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Lewis County PUD

Chehalis River Water Retention Facilities Potential Study

February 2009

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Executive Summary

Increasingly frequent flooding in the Chehalis River Basin is causing severe economic impact on local residents. Widespread flooding, including the most recent in January 2009, has significantly damaged Lewis County property, infrastructure, fisheries, and natural resources. Damage estimates for the 2007 flood total approximately $500 million, and the cost of the 2009 flood has not yet been determined. Impact from the flooding extends beyond Lewis County. The recent floods have affected communities in Grays Harbor and Thurston counties, and regular shutdowns of Interstate 5 (I-5) have inflicted region-wide harm.

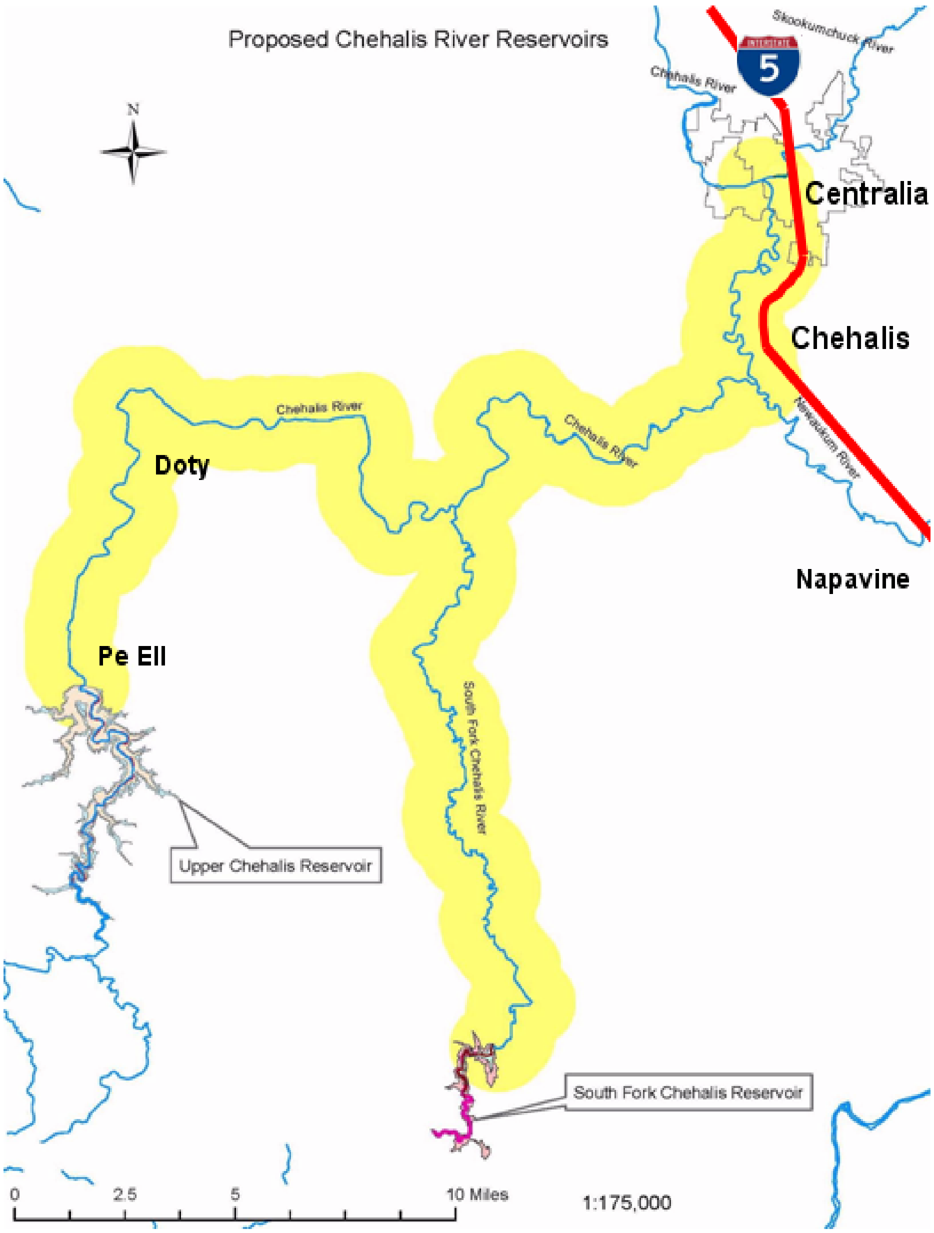
Discussions are currently underway to address this long-standing problem. The U.S. Army Corps of Engineers (Corps) has examined building levees near I-5. While improved levees in specific areas may be part of the solution, levees alone are unlikely to provide a complete solution to address upstream and downstream flooding concerns. In addition, the Corps is studying raising the Skookumchuck Dam, which has the potential to alleviate flooding in that area. The Chehalis Basin Flood Authority (Est. 2008) is also beginning to examine potential flood control projects. The Lewis County Prosecutors Office and its consultant, Northwest Hydraulic Consultants (NHC), have developed a hydrology model of the Chehalis River Basin in order to determine the impacts of alternative solutions. As various approaches to reducing the impact of future flooding are discussed, water retention facilities deserve attention. Additional measures to further retain and reduce the flow of water from the Chehalis River are of particular interest given the magnitude of recent events.

In the interest of developing additional information for local, state, federal, and tribal decision-makers to consider in determining a basin-wide solution, the Lewis County Public Utility District has retained EES Consulting to conduct a preliminary assessment of potential water retention facility options. This assessment examined the following:

- Whether potential flood retention facilities have sufficient merit for further discussion and analysis;
- What are the benefits of investing in flood retention facilities;
- What the potential costs might be; and
- What further studies might be helpful to better inform decision-making about the relative merits of water retention facilities?

This preliminary assessment involved two steps. The first step was an initial review of basin contour maps for the upper Chehalis (above PeEll), the South Fork of the Chehalis River (above Boistfort), the North Fork of the Newaukum, and the South Fork of the Newaukum. The Newaukum sites were then excluded from additional analysis due to lack of drainage area. The second step involved examining the feasibility and cost of building water retention facilities at the remaining two sites as shown in Figure ES-1 below. Although a very large retention facility could be fit into each of these two sites, EES Consulting found that the total mean annual run-off at each site was far less than the possible reservoir capacity. The analysis, therefore, examines a lower retention facility height, more defined reservoir site, and lower costs that more closely matched reservoir to the hydrology of the river at each site. This assessment also identified issues that need additional study.

Figure ES-1
Proposed Chehalis River Reservoirs



The preliminary analysis performed by NHC for Lewis County provides several significant findings. Most importantly, building these two water retention facilities would have reduced the maximum height of the 2007 flood by 2.6 feet at Grand Mound. This in turn would have reduced the water levels by 3.8 feet at the Mellen Street Bridge in Centralia. If these facilities had been in place and existing levees had held during the 2007 flood, a significant portion of the $500 million in damage to businesses, homes, and infrastructure could have been avoided. In addition, retaining this amount of water upstream via water retention facilities would have helped reduced flooding downstream from PeEll, to Chehalis and Centralia and into Thurston and Grays Harbor Counties.

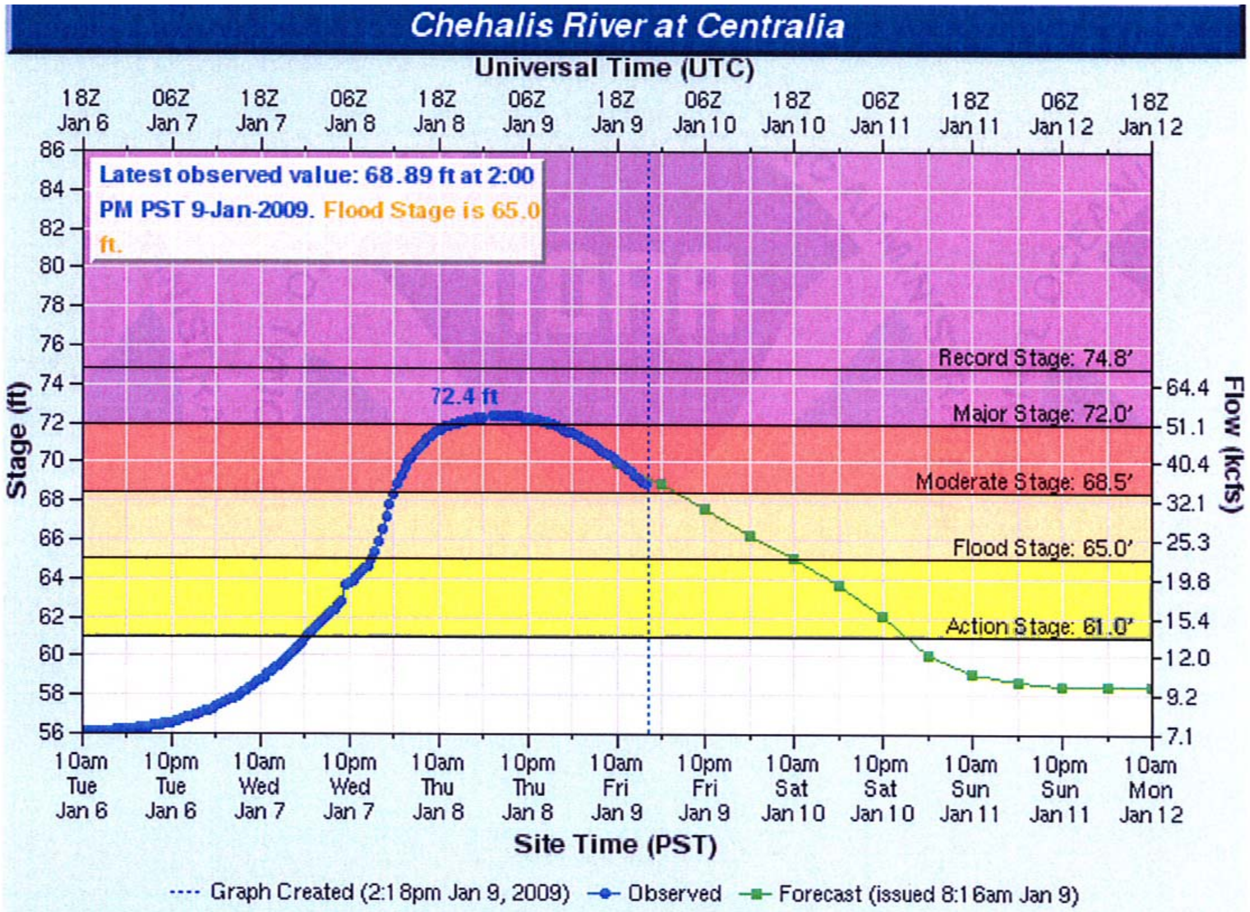
Overall direct benefits due to flood retention facilities would include the following:

- Avoided costs for damages to residential, commercial, industrial, and agricultural property;
- Avoided emergency assistance costs for flood victims;
- Crop values for some farmers not able to replant their fields the year following the flood;
- Increased residential and commercial property values; and
- Avoided infrastructure damages and costs for infrastructure repair and improvement.
- Avoided impact to fisheries and degradation of water quality.

In addition to these benefits, the flood retention facilities provide indirect benefits. For example, avoided damages and expenses from floods mean that funds can be more efficiently allocated to economic expansion in the area. Added jobs due to these flood retention facilities will infuse more wealth into the region. In order to determine the actual impact of these indirect benefits, this report's analysis uses the 1997 Washington State input-output model to calculate further benefits of flood control in Lewis, Thurston and Grays Harbor Counties.

A graphic of flood stages for the Chehalis River at Centralia is shown below on Figure ES-2 for the January 2009 flood. Note that an almost 4 ft. reduction in the flood elevation would have lowered the flood stage from major to moderate.

Figure ES-2
Water Gage Height (Source: NOAA)



In addition to flood control benefits, these water retention structures would provide significant benefits to fish and wildlife. During high flow periods and with water retention facilities, there tends to be a reduction in scouring of habitat without losing the peak flows necessary for the stream's health and maintaining the stream channel. For example, scientists are currently examining the impact of the 2007 and 2009 floods on fish redds (where fish spawn and deposit their eggs) and are concerned about possible loss in fish production. During low flow periods, additional instream flows from the flood retention facilities would also improve water quality and reduce water temperatures by increasing instream flows an additional 120 cfs above the existing 200 to 400 during the summer months near Grand Mound. The Chehalis River is currently listed as failing to meet water quality standards set by the Environmental Protection Agency (EPA)[1]. The EPA establishes the maximum amount of a pollutant or other stress a body of water can receive and still meet water quality standards; this maximum amount is called the total maximum daily loads (TMDLs). The Chehalis River exceeds TMDL for the lack of dissolved oxygen, high temperatures, and high levels of fecal coli form bacteria (from animal

[1] Environmental Protection Agency. "Impaired Waters and Total Maximum Daily Load." Available online. Accessed January 28, 2009 <http://www.epa.gov/owow/TMDL/>

waste)[2]. Improved water quality would benefit downstream municipal, agricultural, recreation, fish populations, and other users of the rivers and tributaries within the Chehalis River Basin.

In total, a flood retention facility on the Upper Chehalis would enhance approximately 106 miles of mainstream and tributary habitat to where it intersects with the South Fork of the Chehalis. A South Fork flood retention facility would enhance an additional 19 miles of river habitat and provide further benefits to the mainstem Chehalis River below River Mile (RM) 88.3, where the South Fork Chehalis River joins the mainstem. Analyses of these benefits consider the potential loss of river habitat above the flood control facilities, including the potential loss of salmon and steelhead spawning and rearing habitat. The analysis also evaluates increases in fish habitat as a result of increased summer flows and reduced winter flood events, provisions for fish passage and mitigation, and improved water temperature and quality. The benefits of water retention facilities to fish and aquatic life will then be compared to the potential loss of habitat within the impoundments.

Finally, these water retention facilities could provide a supplementary benefit of renewable energy resources by facilitating small incremental hydro electric facilities. The combined power output of the potential hydro facilities is approximately 23,741 MWh per year, or enough energy to power 1,600 households. The primary purposes of the water retention facilities are for flood reduction and instream flow enhancement; however, the hydro power provides valuable secondary benefits that could help cover the costs for the facilities.

Total expenditures in the two water retention facilities, fish mitigation measures and hydro generation are estimated at $336 million. In analyzing the economics, this preliminary report examined a variety of benefit-cost scenarios, including looking at direct benefits from flood control only, then all quantifiable benefits, including hydro power. If only direct flood control benefits are included, there is approximately $2 dollars in benefit to every $1 of cost. Under the analysis for all direct and indirect benefits, the ratio improves to nearly $3.6 of benefit for every $1 of cost. Under all scenarios, the potential flood retention facilities offer more benefit than they cost to build and operate.

As discussed above, this report is a preliminary analysis only. Additional engineering evaluation on the potential water retention facilities, including fish passage, is needed. There also needs to be continued outreach and dialogue about potential next steps, and whether there is interest in moving some of these ideas forward.

If there is interest in these ideas, there are several areas where additional study is needed. First, additional information is needed about the geology of the potential water retention facilities. Second, more information is needed about potential environmental concerns and benefits, including both for fish and wildlife, and water quality. Third, information is needed about property values and potential damage estimates for buildings. Finally, aspects of both the water retention and Corps plans may be complimentary and work together. For example, are there

[2] Smith, Carol J. and Mark Wenger. “Salmon and Steelhead Habitat Limiting Factors, Chehalis Basin and Nearby Drainages Water Resource Areas 22 and 23.” Washington State Conservation Commission, Final Report. May 2001.

levee improvements that would maximize the value of water retention, or alternatively are there water retention structures that could maximize the value of levees? Potential ideas include raising the Skookumchuck Dam to provide storage space, addressing local streams like China and Coal creeks, and improving existing levees. This preliminary report provides an initial review of some flood control options for the Chehalis River Basin.

Introduction and Scope of This Study

The purpose of this study is to review the possible benefits of developing water retention facilities in Lewis County, primarily the Chehalis River Basin. According to The Chronicle, public and private property loss totaled $500 million after the December 2007 Chehalis River flood.[3] Given the magnitude of loss, it may be beneficial to consider additional water retention alternatives for the Chehalis River Basin.

In an effort to determine if water retention facilities are feasible, Lewis County and the Lewis County PUD (PUD) have been conducting some preliminary review of the upper basin contour maps for the upper Chehalis (above Pe Ell), the South Fork of the Chehalis (above Boistfort at River Mile 19) the North Fork of the Newaukum, and the South Fork of the Newaukum. Based on this review, it was decided to focus this study on the feasibility and cost of building retention facilities at two sites: Upper Chehalis River site and South Fork Chehalis River site. The Newaukum sites were excluded due to lack of drainage area.

Benefits of flood control in the Chehalis River basin include:

- Avoided costs for damages to residential, commercial, industrial, and agricultural property;
- Avoided emergency assistance costs for flood victims;
- Crop values for some farmers not able to replant their fields the year following the flood;
- Increased residential and commercial property values;
- Avoided infrastructure damages and costs for infrastructure improvement; and
- Avoided impacts to fisheries habitat and water quality.

Based on information available, the benefits of the water retention facilities were determined and compared to the cost of building the facilities. A separate analysis explored the potential cost and benefits of adding power generation turbines at the two retention facilities.

History

From the time pioneers settled in the western part of Lewis County, there has been flooding along the Chehalis, Newaukum, and Skookumchuck rivers from PeEll and Boistfort to Centralia and to Elma, Montesano and Aberdeen. There are numerous accounts of the early settlers struggling with flood waters, and damage to farm and homes. In the 1930's, 40's and ultimately

[3] Schreiber, Dan. "The Flood: One Year On." *The Chronicle Online*. November 26, 2008.

with World War II, a levee was constructed around the Chehalis–Centralia Airport (the area along Interstate 5 next to Wal-Mart, Home Depot, and the Twin City Town Center).

There are accounts of flooding from the 1930's to present day, with minor flooding occurring every 2 to 5 years and major flooding approximately once every 10 years. As a result, there have been extensive efforts and monies spent in evaluating and studying options for controlling the Chehalis River basin flooding. Over the years, the numerous studies were conducted by Lewis County, the cities of Chehalis and Centralia, the Corps of Engineers (Corps), and the Washington State Department of Transportation (WSDOT). Despite these efforts, nothing has been implemented due to lack of consensus and funding.

Recent Flood Events

Over the last 19 years, there have been four major floods in 1990, 1996, 2007, and again in 2009. All four floods resulted in closure of Interstate 5 for days due to flood waters over the freeway. The levee around the airport and Twin City town center either failed or overtopped each time, with the exception of the 2009 flood when the flood waters came within one to two inches from overtopping the levee. According to the U.S. Geological Survey (USGS), the 1990 and 1996 floods were considered 100 year flood events and 2007 was likely a 500 year flood event. The 2009 flood on the Chehalis had peaks that ranged from 51 to 100 year events and some that were equal to or greater than 100 year levels, according to USGS.[4] Tributary streams on the Chehalis River also experienced record peaks.

Flood Mitigation Plans

Following the 1996 flood, both the local jurisdictions and the Corps conducted extensive studies of potential options. Lewis County and the cities contracted with Pacific International Engineering (PIE) and the State relied on the Corps analysis. Initially, the County through PIE briefly looked at upstream storage; however, neither the public in the Pe Ell – Doty area or the Corps supported up stream storage facilities. The public in west Lewis County felt that Chehalis and Centralia were trying to solve a Twin City flooding problem at the cost of the west Lewis County communities. The Corps maintained that storage facilities could not be justified on a benefit / cost basis, which all Corps projects must pass.

As such, all focus then shifted downstream to the Chehalis – Centralia area. PIE and the Corps identified a series of levees, some localized dredging, constructing a couple of bypass channels at constriction points, and gate improvements to the Skookumchuck Dam (owned by TransAlta) to allow for flood storage. Later, a 2004 Corps Plan called for $50 million in state funding and $75 million in federal funding, and agreement from the local jurisdictions to cover annual maintenance of the levees at an annual cost of approximately $600,000. This plan, however, did not go forward due to lack of funding and no local jurisdiction sponsor.

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[4] USGS Washington Water Science Center. "Latest Summary of Flooding in Western Washington, January 2009." Available online: <http://wa.water.usgs.gov/news/flood/summary/>

December 2007 Flood

The December 2007 flood was much more severe than floods in recent history and particularly more devastating in the areas west of Chehalis, the South Fork Chehalis River and main Chehalis River in Boistfort, Adna, Doty and Dryad. Many areas along the upper Chehalis that flooded had never flooded in the past 100 years. The other main Chehalis River tributaries (the Newaukum, and Skookumchuck) did not flood due to lower rain fall. Reported rainfall figures for the 36 to 48 hours leading up to the flood were as follows:[5]

- Upper Chehalis above Pe Ell: 20 inches,
- South Fork of Chehalis above Boistfort: 14 inches,
- Chehalis area local weather station: 6 inches,
- Upper Newaukum River basin: 4.5 inches, and
- Upper Skookumchuck Basin: approximately 3.5 inches.

The primary flooding for 2007 was upstream of the Mellen Street Bridge constriction point (in Centralia); the peak flows registered at the Grand Mound gage (downstream and northwest of Centralia) were approximately 80,000 cfs. At the beginning of the 2007 flood, the TransAlta Skookumchuck Dam was not full and therefore, was able to retain some of the Skookumchuck flows.

The 1996 flood also registered approximately 80,000 cfs at Grand Mound; however, the flooding was more concentrated in Chehalis and Centralia. Centralia had considerably more damage from the 1996 flood compared to the 2007 flood. This was due to the fact the rainfall from 1996 was spread more basin wide and was not as locally concentrated in the upper Chehalis River. In 1996, the Skookumchuck River caused significant damage as the Skookumchuck Dam was not able to retain enough of the Skookumchuck River flows.

January 2009 Flood

As mentioned above, the January 2009 flood resulted in record flooding on some of the Chehalis tributaries. These tributaries provide important fish spawning habitat, and the repeated flooding may have adversely affected the spawning beds. Rushing flood waters are known to wash away gravel and scour fish eggs to reduce future fish populations. In addition to the habitat damage, a 20 mile stretch of Interstate 5 was closed from Wednesday evening through Friday morning. At Green Hill School (just north of Exit 76), the freeway was covered in 1 to 2 feet of water. Due to

[5] Office of Washington State Climatologist. Prepared by: Mote, Philip, Josiah Mault, and Valerie Duliere. "The Chehalis River flood of December 3-4, 2007." Available online:
<http://www.climate.washington.edu/events/dec2007floods/OWSC_Chehalis_Dec08_Flood_Report.pdf>

the timing of the flooding and mountain pass closures, the only detour available totaled 440 miles.[6]

Local, State, Federal and Tribal Interests

Due to the devastating nature of the 2007 flood and the state and national interest in the situation, the legislature, the congressional delegation, the governor, WSDOT, local tribes, and area citizens have all been pursuing new ideas and solutions that would provide flood mitigation for all involved. The local legislative representatives held public meetings in January 2008 to receive input on what should be done, and the 2004 Corps levee plan was discussed once again. At the public meetings, there was interest in developing a flood control plan for the entire basin from Pe Ell to Aberdeen, not just a plan for Interstate 5, Chehalis and Centralia. As a result, the Lewis County PUD Commissioners adopted a Concept Paper, "Discussion of Chehalis River Basin Flooding and Solutions." In addition, Lewis County, the City of Chehalis and the City of Centralia adopted resolutions supporting a flood control plan for the entire Chehalis River Basin.

The governor and the WSDOT then introduced a funding bill in the legislature for the state to provide $50 million for its share of the $125 million Corps levee plan from 2004. The approved bill was modified to allow formation of a three county (Grays Harbor, Thurston, and Lewis) flood control district with 11 members and to allow for $2.5 million of the funds to be used for Chehalis River basin-wide flood control studies.

Summary

Given the amount of discussion of potential options, Lewis County PUD (PUD) was interested in additional detail that might help move the basin-wide discussions forward. Accordingly, Lewis County PUD requested a high level review by EES Consulting to determine whether upstream water storage is feasible and cost effective. In addition, the PUD asked for a preliminary analysis of additional benefits of improving instream flows and from hydro power at potential sites. This report highlights the requested analysis and presents EES Consulting's preliminary findings.

[6] "I-5 at Chehalis reopened to all traffic." Friday January 9, 2009. kgw.com, news channel 8 in Portland. Available online: <http://www.kgw.com/news-local/stories/New_Story_010709_centralia_I-5_closure.2d4da18.html#>

Water Retention Facility Analysis

To evaluate a combination of water retention potential, addition of hydro power generation and augmentation of main stem flows in low-flow summer periods, two sites were examined for this study. The Upper Chehalis site and the South Fork Chehalis site together appear to be able to reduce the flood flow peaks at Grand Mound by about 2.1 feet and at Mellen Street by almost 3 feet in the case of the 100 year flood, if they are operated to have adequate storage volume to capture peak flows during flood conditions. Given this level of flood reduction, it is anticipated that damages will be significantly less and the duration of flooding shorter. This section of the report provides the analysis and cost estimate for building water retention facilities at these two sites.

Study Analytical Approach

EES Consulting used detailed Lewis County digital mapping to estimate the height of the potential water retention facilities, reservoir areas and reservoir volumes. EES Consulting also obtained USGS Chehalis River flow data from gage sites downstream of each potential retention facility, and by area correlation, developed a daily average flow data file for each retention facility site. Using all this data, estimates of the flood reduction potential (at the main stem near the Grand Mound stream gage) of each of the two new potential water retention facility sites was calculated.

EES Consulting found that although a very large water retention facility could be fit into these two sites, the total mean annual run-off at each site was far less than the reservoir capacity. As such, it made sense to lower the height of the water retention facility, the reservoir volume and the cost, to select a more closely matched reservoir to the hydrology of the river at each site.

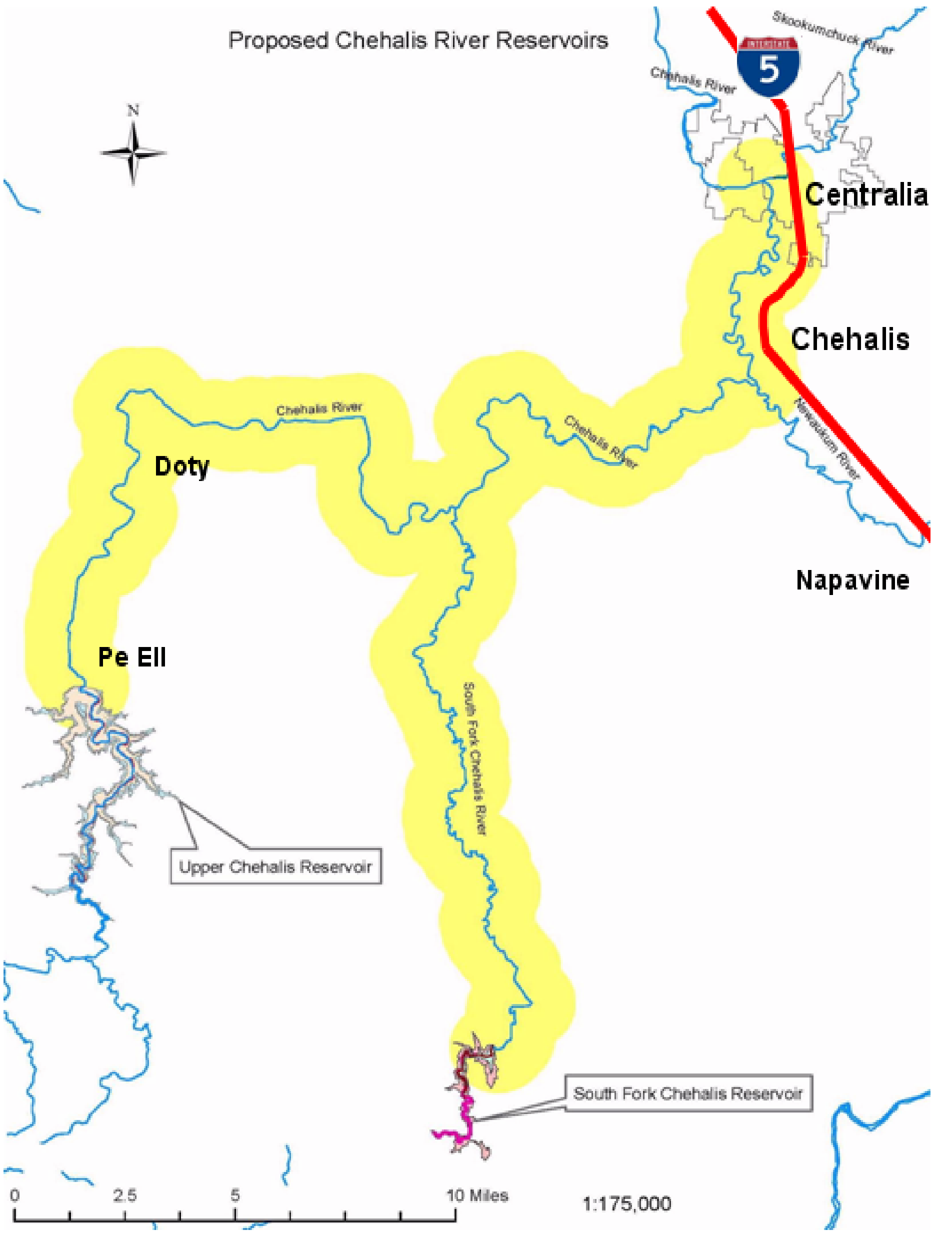
In addition to creating a storage reservoir to capture peak flows, the concept of the addition of hydro power generation at each site was developed. Addition of hydro power would provide a revenue stream from each site that could potentially help offset all other water retention-related costs.

Finally, in the summer months of July, August and September, the main stem Chehalis River near Grand Mound experiences average flows in the 200 cfs to 400 cfs range. These low flows present water quality and water temperature challenges as well as have negative impacts on fish, wildlife and recreation. If these summer low flows could be augmented by release of excess water from new storage reservoirs, significant public benefits could result. The purpose of the next step in the study was to examine what size reservoirs would be appropriate for optimal flood control, evaluate what size hydro power plant could be installed at each site and determine the level of downstream summer flow augmentation that would result.

Upper Chehalis River Site

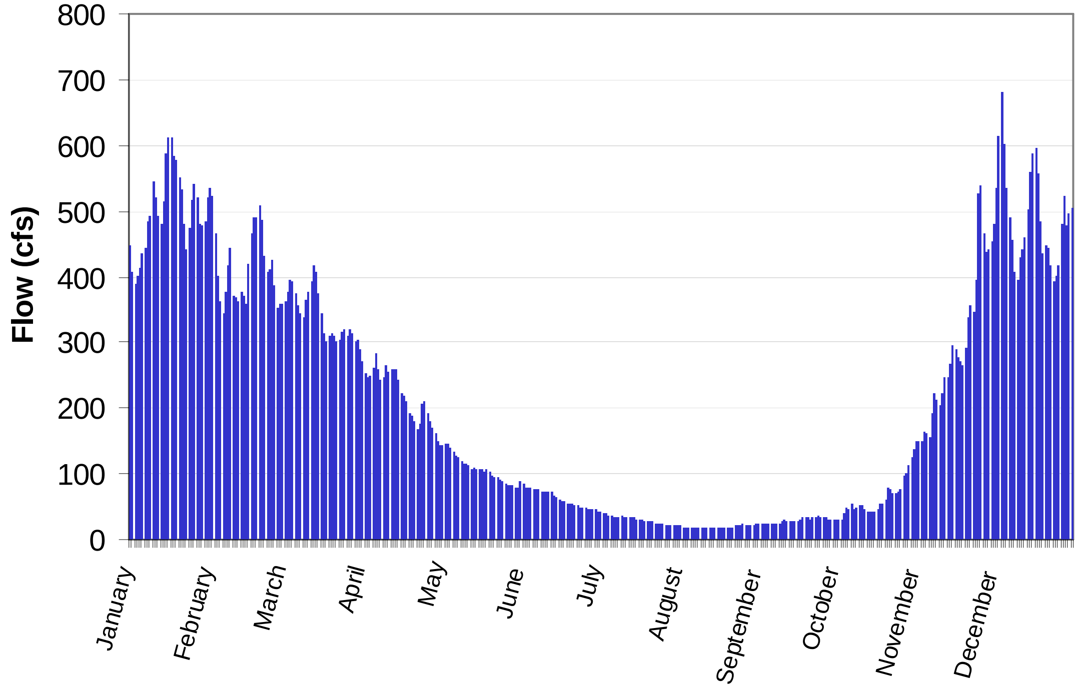
The Upper Chehalis site is located above PeEll and would provide flood relief to PeEll residents and downstream (Doty, Dryad, Ceres, Adna, Chehalis, and Centralia, etc.). See Figure 1 below for more detail on the proposed site.

Figure 1
Project Sites



An estimate of average daily flows at the Upper Chehalis River site was developed by area correlation from the daily average flow records at Grand Mound, based on 68.5 square miles of drainage area upstream of this retention facility site. The resulting flows are distributed throughout the year as shown on Figure 2 below.

Figure 2
Upper Chehalis River Near Doty—Long-Term Daily Average Flows



This flow data file provides the following information:

1. Summer low flows in this section of river get down to an average of about 20 cfs
2. The total run-off at this site in an average year is approximately 154,000 acre-feet
3. From gage data, in the first 20 days of 2007 during the flood, about 80,000 acre-feet passed this site.
4. The mean annual flow at this site is about 215 cfs

Given that the mean annual run-off is approximately 154,000 acre-feet, a water retention facility much bigger than this seems neither necessary nor cost effective. If such a structure is built, a minimum instream flow would be required to be released at all times. A minimum flow release of 10 cfs, or 5% of the mean annual flow, was selected. This minimum release amounts to about 7,240 acre-feet per year. From previous study work, storage of 80,000 acre-feet is necessary to be able to capture the peak flows during an extreme storm event such as the December 2007 storm at this point on the Chehalis River. Therefore, a water retention reservoir with 220,000 acre-feet of storage was selected for this study as can be seen in Table 1 below.

Table 1 Calculation of Water Retention Facility Capacity Upper Chehalis	
Annual Average Runoff	154,000 ac-ft
Less Minimum Flow Restriction	7,240 ac-ft
Plus Flood Storage	80,000 ac-ft
Total Reservoir Capacity	226,760 ac-ft

The water retention facility would be operated from November 1 through March 31 each year to maintain a maximum of 140,000 acre feet of storage, leaving room to capture 80,000 acre feet in a flood. The rest of the year, the reservoir will be allowed to reach whatever levels it needs to, subject to inflows and required outflows.

After addressing basic instream flow considerations, the next question that needed to be answered was what size hydro power project would be appropriate. In addition, how much electricity could be generated on an annual basis and how much downstream flow augmentation could be possible with hydro generation was addressed.

To examine these questions, a reservoir model was developed using EXCEL software that allows the user to vary hydro power unit size, reservoir elevations, and flow releases. A daily time-step set up was used to look at flow each day, how much water was removed for instream flow releases and hydro power production, and the resulting reservoir levels each day were calculated.

The model was initialized to have a reservoir level on January 1 each year of elevation 660 ft. (elevation 720 is "full" elevation). This level results in storage at that time of 140,000 ac-ft and capacity of 80,000 ac-ft more for flood protection, as well as 160 feet of head for hydro power operations. Through model iterations, it was found that a hydro power plant about 8,000 kW in size was able to hold reservoir levels within a foot of elevation 660 at all times January 1 until April 1. After April 1, flows in the Chehalis River begin to fall and if an 8 MW plant continued to operate, the reservoir level would drop quickly. Therefore, on April 1, hydro power production was cut to 1,200 kW (requiring 110 cfs) and this was maintained throughout the summer. This keeps the reservoir levels, and operating head at reasonable levels throughout the summer. On November 1, operation of the full 8 MW of production is resumed to hold reservoir levels at elevation 660 once again through year-end, even though winter rains begin to increase flows in the Chehalis River. The unit operations were adjusted so that the model calculated a reservoir elevation on December 31, at or very near the elevation 660 where it started on January 1. This ensures that the water budget year to year is balanced.

The result of this hydro generation analysis shows the following:

- A hydro power plant would be installed with two machines, one rated at 6.8 MW and one at 1.2 MW, for a total capacity of 8 MW.
- Annual average energy production was calculated at 19,663 MWh.
- An instream flow release of 10 cfs is maintained year round. In months April through October, the hydro power plant releases an additional 110 cfs. In November through March,

the 8 MW plant releases up to 556 cfs. Further analysis is required to determine what flow releases might be required for fish and wildlife habitat preservation.

- Assuming the unregulated summer flow for the Upper Chehalis, before the Upper Chehalis water retention facility is built, reaches a low of about 20 cfs, adding the Upper Chehalis water retention facility will increase that summer flow by 100 cfs above natural and this will in turn augment flows at Grand Mound by the same 100 cfs.

To develop cost estimates to construct the potential water retention facilities, the fill volume necessary to construct this retention facility was estimated, assuming an earth fill type retention facility. The water retention facility would have a crest length of about 1,960 feet, a height above base of 220 feet, and side slopes were assumed of 3:1 on the upstream side and 2:1 on the downstream side. A low level outlet pipe was assumed at the retention facility for flood releases as well as to feed water to the hydro power project. No site geology was available for this site and if more refined analysis is deemed warranted, site conditions would have to be evaluated in detail to develop higher accuracy cost estimates. However, fill volumes estimated below will be a reasonable representation of what will be required. The hydro power part of the water retention facilities was assumed to be installed at a cost of $3,000 per installed kW, which is conservative for a new plant in this size range.

In addition to these costs, the study assumes that fish mitigation measures are required. If it is verified that salmon and steelhead migrate above the proposed water retention facilities, fish mitigation will be required. A cost estimate for fish mitigation of $10 million for each structure is included. Also, a land purchase cost allowance was added, an allowance for indirect costs and owner's costs, and a 30% contingency was added to the overall estimate due to the preliminary nature of this work. The resulting cost estimate is shown below in Table 2.

Table 2
New Flood Control Structure on Upper Chehalis River
Reconnaissance Level Cost Estimate ($2008)

	Base Elevation	500 ft	
	Crest Elevation	720 ft	
	Storage	220,000 ac-ft	
	Approx. Fill Volume	4.93 million cu yd	
	Reservoir Acres	1,600 acres	
	Crest Length	1,960 ft	
Item	**Quantity**	**Unit Price**	**Cost**
Fill	4,930,000 cubic yards	$20	$ 98,600,000
Gates/Pipe	$10,000,000	Lump	10,000,000
Land	1,600 acres	$2,000	3,200,000
Fish Mitigation			$10,000,000
8000 kW Hydro	8,000	$3,000	24,000,000
Subtotal			$145,800,000
Indirects		10%	14,580,000
Contingency		30%	43,740,000
Grand Total			$204,120,000

South Fork Chehalis River Site

The second site for the flood control project is located on the South Fork Chehalis River. See Figure 1 for a map of the proposed site. An estimate of average daily flows at the South Fork Chehalis River site was developed by area correlation from the daily average flow records at Grand Mound, based on 22.49 square miles of drainage area upstream of this water retention facility site.

Based on this flow data, several facts were developed:

- Summer low flows in this section of the Chehalis River get down to about 5 cfs on average.
- The total run-off at this site in an average year is about 50,600 ac-ft.
- From gage data, in the first 20 days of 2007 during the flood, about 20,000 acre-feet passed this site.
- The mean annual flow at this site is about 70 cfs.

Based on the mean annual run-off is 50,600 ac-ft, a reservoir much bigger than this seems neither necessary nor cost effective. If a reservoir is built, a minimum instream flow release will be required to be released from the retention facility at all times. A flow release of 5 cfs was selected, which represents 7% of the mean annual flow. This release amounts to about 3,600 ac-ft per year. From previous study work, storage of 20,000 acre feet would be necessary to be able to capture the peak flows during an extreme storm event such as the December 2007 storm. Based on this information, it was determined that a storage reservoir with a maximum of 40,000 acre feet of storage was sufficient to meet the storage and flood control requirements.

The reservoir would be operated from November 1 through March 31 each year to maintain a maximum of 20,000 acre feet of storage, leaving room to capture 20,000 in a flood. The rest of the year, the reservoir will be allowed to reach whatever levels it needs to, subject to inflows and outflows.

To determine the appropriate size of the hydro power project which would be needed to control water levels to maintain the 20,000 ac-ft storage, the reservoir model developed for the Upper Chehalis site was modified for this site. This model allows the user to vary hydro power unit size, reservoir elevations and flow releases. A daily time-step set up was used to look at flow each day, how much water is removed for hydro power production, instream flow releases and the resulting reservoir level each day. This model also calculated how much electricity could be generated on an annual basis and determined possible downstream flow augmentation.

The model was initialized to have a reservoir level on January 1 each year of elevation 510 feet. (elevation 600 is “full” elevation). This level results in storage at that time of 20,000 ac-ft and capacity of 20,000 ac-ft more for flood protection, as well as 110 feet of head for hydro power operations. Through model iterations, it was found that a hydro power plant 1,200 kW in size was able to hold reservoir levels within a foot of elevation 510 at all times until April 1. After April 1, flows in the South Fork of the Chehalis begin to fall and if a 1.2 MW plant continued to operate, the reservoir level would drop quickly. Therefore, on April 1, hydro power production was cut to 150 kW (requiring 20 cfs) and this was maintained throughout the summer. On November 1, operation of the full 1.2 MW of production resumed to hold reservoir levels at elevation 510 once again, even though winter rains begin to increase flows. The unit operations were adjusted so that the model calculated a reservoir elevation on December 31, at year end, at or very near to elevation 510 where it started on January 1. This ensures that the water budget year to year is balanced.

The results of this analysis show the following:

- Hydro power plant would be installed with two machines, one rated at 1 MW and one at 200 kW, for a total capacity of 1.2 MW.
- Annual average energy production was calculated at 4,078 MWh.
- An instream flow release of 5 cfs is maintained year round. In the months of April through October, the hydro power plant releases an additional 20 cfs. In November through March, the 1.2 MW plant releases up to 163 cfs. Further analysis is required to determine flow releases as required by fish and wildlife habitat preservation.
- Assuming the unregulated summer flow for the South Fork Chehalis reaches a low of about 6 cfs, adding the South Fork Chehalis Water Retention Facility will increase that flow by 19 cfs above natural and this will augment flows at Grand Mound by the same 19 cfs.
- There is not enough inflow in summer months to release more than this 25 cfs and still maintain a water budget balance.

To develop cost estimates to construct water retention facilities on the South Fork, the fill volume necessary to construct this retention facility was estimated, assuming an earth fill type retention facility. The retention facility would have a crest length of about 1,830 feet, a height above base of 180 feet, and side slopes were assumed of 3:1 on the upstream side and 2:1 on the downstream side. A low level outlet pipe was assumed at the retention facility for flood releases as well as to feed water to the hydro power project. No site geology was available for this site, and if more refined analysis is deemed warranted, site conditions would have to be evaluated in detail to develop higher accuracy cost estimates. However, fill volume estimates within this report will be reasonable representations of what will be required. The hydro power part of the water retention facilities was assumed to be installed at a cost of $3,000 per installed kW, which is conservative for a new plant in this size range.

In addition to these costs, it assumed that fish mitigation measures are required. If it is verified that salmon and steelhead migrate above the proposed water retention facilities, fish mitigation would be required. A cost estimate for fish mitigation of $10 million for each retention facility is included. Also, a land purchase cost allowance was added, an allowance for indirect and owner's costs, and a 30% contingency was added to the overall estimate due to the preliminary nature of this work. The resulting cost estimate is shown in Table 3.

Table 3 New Retention Facility on South Fork Chehalis River Reconnaissance Level Cost Estimate ($2008)			
	Base Elevation	420 ft	
	Crest Elevation	600 ft	
	Storage	40,000 ac-ft	
	Approx. Fill Volume	3.49 million cu yd	
	Reservoir Acres	600 acres	
	Crest Length	1,830 ft	
Item	**Quantity**	**Unit Price**	**Cost**
Fill	3,490,000 cubic yards	$20	$ 69,800,000
Gates/Pipe	$9,000,000	Lump	9,000,000
Land	600 acres	$3,000	1,800,000
Fish Mitigation			10,000,000
1200 kW Hydro	1,200	$3,000	3,600,000
Subtotal			$94,200,000
Indirects		10%	9,420,000
Contingency		30%	28,260,000
Grand Total			$131,880,000

Summary

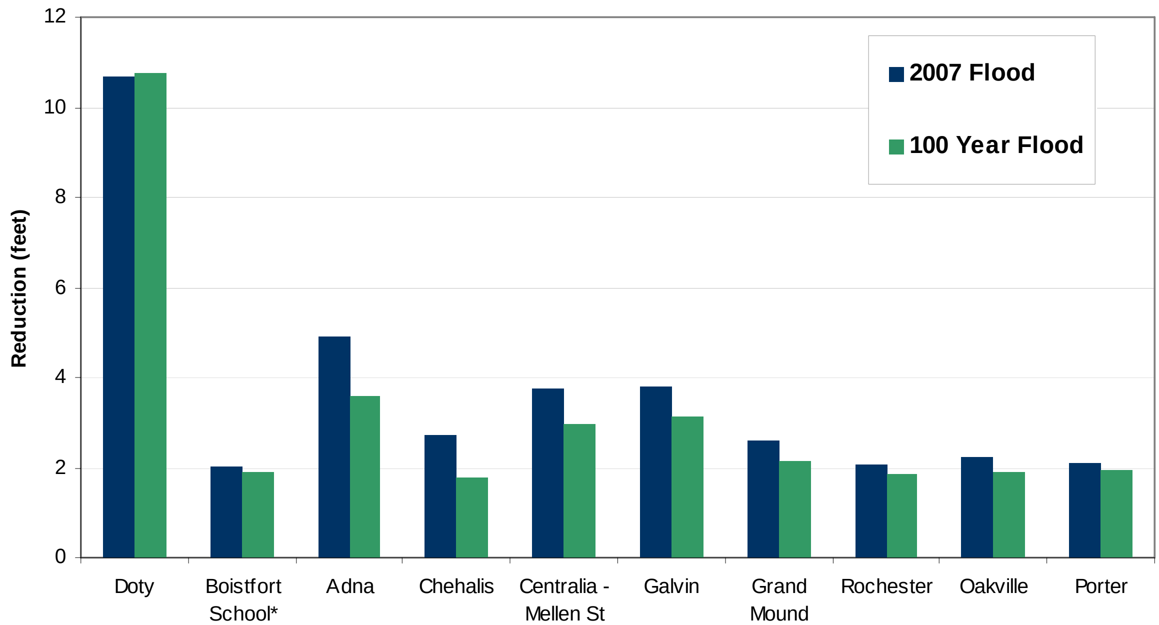
Table 4 shows a summary of project costs. Total initial capital investment is estimated at about $336 million.

Table 4
Cost Summary ($2008)

	Upper Chehalis	South Fork Chehalis	Total
Direct Costs	$121,800,000	$90,600,000	$212,400,000
Indirect Costs	$14,580,000	$9,420,000	$24,000,000
Contingency	$43,740,000	$28,260,000	$72,000,000
Total Non-Hydro Costs	**$180,120,000**	**$128,280,000**	**$308,400,000**
Hydro Generation	$24,000,000	$3,600,000	$27,600,000
Total	**$204,120,000**	**$131,880,000**	**$336,000,000**

If both retention facilities are included, flood stage reduction at Grand Mound is estimated at over 2 feet for both the 2007 and 100 year flood scenarios. Figure 3 shows estimated flood reduction for a 100 year flood and the 2007 December flood, as calculated by NHC. Flood reductions at Mellon Street Bridge are 3 and 3.8 feet for 100 year events and the 2007 event, respectively. In addition, it is projected that summertime main stem flow augmentation of 120 cfs will occur. Finally, a combined power output of 23,741 MWh per year is expected in an average year.

Figure 3
Reductions in Maximum Water Level



*The Boistfort School location measures flood reduction on the South Fork Chehalis. All other locations are measured on the Chehalis River.

Source: NHC

Figures 4, 5 and 6 illustrate flood reduction potential given a 2007 flood event. Red areas would be dry as a result of the potential water retention facilities.

Figure 4
Flood Reduction Potential before Proposed Projects

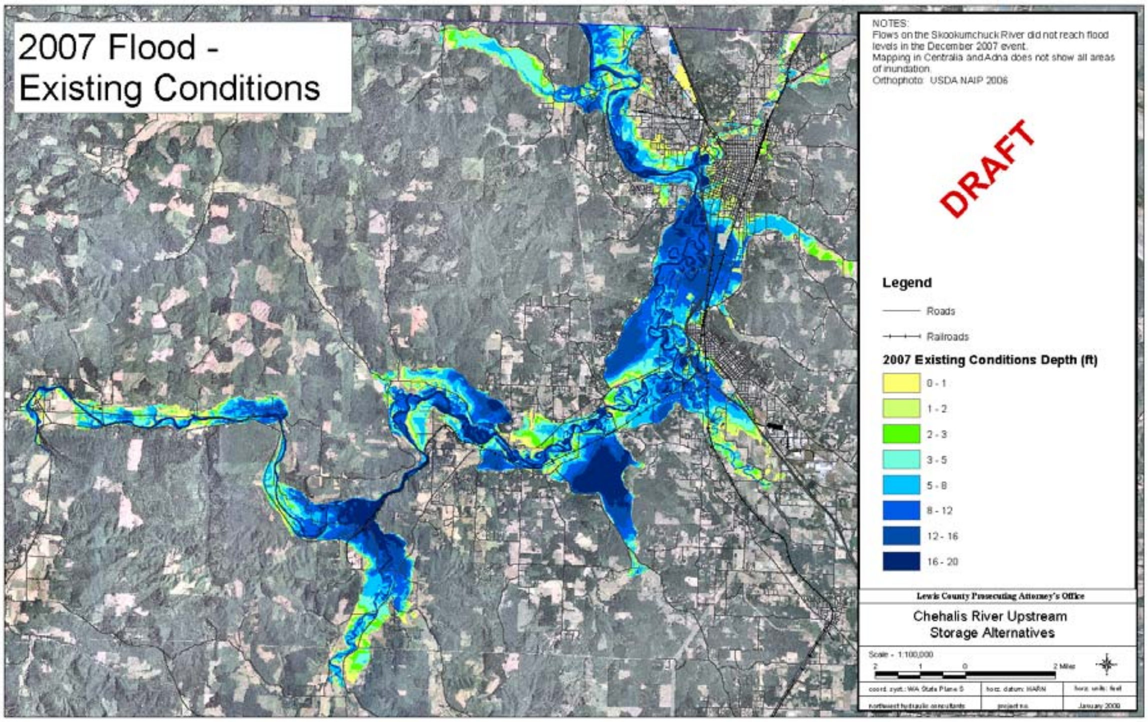


Figure 5
Flood Reduction Potential with Proposed Projects

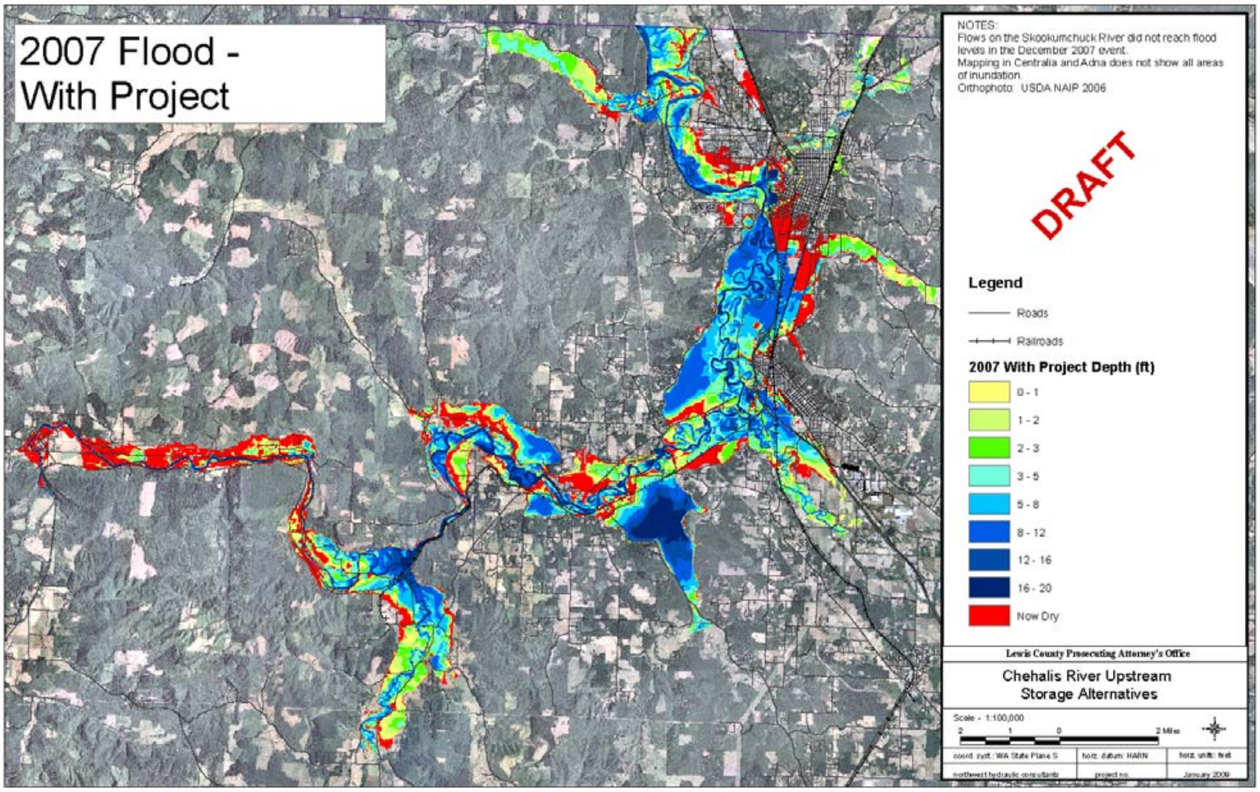
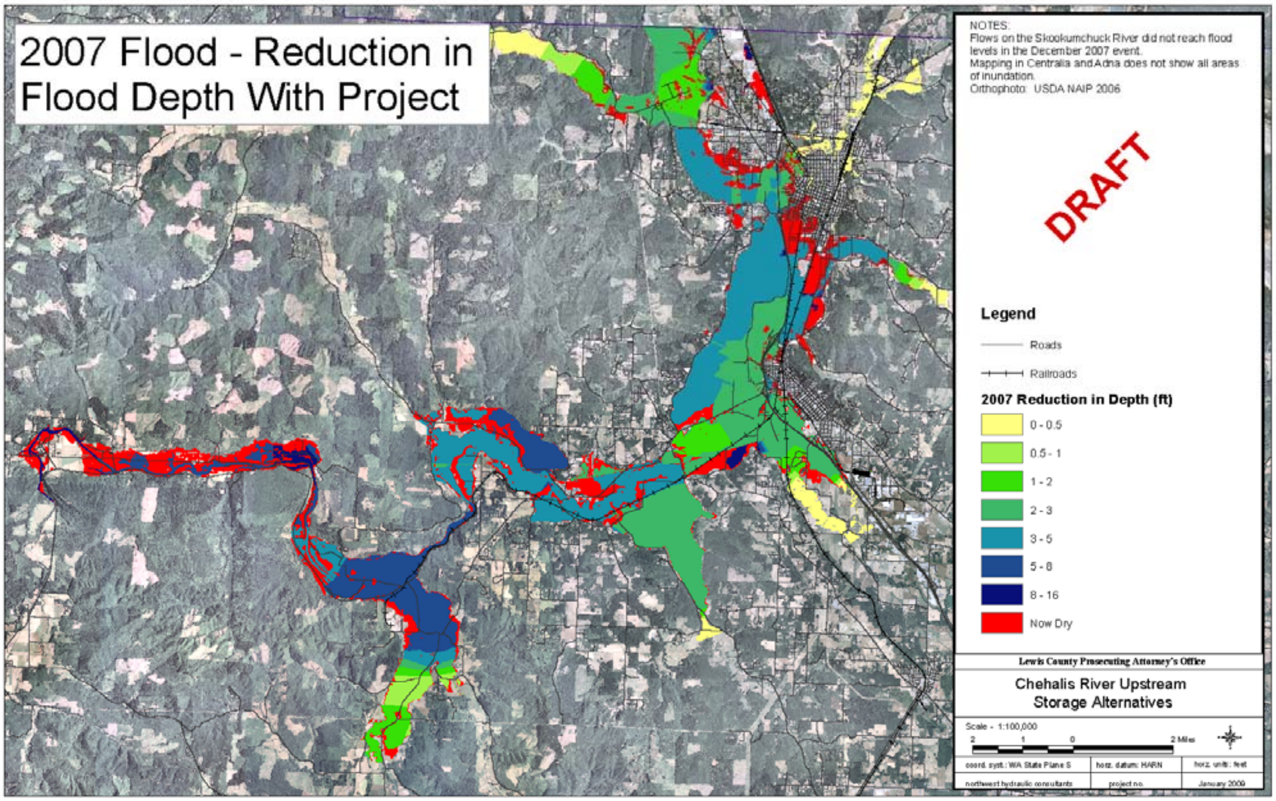


Figure 6
Reduction in Flood Depth with Projects



Estimated Benefits of Water Retention Facilities

The purpose of this section of the study is to review the possible benefits of developing water retention facilities and hydro generation equipment in Lewis County. As stated previously, the main benefits of water retention facilities in the Chehalis River basin include avoided costs for damages to residential, commercial, industrial, and agricultural property; avoided infrastructure damages and costs for infrastructure improvement; avoided damage to fish habitat and water quality; and various benefits for enhanced water quality and wildlife habitat.

Many of these benefits are difficult to quantify; however, this study utilizes previous studies and valuations to evaluate specific characteristics of the Chehalis River to estimate these benefits. Other quantitative benefits of flood control are monetized utilizing previous studies and primary resources. The monetized benefits will also include an analysis of previous studies' estimations, assumptions, and methodologies.

Habitat Changes from Construction of Water Retention Facilities

If the proposed water retention facilities were constructed, there would be some changes in the habitat types and habitat characteristics both at the reservoir sites themselves, as well as downstream. The potential habitat changes for each of the sites are examined below.

Upper Chehalis River Site

Construction of a potential water retention facility at the Upper Chehalis River site would result in a reservoir with about 1,600 acres of surface area when completely full. The riparian habitat of the Upper Chehalis in the area would be covered by the new reservoir. About 9.6 river miles of the Upper Chehalis would be covered by the full reservoir. If it is assumed that an average river bed width is 40 feet in this reach, about 46.5 acres of river habitat would be inundated and converted to still water (reservoir) habitat. About 1,600 acres of terrestrial habitat, mostly forested lands, would be lost due to the inundation, but it would be replaced with 1,600 acres of lake/reservoir habitat.

South Fork Chehalis River Site

Construction of the proposed water retention facility at the South Fork of the Chehalis River site would result in a reservoir with about 600 acres of surface area when completely full. The existing riparian habitat of the South Fork in this area would be covered by the new reservoir. About 4.6 river miles of the South Fork would also be covered. If it is assumed that an average river bed width is 30 feet in this reach, about 16.7 acres of river habitat would be inundated and converted to still water (reservoir) habitat. About 600 acres of terrestrial habitat, mostly forested lands, would be lost due to the inundation, but it would be replaced with 600 acres of lake/reservoir habitat.

Enhanced Riparian Habitat

With construction of the water retention facilities, instream flows in the Chehalis River downstream from the potential retention facility would be enhanced significantly during the summer low flow period. This enhancement is expected to improve temperatures, water quality and fish passage/access to the upper river and tributaries in the enhanced river reach. This benefit is especially important since "water quality problems are well documented in the mainstem Chehalis River… particularly for warm water temperatures and low dissolved oxygen levels. The temperature problems are likely related to riparian loss, increased sedimentation resulting in channel changes, and decreased water flow." [7]

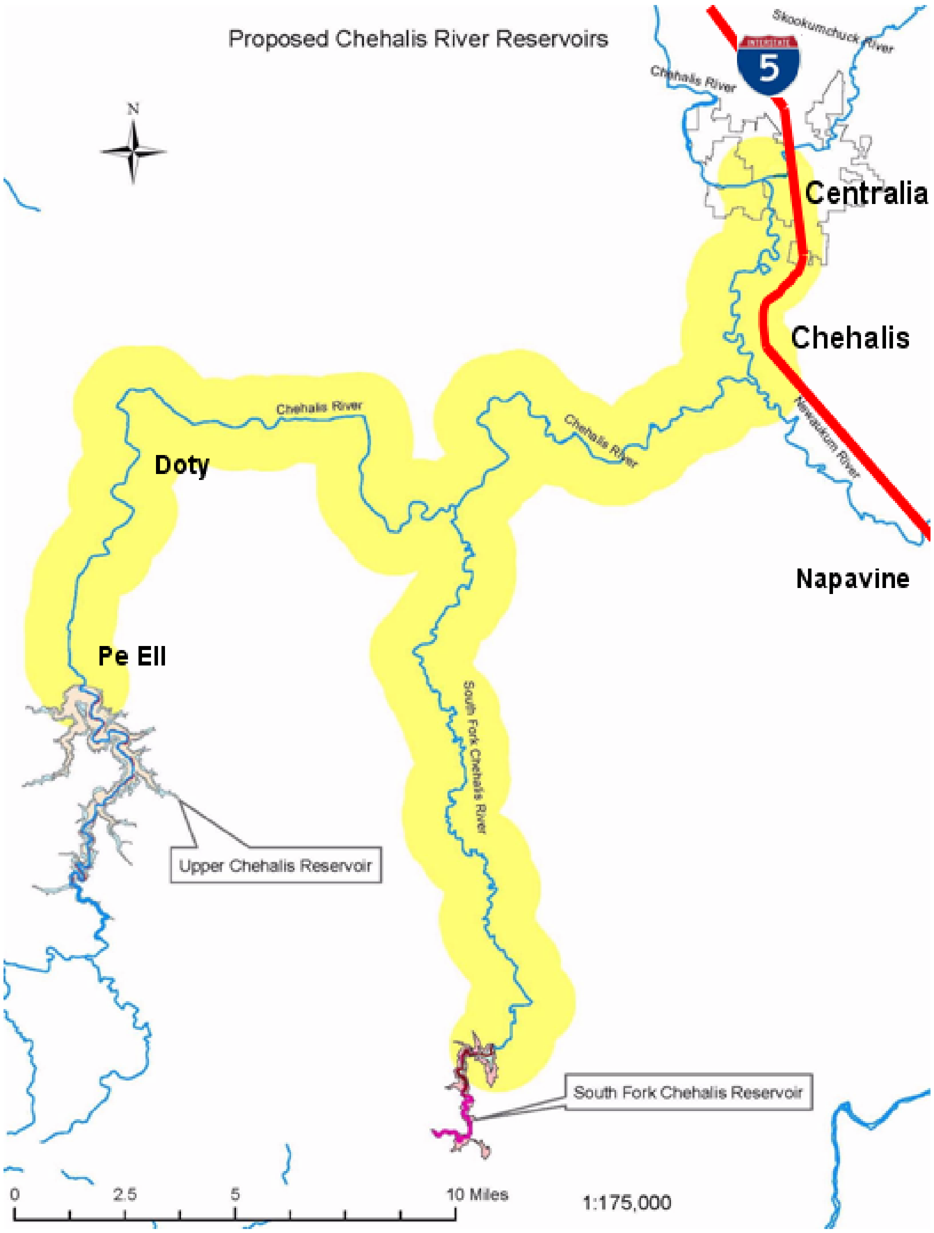
To estimate the enhancement potential, it was assumed that the main stem river would benefit from improved water quality and improved access for fish. The enhanced area would extend from the water retention facility down the entire length of the Chehalis River to its mouth. But for this estimate, the Chehalis River was analyzed from the potential water retention facility sites to Centralia. Figure 7 below shows the area potentially enhanced in yellow.

Using river and stream data from a GIS database, it was determined that a new retention facility on the Upper Chehalis would enhance about 17.7 river miles of main stem from the retention facility to its confluence with the South Fork Chehalis, assuming that the retention facility was situated at RM 106. From the South Fork confluence (RM 88.3) to Centralia (RM 67), 21.3 river miles of main stem could be enhanced. The South Fork retention facility would enhance an additional 19 river miles from the retention location to the confluence with the mainstem, given a location at RM 19. Assuming an average stream bed width of 20 feet for the mainstem, this would amount to 135 acres of enhanced river habitat from the flood control structures.

If both potential water retention facilities are constructed, a total of 58 miles and 135 acres of river habitat would potentially be enhanced. Lost river habitat amounts to approximately 63.2 acres for a net gain of about 62 acres of enhanced river habitat; however, site-specific modeling using the Instream Flow Incremental Methodology (IFIM), or similar methodology, would be employed to quantify the net gain.

[7] Smith, Carol J. and Mark Wenger. "Salmon and Steelhead Habitat Limiting Factors, Chehalis Basin and Nearby Drainages Water Resource Areas 22 and 23." Washington State Conservation Commission, Final Report. May 2001.

Figure 7
River Segments Potentially Enhanced by Increased Summer Flows



Lost riparian and terrestrial habitat is valued according to a Lewis County 2007 U.S. Family Forest Habitat Conservation Plan. The plan utilizes $4 million in state and federal funds to conserve 130,000 acres of land. This amounts to approximately $31 per acre.[8] At this acre-value, lost habitat is approximately $67,700 for all 2,200 acres lost due to the potential structures on the South Fork and Upper Chehalis reaches. The key idea is that there is a value to both the improved riparian habitat below the retention facilities, and to the lost river and terrestrial habitat above the retention facilities. Due to the scale of these areas, it is likely that the lost habitat value does not outweigh the benefits of water quality improvement below the structures; however, this is a subject that will need additional study.

Water Quality Improvement

During the summer months, the Chehalis River and many of its tributaries fail to meet water quality standards for several factors including dissolved oxygen, fecal coli form, pH, and temperature. The Department of Ecology (Ecology) determined that there is no additional loading capacity along the Upper Chehalis and through the Centralia reach.[9] Because the current state of water quality is low, increased quality from gradual release of water from water retention facilities may have significant value, especially during the low flow summer months.

Water quality is measured by six parameters including total suspended solids, dissolved oxygen, temperature, salinity, clarity, and quantity. Water retention facilities on the Chehalis River would improve water quality by reducing average temperatures, increasing clarity, and maintaining or increasing quantity. A study by the US Department of Agriculture, "Evaluating Benefits and Costs of Changes in Water Quality[10]," surveys a number of studies that use various valuation methods to determine the value of water quality. More importantly, the study details the value of water quality by each end-use described below. Benefits of improved water quality vary across region and water source; however, these benefits are estimated and monetized in this section based on previous valuation studies.

Water Quality and Wildlife Habitat

The mainstem of the Chehalis River is characterized by a low-to-moderate gradient with nearby land use dominated by forestry at the upper reaches and agriculture in the lower reaches.[11] The Chehalis River and its tributaries support habitat for many species including salmonids of spring

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[8] Washington Forest Protection Association. Lewis County Submits First-in-U.S. Family Forest Habitat Conservation Plan. September 4, 2007. Available Online. Accessed November 26, 2008.
<http://www.wfpa.org/resource/news/Family%20Forest%20Press%20Release%20Final%209-4-07.pdf>

[9] Donald B. LeMaster v. State of Washington Department of Ecology. Final Findings of Fact, Conclusions of Law and Order. Accessed September 16, 2008.
<http://www.eho.wa.gov/searchdocuments/1997%20Archive/pchb%2096-139%20final.htm>

[10] Koteen, Jessica, Susan J. Alexander, and John B. Loomis. "Evaluating Benefits and Costs of Changes in Water Quality." USDA with the US Forest Service, Pacific Northwest Research Station General Technical Report PNW-GTR-548, July 2002.

[11] The Chehalis Basin Partnership Habitat Work Group. "The Chehalis River Basin Salmon Habitat Restoration and Preservation Work Plan for WRIA 22 and 23." Update June 2007.

and fall chinook, coho, and chum salmon; steelhead; rainbow, sea-run and resident cutthroat trout; American shad; white and green sturgeon; and several exotic warm water species such as largemouth bass, perch, catfish, and sun fish.[12] Southwest Washington Coho are listed as “Undetermined” on the Endangered Species Act Status List.[13] Pacific Coast Chum, Washington Coast Chinook, and Southwest Washington Steelhead are listed as “Not Warranted” at this time.

Controlling flow during the summer months and early fall, as well as reducing winter flooding, is predicted to improve water quality and to increase the quantity and quality of fish habitat. Decreasing the severity of winter-time floods will decrease the negative impacts to fish habitat, spawning bed, and survival rates. Increasing water quantity, dissolved oxygen levels and decreasing temperatures during the summer are listed as factors that may lead to greater carrying capacity in terms of salmon and steelhead habitat in the Chehalis Basin.[14]

Fish Habitat

The mainstem Chehalis River provides spawning and rearing habitat for salmonids as well as access to upper river habitat. Currently, low flows, low levels of dissolved oxygen, and high water temperatures during the summer and early fall limit suitable rearing habitat. High sediment loads also decrease the area and quality of spawning and rearing habitat.[15] During the dry season, water quality frequently fails to meet Class A criteria for temperature and dissolved oxygen.[12] Combined with low flows, fish migration during late summer and the early fall is limited (Corps 2003 Report). From this summary of current water quality and habitat conditions, habitat improvement should be possible with some of the potential water retention facilities.

As an example, Table 5 summarizes information from Koteen et al. and provides point estimates for the value of improving fish habitat in the Pacific Northwest. As the number of current existing fish decrease, the value of additional salmon increases. The water quality improvements include salinity, suspended solids and quantity. These studies use a contingent valuation method to determine the value of water quality related to the number of fish.

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[12] ACOE, Seattle District. “Centralia Flood Damage Reduction Project Chehalis River, Washington. Final Environmental Impact Statement Appendix A: Fish, Riparian, and Wildlife Habitat Study.” June 2003.

[13] NOAA. “Endangered Species Act Status of West Coast Salmon & Steelhead.” Updated September 25, 2008. Available online: <http://www.nwr.noaa.gov/ESA-Salmon-Listings/upload/snapshot-9-08.pdf>

[14] Smith, Carol J. and Mark Wenger. “Salmon and Steelhead Habitat Limiting Factors, Chehalis Basin and Nearby Drainages Water Resource Areas 22 and 23.” Washington State Conservation Commission, Final Report. May 2001.

[15] Smith, Carol J. and Mark Wenger. “Salmon and Steelhead Habitat Limiting Factors, Chehalis Basin and Nearby Drainages Water Resource Areas 22 and 23.” Washington State Conservation Commission, Final Report. May 2001.

Table 5
Non-Market Non-Use Values of Additional Salmon
Due to Increases in Water Quality

Citation	Location	Value $1998	Current Number of Salmon
Loomis 1999	Pacific Northwest and California	1,400	1,000,000
Loomis 1999	Pacific Northwest and California	10,712	250,000
Olsen and others 1991	Pacific Northwest and California	203	2,500,000
Loomis 1996	Pacific Northwest	3,325	300,000
Hanemann and others 1991	California	232,356	14,900

Source: Koteen, Table 11.[16]

Fish Species in the Chehalis Watershed

Specifically, the Upper Chehalis watershed provides important spawning habitat for anadromous fish including chinook, coho, chum and steelhead salmon. Low summer flows, high temperature, and low levels of dissolved oxygen are limiting factors for the river's carrying capacity (Lemaster v. Ecology). Figure 8 below illustrates temperatures observed in the Upper Chehalis Basin and crucial survival temperature for salmon.[17] The lethal temperature is for migrating adults. Juvenile fish have a slightly higher tolerance to temperature at about 23 to 26°C and one week exposure. Appropriate temperatures are dependent upon life stage, time of year, and food availability among other factors. Increased water flow has potential to increase fish migration by cooling water temperatures in the summer months.

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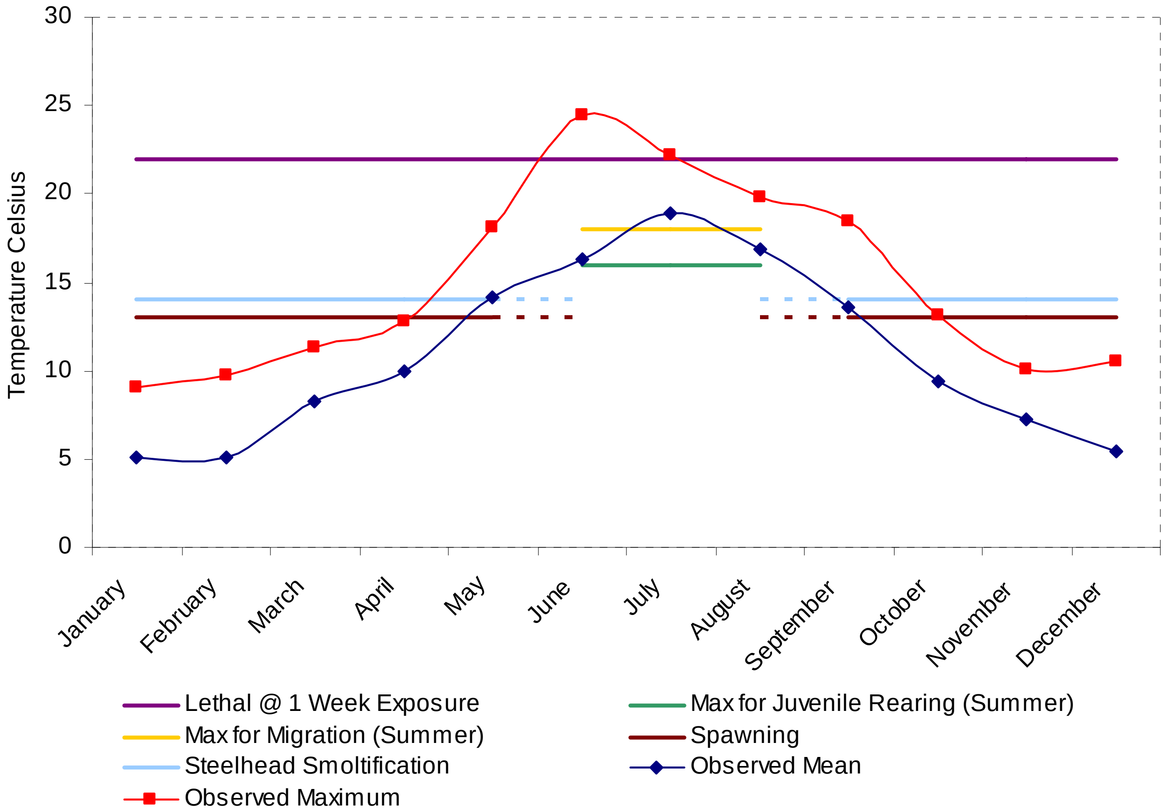
[16] Koteen, Jessica, Susan J. Alexander, and John B. Loomis. "Evaluating Benefits and Costs of Changes in Water Quality." USDA with the US Forest Service, Pacific Northwest Research Station General Technical Report PNW-GTR-548, July 2002.

[17] Washington State Department of Ecology. "Upper Chehalis Basin Temperature Total Maximum Daily Load." Revised July 2001. Olympia, Washington. Publication No. 99-52.

And

Environmental Protection Agency. "EPA issues Final Water Temperature Guidance – April 2003." Region 10, Seattle, Washington. Available online: <www.epa.gov/r10earth/temperature.htm.>

Figure 8
Upper Chehalis Basin Observed Temperatures



Value of Additional Fish Production

To estimate value for improved fish habitat, values per additional fish are calculated using the Bonneville Power Administration's (BPA) annual expenditures on fish mitigation and geometric means for evolutionary specific units (ESUs) in the Columbia River Basin. In 2005, BPA spent over $358 million for Columbia River Fish Mitigation (dollars are in 2008 terms). According to a report prepared for BPA[18], approximately 391,901 adult fish were counted in the Columbia River Basin. The fish count is a geometric mean over several recent years. Expenditures per fish amount to $914 in 2008 dollars. These values are considered total values. It is supposed that sport fishing values are included in this estimate since BPA fish mitigation strategies include both intrinsic and sport fishing benefits.

Increased Fish Production Estimates

Increased summer flows in the lower and upper Chehalis River could result in additional summer rearing for spring chinook and coho salmon and steelhead trout. All three of these species reside in a stream for at least a year (although there may be exceptions to this life history for spring

[18] Fisher, Tim and Rich Hinrichsen. "Abundance-Based Trend Results for Columbia Basin Salmon and Steelhead ESUs." Bonneville Power Administration Division of Environment, Fish, and Wildlife. November 14, 2006.

chinook salmon in the Chehalis River), so that summer flows would be beneficial. All chinook stocks are different, but generally fall chinook do not over-winter and rear in fresh water like coho, steelhead, and spring chinook typically do. They tend to migrate to saltwater in summer. If that is the case for these fall chinook and they leave in the late spring-early summer, the increased rearing flows during the summer period would increase production for this species of chinook salmon. Chum salmon, if present in the system, typically hatch out in early spring and the fry migrate directly from the river to the estuary. Increased summer flows would most likely not be beneficial to this species.

Due to proximity and similar climate, salmon runs on the Chehalis River may be similar to runs on the Olympic Peninsula. Typically runs on the Olympic Peninsula are limited by high winter flows as well as summer low flows. They need refuge areas when the flows get high. These high flows normally force juvenile fish to seek refuge at the outer edges of the river and these fish are frequently isolated in low lying areas when flows recede. Therefore, the proposed retention facilities could have some winter benefits by regulating flow. Also, flood control during the winter months could improve future fish populations by increasing egg-to-fry survival and reducing redd scour.

The number of additional fish subsequent to increased summer flows is calculated assuming that some populations will increase relative to the change in flow. Current average summer flows are approximately 38 and 12 cfs for the Upper Chehalis and South Fork Chehalis, respectively. The proposed water retention facilities would increase flows by 100 and 19 cfs for these two rivers, respectively. This results in average daily summer flows increases of 260 percent on the Upper Chehalis and 160 percent on the South Fork Chehalis. The increased summer flows are recorded at the water retention facility locations; however, summer flows downstream will not increase by as much. Because of the current downstream flows, the average daily summer flows would increase by a lower percentage of approximately 25 percent near Grand Mound.

For this study, an increase in fish populations is estimated at 1,028 additional fish. This increase equates to a 5 percent increase in populations of spring chinook, coho, and winter steelhead. Additional study is required to more accurately estimate positive effects of water improvements on fish populations. Also, since these fish stocks are considered healthy according to the Washington State Department of Fish and Wildlife,[19] a small (and conservative) population increase is assumed based on increased summer flows and decreased probability of flooding events impacting incubating eggs, redds, or over-winter juvenile survival. According to the Washington State Department of Wildlife, coho salmon are found to spawn in areas above the proposed sites.[20] The reservoir capacity would then significantly increase over-winter capacity. Figure 9 below shows a map of coho salmon spawning location in the Chehalis River basin and the approximate location of the Upper Chehalis and South Fork Chehalis water retention sites.

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[19] Washington State Department of Fish and Wildlife. *Salmonid Stock Inventory*. Accessed November 2008. <http://wdfw.wa.gov/cgi-bin/database/sasi_search_new_db.cgi?keyword=26&field=4&search_sort=sort&srchtype=within&job=search&wria=wria>

[20] Washington Department of Fish and Wildlife. *Map of Chehalis Coho*. Available online: <http://wdfw.wa.gov/webmaps/salmonscape/sasi/maps/3605.jpg>

Figure 9
Chehalis Coho Spawning Distribution

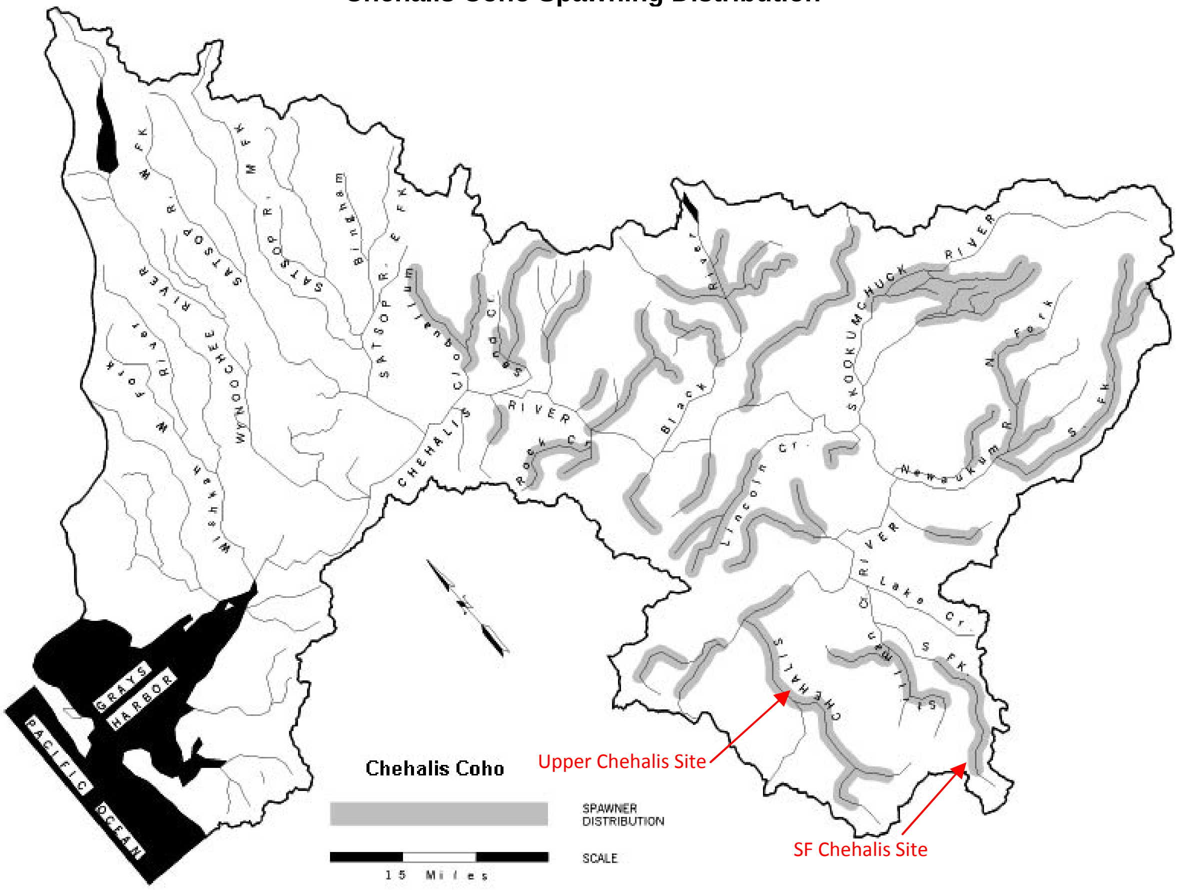

Table 6 shows fish stock data for the Chehalis River. Shaded years indicate flood event years. While this study concludes that fish stocks will improve, it should be noted that these fish stocks are currently at healthy population levels, and values per additional fish are based on fish stocks that may not be classified at the same level of health as the fish in the Chehalis area. To better define the fish production effects from water retention facilities on the Chehalis River, further study is required.

Table 6 Fish Stock Status on the Chehalis River Number of Returning Adult Fish	Spring Chinook*	Fall Chinook*	Fall Chum	Coho	Summer Steelhead	Winter Steelhead*
1986	874	3,348	4,423	8,357	Unknown	3,322
1987	841	6,124	2,415	5,803		3,682
1988	3,106	7,685	14,489	22,108		2,264
1989	2,068	7,837	2,437	22,824		2,392
1990	1,567	2,941	2,589	10,768		2,596
1991	1,289	4,516	4,472	29,519		1,584
1992	1,813	4,058	5,414	13,358		1,888
1993	1,254	4,037	4,735	13,738		1,762
1994	1,403	2,830	7,718	4,442		1,970
1995	2,070	3,797	3,926	17,364		1,730
1996	4,305	7,297	3,659	30,695		1,564
1997	4,406	6,701	3,330	10,609		1,913
1998	2,283	4,432	10,680	15,493		998
1999	1,285	3,946	3,684	15,475		2,620
2000	3,135	4,430	2,313	21,968		3,620
2001	2,860	3,804	2,765	33,166		2,794
2002	2,598	1,584	13,695	Unavailable		2,350
2003	1,904	8,746	10,438	Unavailable		1,991
Geometric Mean Post 1990	2,150	4,274	5,086	16,444		1,968
Standard Deviation Post 1990	1,077	1,903	3,585	9,084		660
Minimum	841	1,584	2,313	4,442		998
Maximum	4,406	8,746	14,489	33,166		3,682

*Indicates that population is projected to increase due to water quality improvements from proposed projects.

Municipal Water Use

Flooding can significantly reduce the quality of municipal water. Municipal water includes demand from residential, public (firefighting and maintenance of public facilities), and other (commercial and industrial). Municipal water use requires high-quality input water in quantity, salinity and suspended solids. Having enough water quantity is valuable since suppliers then do not have to search for water elsewhere. Low salinity is valuable since salt damages equipment used to treating, storing, and transporting water. Lastly, suspended solids increase costs and safety concerns regarding treatment. Adding to the municipal water supplier concerns, consumers of municipal water generally value water clarity. Currently, the Boistfort water company supply receives water from the South Fork Chehalis and Pe Ell receives its water near the proposed Upper Chehalis site. Both of these areas may benefit from municipal water improvements in the future, though currently there is no plan in place.

Koteen et al analyzed several studies to estimate the value of increased municipal water quality (salinity and suspended solids). The studies surveyed measure the value of increased water quality by a cost savings valuation method. The average benefit from decreases in salinity and total suspended solids is $0.0469 per household annually (1998 dollars). This value is for 1 milligram per liter improvement in water from the Colorado River, Colorado. It should be noted that these values may vary with regional cost differences and initial water quality.

In addition, Koteen, et al. summarized several studies that estimated the value of municipal water use in terms of water quantity improvements. According to the studies surveyed, a 10 percent reduction in water quantity costs $41 to $653 per acre-foot depending on geographic location. The location analyzed in the South Atlantic Gulf produced values of $41 per acre-foot for both summer and winter seasons (1998 dollars); however, in Lower Colorado summer values reached $351 per acre-foot in the summer and $54 per acre-foot in the winter (1998 dollars). Water quantity values vary greatly between regions due to differences in climate, initial amount of water, industry, and population among other variables. For the purposes of this study, municipal water quality improvement benefits are estimated conservatively at $50.75 per additional acre-foot of water quantity.

Agriculture Water Use

From a study conducted in the Pacific Northwest, the value per acre-foot of water quality improvement is approximately $34 (1998 dollars). This study by Ailery and others (1994), measures the change in production costs given a 1-acre-foot change in water availability (Koteen, et al. @13). These values are used to calculate benefits to agriculture for increased water quantity during the summer months. According to the state DOE, existing minimum instream flows do not meet current certificated rights of irrigators during the summer months.[21] These low water levels imply that additional water flow during the prime irrigating months would provide significant benefits – possibly more than $34 per acre-foot. Currently, there is over 99,850 acres of irrigated land in the Chehalis River Basin. Water quantity improvements could prove to provide substantial benefits.[22]

Recreation

Because each recreational activity utilizes water differently, a different value by activity will inherently be assigned to water quality improvement. For instance, activities such as swimming and fishing require high water quality whereas boating activities require lower water quality levels. Also, different activities will value water quality parameters differently. For instance, high sediment loads may be fine for white water rafters; however, water quantity is a major concern. The value of water quantity improvements will also vary with rafter skill level. In regard to the Chehalis River, most recreational use is in the form of fishing, canoeing, kayaking,

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[21] The Chehalis Basin Partnership Habitat Work Group. "The Chehalis Basin Salmon Habitat Restoration and Preservation Work Plan for WRIA 22 and 23." Updated June 2007: page 114.

[22] Washington State Department of Ecology. "Chehalis River and Grays Harbor Watershed Water Quality Improvement Projects." Chehalis River and Tributaries, TMDL Summary. Available online: <http://www.ecy.wa.gov/programs/wq/tmdl/ChehalisRvrTMDLSummary.html>

swimming, birding, and hunting.[23] Most of these activities (swimming and fishing in particular) place the largest values on water quality.

Value of an additional acre-foot per day on the Chehalis River is estimated at $18.40 per additional acre-foot per day (2008 dollars). This value is based on valuations for water quality improvements such that water use for shoreline activities is improved. Recreation benefits are calculated over the 92 day period in the summer where Upper Chehalis River flows are increased by over 16,000 acre-feet and South Fork flows increased by over 3,000 acre-feet.

Intrinsic Value

Intrinsic values encompass a wide array of water uses that are indirectly related to the water source. These may include ecological value, preservation benefits and option or bequest values (Koteen et. al @22). Specifically there is an inherent value for the existence of the river and the quality of the river. By simply existing, the river provides value to nearby ecosystems, residents, and future generations without direct use. Intrinsic values (non-recreation values) are estimated at $127 per household in the following towns: Centralia, Chehalis, Napavine, and PeEll. These estimates account for existence and bequest values, and exclude any values associated with the fishing industry. Specific values for improved fish habitat are nonuse values and are discussed in more detail below.

Summary of Water Quality Benefits

Table 7 details water quality benefits for water retention facilities within the Chehalis River basin. The average case uses values described above. The low and high cases for fish habitat correspond to the $258 and $4,218 per fish estimated from Columbia River fish mitigation projects (in 2008 dollars). The low and high cases for municipal, agriculture, recreation, intrinsic values are 80 and 120 percent of the base case respectively. Table A-2 provides the assumptions used to calculate annual water quality benefits. For the benefit calculation, these annual benefits are assumed to occur every year once the water retention facilities are built.

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[23] The Chehalis River Council, accessed May 2008. <http://www.crcwater.org/actplan/13lowch.html#1240>

Table 7 Water Quality Benefits ($2008)						
				Total per Year		
	Low	**Base**	**High**	**Low**	**Average**	**High**
		$ per acre-foot				
Municipal	$40.60	$50.75	$60.90	$811,162	$1,013,952	$1,216,743
Agriculture	$34.51	$43.14	$51.76	$689,488	$861,860	$1,034,231
		$ per Additional 100 cfs				
Recreation	$14.72	$18.40	$22.08	$270,523	$338,153	$405,784
		$ per Household				
Intrinsic Value	$101	$127	$152	$1,155,033	$1,443,791	$1,732,549
		$ per Additional Salmon				
Fish Habitat	$258	$914	$4,218	$264,785	$940,096	$4,336,526
Total				**$3,190,990**	**$4,597,852**	**$8,725,833**

Disaster Aid

Disaster aid to qualifying individuals and businesses comes in the form of loans, direct funds or other relief. In addition to any federal or state aid, building owners pay out-of-pocket for damages above what their insurance benefits cover. This section examines the benefit of avoiding disaster aid payments.

FEMA Estimate of 2007 Flood Aid

The Federal Emergency Management Agency (FEMA), Washington Emergency Management Division (WA-EMD), and the US Small Business Administration (SBA) all provided disaster relief to flood victims during the December 2007 Chehalis River flood. As of March 18, 2008 total flood disaster aid tallied to $40.2 million[24] for Lewis and Thurston Counties across all disaster relief programs. Table 8 details the disaster relief totals. Lewis County alone received the majority of the $40 million for damages caused when the Chehalis River basin flooded. These damages are used in this study.

[24] FEMA. “Washington Disaster Aid Tops $72.5 Million.” Release Number 1734-071, March 18, 2008. The figure quoted in the text is 95 percent of aid for Lewis County and 100 percent of aid for Thurston County.

Table 8
2007 Storm Disaster Aid Summary ($2008)

County	Housing Assistance	Other Needs Assistance	Small Business Administration (disaster loans)	Public Assistance*	Total
Clallam	$219,359	$11,623	$251,400	$277,978	$760,360
Grays Harbor	$1,556,046	$234,918	$3,867,600	$2,326,407	$7,984,971
Jefferson	NA	NA	NA	$201,216	$201,216
King	$1,370,211	$160,353	$1,594,700	$1,845,386	$4,970,650
Kitsap	$1,401,024	$59,419	$1,255,500	$1,195,046	$3,910,989
Lewis	**$9,583,635**	**$2,266,483**	**$19,615,500**	**$8,034,990**	**$39,500,608**
Mason	$1,202,781	$58,506	$1,984,700	$1,997,304	$5,243,291
Pacific	$475,217	$49,697	$1,340,100	$231,576	$2,096,590
Skagit	NA	NA	NA	$21,050	$21,050
Snohomish	$494,205	$37,233	$724,700	$1,398,783	$2,654,921
Thurston	$726,581	$4,180	$823,400	$1,117,943	$2,672,104
Wahkiakum	$128,659	$28,531	$85,800	$160,561	$403,551
Statewide PA	NA	NA	NA	$2,104,756	$2,104,756
Total	$17,157,718	$2,910,943	$31,543,400	$20,912,996	$72,525057

*PA is for state and local governments, tribes, and non-profits

The Corps Property Damage Numbers: 2007 Flood

The US Army Corps of Engineers (Corps) has also estimated specific damage amounts to residential, commercial, and agriculture properties similar to the disaster aid estimate above. However, the Corps estimates are on the low end of the spectrum based on the actual damages experienced during the 2007 flood. The Corps damage estimates are separated into flood inundation damages and clean-up damages. Table 9[25] shows estimated damages for 100-year flood of the Chehalis River in 2008 dollars. These Corps estimates are likely much underestimated considering the economic development since the report was published in 2003.

[25] Data for tables is taken from "Centralia Flood Damage Reduction Project Chehalis River, Washington Final General Reevaluation Report, Appendix D: Economics" by the Seattle District of US Army Corps of Engineers, June 2003. The values were originally given in $2003 but were escalated to $2008 using the GDP deflator.

Table 9 Chehalis River 100-Year Flood Event Costs in 2008 Dollars			
	Flood Inundation Damages		
	Structure	Content	**Clean-up Costs**
Residential	$21,811,675	$12,499,089	$6,156,251
Commercial	$16,463,223	$22,475,344	$4,209,937
Public Structures	$5,561,854	$4,525,012	$471,495
	Temporary Relocation	**Public Assistance**	
Emergency Costs	$1,032,373	$3,588,726	

The commercial damages in Table 9 assume 2.5 million square feet of commercial and industrial floor space with average square foot cost of $52.53 (structure value in 2008 dollars). The residential clean-up costs represent a mean cost of approximately $4.60 per square foot in 2008 dollars and $52.53 per square feet in structure damage. Emergency costs include assistance to infrastructure, public utilities, debris removal, emergency protective measures, water control facilities, and other activities of a governmental nature. As stated previously, the Corps estimates are most likely underestimating the actual cost due to new development in the area since these estimates were made. The development in residential and non-residential structures since 2003 is discussed further below.

Commercial Structure Development

Lewis County and the City of Chehalis have experienced significant economic growth since 2003 when the Corps study was completed. Because of its proximity to major metropolitan areas (Seattle and Portland) and the easy access to I-5, the Chehalis commercial sector is growing rapidly. Property values are increasing steadily due to growth in neighboring metropolitan areas, but home prices are still significantly lower in Chehalis compared with other cities near I-5. These comparably lower home prices attract residents and businesses to the area.

In addition, the Port of Chehalis and the Port of Centralia have been actively acquiring land, building, and other resources to help draw business to the area. The Port of Chehalis Comprehensive Plan from September 2006 notes that in 2005, 35 acres of industrial-zoned property was sold to Fred Meyer for their planned expansion that will bring in 200 more jobs. In another instance, the sale of a leased building in 2005 is estimated to bring in 50 additional jobs. The Port continually expands its property holdings and promotes economic growth. In 2005, the Port purchased 91 additional acres for future development.[26] Table 10 summarizes personal income and employment data for Lewis County.[27] Both employment and personal income have

[26] "Port of Chehalis Comprehensive Plan." September 2006. Chapter V.

[27] Employment and income data is from the Washington Regional Economic Analysis Project. www.pnreap.org.

grown significantly since 2003. From the developments since 2003, it appears likely that the Corps estimate of 2.5 million square feet of commercial and industrial buildings is now too low.

Table 10
Lewis County Data
2008 Dollars

	Personal Income	Growth Rate	Employment	Growth Rate
2001	$1,897,312,576.90		34,284	
2002	$1,886,940,416.65	-0.55%	34,684	1.17%
2003	$1,893,783,127.45	0.36%	34,334	-1.01%
2004	$1,924,100,308.75	1.60%	34,846	1.49%
2005	$1,924,707,136.71	0.03%	35,739	2.56%
2006	$2,017,479,081.59	4.82%	36,941	3.36%
Average Annual Growth Rate				
2001-2006	1.06%		1.29%	

Residential Structures Development

Tables 11 and 12 show residential real estate and city data for Lewis County. These data reinforce the commercial and industrial sector growth information above. Table 11 shows that the average annual growth rates are significantly higher for the period 2002 through 2006 than the growth rates for 2000 to 2002. Because the Corps report was published in June 2003, growth data since then is not incorporated in their analysis.

Table 11
Lewis County Real Estate Data

	Total Housing Inventory	Single Family Housing Inventory	Multi-Family Housing Inventory	Median Home Prices	Residential Building Permits
2000	29,585	20,207	9,378	$89,000	184
2001	29,897	20,510	9,388	$104,600	174
2002	30,120	20,719	9,402	$106,000	223
2003	30,494	21,025	9,470	$115,000	374
2004	30,890	21,362	9,529	$124,500	396
2005	31,419	21,861	9,559	$141,000	529
2006	31,990	22,360	9,631	$170,000	571
Average Annual Growth Rate					
2000-2002	0.60%	0.84%	0.09%	6.37%	7.07%
2002-2006	1.24%	1.58%	0.49%	12.1%	31.2%
2000-2006	1.16%	1.52%	0.39%	13.0%	30.0%

Table Source: Washington Center for Real Estate Research, Washington State University

Table 12 provides the population growth by city in Lewis County. The cities of Centralia and Chehalis make up 60 percent of total county population change.

Table 12
Cities of Lewis County
Population Growth

City	2000	2007	Annual Average Change	2000-2007 Change	2000-2007 Number Change	Average Annual Population Change	Percent of County Growth
Centralia	14,720	15,520	0.78%	5.43%	800	133	57%
Chehalis	7,003	7,045	0.09%	0.60%	42	7	3%
Morton	1,059	1,140	1.09%	7.65%	81	14	6%
Mossyrock	463	485	0.68%	4.75%	22	4	2%
Napavine	1,319	1,492	1.87%	13.12%	173	29	12%
Pe Ell	688	670	-0.37%	-2.62%	-18	-3	-1%
Toledo	612	685	1.70%	11.93%	73	12	5%
Vader	617	620	0.07%	0.49%	3	1	0%
Winlock	1,135	1,370	2.96%	20.70%	235	39	17%
Total:	**29,616**	**31,034**			**1,411**	**235**	**100%**

Table Source: 2007 Washington Data book, Office of Financial Management. 2000 Census.

Because significant new development has occurred in Lewis County since the Corps report was developed, this study use the FEMA estimate provided in Table 8. According to FEMA, the total Washington disaster aid tallied to $72,525,057[28] across all disaster relief programs. In order to determine the avoided cost of disaster aid due to the flood, the actual disaster aid for Lewis and Thurston Counties from 2007 was used. The disaster aid for Grays Harbor County was not included since a majority of the damage was due to wind in that County. In addition, the disaster aid for Lewis County was reduced by 5% to account for aid due to wind damage. This calculation resulted in avoided disaster aid cost of $40.2 million.

Damages in Excess of Disaster Aid and Insurance Benefits

In addition to the FEMA-paid damages, building owners paid out-of pocket for damages above FEMA aid or and insurance payments. This section describes the assumptions and estimates regarding building and content damages in the 2007 flood event.

Two-thirds of damaged homes and commercial buildings were insured in the 2007 flood. Based on this share of buildings and average insurance benefits, it is estimated that 95 percent of the residential and 90 percent of the commercial building and content damages are covered by insurance. Residential buildings are covered 100 percent (replacement value) while residential contents are covered taking into account depreciation. On the other hand, both commercial buildings and contents are covered up to their depreciated value; however, insurance companies

[28] FEMA. "Washington Disaster Aid Tops $72.5 Million." Release Number 1734-071, March 18, 2008.

have historically been lenient on depreciated values. Accordingly, 90 percent of commercial building and content damages are assumed to be covered.

Approximately one-third of building owners did not have insurance. Homes in Centralia and Chehalis were damaged to the point where FEMA aid covered nearly all of the replacement costs. Homes near Doty; however, were severely damaged. Anecdotal evidence indicates that a home could be damaged by as much as $60,000 above the $28,800 in aid from FEMA. For this study, it is assumed that severely damaged homes without insurance (nearly all homes in the Doty area) were damaged $30,000 above FEMA aid. The number of severely damaged homes is calculated using population data for the Doty area. Commercial building damages with out insurance are calculated with the same methodology except damages are assumed to be $40,000 above what FEMA aid covered.

The assumptions above total to damages in excess of $4 million dollars. These damages are added to the FEMA and other disaster aid in this analysis.

Agriculture

The Corps report calculated damages to agriculture crops differently based on the type of crop as defined by the Planning Guidance Notebook of the Corps (ER 1105-2-100). These calculations include loss of income for hay crops only and variable costs for corn and peas. The weight for each crop was attained from surveys of nearby land (see Table 13). The actual crop mix may vary. The "Cropland Restoration Costs" include "additional cycles of fertilizer, weed control, and pest control, based upon consultation with the Lewis County Farm Advisor" ("Centralia Flood Damage Reduction Project" 2003). Given 2,200[29] acres of affected farmland, total crop losses amount to $1,080,200. It should be noted that the 2,200 acres of farmland is accounts for agricultural land that is used only for specific crops. For example, several additional acres used for farm animal grazing were damaged due to flooding. The recent floods left these grazing lands littered with logs and debris and needed clearing before the animals could continue to graze. Lost output from these damages is not included in the Corps estimates and could increase the damage estimate significantly.

Table 13
Chehalis River 100-Year Flood Event
Per Acre Crop Damage
2008 Dollars

Crop Type	Per Acre Damage	Weight	Weighted Loss
Hay	$246.34	60%	$147
Corn	$58.96	25%	$15
Peas	$68.82	15%	$10
		Subtotal:	**$173**
Cropland Restoration Costs:			$318
		Total:	**$491**

[29] The number of acres included in the Corps study and subject to Chehalis flood events.

While the Corps report estimates agriculture damages for 100 and 500 year events at $1,080,200 in total, this estimate includes only damages to crops, crop losses, and cropland restoration. The 2007 flood damages to all agriculture sub-sectors totaled $12.5 million[30]. These damages are for over 150 farmers and include loss of feed, livestock (1,600 head of livestock reported lost), fence damage, debris, diary products, irrigation systems, greenhouses, seeds, and planting equipment. In addition to the damages and lost crops, some farms were unable to plant in 2008 due to silt, mud, and wood debris. All together, it is estimated that future flood events will cause a minimum of $12.57 million in damages in the agriculture sector.

Summary of Disaster Aid Damages

Table 14 details the estimated disaster aid avoided cost for flood control on the Chehalis River.

Table 14 Disaster Aid Avoided Costs ($2008)	
FEMA Disaster Aid	$40,200,000
Additional Damages	4,600,000
Agriculture	12,600,000
Total	$57,400,000

The avoided costs listed in table 14 are costs avoided every year a flood is avoided. For this study, the property damages and clean-up benefits are calculated annually using the benefit dollar amount and the change in flood probability due to mitigation.

In order to estimate the flood probability due to mitigation, previous work by the Corps[31] was examined to determine the current probability of flooding by type of damage. Based on the stage damage functions estimated by the Corps, a weighted average flood probability for a 100 year event was estimated at 6.5 percent.

In order to estimate the reduction in flooding probability, flood reduction levels were applied to historic data to estimate the reduced number of flood events if the projects are implemented. Flood reduction capability for a 100 year event is used in this analysis. Based on this analysis, it was determined that major flood events are reduced by over 50 percent for each site. Therefore it is estimated that the Upper Chehalis and South Fork water retention facilities will reduce the probability of flooding by approximately 3 percent for a 100 year event. As a result, the disaster aid avoided costs used in this study were calculated at 3 percent of $57.4 million per year.

[30] June 10, 2008, agweekly.com

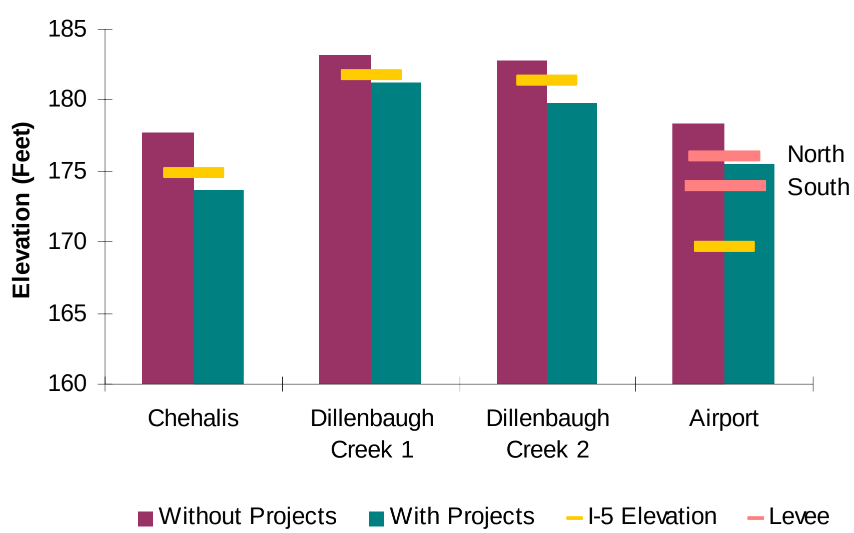
[31] Army Corps of Engineers. "Centralia Flood Damage Reduction Project Chehalis River, Washington Final General Reevaluation Report" by the Seattle District of US Army Corps of Engineers, June 2003.

Avoided Infrastructure Improvements

Interstate 5 has experienced closures of one to four days during the four flood events in the past seventeen years. As such, the Washington State Department of Transportation has made plans to both raise and widen the section of I-5 that passes through Centralia and is subject to flooding from the Chehalis River. Flood control on the Chehalis River would lower the total project costs for road widening. The road widening project includes a 6 mile stretch of the freeway that will be raised up to 15 feet in some locations. The Corps estimates the avoided cost for raising I-5 at $49,516,656 in 2008 dollars. This avoided cost is attributed to savings in wetland mitigation, gravel haul, embankment compaction, surfacing, and other miscellaneous costs. However, on December 5, 2007, the Seattle PI quoted WSDOT as stating that estimates for raising the freeway could cost $300 to $400 million.

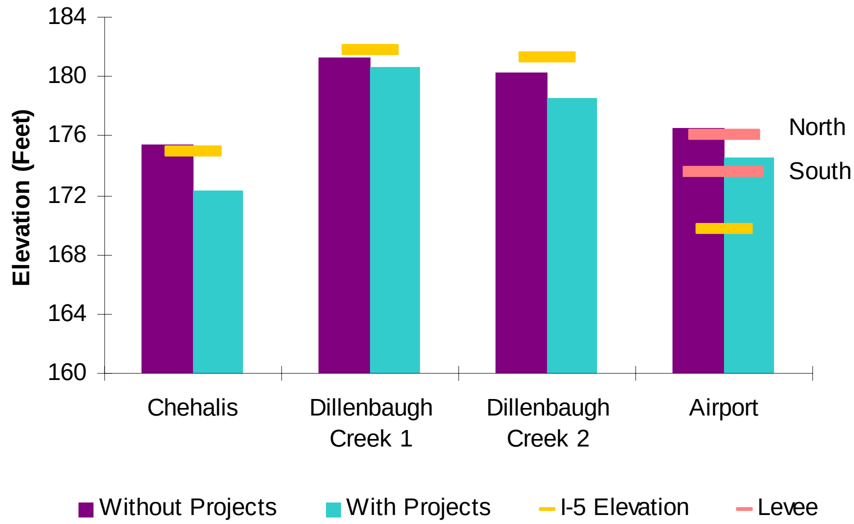
Figures 10 and 11 provides the estimated flood reduction on I-5 with the proposed projects, in addition to the current elevation of I-5 at four locations for the 2007 flood and the 100 year flood, respectively. In addition, the current airport levee (north and south) elevations are provided for reference.

Figure 10
Estimated Flood Reduction on I-5 – 2007 Flood Event



Source: NHC

Figure 11
Estimated Flood Reduction on I-5 – 100 Year Flood Event



Source: NHC

It is clear from these two figures, that some work would still be needed near the airport to avoid any flooding of I-5. Based on the most recent information and the figures above, this study uses $300 million as the expected avoided cost for raising I-5. This avoided cost was selected to allow for up to $100 million of related levee work to further reduce flood levels. The study assumes that the $300 million is a onetime expenditure, which can be avoided in 2020.

I-5 Closures

A 100-year flood event results in I-5 closures for 4.5 days, or a total loss of over $47 million (increased from $15 million per USACE estimates). These losses assume floods occur in the future at 2008 costs. For this study, the I-5 closure benefits are calculated annually until 2020 using the benefit dollar amount of $47 million and the change in flood probability due to mitigation of 3%. After, 2020 when I-5 would have been raised, no additional benefits for I-5 closures are calculated.

In addition to closure of I-5, the rail service between Portland and Seattle was halted as well. Therefore, $1.2 million in avoided damages was included in this analysis for the impact on the railroad. These railroad damage figures are from the 2003 Corps report and updated to 2008 dollars. For this study, the railroad benefits are calculated annually using the benefit dollar amount of $1.2 million and the change in flood probability due to mitigation of 3%. These benefits continue past 2020, as the raising of I-5 would not affect flooding of the railroad.

Property Values

With water flow restriction facilities, property values will increase for those properties located in the flood plain. The increased property values are estimated using flood insurance premiums for residential and non-residential properties (building only insurance). Premium reductions from high risk to low risk areas ranged from 28 to 50 percent for residential buildings and 31 to 64 percent for non-residential buildings (depending on amount of coverage). In other words, for $100,000 in coverage, annual premiums are decreased by 37 percent given risk of flooding is reduced from high to low or moderate.

Non-residential property values are estimated at an additional $53,600 per property over 30 years. This average value increase is based a weighted average given half of property owners buy insurance at lower rate and half do not buy insurance at all. The total estimate for increased property values is based on the 159 buildings damaged during the 2007 flood. These increases in property values are escalated at 4 percent per year to account for inflation in insurance premiums.

Thirty year levelized residential property value benefits are estimated at $15,000 per affected house. This value is a weighted average assuming that one-third of homeowners purchase flood insurance but at lower rates, and two-thirds no longer purchase flood insurance at all. The total values are based on the 987 homes damaged in the 2007 flood. These increases in property value may be understated due to other property values that result from flood mitigation but are not measured by flood insurance premiums. Also, this analysis could be expanded to areas further downstream thus increasing benefits.

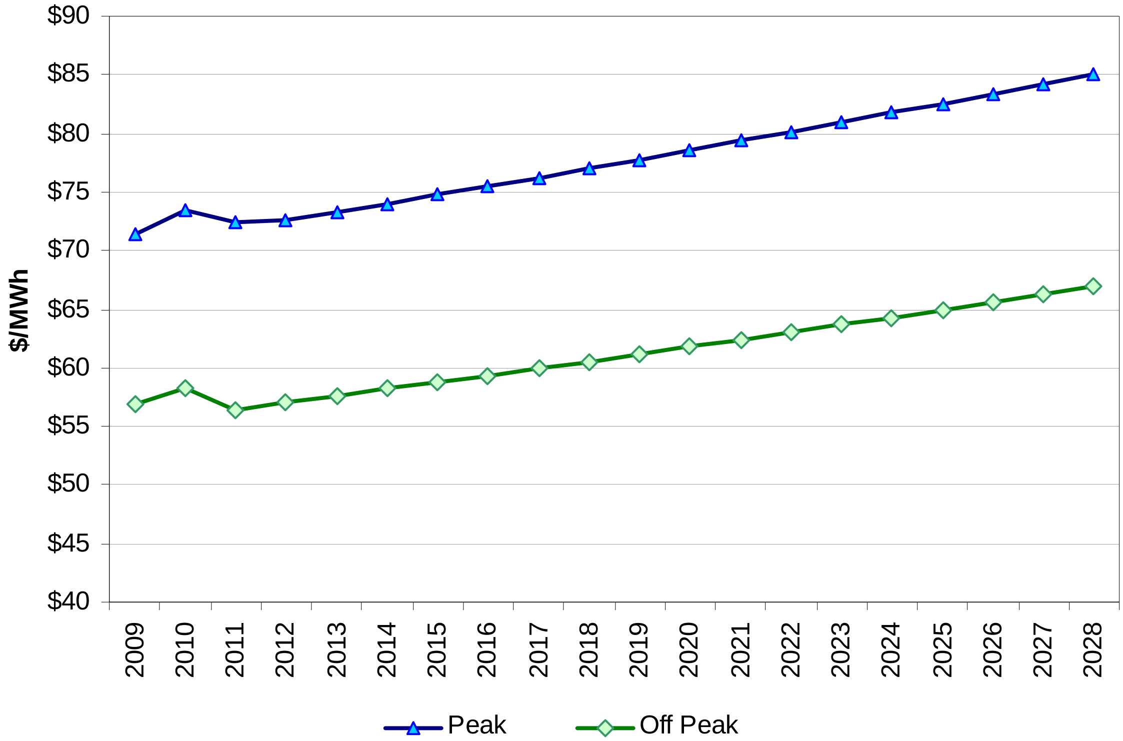
The benefit of increased property values is included in the analysis as a one-time benefit of $24 million in 2009.

Hydro Power Generation Benefits

If flood control structures with hydro power generation are built as part of the flood control strategy, a benefit will be the value of the electricity produced by the plant. These benefits include the value of electricity produced from two small hydro electric projects, the renewable energy credits (RECs) associated with the type of power and the avoided cost of carbon dioxide emissions due to the power source.

To estimate the energy benefits, a monthly forecast of electricity prices at the mid-Columbia (Mid-C) hub is analyzed by monthly output. Peak 30-year levelized cost for Mid-C electricity is $79.05 per MWh and off-peak electricity levelized costs are $62.28 per MWh. Figure 12 below illustrates the peak and off-peak Mid-C price forecasts in nominal dollars.

Figure 12
Mid-Columbia Price Forecast
Nominal Dollars



Chapter 194-37 WAC (Energy Independence Act) allows for incremental hydro power documentation toward a utility's renewable energy requirement. The hydro power facilities must be owned by a qualifying utility, an electric utility with 25,000 customers or greater, where new generation does not result in water diversions or impoundments. Since any installed hydro projects are ancillary to flood control, the energy produced from these projects may qualify as renewable and for Renewable Energy Credits (RECs) under Washington State's Energy Independence Act. It is estimated that the future REC value will be in the order of $10 to $50 per MWh. For this study, REC values are estimated at $25 per MWh in the base case.

In addition, operating and maintenance costs are included in the benefit-cost analysis. It is assumed that O&M costs are $3 per MWh. These O&M costs include costs associated with maintaining the structures, hydro facilities, and costs of keeping operators on duty. Hydro projects in the Pacific Northwest typically have O&M costs in the range of $1.9 to $3 per MWh; therefore, this estimate is consistent with other projects. O&M costs are also included for the scenario without the hydro electric generation. To be conservative, the same annual dollar amount for the scenario without hydro is used.

The project annual operation will primarily be for flood control, and increased summer flows for water quality and riparian habitat improvements. The hydro electric portion of the benefit is less than 10% of the project value. It is anticipated that project design, permitting, and environmental studies will establish operational procedures for reservoir flood storage, reservoir levels, instream flow release requirements, and summer flow enhancement.

Benefit to Cost Analysis

Benefits Summary

Annual values for the benefit analysis are calculated depending on when the benefit is realized. The property damages and clean-up benefits are calculated annually using the benefit dollar amount and the change in flood probability due to mitigation. For example, $5,000 of avoided damages, due to flood mitigation, and reduced flood probability of 3 percent produce an annual benefit of $150. Benefits that fall under this category include property damage (public, residential, commercial and agriculture), relocation and emergency costs, and avoided I-5 closures.

The second type of benefit calculation is for those benefits that occur annually and do not depend on whether or not a flood occurs. These values include energy benefits from new hydro resources and water quality benefits. The full values of these benefits are included on an annual basis as they occur.

Lastly, one-time benefits occur for a period of one year or at one instance. The I-5 infrastructure improvement and property value increases are examples of a one-time benefit. Since I-5 may not have to be raised if water retention measures were in place, the cost savings are realized only in the years during construction. For this study, it is assumed that all one-time benefits occur in 2019. Table 15 shows the present value (in 2008 dollars) and levelized benefits for all benefits outside of hydro project benefits.

Table 15
Benefit Analysis
Excluding Hydro Benefits, 2008 Dollars

	Agriculture Crop/Land Damage	Residential, Commercial, Public Structure Damage	Relocation & Emergency Costs	Increased Residential Property Values	Increased Non-Residential Property Values	Infrastructure Benefits (not raise I-5)	Avoided I-5 Closure plus Railroad Damages	Water Quality Benefits	Total
Total Value	$12,570,000	$33,912,159	$10,908,522	$15,123,108	$8,534,867	$300,000,000	$48,233,254	4,597,852	**$433,879,763**
30-Year NPV	$9,410,567	$25,388,436	$8,166,697	$14,979,078	$8,453,583	$247,276,622	$14,975,379	114,739,835	**$443,390,195**
30-Year Levelized Benefit	$612,171	$1,651,554	$531,255	$974,411	$549,918	$16,085,699	$974,170	7,463,991	**28,843,168**

In addition to the benefits above, other regional benefits occur due to flood reduction projects. Avoided expenses and added jobs due to these projects will infuse more wealth into the region. In order to determine the actual impact of indirect benefits, the 1997 Washington State Input-

Output model is used to calculate further benefits of flood control in Lewis County. The economic Input-Output model is used to predict the effect of changes in one industry on others. Input-output analysis considers inter-industry relations in an economy, depicting how the output of one industry goes to another industry where it serves as an input, and thereby makes one industry dependent on another, both as customer of output and as supplier of inputs.

Based on the Washington State Input-Output model, the indirect benefits to the regional economy adding an additional $28 million in annual benefits distributed across several industries and 707 new jobs. As part of the $28 million in output, approximately $19 million in labor income is created. Together the direct benefits and the indirect benefits sum to $56 million dollars on an annual basis (in 2008 dollars). Over 30 years, the indirect benefits for the region reach $380 million, while the total direct and the indirect benefits sum to $868 million.

Table 16 provides the additional benefits from installing turbines at the two flood control sites. This benefit includes the forecasted revenues of energy sales only. Table 16 shows that adding the hydro generation capabilities would result in revenues of approximately $3 million per year in current dollars.

Table 16
Hydro Electric Project Benefits
2008 Dollars

	Upper Chehalis Hydro Electric Benefits	South Fork Chehalis Hydro Electric Benefits	Total Hydro Electric Benefits	Total of All Benefits
30-Year NPV	$37,865,851	$7,620,128	$45,485,979	**$488,876,174**
30-Year Levelized Benefit	$2,463,228	$495,700	$2,958,928	**$31,802,097**

Benefit Cost Analysis

Table 17 shows the benefit to cost ratios for water retention facilities only and without hydro projects using only direct benefits as calculated in the benefit analysis. Table 18 shows water retention benefit to cost analysis for the retention facility including both direct and indirect benefits from the Washington State input-output model. In both cases, water retention facilities appear to be cost-effective.

Table 17
Benefit-Cost Analysis – Direct Benefits Only
2008 Dollars

	Total Direct Benefits	Upper Chehalis Retention Facility Costs	South Fork Chehalis Retention Facility Costs	Total Costs	Benefit Cost Ratio	Benefit - Cost
30-year NPV	$488,876,174	$139,315,305	$103,045,802	**$242,361,108**	**2.02**	$246,515,066
30-year Levelized Benefit	$31,802,097	$11,179,021	$8,268,662	**$19,447,682**	**1.64**	$12,354,414

Table 18
Benefit-Cost Analysis – All Quantitative Benefits
2008 Dollars

	Total Direct & Indirect Benefits	Upper Chehalis Retention Facility	South Fork Chehalis Retention Facility	Total Costs	Benefit Cost Ratio	Benefit - Cost
30-year NPV	$868,076,510	$139,315,305	$103,045,802	**$242,361,108**	**3.58**	$625,715,402
30-year Levelized Benefit	$56,469,623	$11,179,021	$8,268,662	**$19,447,682**	**2.90**	$37,021,940

Table 19 shows benefit cost analysis for hydro electric projects installed in the proposed Upper Chehalis and South Fork water retention facilities. It is assumed that the capital costs for these projects are financed over the 30 year planning period. Operation and maintenance costs for the hydro projects are $3 per MWh in this analysis. As can be seen from table 19, the ratio of the present value of benefits to the present value of costs for the hydro projects are approximately 1.7 to 1.8. These benefit-cost ratios suggest that the projects are cost effective over the 30 year planning period.

Table 19
Hydro Electric Project Benefit-Cost Analysis
2008 Dollars

	Upper Chehalis Hydro Benefits	South Fork Chehalis Hydro Benefits	Upper Chehalis Hydro Costs	South Fork Chehalis Hydro Costs	Upper Chehalis Benefit Cost Ratio	South Fork Chehalis Benefit-Cost Ratio
30-Year Present Value	$37,865,851	$7,620,128	$22,013,876	$4,304,410	**1.72**	**1.77**

The benefits in Table 19 include a REC value of $25 per MWh. If REC values are $0, then benefit cost ratios for the Upper Chehalis and South Fork Chehalis fall to 1.1 and 1.2, respectively.

Summary

Water retention facilities within the Chehalis River basin have potential to realize significant benefits when both direct and indirect benefits are considered. Benefits such as water quality for domestic, agricultural, and recreational use, and improved fish habitat are significant, but are harder to quantify. On the other hand, considerable benefits such as avoidance of property damage, relocation costs, property values, infrastructure improvements, and energy benefits from hydro electric projects can more easily be quantified.

Based on the estimates provided in this study, the annual benefits for avoided flood events are approximately $56 million dollars. These benefits are based on 100-year flood event damages, the assumed interest rate (5 percent), estimated change in the probability of flooding (3 percent), and results from the Washington State Input-Output model. The value of these benefits will vary as these and other assumptions are modified. Construction is cost effective when considering all benefits; however, hydro electric projects are cost effective in cases where REC values are high and the new hydro electric generation is considered renewable per Washington State law.

Based on this study, the benefit to cost ratios for Chehalis River water retention facilities without hydro projects using only direct benefits as calculated in the benefit analysis is 2.0. Adding the indirect benefits from the Washington State input-output model, increases the benefit cost ratio to 3.6. In both cases, water retention facilities appear to be cost-effective.

The benefit to cost analysis for hydro electric projects installed in the proposed Upper Chehalis and South Fork retention facilities are above 1, demonstrating that the benefits are greater than the costs. This benefit to cost ratios include the potential revenues from renewable energy credits but not carbon offsets. If carbon offset benefits were included, the hydro projects are projected to be even more cost-effective.

Appendix A

Table A-1 General Assumptions	
Borrowing Term	30
Borrowing Rate	5%
RECs $2008/MWh	$25.00
2012 Carbon Cost ($/ton)	0
Inflation	4%
Change in Flood Probability	3%
Number of Residential Homes Damaged	987
Number of Commercial Buildings Damaged	159
Upper Chehalis Turbine Costs	$24,000,000
South Fork Turbine Costs	$3,600,000
Contingencies & Indirects	40%

Table A-2 Assumptions for Water Quality Improvement Estimates	
Additional Salmon	1,028
Households in Chehalis Basin, Lewis County	11,380
Mean Annual Run-Off	**Acre-foot**
Upper Chehalis	154,000
SF Chehalis	50,600
Change in Summer Flow	
Upper Chehalis	16,787
SF Chehalis	3,193
Recreation	**Additional cfs**
Upper Chehalis	100
SF Chehalis	19

Figure A-1
Mellen Street Bridge

Notes Regarding Assumptions

The analysis in this report combines assumptions from varying levels of certainty. To perform a more precise analysis, further research may be required. Specifically, among the less certain assumptions are those regarding values for fish population increases due to improved habitat. Extensive fish population analysis is required to accurately model the effects of increased water quality on the Chehalis. This section separates the assumptions by level of certainty.

Assumptions with Most Confidence

1. Project Costs – EES Consulting Engineers have provided cost estimates that accurately reflect current market conditions for the designed projects.

2. Value of energy produced – Historical stream flow data and energy price forecasts determine the value of electricity produced from the proposed hydro electric projects.

3. Agriculture damages – Recent flood events predict future damages to agriculture crops, equipment, buildings, stores, supplies, and livestock. However, a more comprehensive survey of affected farmers may provide additional data. It was noted in The News

Tribune that 20[32] percent of farm land was not replanted for the next season; however, we do not know what the value is or the total land affected.

Additional Research

1. Fish Populations and Values – As mentioned above, significant analysis of specific Chehalis River fish populations and fish values would be needed to more accurately define benefits to improved habitat from water quality improvements. This analysis uses fish populations in the Columbia River to proxy the value of additional fish in the Pacific Northwest. Also, it is assumed that a 5 percent population increase would result from the proposed flood control projects. However, the magnitude of effect on fish populations from water quality improvement and decreased flooding is not known. Based on this preliminary review, it appears that it is highly likely that fish mitigation will be needed at the retention facilities. In addition, while the increased summer flow may improve the habitat, and therefore the fish production, determining the exact impact is complicated and would require additional work.

2. Building Damages – Disaster aid damages from the 2007 flood is used to estimate total building and property loss due to flooding. In addition to these costs, Larry Peterson, a local insurance agent with V.R. Lee and Son, provided estimates for damages not covered by insurance, FEMA, or other aid.

3. Avoided I-5 closure benefits – Recent flood event data provides reasonable estimates for the value associated with avoiding road closures. Further study is required to determine if closure is still likely given flood water reduction potential of the projects.

4. Probability of Flooding – The expected annual damages are estimated based on the changed probability of flooding. The probabilities are estimated based on the work by the Corps and estimates of flood reduction levels at Mellen Street. To determine the precise reduction in flood probability, further research and modeling may be required.

5. Property Values – Increased property values are calculated using avoided insurance payments. These property values do not include the effect of increased commercial activity due to reduced flood probability. Specifically, reducing flood probability in the Chehalis-Centralia area may have a significant impact on economic activity given the unique placement of these cities next to I-5 and between two major metropolitan areas, Seattle and Portland. Since the industrial area is outside of the flood area, the additional economic effect of reduced flooding may not be as significant as if the industrial zone were located in a threatened area.

6. Water Quality Benefits – Improved water quality is assumed due to increased summer flows; however, the value and amount of water quality improvement is estimated based on regional studies that are not up to date. Specific analysis for the Chehalis River in

[32] Hill, Christian. "Flood Recovery in Lewis County – one year later." The News Tribune. December 3, 2008.

current and projected economic and environmental conditions would be required to accurately model the effect of increased summer flows in the Chehalis River.