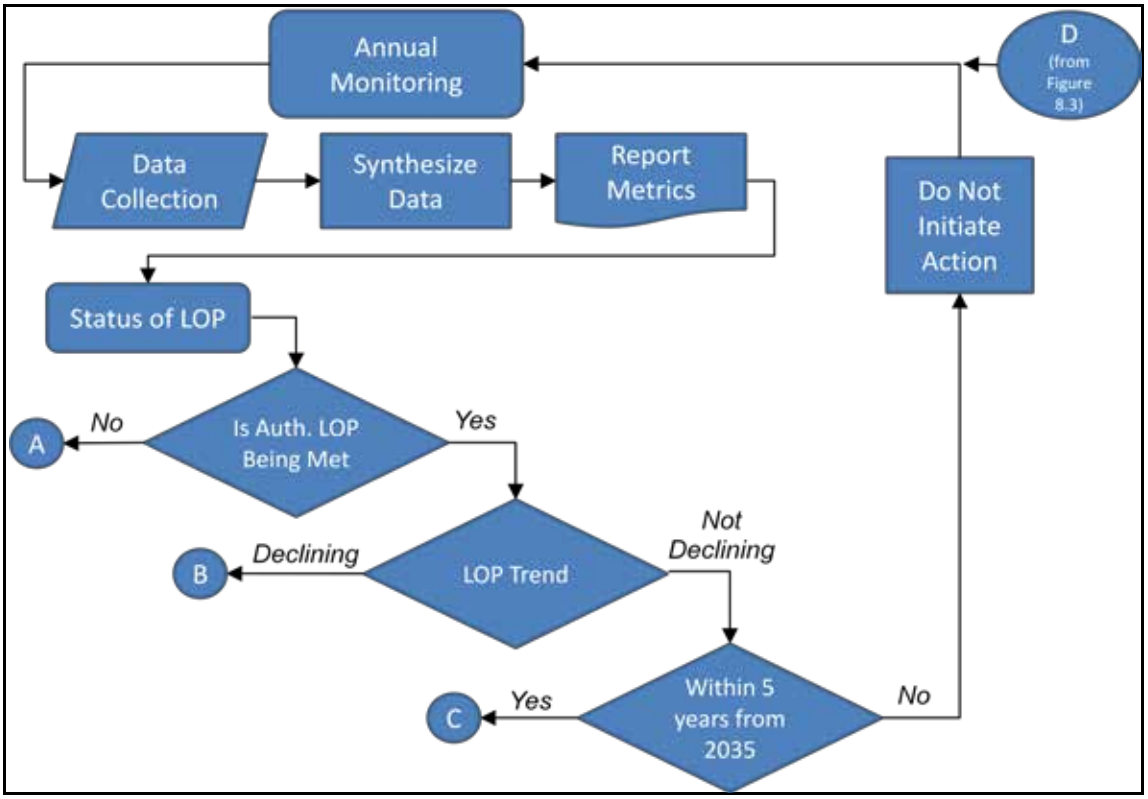
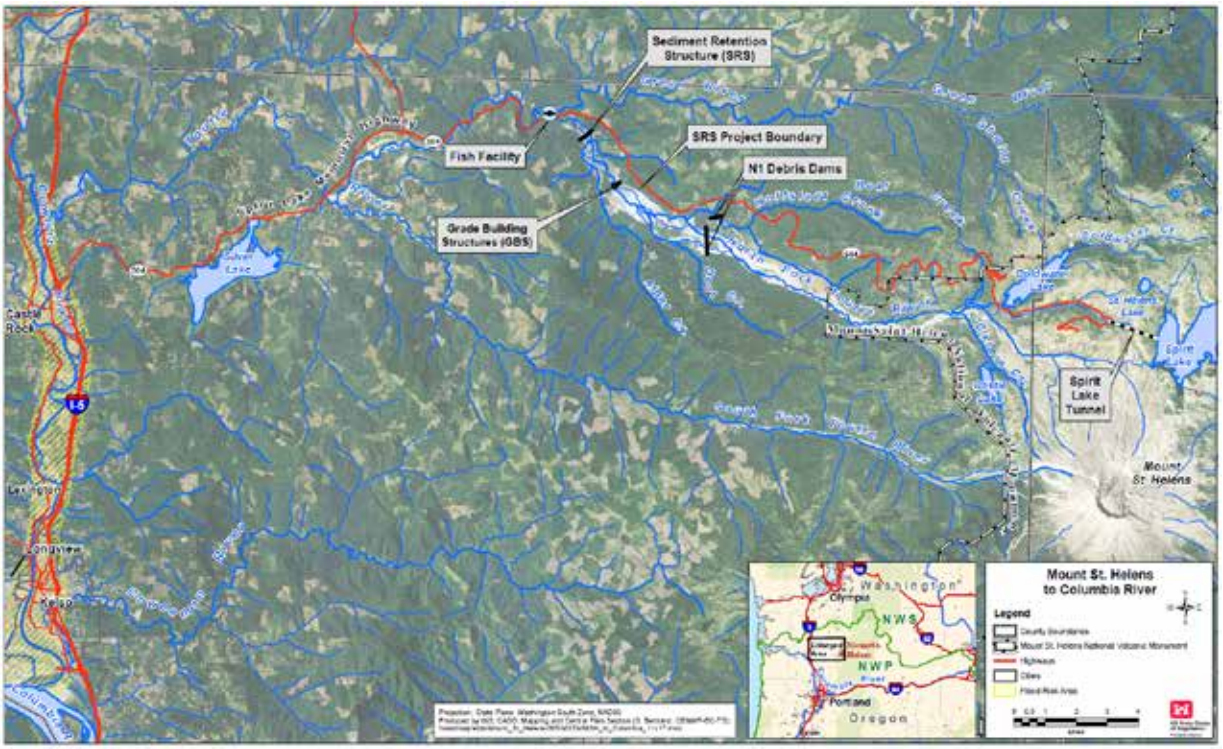


Figure 8-2. Map of Annual Monitoring for Phased Construction Plan



The information gathered annually would be synthesized to garner an understanding of the level of protection of the Cowlitz River levees, annual sediment loads within the basin, and deposition in the Toutle/Cowlitz system. The results of the annual analyses would be reported in annual hydrologic reports, presented to management within the Portland District, and presented to the affected communities (including the appropriate diking districts and County). Included in this annual report would be an assessment of whether the authorized LOP was met and the trend in LOP over time.

8.2.1.1. USGS Gages on the Toutle and North Fork Toutle Rivers

The USGS maintains an extensive network of gages on the Toutle and Cowlitz rivers. Over the period from about 1920 to present, 14 different gage locations have been utilized. Table 8-2 lists the gage location and indicates the period of water and/or sediment discharge record for each gage. Of the 14 gages, only a handful still provide an ongoing period of record that supports water volume/sediment load monitoring in the system: Cowlitz River at Castle Rock, Toutle River at Tower Road, SF Toutle River at Toutle, and the NF Toutle River below the SRS.

The USACE partnered with the USGS to support on-going data collection at the gages on the Toutle River and tributaries. Tacoma Light and Power currently provides funding for the Cowlitz River gage at Castle Rock. The gages on the Toutle River, NF Toutle and SF Toutle provide both discharge measurements and sediment load estimates that help define the distribution of sediment within the system as well as the annual volume of water passing each gage respectively. The USGS gage on the Cowlitz River at Castle Rock provides an essential long-term discharge record that provides not only information in regard to annual volume of water but also provides information as to the relative frequency of individual and annual storm events.

The largest degree of uncertainty in the system stems from the volume of future sediment load generated from the MSH debris avalanche. Thus, it is critical to collect the necessary information to determine the rates of sediment load and water volume in each of the contributing river basins.

Table 8-2. USGS Gaging Stations and Periods of Record

Gage Name	USGS Gage No.	Drainage Area (mi^2)	Water Year								
			1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000-2007
Coldwater Lake Canal near Spirit Lake	14240352	36.2									
North Fork Toutle River Below Maratta Creek near Spirit Lake	14240370	--									
North Fork Toutle River at St. Helens	14240500	124									
North Fork Toutle River Below SRS near Kid Valley	14240525	175									
Green River above Beaver Creek near Kid Valley	14240800	129									
Green River near Toutle	14241000	131									
North Fork Toutle River at Kid Valley	14241100	284									
South Fork Toutle River above Herrington Creek near Spotted Buck Mtn.	14241465	34.4									
South Fork Toutle River at Camp 12 near Toutle	14241490	117									
South Fork Toutle River at Toutle	14241500	120									
Toutle River near Silver Lake	14242500	474									
Toutle River at Tower Road	14242580	496									
Toutle River at Hwy. 99 Bridge near Castle Rock	14242690	511									
Cowlitz River at Castle Rock	14243000	2238									

Discharge Data, Full Water Year
Discharge Data, Partial Water Year
Suspended Sediment Data, Full Water Year
Suspended Sediment Data, Partial Water Year

8.2.1.2. Precipitation Gages

In addition to USGS stream gages on the Toutle and Cowlitz rivers, precipitation data is collected by the USACE at the SRS and Coldwater Ridge to evaluate the intensity and distribution of the rainfall input into the Toutle River basin. The rainfall data helps inform the characteristic of an event and real time information as it relates to antecedent saturation and snow in the basin. This information would be necessary for immediate evaluation of an event, as well as a component into the potential for decay of sediment loads from the debris avalanche.

In addition, the Natural Resource Conservation Service (NRCS) collects rainfall and snow data in the basin at two locations in the upper NF Toutle: one gage at Coldwater Ridge (NRCS Gage #777) and another gage at Sheep's Canyon (NRCS gage #748). The Sheep's Canyon gage has been in operation since October 1980 and the Coldwater Ridge gage has been reporting since October 1983.

8.2.1.3. Hydrographic Surveys on the Lower Cowlitz River

Bathymetric data collected annually on the lower Cowlitz River has been analyzed to develop metrics necessary to evaluate whether the authorization is met and what, if any, action would be required to maintain the authorized LOP levels. Hydrographic surveying in the lower Cowlitz River has been used to track how much sediment has accumulated in the lower Cowlitz. Deposition in the lower Cowlitz could compromise the performance of the adjacent levees. The bathymetric data also could be used in conjunction with the hydraulic models of the Cowlitz River to support a direct LOP assessment.

8.2.1.4. LiDAR Upstream of SRS

Year-to-year LiDAR information has been used to quantify the volume of sediment that deposits behind the SRS. The LiDAR also has been essential in understanding the sediment plain and basin response to the existing and proposed actions. Information obtained from the LiDAR flight has been used to directly assess the need for future actions within the basin. The footprint of the LiDAR data collection area generally extends from the SRS to Elk Rock. However, it may be necessary to extend this footprint up to the MSH crater if a major change in the channel network is observed, a major sediment load is measured, or if there were any other changes in the debris avalanche that need to be captured in the LiDAR footprint. Barring an extraordinary event, the LiDAR footprint would be extended to the MSH crater every 5 years. This periodic survey up to the crater would be essential in evaluating the stability and channel evolution of the debris avalanche.

8.2.1.5. Site Visits

Cowlitz River

A lower Cowlitz River site visit has been performed annually to validate the results from the lower Cowlitz River hydraulic models and verify survey information. The site visit would be essential to visually assess any particular areas of concern that did not necessarily show up on the computer models or surveys.

Toutle River

Toutle River site visits have been used to evaluate conditions of the sediment plain, tributaries to the sediment plain, and the impacts of the executed actions. In the past, the USGS has provided the USACE with photographs taken from helicopter flights over the Toutle River basin. These photographs have been extremely helpful and informative in understanding and communicating changes in the basin. If the USGS ceases this flight photography, it is recommended that USACE personnel collect this information as an essential component in documenting the evolution of sediment deposition in the sediment plain and debris avalanche.

8.2.1.6. Sediment Sampling

In-situ sediment sampling in the Toutle and the Cowlitz rivers has been used to characterize the migration of deposited material from the MSH debris avalanche to the mouth of the Cowlitz River. Sediment mobilized from the debris avalanche moves through the system slowly over the course of several years. Sediment sampling provides information regarding where plugs of sediment occur and the locations of future sources of sediment. This information would provide the data necessary to determine whether an action would be needed. If a plug of medium sand was located just upstream of Castle Rock, for instance, then it may be necessary to consider an action to preserve the LOP for the marginal levee systems. If, however, there was no such source of sand in the system, then it may be that spikes in the sediment load observed at the gages represent sediment that has been successfully flushed through the system, and no action would be necessary.

8.2.1.7. Lower Cowlitz Stage Gages

A series of six USACE stage gages have been deployed at locations in the lower 20 miles of the Cowlitz River in order to provide an on-going stage record that can then be used to validate and calibrate the hydraulic model. The hydraulic model is a key component of the LOP estimate for the levees in the lower river reaches. The stage data collected helps verify that the model is providing adequate results for use in the LOP estimates.

8.2.1.8. Upstream Tributary Information

The SEIS prepared for the updated long-term sediment management plan concluded that the habitat provided by Hoffstadt Creek and Alder Creek, tributaries used for outplanting fish, would be key to the survival of salmonid species in the Toutle River basin. Therefore, sediment deposition at the mouth of these tributaries cannot be allowed to totally block access for downstream migrating salmonids. Information used in decisions for actions associated to ensure this connectivity remains would need to be gathered regularly.

Stage gage measurements have been deployed on these tributaries. These stage gages along with the survey of the channel at the sites provided discharge measurements that can be used to evaluate connectivity in key times of the year. In addition to the stage gages, the contractor deployed piezometer sensors at the mouth of Alder Creek (a point particularly impacted by NF Toutle sediment deposition) to measure the trend of the groundwater at this location. This information would help determine the potential for sediment deposition to cause surface flow of Alder Creek to be interrupted. These gages need to be maintained to provide a record of data used to monitor the environmentally sensitive areas of the sediment plain and provide information needed for future decision criteria.

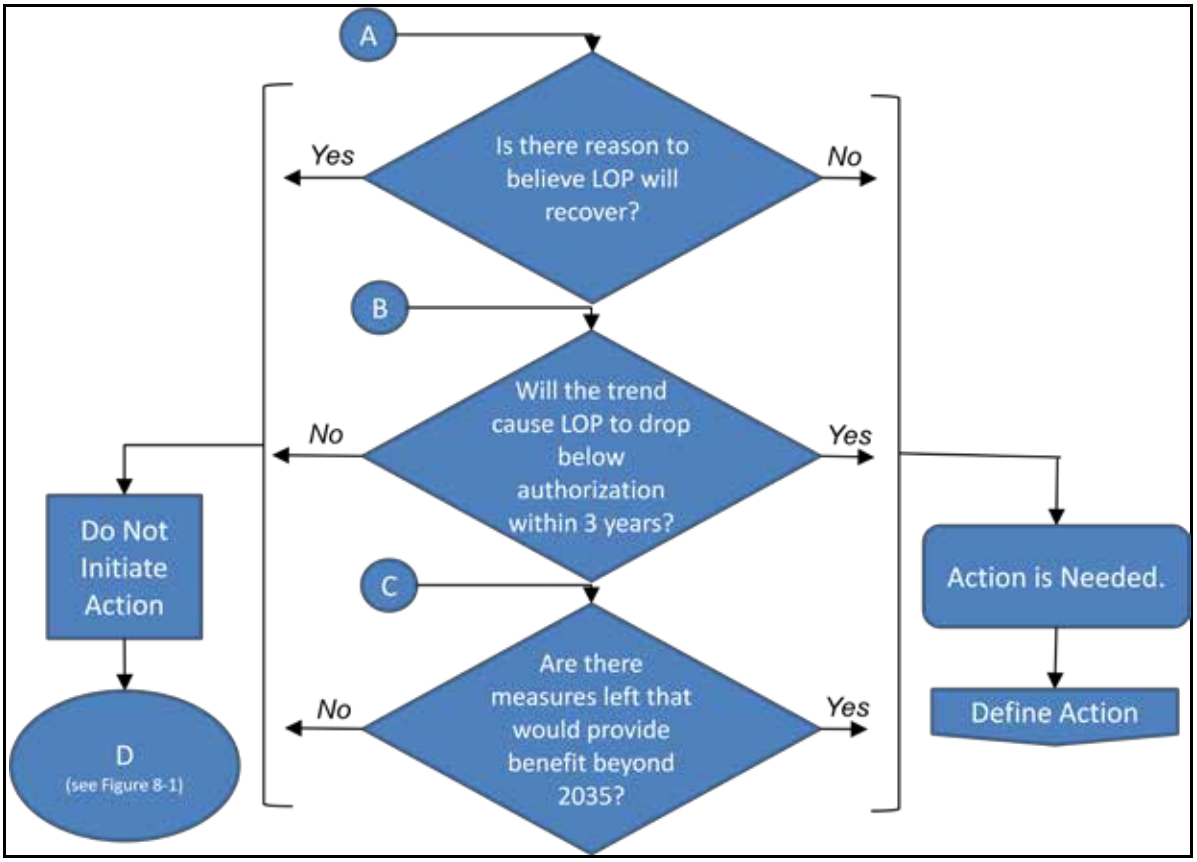
8.2.2. Need for Action

The need for action would fundamentally depend on whether the authorized LOP levels for the lower Cowlitz River levees are being met. If the authorized LOP levels are not being met, then further evaluation would be made as to the expected trend in LOP levels. For instance, if there is a dip in LOP levels but an action was constructed immediately prior to the evaluation, then there would be reason to believe that the LOP levels could recover. In this instance, no action would be necessary. If there is no reason to believe that LOP levels could recover, then action would be necessary and the Phased Construction Plan would enter an implementation phase.

If there is a precipitous drop in the trend of the LOP levels, but authorized LOP levels are being met and/or it is expected that the LOP would drop below authorization within 3 years, it may be necessary to perform a preemptive action. This would allow time to budget for future action. If the declining trend in LOP levels is not expected to continue, then it would not be necessary to preemptively plan for an action.

Authorization to maintain LOP levels for the lower Cowlitz River levees extends to 2035, beyond which the USACE currently has no authority to maintain the LOP levels and consequently, no authority to construct any sediment management actions. If the LOP adequately meets the authority but the authorization period is within 5 years, then preemptive action may be necessary to provide additional sediment management beyond 2035. At this point, an evaluation would need to be conducted to determine if there are any other actions that can be performed to provide additional sediment management. If so, then an action would be triggered. This process for determining the need for action is illustrated in the flow chart in Figure 8-3.

Figure 8-3. Phased Construction Plan (Part 2), Need for Action



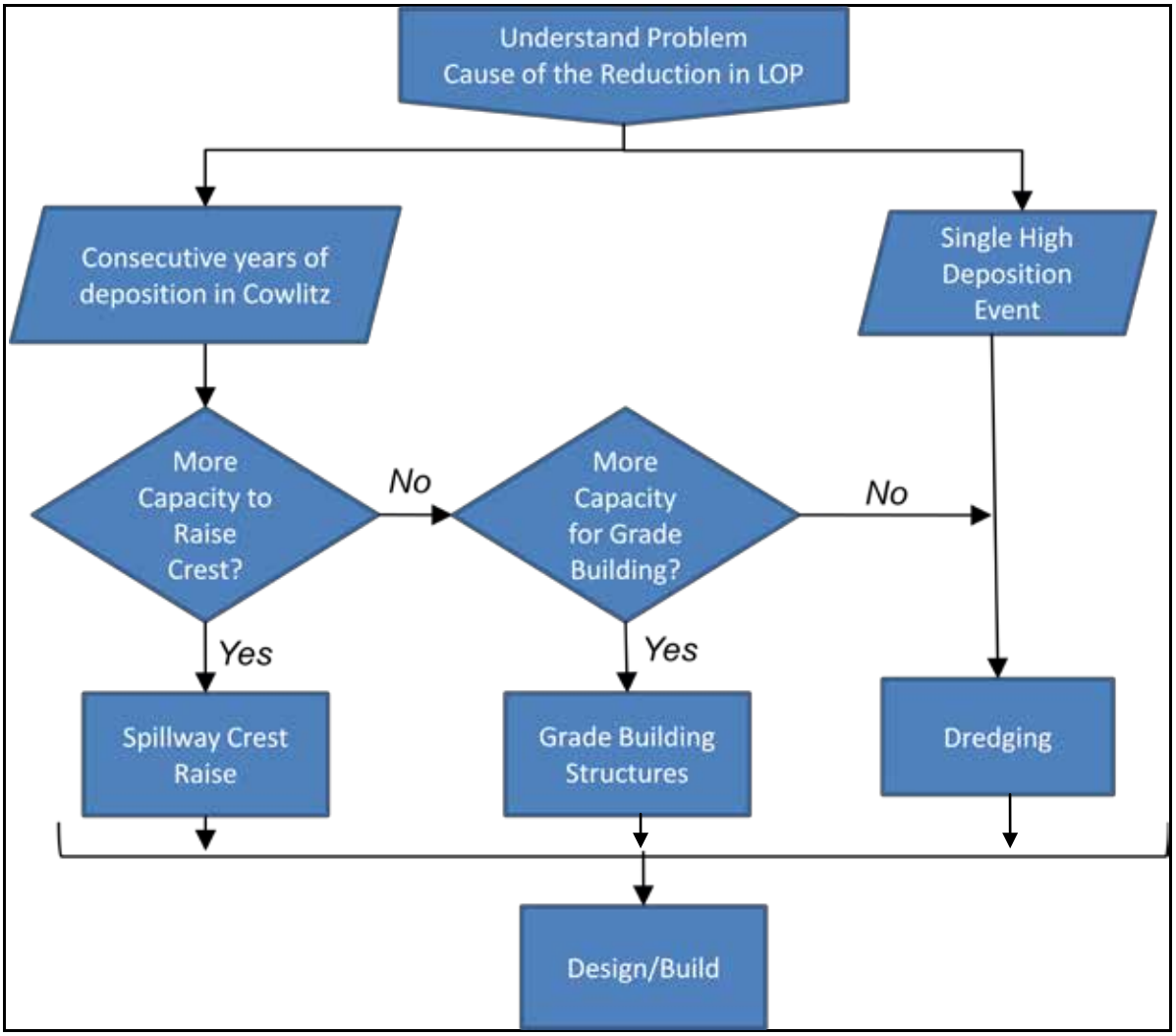
8.2.3. Evaluation of Action Required

Once it is determined that action is needed, then it must be determined what appropriate action to take. The phased construction plan contains three possible actions that could be implemented: spillway crest raise, GBS within the sediment plain, and dredging in the lower Cowlitz. In order to determine what action is needed, it must be determined what sort of event the action is in response to. For example, if a large sediment load migrated through the system during a single large event then a measure, such as GBS in the sediment plain, may not directly address the problem. In this instance, it would be necessary to dredge in the lower Cowlitz.

If there is a declining trend in the LOP, or a drop in LOP below authorization, then a raise in the SRS spillway crest may be necessary. If there is no more capacity to raise the spillway crest any further then grade building structure may be necessary. Because the spillway crest raises effectively raise the bed level of the sediment plain, GBS could only be effective after the last spillway crest raise. Grade building within the sediment plain, therefore, would only be implemented after all spillway crest raises are implemented.

The flowchart in Figure 8-4 illustrates the decision process for what action is needed for the Phased Construction Plan.

Figure 8-4. Phased Construction Plan (Part 3), Evaluation of Action Required



In all cases where action would be necessary, the selected action would require engineering design before plans and specifications can be developed.

As a component of the recommended plan, it is recommended that a reassessment of the Cowlitz River sedimentation situation be undertaken in 2025. It is important to assess conditions at that time in order to verify that full implementation of the recommended plan meets the long-term needs, or if the local communities and sponsor need to explore how to address sedimentation after year 2035.

8.3. ENVIRONMENTAL REQUIREMENTS

Compliance with environmental laws is required prior to construction of the Phased Construction Plan and would be documented as follows:

- NEPA. A final SEIS and Record of Decision.
- ESA Section 7. A Biological Opinion from NMFS and Letter of Concurrence from FWS.

- Clean Water Act Section 401. A water quality certification.
- NHPA Section 106. Programmatic Agreement and/or Memorandum of Agreement with Washington Department of Archaeology and Historic Preservation.

8.4. REAL ESTATE REQUIREMENTS

Once a preferred plan is approved, the USACE would work with the State of Washington on acquiring all lands. It is the responsibility of the State of Washington to provide all required lands under the original 1986 local cooperation agreement. Refer to Appendix E (Real Estate) for additional information.

8.5. LOCAL COOPERATION REQUIREMENTS

On April 26, 1986, the Department of the Army and the state of Washington/Cowlitz County Diking Districts signed a Local Cooperation Agreement. This agreement, which was based on the MSH 1985 Decision Document, pertains to all required project work to maintain the authorized flood risk reduction benefits through 2035. The agreement describes the non-federal sponsors' responsibilities which include: (1) operation and maintenance of all project mitigation measures, as well as the dredged material disposal sites; (2) operation and maintenance of the levees constructed/improved; and (3) providing all lands, easements, and rights-of-way required for project construction.

8.6. PREFERRED PLAN SUMMARY

With the SRS on the NF Toutle River now in a run-of-river condition, more sediment from the debris avalanche is passing the structure. The sediment trapping efficiency of the SRS in the run-of-river condition is approximately 31%, and is decreasing as the slope of the sediment plain steepens, as compared to the approximately 92% achieved when all flow passed through the outlet works. Modeling of future conditions, if no further action is taken, indicated that levels of flood protection for communities along the Cowlitz River would drop below the authorized levels prior to year 2035.

In the 1985 Decision Document, dredging in the Cowlitz River was identified as the most likely measure to manage sediment in the out-years of the planning period; but it was also recognized in that document that other options should be explored. This LRR and the SEIS summarize the evaluation of options and documents that a phased construction approach would be the most effective for flood risk management while minimizing environmental impacts. The recommended plan is the least-cost plan, adaptable to uncertain sedimentation conditions through 2035 and beyond, effective at handling extreme events, and would have the lowest degree of adverse environmental impacts in the near term and over time.

The recommend plan is a phased construction plan that includes raising the spillway crest elevation of the SRS in two increments by a total of 23 feet; constructing dikes in the sediment plain; and dredging in the Cowlitz River in response to extreme events, as necessary.

Assuming a 3.5% discount rate and 18-year period of evaluation (2017-2035), the average annual cost for the two spillway raises and grade building structures would be $5.8 million. The potential need for dredging also has been included. According to the sediment modeling results, Cowlitz River dredging could be required to address unusual events and is therefore included in the overall plan. It is uncertain when and even if Cowlitz River dredging would be required; therefore, a range of costs have been included to account for any dredging that may be required. If there were a

requirement for early-year dredging (2018-2025), it would result in an average annual dredging cost of $9.97 million, whereas late-year dredging (2028-2035) would result in an average annual cost of $6.4 million. Therefore, the overall cost of this plan would range from an average annual cost of $5.8 million (no dredging required) to $15.8 million (dredging required early in evaluation period. See Appendix C (Costs) and Appendix D (Economics) for additional information.

8.7. IMPLEMENTATION SCHEDULE/TIMELINE

Implementation of the Phased Construction Plan would be initiated once all reviews of the LRR and SEIS have been completed and the SEIS Record of Decision is signed. Key implementation steps would include a request for and receipt of funding, work with State of Washington on acquisition of real estate required for the plan, and assessment of current and projected sediment levels and associated LOP levels in the lower Cowlitz River to determine if there is a need to initiate design and construction of sediment management actions. Current data indicates design work should begin on the first spillway raise in 2017 with construction in 2018. Future years would require ongoing sediment monitoring to determine when the next spillway raise or GBS should be designed and constructed. Annual monitoring would also include assessing the environmental conditions and the need for mitigation actions. Both monitoring activities would be reported and the appropriate actions would be taken to address any concerns or needs.

As a component of the Phased Construction Plan, it is recommended that a reassessment of the Cowlitz River sedimentation situation be undertaken in 2025. It is important to assess the conditions at that time in order to verify that full implementation of the plan meets the long-term needs, or if the local communities and sponsor need to explore how to address sedimentation after year 2035.

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