

# WSDOT Report

## Chehalis River Basin I-5 Flood Protection near Centralia and Chehalis

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*Final - November 26, 2014*

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# Executive Summary

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This report summarizes work by the Washington State Department of Transportation (WSDOT) to evaluate possible alternatives to protect Interstate 5 (I-5) from flood waters between the 13th Street (Exit 76) and Mellen Street (Exit 81) interchanges near the cities of Centralia and Chehalis.

This work is part of a larger effort by the Washington State Legislature (ESSB 5035, Section 1083) to conduct a number of feasibility studies in the Chehalis River Basin. Other studies include water retention; hydrology and hydraulics; environmental characterization and assessment; flood risk management and survey of floodplain structures; comparison of potential flood hazard-reduction actions; aquatic-species restoration; and implementation of smaller flood-risk-reduction and environmental-enhancement projects. The Governor's Chehalis Basin Work Group (Work Group) will use the feasibility studies to make recommendations for a long-term strategy to reduce flood damage and restore aquatic species in the Chehalis River Basin, and next steps and budget priorities for the 2015–2017 biennium to the Governor and Legislature in November 2014.

If one of the alternatives for I-5 protection described here is recommended by the Work Group, it is to inform decisions on programmatic approaches and for budgetary purposes only. This effort is not intended to fulfill or preclude the National Environmental Policy Act (NEPA) process where all reasonable alternatives, including a "No Build" alternative, would be considered and a preferred alternative would be selected.

Through hydrologic and hydraulic analyses, it was determined that construction of a water retention structure (dam) on the upper Chehalis River would have the most impact on flood levels in the Basin of any single action being studied. Model results show that a dam would significantly reduce flood levels and shorten the duration of I-5 closures during major flood events. In a simulated 100-year flood event with current baseline conditions, model results show that I-5 would be closed for approximately five days; with construction of a dam, in a simulated 100-year flood event, model results show that I-5 would only be closed for approximately one day. Construction of features for full-flood-protection of I-5 would not be cost-effective under the scenario in which a dam is constructed. Based on these results, if the State moves forward with the process to construct a dam as it is anticipated to, WSDOT will not pursue a separate full-flood-protection project for I-5. In the future, this segment of I-5 will require additional capacity. If a dam continues to move forward, any project to widen this stretch of highway will include minor enhancements to promote flood resistance on I-5, where possible (e.g.—solid barrier in place of guardrail), but would not incorporate the significant investment required to ensure robust and reliable flood proofing.

During WSDOT's analysis of potential flood proofing alternatives for I-5, a scenario was also studied which did not include construction of a dam or any other Basin improvements. This scenario reflected a large flooding effect on I-5, and as such, warranted a commensurate level of analysis and documentation. Alternative 1: I-5 Levees and Walls, studied for budget and schedule purposes, is a combination of earthen levees and structural walls along I-5, including improvements to the existing Chehalis-Centralia Airport levee, a new mile-long Chehalis Avenue Levee (CAL), and bridge replacements over Dillenbaugh and Salzer Creek. Placement of levees

and walls would be designed to maximize the cost-effective protection of I-5 along with optimizing potential collateral benefits such as protection of urban areas, and to minimize adverse impacts.

The analysis to determine the scope and layout of levees and walls described in Alternative 1 assumes that the I-5 project is constructed without any of the other possible Basin improvements that are under consideration. This is a conservative view for purposes of this analysis. Alternative 1 would only be warranted and cost-effective if a dam was not planned to be built. WSDOT will not pursue full-flood-protection of I-5 with Alternative 1 if the process to construct a dam continues to move forward.

# I. Introduction

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As part of the 2013 capital budget (ESSB 5035, Section 1083), the Washington State Legislature required the Office of Financial Management (OFM) to conduct a number of feasibility studies in the Chehalis River Basin in the areas of I-5 protection; water retention; hydrology and hydraulics; environmental characterization and assessment; flood risk management and survey of floodplain structures; comparison of potential flood hazard-reduction actions; aquatic-species restoration; and implementation of smaller flood-risk-reduction and environmental-enhancement projects. The results of these studies will be used by the Governor's Chehalis Basin Work Group (Work Group) to make recommendations to the Governor and Legislature in November 2014 for a long-term strategy to reduce flood damage and restore aquatic species in the Chehalis River Basin, and next steps and budget priorities for the 2015–2017 biennium.

As the Washington State Department of Transportation (WSDOT) is responsible for construction, maintenance, and operation of state highways, OFM asked WSDOT to evaluate possible alternatives that potentially protect Interstate 5 (I-5) from flood waters between the 13th Street (Exit 76) and Mellen Street (Exit 81) interchanges near the cities of Centralia and Chehalis. This report summarizes WSDOT's work.

Readers interested in learning more about the results of the other analyses related to water retention, aquatic species restoration, or a comparison of potential flood hazard-reduction actions can refer directly to those technical memorandums.<sup>1</sup> The proposed alternatives to protect I-5 described here are for purposes of further work to consider budgets and schedules; if a decision is made to move forward with a flood-protection project in the area, project-specific environmental review and associated-alternatives analysis and decision-making will occur at that time.

While this report is focused on protection of I-5 from flooding, WSDOT's analysis has not been done in a vacuum. WSDOT has taken into consideration other work being completed as part of the legislative directive because it would influence or change implementation and design of any I-5 protection alternatives. This work includes:

- The potential construction of a dam on the upper Chehalis River.
- The potential construction of a series of small, local flood-damage-reduction projects aimed at protecting key infrastructure, reducing shoreline erosion, and improving flow conveyance and drainage at priority areas throughout the Chehalis Basin.
- An analysis that considered the potential impacts of climate change in the Chehalis Basin based on projections from the Climate Impact Group (CIG) at the University of Washington.

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<sup>1</sup> The report with recommendations to the Governor and technical memorandum appendices will be available on the Chehalis project page on the William D. Ruckelshaus Center website: <http://www.ruckelshauscenter.wsu.edu/ChehalisFlooding.html>

This report addresses each of these issues and describes how various decisions about these related issues would change the overall design, implementation, and costs of the I-5 protection alternatives.

## Navigating the Report

This report is divided into five sections:

- Section I provides a brief overview of the purpose of this report and the project area and history of flooding.
- Section II describes the current recommended alternative with a dam.
- Section III describes the current recommended alternative without a dam.
- Section IV describes other conceptual alternatives considered.
- Section V describes the need for protection of SR 6 and US 12, regardless of I-5 protection.
- Section VI describes conclusions and next steps.

## Background

As part of the 2011 capital budget (ESHB 2020, Section 1033), the Legislature required OFM to prepare a report on alternative flood-damage reduction projects and to recommend priority, flood-hazard mitigation projects in the Chehalis River Basin for continued feasibility and design work. The OFM report explored a range of alternatives to protect people and communities from flooding, including I-5 protection, water retention in the upper Chehalis, smaller scale infrastructure protection, floodplain management and other projects to improve ecological and natural floodplain function, as well as land-use-management approaches to reduce potential flood damages. The Chehalis Basin Flood Mitigation Alternatives Report was made available for public review in July 2012 and finalized in December 2012.

As part of the 2011–2012 work, WSDOT was tasked with evaluating alternatives that could be used to protect I-5 from flooding. Six I-5 protection project alternatives were evaluated:

- Alternative 1: I-5 Levees and Walls, Raise Airport Levee, New SW Chehalis Levee;
- Alternative 2: I-5 Raise and Widen Only;
- Alternative 3: I-5 Express Lanes;
- Alternative 4: I-5 Temporary Bypass;
- Alternative 5: I-5 Viaduct; and,
- Alternative 6: I-5 Relocation.

WSDOT developed a report on its analysis entitled, “I-5 Protection from 13th Street to Mellen Street near Centralia and Chehalis,” and made it available for public review in August 2012, finalizing it in December 2012. For each alternative, WSDOT provided a description of project details, potential costs, and implementation issues; and potential impacts to nearby people and communities, major infrastructure, and the environment. The report looked solely at options for protecting I-5 and did not recommend a specific alternative.

In November 2012 then-Governor Christine Gregoire convened a small group of leaders in the Chehalis River Basin to recommend next steps for reducing flood damage and enhancing aquatic species in the basin. The Governor’s Chehalis Basin Work Group developed a set of recommendations that garnered broad support across the basin. Governor Gregoire included \$28M in her proposed 2013–2015 capital budget to the Legislature to implement the Work Group’s recommendations. Governor Inslee subsequently endorsed this investment in the Chehalis Basin, as did the Legislature.

Relative to I-5 protection, the Governor’s Work Group recommended that funding be provided to determine the best combination of walls, levees, pumps, bypasses and other structures needed to protect I-5 traffic, the airport, and key urban areas of Centralia and Chehalis if a dam were constructed; and to evaluate changes to the project needed to secure comparable protection without a dam. The Work Group also recommended that funding be provided to improve damage estimates to residential and commercial structures, and to improve the estimate of economic impacts from I-5 closures.

## Project Area and History of Flooding

The project area is in the Lewis County cities of Chehalis and Centralia along a 5-mile stretch of I-5. It begins near the 13th Street interchange (Exit 76) and extends north to the Mellen Street interchange (Exit 81). WSDOT evaluated potential inundation during a 100-year flood event from the Rush Road interchange (Exit 72) north to the Mellen Street interchange. No potential was found for inundation from the Rush Road interchange to just south of the 13th Street interchange.

This stretch of I-5 is the midpoint between Seattle and Portland, Oregon, connecting two of the West Coast's major population and industrial centers. I-5 is the West Coast's major north-south transportation corridor. Floods closed I-5 at Chehalis and Centralia for four days in both February 1996 and December 2007, and flooding in January 2009 closed the same stretch for two days. WSDOT estimates the total cost of the closure and delays in 2007 alone in the tens of millions of dollars<sup>2</sup>. The major costs come from limited freight movement through the area, including costs incurred by private companies as a result of that limited movement. Since the two flood events in 2007 and 2009, WSDOT has developed an emergency detour route, for priority shipments only, that takes drivers around I-5 using SR 7 and US 12. WSDOT also developed two other detour routes for trucks: one takes drivers around I-5 using I-84, SR 97, I-82, and I-90, which is the anticipated preferred truck detour; the other route uses I-84, I-82, and I-90, which is a secondary detour for trucks. See Appendix A for a more detailed discussion of the detour routes.



Photo courtesy of *The Chronicle*, Centralia, Washington

<sup>2</sup> Washington State Department of Transportation (WSDOT). 2008. Storm-Related Closures of I-5 and I-90: Freight Transportation Final Report. September, 2008. Available at: <http://www.wsdot.wa.gov/research/reports/fullreports/708.1.pdf>.

# Goals of I-5 Protection

The primary goal of the project is the full protection of I-5 from 13th Street to Mellen Street, access to major infrastructure, and optimization of any potential ensuing benefits to people, communities, and the environment. Completion of any project providing full protection of I-5 would require a significant investment, and would be considered in the overall strategy to reduce flood damage in the Basin.

## Freeboard

WSDOT must ensure that any significant investment provides enough freeboard for full and robust protection for a significant period of time. The measure of freeboard is defined as the distance between the potential flood-water surface and the top of the flood-protection element. WSDOT's analysis for full-flood-protection incorporates a freeboard similar to that used by the US Army Corps of Engineers: 3 feet above the projected 100-year flood level. This level of freeboard is intended to provide robust, reliable protection for I-5.<sup>3</sup>

### Climate Change

WSDOT's decision to use 3 feet of freeboard above the projected 100-year flood level does not directly factor the potential need for further protection due to climate change. As a separate study within the broader Chehalis Basin work effort, a consultant team defined and modeled two different climate change scenarios to provide decision makers with information on how projected changes associated with climate may affect peak flows during storm events. The analysis considered the impacts of climate change in the Chehalis Basin based on projections from the Climate Impact Group (CIG) at the University of Washington, and included two scenarios, an 18% and 90% increase in annual peak flows. If a decision is made to move forward with any major flood-protection project in the area - WSDOT or otherwise - that incorporates climate change scenarios, a much larger state-wide conversation must take place, as well as further study and cost analysis.

### Future Widening of I-5

In addition to being susceptible to flooding, the stretch of I-5 from 13th Street to Mellen Street remains four lanes wide (2 lanes in each direction). According to WSDOT's Highway System Plan, this section of I-5 will require additional capacity at some point in the future; however, this work is currently unfunded. To ensure funds are invested properly when a widening project along this stretch occurs, and due to the uncertain timing of funding, WSDOT identified modifications to the I-5 protection alternatives analyzed that would allow for construction before, during, or after the widening of I-5. WSDOT worked to optimize the design of each alternative to minimize public investment, and from that analysis, it became clear that the most efficient use of public funds would be to build the flood features with the I-5 widening.

<sup>3</sup> For more information on how WSDOT determined the level of freeboard, see Appendix A of the 2012 WSDOT I-5 Report, located at: [http://www.ruckelshauscenter.wsu.edu/documents/WSDOTI-5FloodReportFinal\\_12-19-12.pdf](http://www.ruckelshauscenter.wsu.edu/documents/WSDOTI-5FloodReportFinal_12-19-12.pdf)

# University of Washington – Transportation Research Center (TRAC) Study

The University of Washington Transportation Research Center (TRAC) recently completed a report that estimated the travel costs associated with the closure of I-5, US 12, and SR 6 in the greater Centralia-Chehalis region due to modeled 100-year flood conditions from the Chehalis River. A full copy of the report is provided in Appendix A.

The estimates describe only costs directly related to travel that would otherwise have occurred were it not for flooding closures. These include the added costs of time and vehicle mileage associated with available detour routes, and costs for abandoned trips. The estimated value of travel disruptions directly associated with I-5 for a 100-year flood event without any flood-protection work is approximately \$11.9M to \$20.6M<sup>4</sup> (5 days) per event. The range of costs is based on the share of through traffic that takes a detour rather than delays a trip. The higher figure of \$20.6M assumes that all through traffic would take a detour in the event of a closure. The estimated value of travel disruptions directly associated with US 12 and SR 6 without any flood-protection work is less than \$350,000<sup>4</sup> (over 6 days) per event for US 12 and less than \$150,000<sup>4</sup> (about 2 days) per event for SR 6. This study helps to inform the cost-effectiveness of any I-5 protection scenario.

## How the Report Will Be Used

The results of this report on I-5 protection alternatives, as well as concurrent feasibility analyses related to a water-retention facility, aquatic-species restoration, and small-flood-control projects, will be included in a benefit-cost analysis (BCA) used by the Governor’s Work Group when it makes its next set of recommendations to the Governor and Legislature. Alternatives under evaluation include baseline conditions, I-5 alternatives, a flood-retention dam, a multi-purpose dam, small flood projects (including raising residential and commercial structures within the 100-year floodplain that would not be fully protected through the construction of a water retention structure), aquatic-species restoration plan, and combinations of these alternatives.

If an alternative is identified by the Governor’s Work Group for I-5 protection, it is for budgetary purposes only. This effort is not intended to preclude the National Environmental Policy Act (NEPA) process where all reasonable alternatives, including a “No Build” alternative, would be carried forward and where a preferred alternative would be selected.

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<sup>4</sup> The estimates do not include economic losses associated with delays in the delivery of goods or services due to flood closures, losses in economic activity attributable to travelers being unable to reach their intended destinations, or economic losses associated with the loss of goods because they could not be delivered.

## II. Current Recommended Alternative with Dam

As part of the analysis of I-5 flood protection options, a scenario was studied that assumes construction of a dam on the Upper Chehalis River. Hydrologic and hydraulic modeling was undertaken in the Chehalis River Basin which predicted flood levels for a 100-year event using the assumption that a dam would be constructed. The results of this analysis indicate that a dam would reduce flood elevations throughout much of the upper Chehalis Basin, and in the Centralia and Chehalis area. As currently modeled, a dam would not fully protect I-5 from flood events like those in 1996, 2007 and 2009, or in a simulated, 100-year flood event, but the duration of I-5 closures in those storm events would reduce significantly. In a simulated 100-year flood event with current baseline conditions, model results show that I-5 would be closed for approximately five days; with construction of a dam, in a simulated 100-year flood event, model results indicate that I-5 would only be closed for approximately one day.



Photo courtesy of *The Chronicle*, Centralia, Washington

To provide full protection of I-5 in this scenario, additional flood protection features along I-5 would be needed in addition to a dam. These modeled features consisted of levees and walls adjacent to I-5, similar to those described in Section III of the report. Although the flood protection features could be slightly reduced compared to a scenario without a dam, the investment required to build this additional infrastructure would be significant. This additional investment is not cost-effective to prevent a one-day closure of I-5.

Because of the dam's ability to reduce flood levels and shorten the duration of I-5 closures during major flood events, if the State moves forward with the process to construct a dam as it is anticipated to do, WSDOT will not pursue funding for a project providing full protection of I-5 with levees and walls. As part of a future widening project, WSDOT would plan to incorporate flood resistant features, where possible, as minor enhancements. These would constitute small investments such as an upgrade from guardrail to solid barrier, to increase flood resistance. Although these would not ensure the robust protection of I-5 afforded by a larger investment in levees and walls, these improvements would have the potential to reduce the duration and frequency of closures of I-5.

# III. Current Recommended Alternative without Dam

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This section represents the alternative that would be recommended if a dam was not planned to be constructed, Alternative 1: I-5 Levees and Walls, and is for budget and schedule purposes only. This scenario represents a large flooding effect on I-5, and as such, warrants a significant level of analysis and documentation. It assumes no other flood mitigation improvements are built in the Basin. If other projects are constructed, they would potentially influence the alternative being described. This section includes project details; project considerations; potential impacts to nearby people and communities, major infrastructure, and the environment; and potential costs. Although this alternative is not moving forward since it is anticipated that construction of a dam will be pursued, it is described herein for future reference in the event of a change.



## ALTERNATIVE 1: I-5 Levees and Walls

Alternative 1: I-5 Levees and Walls, is a combination of earthen levees and structural walls along I-5, including improvements to the existing Chehalis-Centralia Airport levee, a new mile-long Chehalis Avenue Levee (CAL), and bridge replacements over Dillenbaugh and Salzer Creeks. Stormwater-treatment areas would be constructed to address stormwater runoff from I-5, because rain that falls on I-5 during storm events would need to be collected, conveyed, stored, or discharged to prevent rain water from covering the lanes of I-5. Placement of levees and walls would be designed to maximize the cost-effective protection of I-5 along with optimizing potential collateral benefits such as protection of urban areas, and to minimize adverse impacts. A detailed map showing the anticipated layout of levees and walls is provided in Figure 1.

The approximate locations of new walls are shown as yellow lines paralleling I-5. New and modified levees are shown as red lines throughout the corridor. The levees and walls begin just south of the 13<sup>th</sup> Street Interchange (Exit 76) and continue as needed to the north, where they tie into the Mellen Street Interchange (Exit 81). Typical cross sections of floodwalls and levees are shown in Figure 2 and Figure 3.

The analysis to determine scope and layout of levees and walls described here assumes that the I-5 project is constructed without any of the other possible Basin improvements that are under consideration. That is, it analyzes protection of I-5 as a “standalone” project, which is a conservative view for purposes of analysis. The exact scope and placement of levees and walls to protect I-5 would depend on other decisions about the interrelated flood-damage reduction projects which move forward.

Figure 1: Alternative 1: I-5 Levees and Walls

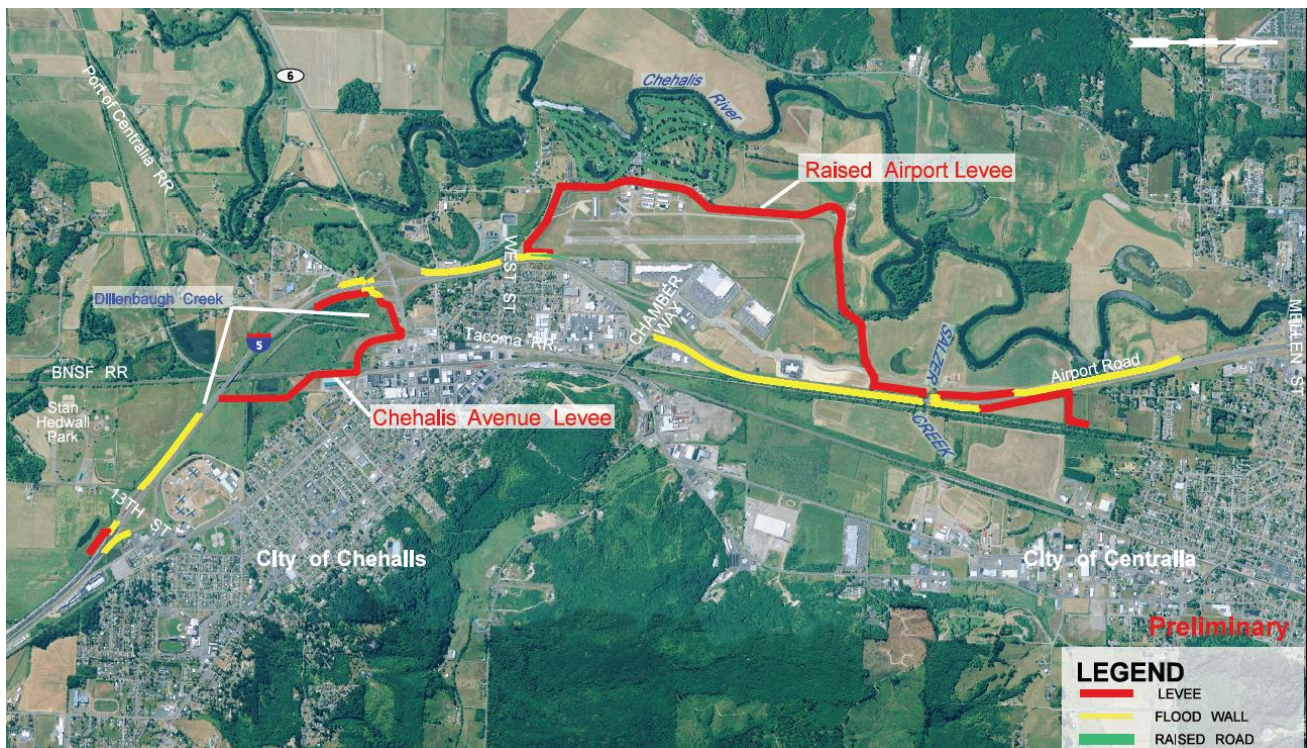


Figure 2: Typical Cross-Section of Floodwall

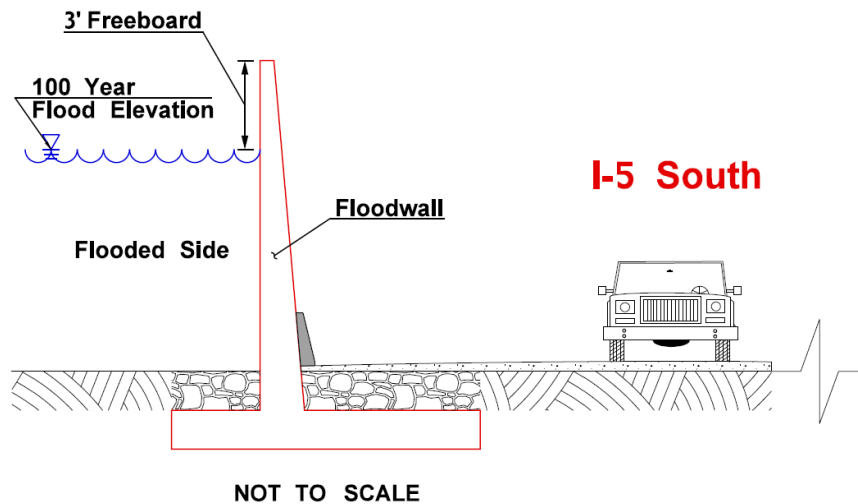
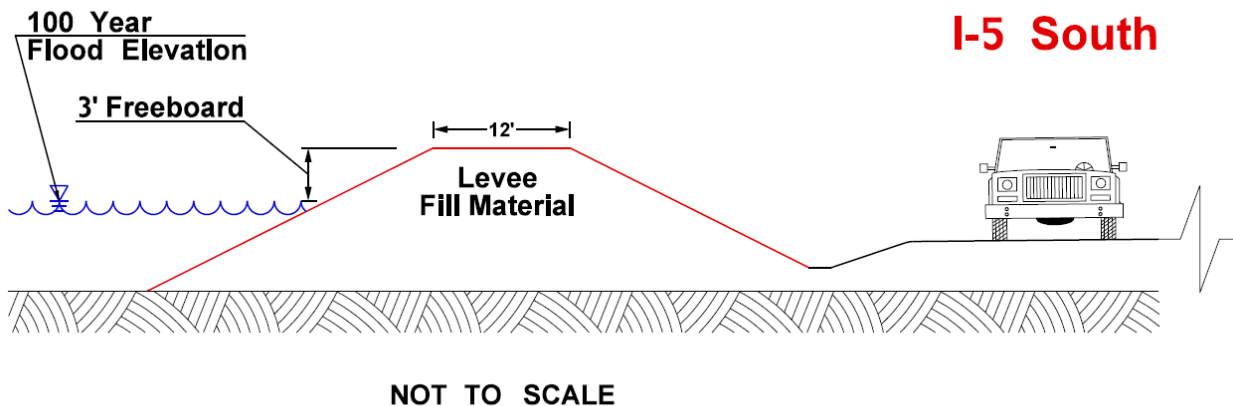


Figure 3: Typical Cross-Section of Levee



## HOW DOES ALTERNATIVE 1 INCREASE OR DECREASE FLOOD LEVELS IN NEARBY AREAS?

Alternative 1 would both increase and decrease water surface elevations throughout the basin and is widely variable due to multi-factorial influences. In a simulated 100-year flood event, model simulations show that Alternative 1 would either not change or would decrease flood water surface elevations between 0 to 0.5 feet east of I-5, particularly the developed area in Centralia and along the Miracle Mile (a stretch of Kresky Avenue in Centralia containing many businesses susceptible to damage from flooding in the basin). The drop in floodwater surface elevations would be more than 11 feet in some places protected by the raised Airport levee. In the area west of I-5 and west of the Airport levee, which is closer to the river and more rural, floodwater surface elevations are modeled to increase up to 0.9 feet. Increases in floodwater surface elevations shown in the model are largely because levees and walls would prevent floodwater from crossing over I-5 and over the Airport levee

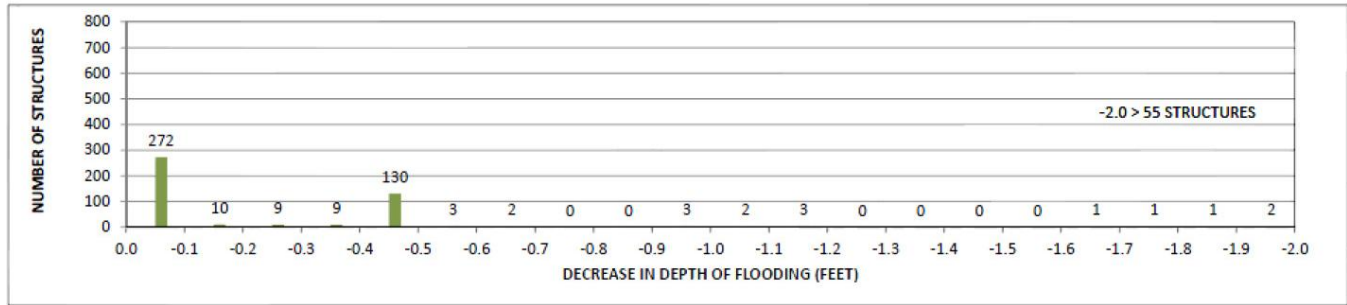
from west to east, resulting in more water staying on the west side of I-5 and the Airport levee closest to the river.

Appendix B provides a detailed map showing representative changes in the predicted peak-water surface elevations throughout the project area in a simulated 100-year flood event. The model simulations for determining the water-surface elevations were conducted in May 2014.<sup>5</sup>

Also, to improve estimates of potential future flood damage, work has been done to refine inventories of structures in the Chehalis floodplain. Previous analyses, including the 2012 WSDOT I-5 report, relied on preliminary data to identify structures. The updated analysis uses actual structure locations and predicted depth of water in buildings. This allows for estimates, based on the actual development in the Basin, about potential impacts and benefits of alternatives on particular structures in the floodplain. The updated analysis is used in this report.

Figures 4 and 5 summarize how Alternative 1 would affect the number of structures inundated during a major flood event. It should be noted that the majority of the structures that see a decrease or increase in depth of flooding are already significantly wet in a 100-year flood event. In regards to structures that would see a *decrease* in the depth of flooding, in a 100-year flood event: 272 structures would see a decrease in the depth of flooding between 0 and 0.1 feet; 10 structures would see a decrease in the depth of flooding between 0.1 and 0.2 feet; 9 structures would see a decrease in the depth of flooding between 0.2 and 0.3 feet; 9 structures would see a decrease in the depth of flooding between 0.3 and 0.4 feet; 130 structures would see a decrease in the depth of flooding between 0.4 and 0.5 feet, and; 55 structures would see a decrease in the depth of flooding over two feet.

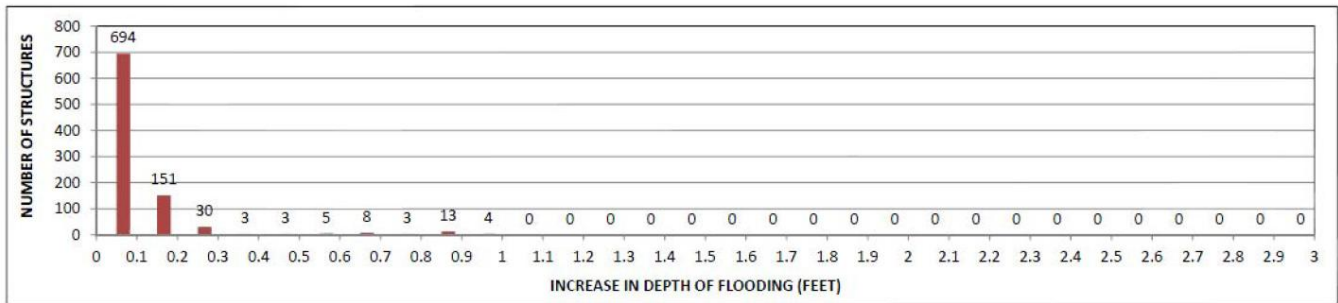
Figure 4: Summary of Structures at Risk of Flooding in Chehalis River Floodplain – 100 Year Decrease



In regards to structures that would see an *increase* in the depth of flooding, in a 100-year flood event: 694 structures would see an increase in the depth of flooding between 0 and 0.1 feet; 151 structures would see an increase in the depth of flooding between 0.1 and 0.2 feet, and; 30 structures would see an increase in the depth of flooding between 0.2 and 0.3 feet. The majority of these structures that see an increase in the depth of flooding would already be wet during a 100-year flood event.

<sup>5</sup> As part of the 2013-2014 work, hydrologic and hydraulic analyses have been completed to better define baseline conditions and support evaluation of alternative designs in the Basin to reduce flood damage. Recent work completed includes a review and analysis of hydrology data from the Chehalis River flow measurement gage at Doty, Washington, and updates to the Chehalis Basin hydraulic model to provide more accurate flood-inundation information. These updates have been used in the evaluations described in this report.

Figure 5: Summary of Structures at Risk of Flooding in Chehalis River Floodplain – 100 Year Increase



## COST ESTIMATE

Alternative 1 has an estimated cost of \$90-110M<sup>6</sup>. This cost estimate includes funding for mitigation that may be needed. The complexity of different project assumptions and design considerations described in this report accounts for the range in cost estimates.

While it does not actually widen I-5, the improvements built as part of Alternative 1 would be needed whenever I-5 is widened. It was determined that if Alternative 1 was constructed during a widening project it would provide significant efficiencies and cost savings over building I-5 protection separately. For example, some walls would be shorter in height and length; excavation would be minimized; and mobilization, erosion control, and traffic control would be optimized. If Alternative 1 were to move forward, WSDOT would seek to build flood protection features and the widening of I-5 concurrently.

## CHEHALIS BASIN SMALL FLOOD DAMAGE REDUCTION PROJECTS

As a separate component of the 2013-2014 work effort, a consultant team is working with the Flood Authority, local governments, conservation districts and other interested parties to identify small, local flood-damage-reduction projects aimed at protecting key infrastructure, reducing shoreline erosion, and improving flow conveyance and drainage at priority areas throughout the Chehalis Basin.<sup>7</sup> Three of these projects currently under consideration would have an impact on the design of Alternative 1:

- Dillenbaugh Creek Realignment (proposed by City of Chehalis)
- SR 6 Flow Bypass and Road Raise (proposed by Lewis County)
- Main Street (proposed by City of Chehalis)
- Salzer Creek Backwater Control (proposed by Lewis County)

Figure 6 provides a map showing the location of each of these small projects, which are described in more detail in Appendix C.

<sup>6</sup> The 2012 WSDOT I-5 report had a slightly lower cost estimate for Alternative 1 of \$80-100M. The difference in cost estimates is largely attributable to the refined analysis including hydraulic modeling and effects, soils and structure investigation, and further project development.

<sup>7</sup> The Chehalis Basin Small Projects Scenario technical memorandum will be available on the Chehalis project page on the William D. Ruckelshaus Center website: <http://www.ruckelshauscenter.wsu.edu/ChehalisFlooding.html>

Figure 6: Chehalis Basin Small Projects that Impact Design of Alternative 1



## Benefit-Cost Analysis and Input-Output Analysis

WSDOT recently asked the OFM consultant team to conduct a separate Benefit Cost Analysis (BCA) on Alternative 1 as well as an Input-output (IO) analysis that estimates the impacts on economic development resulting from Alternative 1. More detail on the methodology and results of this study is available in Appendix D. This work was separate from the larger BCA and IO analyses being conducted that compare to value of different suites of flood-damage reduction alternatives, such as I-5 protection, a dam on the Chehalis River, and aquatic species restoration, against each other.<sup>8</sup>

The BCA for Alternative 1 accounted only for direct damages and benefits. As shown in Table 1 Alternative 1 has a benefit-cost ratio of less than 1 and has a negative net-benefit using both the net-present value of expected annual impacts or as a one-time 100-year event.

<sup>8</sup> The technical memorandum that includes the economic analysis that compares the value of different flood-damage reduction alternatives against each other will be available on the Chehalis project page on the William D. Ruckelshaus Center website: <http://www.ruckelshauscenter.wsu.edu/ChehalisFlooding.html>

**Table 1: Alternative 1 Benefit-Cost Analysis (\$2014), Millions**

	EXPECTED ANNUAL IMPACT	ONE-TIME 100-YEAR EVENT
Structure Content Inventory	\$30.3	\$5.4
Emergency Aid	\$20.2	\$5.6
Clean-up Costs	\$9.8	\$1.2
I-5 Delay	\$16.2	\$11.5
Agriculture	(\$0.1)	\$0.1
<b>Total Impact</b>	<b>\$76.4</b>	<b>\$23.9</b>
Project Cost (Capital, O&M, IDC), 100-year NPV	\$106.8	\$106.8
<b>Net Benefit</b>	<b>(\$30.4)</b>	<b>(\$83.0)</b>
<b>Benefit/Cost Ratio</b>	<b>0.7</b>	<b>0.2</b>

The IO analysis accounted for both direct and indirect or induced effects. IO modeling is a quantitative analysis representing relationships (dependence) between industries in an economy. IO models are based on the implicit assumption that each basic sector has a multiplier, or ripple, effect on the wider economy because each sector purchases goods and services to support that sector. These effects account for additional impacts not directly affected by flooding. For example, when a retail store closes due to a flood event (temporarily or permanently), impacts to industries inside and outside the study region are realized when the closed store reduces its purchase of goods from its suppliers. As shown in Table 2, with the IO Analysis, Alternative 1 has a benefit-cost ratio of 1.2 and has a \$20.2M net-benefit when looking at the net-present value of expected annual impacts.

**Table 2: Alternative 1 Economic Analysis Results with IO Impacts, (\$2014), Millions**

	EXPECTED ANNUAL IMPACT	100-YEAR EVENT
Direct Impact	\$76.4	\$23.9
Value Added	\$50.6	\$18.90
<b>Total Impact</b>	<b>\$127.1</b>	<b>\$42.8</b>
Project Cost (Capital, O&M, IDC), 100-year NPV	\$106.8	\$106.8
<b>Net Benefit</b>	<b>\$20.2</b>	<b>(\$64.1)</b>
<b>Benefit/Cost Ratio</b>	<b>1.2</b>	<b>0.4</b>

Based on the above analysis, when considering both the direct and indirect societal benefits, the project has a benefit-cost ratio greater than one.

## IV. Other Conceptual Alternatives

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This section describes the other conceptual alternatives that WSDOT considered for I-5 protection:

- Alternative 2: I-5 Raise and Widen Only;
- Alternative 3: I-5 Express Lanes;
- Alternative 4: I-5 Temporary Bypass;
- Alternative 5: I-5 Viaduct; and,
- Alternative 6: I-5 Relocation.

WSDOT currently recognizes Alternatives 2-6 as on hold, given that initial work indicates these concepts may be impracticable. Each of these alternatives includes a description of project details, implementation issues, and potential impacts to nearby people and communities, major infrastructure, and the environment.

### ALTERNATIVE 2: I-5 Raise and Widen Only

Alternative 2 would raise I-5 using fill material in areas where the interstate falls below the desired flood protection elevation, and widen I-5 from four to six lanes. It also would raise bridges within the project to above the flood elevation.

Raising I-5 using fill material would require reconstruction of all pavement, stormwater systems, illumination systems, and guardrail in the project area. In addition, because raising I-5 would reduce clearance for existing ramps and overpasses, it would require reconstruction of all aspects of the 13<sup>th</sup> Street, SR 6, and Chamber Way interchanges and the West Street bridge. Reconstruction of these interchanges could cause large local impacts to city streets as well as traffic disruptions on I-5 and all the connecting roads.

Alternative 2 has an estimated total cost of \$450-550 million, which appears to be cost-prohibitive. Therefore, Alternative 2 is considered on hold.

### ALTERNATIVE 3: I-5 Express Lanes

Alternative 3 would construct new express lanes adjacent to I-5. Express lanes would be 4 miles in length and one lane in each direction, constructed a minimum of 3 feet above the 100-year flood elevations. This would provide traffic the opportunity to bypass I-5 if the main interstate was closed by a major flood. Outside of any flood events, express lanes also would be available to traffic 24 hours a day, seven days a week.

The express lanes would diverge from I-5 at 13<sup>th</sup> Street, and then follow the existing Tacoma Rail line through Chehalis, with bridges over West, Prindle, and Main streets in Chehalis. To minimize right-of-way acquisition and impacts to adjacent properties, the lanes would be built on fill material with side slopes in rural areas and would

be built on fill material contained by walls in urban areas. For the most part, the Tacoma Rail line runs through the industrial area of Chehalis, but also lies adjacent to several homes and businesses in the Westside Chehalis neighborhood. The lanes would likely be visible from some homes on the edge of the Westside neighborhood. A noise study has not been conducted yet, but cost estimates for the project include funding for noise walls in the event they are needed.

The Lewis County Public Utility District (PUD) has expressed concerns that the express lanes would encroach on a project being built where the Tacoma Rail track borders PUD property at Main and Quincy avenues in Chehalis. Residents of the Westside neighborhood, and businesses such as the Wilco Agricultural Center, CENEX, Chehalis West Assisted Living, and National Frozen Foods have also expressed strong concerns about the potential long-term adverse impacts on property value and business revenue, increased air pollution, noise levels, and traffic volume adjacent to and through the project area.

There are other significant uncertainties with the express lanes. The City of Chehalis has expressed strong concerns about the express lanes alternative and its potential effects on the community. The express lanes would not provide local access between 13<sup>th</sup> Street and Mellen Street. Perhaps most importantly, it is not known whether the City of Tacoma would sell the right-of-way along the Tacoma Rail line, and if so, at what cost. The City of Chehalis and Lewis County recently approached Tacoma Rail, and are currently conducting a study of the area near the rail line to determine if purchasing it would be beneficial to the City and County for economic development purposes. Until that study is complete, Alternative 3 is considered on hold.

## ALTERNATIVE 4: I-5 Temporary Bypass

Alternative 4 would construct temporary bypass lanes adjacent to I-5. Similar to the express lane alternative, the bypass lanes would diverge from I-5 at 13<sup>th</sup> Street, and then follow the existing Tacoma Rail line through Chehalis, with a bridge over Main Street. Prindle and West streets would be at-grade intersections; however, flood gates would close these access points during flood events to keep flood waters out of the temporary bypass. The lanes would be built on fill material with side slopes in rural areas and would be built on fill material contained by walls in urban areas to minimize right-of-way acquisition and impacts to adjacent properties.

The bypass lanes would be four miles in length with one lane in each direction, constructed a minimum of 3 feet above the 100-year flood elevations. This would provide a local bypass opportunity if the main part of I-5 were to be closed by major floods. Because the bypass lanes would only be used during major flood events, they would not eliminate the need to widen I-5 in the future. In addition, the connections to and from I-5 could be built at the ground level (unlike express lanes which would require high speed flyover ramps).

As with the express lanes alternative (Alternative 3), the Lewis County Public Utility District (PUD) has expressed concerns that the bypass lanes would encroach on a project being built where the Tacoma Rail track borders PUD property at Main and Quincy avenues in Chehalis. Residents of the Westside neighborhood, and businesses such as the Wilco Agricultural Center, CENEX, Chehalis West Assisted Living, and National Frozen Foods have also expressed strong concerns about the potential long-term adverse impacts on property value and business revenue, increased air pollution, noise levels, and traffic volume adjacent to and through the project area.

There are other significant uncertainties with the bypass lanes. The City of Chehalis has expressed strong concerns about the bypass lanes alternative and its potential effects on the community. The bypass lanes would not provide local access between 13<sup>th</sup> Street and Mellen Street. Perhaps most importantly, it is not known whether the City of Tacoma would sell the right-of-way along the Tacoma Rail line, and, if so, at what cost. The City of Chehalis and Lewis County recently approached Tacoma Rail, and are currently conducting a study of the area near the rail line to determine if purchasing it would be beneficial to the City and County for economic development purposes. Until that study is complete, Alternative 4 is considered on hold.

## ALTERNATIVE 5: I-5 Viaduct

Alternative 5 would construct a viaduct by elevating I-5 on piers from south of SR 6 to Mellen Street. This project would widen I-5 to six lanes and require reconstruction of all interchanges in the project area. WSDOT determined that widening should be included in any viaduct project because it would be completely ineffective to build only four lanes when six are needed to serve capacity.

The viaduct alternative has an estimated cost of more than \$1.5 billion. It would reduce flood elevations west of I-5 along the Chehalis River, but would increase flood elevations east of I-5 in the urban area of Centralia. For these reasons, WSDOT does not consider this project a feasible alternative and did not evaluate the project in further detail.

## ALTERNATIVE 6: I-5 Relocation

Alternative 6 would relocate I-5 outside of the flood area. The project would build a six-lane I-5, and would require constructing new interchanges in the project area.

The relocation alternative has an estimated cost of more than \$2 billion. Relocating I-5 would diverge outside of the existing interstate and cut through Centralia and Chehalis, splitting neighborhoods and impacting the urban and natural environment in and around both cities. For these reasons, WSDOT does not consider this project a feasible alternative and did not evaluate the project in further detail.

## V. Flooding of SR 6 and US 12

The protection of I-5 from 13<sup>th</sup> Street to Mellen Street is the main focus of the alternative evaluated in this report. However, WSDOT also recognizes that flooding occurs on SR 6 and US 12. Table 3 shows the maximum simulated flood depths over the roadway during flood events at SR 6 and US 12. Chehalis Basin floods in 1996, 2007, and 2009 flooded US 12 east of the Black River Bridge and SR 6 near Scheuber Road, Adna, and Rainbow Falls State Park anywhere from 0.6 to 9.5 feet. In a simulated 100-year flood event, model simulations show that even with a dam on the upper Chehalis, SR 6 and US 12 would still flood anywhere from 0.1 to 5.1 feet. By itself, WSDOT Alternative 1 has minimal impacts, positive or negative, on flooding of SR 6 and US 12 during major flood events.

**Table 3: Maximum Simulated Flood Depths over Roadway during Flood Events at US 12 and SR 6**

		US 12	SR6		
		East of Black River Bridge	Near Scheuber Road	Near Adna	Near Rainbow Falls State Park
WITH NO FLOOD CONTROL	1996	1.7	2.6	7	2.1
	2007	1.8	3.5	9.5	4.7
	2009	1.7	1.8	4	0.6
	100-year	1.8	2.8	7.5	3.2
WITH DAM AND AIRPORT LEVEE	1996	1.1	2	4.8	0
	2007	0.5	2.7	7.8	1.6
	2009	0	0.6	0	0
	100-year	1.1	2.1	5.1	0.1

WSDOT has evaluated preliminary improvement concepts that involve raising the roadway in the flood-prone stretches of SR 6 and US 12. If a dam was constructed on the upper Chehalis River, pre-scoping cost estimates for improvements to SR 6 and US 12 are estimated at \$30-40 million; these cost estimates do not include costs for mitigation, and potential impacts to surrounding areas from raising the roadway has not been evaluated.

## VI. Conclusions and Next Steps

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The effort to evaluate options to protect I-5 from flooding is part of a larger state-wide effort to reduce flood damage and restore aquatic species in the Chehalis Basin. While it is desirable that I-5 protection be part of a Basin-wide solution to flooding in the Chehalis, I-5 protection is not the only flood-damage reduction project under consideration and its advancement is tied to other efforts in the Basin to provide broader protections for people and communities.

In support of the larger effort to identify Basin-wide approaches to flood damage reduction in the Chehalis River Basin, this report looked only at options to protect I-5. However, there are other approaches that could be used to protect I-5, most notably the construction of a dam on the upper Chehalis River. Currently, the Work Group is crafting its recommendations to the Governor for a Basin-wide flood hazard mitigation approach. The State is planning to move forward with the process to construct a dam, and as such, WSDOT will not pursue funding for a separate full-flood-protection project for I-5. If a dam is built, a future I-5 widening project could include small upgrades in features to promote flood resistance with a minor cost increase. Although these would not ensure the robust flood protection of I-5 afforded by a larger investment in levees and walls, these have the potential to reduce the duration and frequency of I-5 closures.

In the event that construction of a dam is not pursued, WSDOT would currently recommend construction of Alternative 1 to provide robust, reliable protection of I-5. Construction of full-flood-protection features would be combined with an I-5 widening project for the most efficient use of public funds.

# **Appendix A: University of Washington Transportation Research Center (TRAC) – Travel Costs Associated with Flood Closures Study**

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**Research Report**  
Agreement T1461, Task 07  
I-5 Chehalis

# **TRAVEL COSTS ASSOCIATED WITH FLOOD CLOSURES OF STATE HIGHWAYS NEAR CENTRALIA/CHEHALIS, WASHINGTON**

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16. ABSTRACT <p>This report discusses the travel costs associated with the closure of roads in the greater Centralia/Chehalis, Washington, region due to 100-year flood conditions starting on the Chehalis River. The costs were computed for roadway closures on I-5, US 12, and SR 6, and are based on estimated road closure durations supplied by WSDOT. The computed costs are only those directly related to travel that would otherwise have occurred on the roads affected by the flooding closures. The computed costs <u>do not</u> include the economic losses associated with delayed delivery of goods or services, losses in economic activity attributable to travelers being unable to reach their intended destinations, or economic losses associated with the loss of goods because they could not be delivered. The reported costs <u>do include</u> the added costs of time and vehicle mileage associated with available detour routes. Costs were also estimated for each trip that will be abandoned. That is, this study estimated the number of trips that will not be made as a result of road closures.</p> <p>The researchers also conducted a sensitivity analysis of the findings for the I-5 cost computation. Sensitivity tests were conducted for the value of time, the speeds and level of congestion assumed to occur on the routes used for detours, the values associated with trips that are not made via the expected detours, the percentage of personal trips made for work/business purposes versus those being made for personal reasons, the fraction of cars and trucks willing to detour, the effects of flood closure during the weekend or the summer, and growth in traffic volumes on I-5.</p>					
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## **DISCLAIMER**

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# EXECUTIVE SUMMARY

## INTRODUCTION

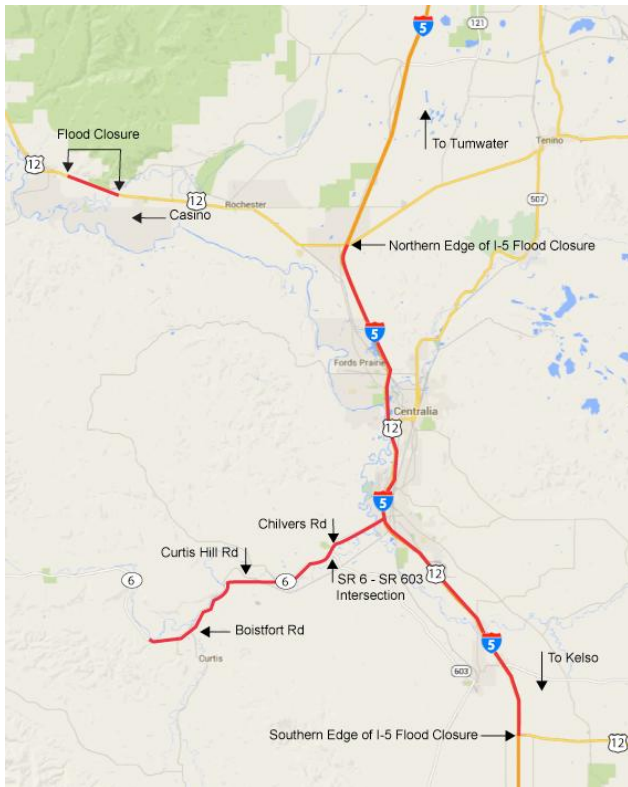
This report discusses the travel costs associated with the closure of roads in the greater Centralia/Chehalis, Washington, region due to 100-year flood conditions starting on the Chehalis River. Costs are predicted for roadway closures on I-5, US 12, and SR 6, and are based on estimated road closure durations supplied by the Washington State Department of Transportation (WSDOT). Those duration estimates were the result of extensive hydraulic modeling of the region conducted for WSDOT to specifically examine flood risk.

The costs described in this paper are only those directly related to travel that would otherwise have occurred on the roads affected by the flooding closures. The computed costs do not include the economic losses associated with delayed delivery of goods or services, losses in economic activity attributable to travelers being unable to reach their intended destinations, or economic losses associated with the loss of goods because they could not be delivered.

The reported costs do include the added costs of time and vehicle mileage associated with available detour routes. Costs were also estimated for each trip that will be abandoned. That is, this study estimated the number of trips that will not be made as a result of road closures. A “travel cost” was associated with each trip to represent the value of the trip not taken. Costs were also assigned for trips that will be made to a different destination than originally planned because the original destination cannot be reached in an acceptable fashion. Both the number of trips not made and the number of trips diverted to an alternative destination are reported, along with their assigned costs, so that readers can readily assign different values and change the assumptions.

More details on the values used and assumptions made are provided in the General Assumptions chapter of the report. The final chapter of the report explores the effects of applying different assumptions. Assumptions tested included the value of time used, whether the flooding occurs over a weekend when passenger car volumes are higher but truck volumes are lower, the size of expected trip diversion movements, and the value assigned to trips that are abandoned instead of using alternative routes.

## **SUMMARY OF PROJECT FINDINGS**



**Figure ES-1. Roadways closed during 100-year flood of the Chehalis River**

During the 100-year flood of the Chehalis River, water will flow over I-5, US-12 and SR 6. **Hydrology models estimate that I-5 will be closed for 123 hours (five days and three hours).** The closure will encompass 20 miles of I-5, from milepost 68 to milepost 88. This closure will prevent north/south traffic from moving on this 20-mile section of I-5 and will also severely restrict travel to, from, and within the Centralia/Chehalis area. **US 12 will be closed for 152 hours (six days and eight hours).** The primary closure will occur east of Oakville and west of Anderson Rd (also known as County Line Rd). **SR 6 will close for 51 hours (two days and 3 hours).** The closure will occur in multiple places on SR 6, as this road parallels and crosses over the Chehalis River several times. In addition, some of the roads that collect and deliver traffic to (or

accept traffic from) SR 6 cross the river and are subject to flooding. Figure ES-1 shows the affected flood areas.

The base case estimates of added travel costs that will be shouldered by travelers affected by the 100-year flood in the Centralia/Chehalis basin are

- **\$11,872,000 for travelers using I-5**
- **\$340,000 for travelers using US 12**
- **\$114,000 for travelers using SR 6.**

If the assumptions that underlie these estimates are changed to other values within a reasonably expected range (e.g., alternative values of time are used, or a much larger fraction of vehicles is assumed to take available detours), then the added travel costs are estimated to range from around \$10,000,000 to slightly over \$20,000,000. The highest cost estimate was derived by using an interpretation of the methodology described in the U.S. Army Corp of Engineers' National Economic Development report,

*Flood Risk Management* (IWR Report 2013-R-05). That report suggested that the cost of the disruption to traffic should be based on the assumption that all disrupted travelers can, and do, take the available detours to reach their intended destinations. That assumption greatly increases the number of travelers estimated to take the long detours over the mountains, which greatly increases the calculated travel cost.

Below are the key assumptions underlying the computation of these estimates for each of the three corridors. More detail is provided in the report.

### **ASSUMPTIONS AND DETAILED CORRIDOR RESULTS**

When roads are closed for long periods of time, travelers may react in the following ways:

- They find an alternative path to reach their destination (reroute).
- They postpone their trip until sometime after the road reopens.
- They change mode to make their trip. (In the case of I-5, take a plane, since the rail line will also be closed. US 12 and SR 6 have no realistic alternative modal options.)
- They change their trip's destination to one that can be reached (thus taking a completely different route).
- They abandon the trip altogether. (That is, the trip is not worth the effort, so they do not make it. This is the case for all SR 6 trips that start in neighborhoods north of SR 6, as no alternative exit exists for those trips.)

All of these behaviors have a cost associated with them. They all represent a “loss” to travelers, who would have preferred to drive on I-5 for their original itinerary.

The next three subsections of this summary describe the study team's best estimate of the travel costs associated with each roadway corridor. The final subsection discusses the effects that different critical assumptions have on these estimates. The intent is to provide a better understanding of the potential range of the “actual” travel costs when the 100-year flood occurs.

## **I-5 Closure Costs**

The “base case” estimate for the 123-hour closure of I-5 as a result of the predicted 100-year flood is in an additional travel cost of **\$11,872,000**. This cost represents the dollar amount computed by using the project team’s preferred assumptions for travel behavior and value of time. This cost includes \$8,508,000 for additional time and mileage for individuals who must take detours to reach their destinations. Another \$1,614,000 in costs is associated with abandoned trips (that is, trips that would have been made, but either could not be made or were not made because the effort required exceeded the value travelers placed on them). The remainder are costs incurred by the need to take alternative modes (primarily air travel), costs associated with shifting to alternative destinations, and costs associated with choosing to postpone a trip from a preferred time of travel until some time after the flood has receded.

During the first day of the five-day closure, the primary diversion route for commercial trucks (using SR 12 and SR 7/SR 161) will not be open. As a result, the costs associated with the closure differ between the first day and the rest of the closure. Table ES-1 shows the total added travel cost for trips that normally use I-5. Estimated travel costs per day are also shown.

**Table ES-1. Total I-5 Closure Travel Cost Summary**

	<b>Direction</b>	<b>Cost</b>	<b>Cost / Day</b>
Day 1	NB	\$1,243,000	
	SB	\$1,243,000	
Day 2 – 5	NB	\$4,693,000	\$1,136,000
	SB	\$4,693,000	\$1,136,000
<b>Total</b>		<b>\$11,872,000</b>	

On weekdays, cars make up about 80 percent of I-5 traffic leading into the area closed by flooding. However, despite the higher car volumes, the value of truck trips is perhaps the largest determining factor in the cost estimation process. There are several reasons for this. 1) The cost of detours (both hourly rate and the cost per mile) is higher for trucks than for passenger cars. 2) A large portion of truck trips comprises long distance trips, which require long detours, while a much larger proportion of car trips involves shorter detours and is thus assigned smaller travel costs. 3) In comparison to truck trips, a much larger portion of travelers on long distance car trips abandon their trip rather than choosing to detour.

The travel costs (and costs associated with the loss of travel opportunity) associated with the 123-hour closure for cars and trucks are shown in Table ES-2.

**Table ES-2. Total Travel Cost by Original Mode of Travel**

	Direction	Costs Associated with Cars	Costs Associated with Trucks
Day 1	NB	\$409,000	\$834,000
	SB	\$409,000	\$834,000
Day 2 – 5	NB	\$1,847,000	\$2,846,000
	SB	\$1,847,000	\$2,846,000
<b>Total</b>		<b>\$4,512,000</b>	<b>\$7,360,000</b>

Travelers will react to the closure of I-5 in different ways, depending on the type of trip they were planning to take and the options that remain to them after I-5 has been closed. The travel costs associated with detours are relatively easy to estimate. Costs associated with abandoning trips or shifting destinations because the planned destination is not accessible (or cannot be served by the regular freight depot) are more nebulous. To clarify the relative importance of these behaviors, Table ES-3 shows the estimated number of trips associated with each of these behaviors. Table ES-4 then shows the costs computed for each of these activities. The sensitivity analysis performed as part of this project examined the effects of different costs associated with each of these behaviors, as well as the effects of different levels of each behavior.

**Table ES-3. Estimated<sup>9</sup> Number of Trips by Type of Behavior Resulting from the Closure**

	Trips Made Via Detours	Trips Abandoned	Trips Postponed	Trips That Shifted Mode	Trips That Changed Destination
<b>Trips Per Day</b>					
Day 1	32,000	22,600	17,200	800	5,500
Days 2-5+	33,000	19,300	15,900	800	8,000
<b>Total Number of Trips for Days 2 – 5+</b>					
Days 2-5+	135,900	79,800	65,600	3,100	33,000
<b>Total</b>	166,900	102,400	82,800	3,800	38,500
<b>Total Number of Trips Modeled</b>			<b>394,400</b>		

**Table ES-4. Estimated Costs by Type of Behavior Resulting from the Closure**

		All Travel Costs Due to Detours	All Trip Abandonment Costs	All Costs Associated With Trip Postponement	Costs Associated with Mode Shifts	Costs Associated with Destination Changes
Day 1	NB	\$903,000	\$199,000	\$61,000	\$53,000	\$21,000
	SB	\$903,000	\$199,000	\$61,000	\$53,000	\$21,000
Day 2-5	NB	\$3,351,000	\$608,000	\$181,000	\$220,000	\$308,000
	SB	\$3,351,000	\$608,000	\$181,000	\$220,000	\$308,000
<b>Total</b>		\$8,508,000	\$1,614,000	\$484,000	\$547,000	\$658,000

Table ES-3 shows that only about 42 percent of trips normally occurring on I-5 in the Centralia/Chehalis area are estimated to take alternative routes when I-5 is closed. Nevertheless, over 70 percent of the estimated “travel costs” of the closure will be due to the costs of the additional miles and time required to use the available detours. If even higher cost values are assigned to trips that are not taken or trips that shift to alternative, less desirable destinations, then the total value of the I-5 closure could increase substantially. In fact, if all trips that typically use I-5 are assumed to take the available detours, then the total increase in “travel cost” caused by the flood is estimated to be \$20,576,000. This estimate is higher than the base case estimate because it is assumed that when a trip is “abandoned,” it means that the traveler values the trip less than the added cost of the detour. The level of “trip abandonment” in the base case cost computation is based on the travel behavior observed during the four-day I-5 closure in 2007.

<sup>9</sup> The number of estimated trips is rounded to the nearest 100 trips. Note that the number of trips made per day is assumed to be relatively unchanged from current traffic levels, which have been reasonably stable for the past 10 years.

## **US 12 Closure Costs**

**Flooding of US 12 for 152 hours (six days and eight hours) will result in an expected additional travel cost of \$340,000.** That cost includes \$206,000 for additional time and mileage, as individuals who must travel will have to take extensive detours to reach their destinations. Another \$134,000 in costs is associated with abandoned trips (that is, trips that would have been made, but either could not be made or were not made because the effort required exceeded the value travelers placed on them).

Of the just under 41,200 trips that would have used US 12 over the 152-hour period, this analysis concluded that only about 11,500 trips will still be made. The remaining 29,700 trips will be abandoned. Note that the above cost estimates place a value of just over \$3.20 per personal trip and \$9.00 for a truck trip for abandoned trips. This is based on the value of 80 percent of the lowest detour cost modeled. If a higher value is assigned to abandoned trips, then the cost of abandoned trips due to the flooding of US 12 will be higher, but it will still be very small in comparison to the value of travel disruption on I-5.

## **SR 6 Closure Costs**

**A flood closure of SR 6 for 51 hours will result in an expected additional travel cost of \$114,000.** That cost includes \$29,000 for additional time and mileage, as individuals who do travel will need to take back roads to reach their destinations, and \$85,000 in costs associated with abandoned trips. Of the just under 24,000 trips that would have used SR 6 over the 51-hour period (assumed to be weekdays), this analysis assumed that only about 4,200 trips will still be made. Many trips must head to alternative destinations, because their original destinations in Centralia and Chehalis cannot be reached by road. The remaining 19,800 trips are assumed to be abandoned. A significant fraction of those trips will be trapped in their neighborhoods because the only access to those neighborhoods will be via the flooded sections of US 6.

## **Sensitivity Analysis**

Because the combined travel costs associated with US 12 and SR 6 flooding are estimated to be less than 3 percent of the I-5 travel costs, the sensitivity tests were applied only to the I-5 cost computations. The project team studied the sensitivity of the travel cost estimate to the following values used in the analysis:

- the value of time
- the speeds and level of congestion assumed to occur on the routes used for detours
- the values associated with trips that are NOT made via the expected detours as a result of flooding
- the percentage of trips made for work/business purposes versus those made for personal reasons
- the fraction of cars and trucks willing to detour
- the effects of flood closure during the weekend or the summer
- growth in traffic volumes on I-5.

The value of time recommended by USDOT was used to compute the costs for the base case cost estimates. These values are slightly higher than the values that WSDOT has adopted for other studies. If the WSDOT values are used, then the computed cost for all closure impacts drops by 3.5 percent, from \$11,872,000 to \$11,455,000.

It was assumed that most trucks will travel slowly on the emergency truck detour route because of poor road conditions, higher volumes, and the geometric limitations of the corridor. If the “congested” travel time on the emergency truck detour is 50 percent faster than the base case assumption, then the expected cost of the entire I-5 closure drops 1.6 percent to \$11,685,000. If all trucks using the emergency truck detour operate at the estimated free flow speed, then the total costs for the I-5 closure will drop to \$11,498,000. If all three of the long distance detours are assumed to operate under free flow conditions (meaning that loaded trucks operate at the speed of free flowing cars), then total estimated costs for the long distance detours for both cars and trucks will drop further, producing a total estimated cost of \$10,746,000.

If the value of abandoned, diverted, or long-term postponed trips is 60 percent of the minimum applicable detour cost (holding constant all of the other original assumptions), rather than the 80 percent value used for the base case computation, then the total value of the flood closure decreases to \$11,304,000. This is a roughly 5 percent less than the base case estimate.

A large survey performed as part of this project indicated that 50 percent of local trips on I-5 were work related, 36 percent of internal/external trips were work related, and 33 percent of long distance trips were work related. These values were used in the base case computation. In contrast, the National Household Travel Survey (NHTS) taken in 2009 indicated that nationally, only 16 percent of trips are work related. If the estimated fraction of trips that are work related is halved to better reflect national conditions, and those trips are distributed among the other travel purposes, then the estimated cost of flooding is reduced by 2.6 percent, to \$11,564,000, reflecting the lower value associated with personal trip making, which is lower than that of business-oriented trips.

The base case cost estimate assumes that roughly 2,800 total trucks per direction will take the available detours, a slight increase over the 2,500 trucks observed to detour in the 2007 flood. Of those trucks, 43 percent are assumed to use the emergency truck detour starting on day two of the closure. The remainder will use the traditional I-90 detour, 89 percent using US 97 to reach I-82 and then I-90, and the remainder using I-84 to reach I-82 and then I-90.

Early estimates of the emergency truck detour's capacity were 100 trucks per hour southbound and 250 trucks per hour northbound. Given these estimates, the northbound capacity of the emergency truck detour can accommodate all I-5 trucks, but the southbound capacity will not allow all trucks to use the detour. Therefore, it can be assumed that northbound, no through-trucks currently using I-5 will change behavior, other than to use the emergency truck detour. (That is, all through-trucks will use this detour. No trucks will abandon their trips or divert their trips to other destinations.) However, southbound, it is assumed that only 81 percent of the normal truck volume (4,300 trucks) will continue to make the through-trip, and only 55 percent of those trucks will be able to take the emergency truck detour. The remaining trucks are assumed to use I-90 and travel over the mountain passes. Under these assumptions, the total estimated cost of the I-5 flood closure decreases slightly to \$10,970,000. The changes that result from these differing assumptions is a decrease (\$450,000) in the costs attributed to time and mileage associated with detours, as well as a decrease of \$220,000 in the costs associated with abandoned trips and a similar amount (\$220,000) associated with trips that must serve or be served by alternative destinations.

If a much lower cost is attributed to abandoned trips (e.g., 50 percent of the detour cost instead of 80 percent), then adding capacity to the emergency detour route—thus increasing the total number of trucks using one of the detours—will actually make the flood more costly than if no detour were provided and will thus limit the number of trucks selecting to detour rather than abandon the trip entirely. For that reason a value of 80 percent of the minimum detour cost was selected as the value of an abandoned trip.

The highest cost estimate was derived by using an interpretation of the methodology described in the U.S. Army Corp of Engineers' National Economic Development report, *Flood Risk Management* (IWR Report 2013-R-05), published in June 2013, which states, "The cost of traffic disruptions caused by flooding is equal to the value of the resources required to use alternative modes of transportation or routes for the disrupted traffic. This can include increased fuel costs, increased wear and tear on equipment, and the value of the time spent in longer routes." If this is taken literally, then the cost of the disruption to traffic should be based on the assumptions that all disrupted travelers can, and do, take the available detours to reach their intended destinations. If all planned trips are assumed to use the available detours—and the emergency truck detour capacity is set at 50 trucks per hour in each direction, starting on the second day of the disruption—then the estimated I-5 traffic cost of the 100-year flood will be \$20,576,000.

All of the above cost estimates assume that the flood occurs on a Monday and affects only weekday travel. On weekends, travel volumes are very different, with truck volumes being essentially halved, and car volumes increasing modestly. The fraction of car trips made for business purposes also decreases significantly. If weekend traffic volumes and trip purposes are assumed as part of the flood, traffic costs of the flood decline to \$10,717,000.

Finally, to examine the effects of possible traffic growth on I-5, the researchers increased volumes by 20 percent uniformly for through-trips, internal/external trips, and local trips, and to both truck and car volumes. Diversion rates and trip purposes were not changed from the primary cost computation. All of the added through-trucks were assumed to take the cross-mountain detour, since the emergency truck detour would already be at capacity. The estimated costs resulting from this 20 percent increase in traffic rose 23 percent: from the original estimate of \$11,872,000 to \$14,570,000. Thus, as volumes increase, costs also increase, but slightly faster in percentage terms than traffic volumes. This is because all of the additional through-trips that are predicted to detour will have to take one of the long detours, thus making the cost per trip higher than that initially used.

## I. INTRODUCTION

This report discusses the travel costs associated with the closure of roads in the greater Centralia/Chehalis, Washington, region due to 100-year flood conditions starting on the Chehalis River. Costs are computed for roadway closures on I-5, US 12, and SR 6, and are based on estimated road closure durations supplied by the Washington State Department of Transportation (WSDOT).

The costs described in this paper are only those directly related to travel that would otherwise have occurred on the roads affected by the flooding closures. The computed costs do not include the economic losses associated with delays in the delivery of goods or services due to flood closures, losses in economic activity attributable to travelers being unable to reach their intended destinations, or economic losses associated with the loss of goods because they could not be delivered.

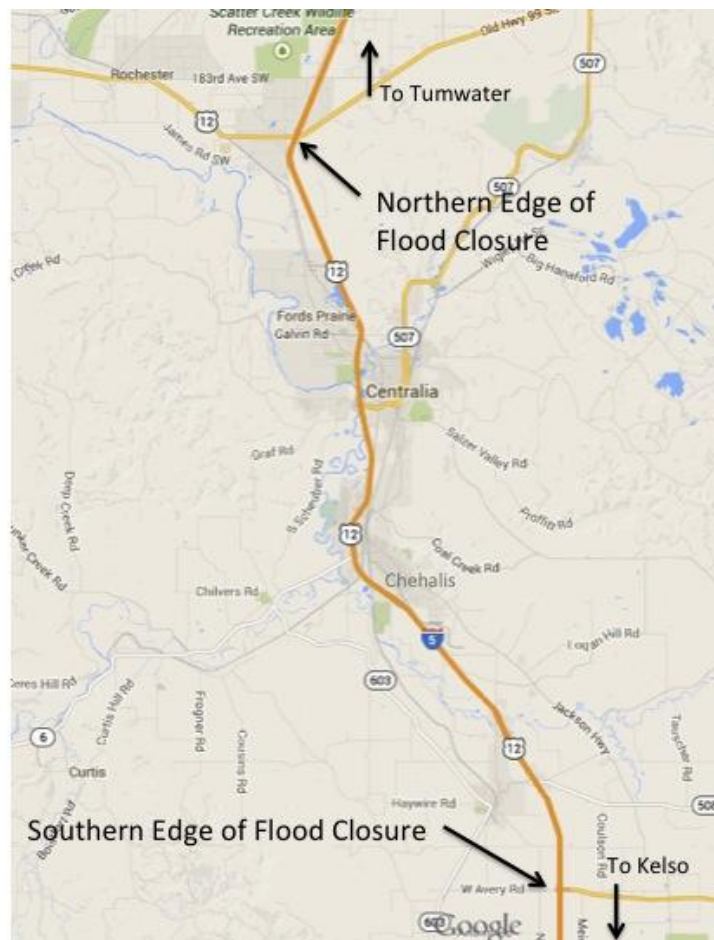
The reported costs do include the added costs of time and vehicle mileage associated with available detour routes. Costs are also estimated for each trip that will be abandoned. That is, this study estimates and reports the number of trips that will not be made as a result of road closures. A “travel cost” is associated with each trip to represent the value of the trip not taken. Costs are also assigned for trips that will be made to an entirely different destination than originally planned because the original destination cannot be reached in an acceptable fashion. Both the number of trips not made and the number of trips diverted to an alternative destination are reported, along with their assigned costs, so that these assumptions can be readily changed if readers wish to assign different values to those circumstances.

More details on the values used and assumptions made are provided in the Assumptions chapter of this report.

Travel costs and the key traffic statistics used to compute those costs are given separately for I-5, US 12, and SR 6 in the following three chapters.

## II. I-5 FLOOD CLOSURE IMPACTS

During the 100-year flood of the Chehalis River, water will flow over I-5. As a result, WSDOT estimates that I-5 will be closed for 123 hours (five days and 3 hours). The closure will encompass 20 miles of I-5, from milepost 68 (the interchange south of Chehalis where US 12 carries traffic to the east) to milepost 88 (the interchange north of Centralia where US 12 carries traffic to the west). This closure will prevent north/south traffic from moving on this 20-mile section of I-5 and will also severely restrict travel to, from, and within the Centralia/Chehalis area. Figure 1 shows the section of I-5 that will be closed to traffic during the 100-year flood.



### Figure 1: I-5 Closed During a 100-Year Flood

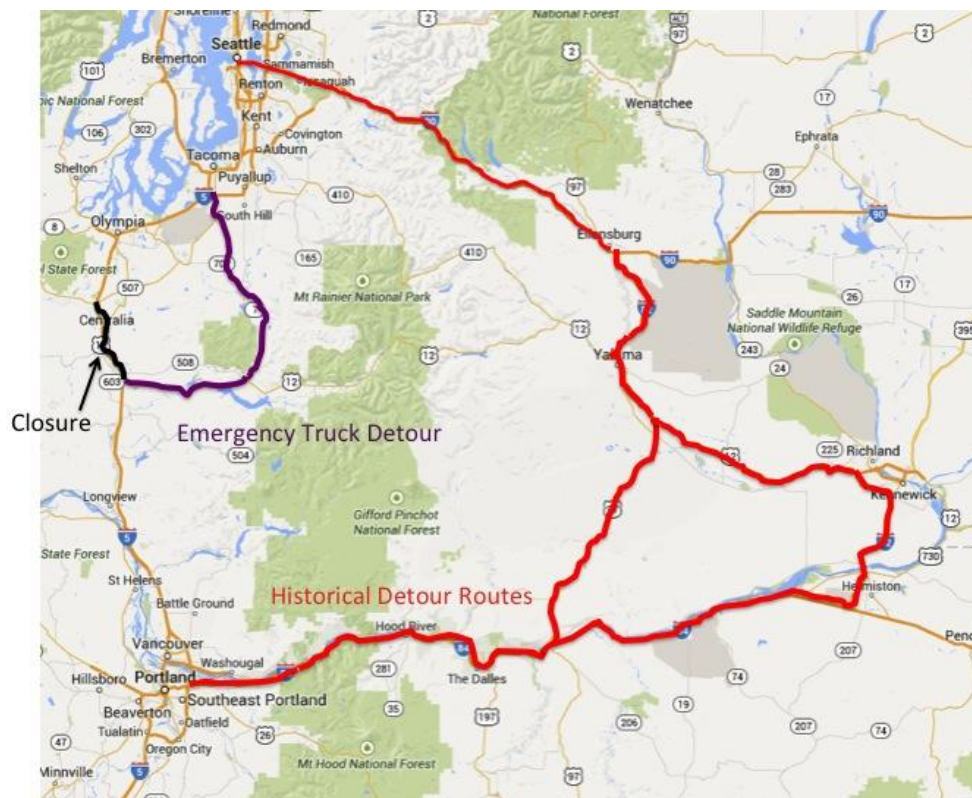
The flood will eliminate most access to Centralia from the north or to Chehalis from the south. It will also affect access to Chehalis from SR 6 to the west. (This is discussed in more detail in the SR 6 chapter later in this report.) The fact that a large geographic area will be affected by the I-5 closure, and

not just a single point such as when a bridge closes, makes the analysis of traffic changes caused by the I-5 closure different from other road closure analyses.

For the I-5 analysis, three different traffic movements had to be estimated and the costs to those travelers computed. Those three traffic movements are

- a through-traffic movement (essentially from California and Oregon to the Puget Sound region and Canada)
- travel to and from the Centralia/Chehalis area from the metropolitan regions to the north and south, and
- local traffic within the Centralia/Chehalis area.

Travelers making each of these types of trips will respond differently, as each will be confronted with very different travel options when I-5 is closed. For example, travelers between Portland and Seattle have a good—but expensive—modal alternative: they can fly. (The train will not be an option, as the train tracks from Seattle to Portland will be closed by any flood that is high enough to close I-5.) Those travelers can also drive around the mountains via I-90, I-82, SR 97, and I-84, as shown in the red line in Figure 2.



**Figure 2: Detour Routes for an I-5 Closure at Centralia/Chehalis**

Some local trips (trips that currently use I-5 to move within the Centralia/Chehalis urban area) will have considerably fewer travel options. A limited number of those local trips may be able to take transit buses, depending on the ability of Twin Transit to operate services during the flood conditions. Other travelers may be able to find ways to their intended destinations via local roads that are not inundated by water. Other local travelers will change destinations to other local destinations that are not affected by the flood. (That is, someone might go to a different grocery store if they cannot reach their “normal” store.)

Similarly, trips coming to the area or leaving the area will have relatively few travel options. These “internal/external” trips will generally not be served by alternative modes of travel and will only be served by alternative routes when both trip ends are on the same side of the Centralia/Chehalis urban area. For example, a trip from Olympia to northern Centralia may be possible via roads other than I-5 (e.g., using SR 507), while a trip from Olympia to Chehalis will not be possible unless the detour includes travel over Snoqualmie Pass and the destination in Chehalis is accessible from the south via roads such as the Jackson Highway.

For trucks, through-traffic is expected to receive notification of the I-5 closure well in advance of arriving at the point where I-5 is closed. This will allow trucks coming up from Oregon to detour via I-84 and SR 97 without back tracking on I-5. Because of the long duration of the closure (five-plus days), no trucks are assumed to “wait out” the closure.

Given that public information is expected to be widely disseminated about the locations and duration of the closure, some businesses are expected to change their delivery patterns. Where possible, they will change the markets served by specific distribution centers. For example, a store south of Chehalis that is currently served from a warehouse in Seattle may instead be served by a Portland warehouse during the I-5 closure. However, other freight trips will simply not occur. Data from the four-day closure of I-5 during the 2007 flood indicate that as much as 25 percent of truck traffic simply disappeared. Some of this “missing” truck traffic was from “abandoned” trips. (i.e., trips that simply were not made because the detour costs were too high); the remainder of those “missing” trips were the result of changed distribution patterns.

The complexity of these different travel movements made it necessary to build a relatively complex traffic model to estimate the costs imposed on travelers affected by a 100-year flooding of I-5. The following sections describe the basic assumptions and decisions made to model those movements and the resulting estimates of additional travel costs imposed by the flood.

## **CURRENT TRAFFIC VOLUMES**

The traffic data used to populate the I-5 closure model were taken from two primary sources: WSDOT Annual Traffic Reports (2011 and 2012) and data collected at a number of WSDOT's permanent counter locations. For this analysis, the most important count locations were R097, at milepost 100.54 just south of the City of Tumwater, and P8, a weigh-in-motion scale located at milepost 44.3, just north of Kelso. The Annual Traffic Report provides estimates of traffic volumes by milepost. The traffic counter provides detailed data about both car and truck volumes at specific locations on specific days—including during the 2007 and 2009 I-5 closures.

The traffic counter data were used to determine the difference between weekday and weekend traffic volumes on I-5. In particular, they showed that *weekday* truck volumes are as much as double *weekend* truck volumes. Conversely, weekend (and Friday) passenger vehicle volumes are frequently higher than weekday volumes both north and south of the Centralia/Chehalis region. Thus, when (what days of the week) a flood event occurs will effect both the size and nature of the traffic stream that is disrupted.

Detailed traffic counter data were available for both the Kelso and South Tumwater sites during the 2007 flood closure. Using those data, it was possible to estimate the fraction of I-5 traffic normally passing those two sites that abandoned I-5 during the 2007 closure. Not all traffic at those two sites (each site is ~20 miles from the actual closure points) disappeared during the 2007 or 2009 closures. The remaining traffic volume during those periods was assumed to be traffic that flowed past those two major count sites but exited I-5 before reaching the closures at mileposts 68 (from the south) or 88 (from the north). The analysis then removed that traffic from the traffic volume estimates on I-5 within the Centralia/Chehalis area. The traffic that “disappeared” from I-5 was assumed to be either through-traffic<sup>10</sup> or “internal/external<sup>11</sup>” traffic.

The 2007 data showed that more traffic “disappeared” from I-5 north of the closure than from I-5 south of the closure. For this analysis, internal/external traffic was set to a modest amount (300 car trips per day and 300 truck trips per day) for the southern approach to Chehalis. The remainder of the traffic that “disappeared” was assumed to be through-traffic. The difference between that volume and the “disappeared” traffic on the north end was assumed to be internal/external traffic heading to Centralia from the north. The difference between the traffic volume reported on I-5 in the Centralia/Chehalis area

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<sup>10</sup> Through-traffic is traffic that passes Kelso, Centralia and South Tumwater, going either north or southbound.

<sup>11</sup> Internal/external traffic is traffic that has one trip end within the Centralia/Chehalis closure and one trip end outside of the closure.

and the through-traffic plus internal/external traffic from the north end was assumed to be locally generated traffic. That is,

$$\text{Local traffic} = \text{AADT}_{\text{Centralia}} - \text{Through-Traffic}_{\text{SouthTumwater}} - \text{Internal/External Traffic}_{\text{SouthTumwater}}$$

For the primary cost estimate, the flood costs were based on weekday traffic volumes. The assumption was that the 123-hour flood closure will occur very late on a Sunday or early on a Monday, and I-5 will reopen late on a Friday or very early on Saturday. If the closure occurs on a weekend, truck volumes will be lower than estimated, while traffic volumes will be higher. The effects of these differences are explored in the Sensitivity Tests chapter. The actual volumes that were used in the primary cost analysis are discussed below.

### **From South of Tumwater, Heading South**

At South Tumwater on I-5, roughly 27,000 cars and 7,900 trucks travel in each direction on a normal late Fall weekday. Even during the 2007 closure, 5,000 cars and 200 trucks remained on I-5 at this point. Those vehicles are assumed to be destined for points north of the closure and are subtracted from the total.

Consequently, combined through-traffic and internal/external traffic volumes to and from the north are 22,000 cars and 7,700 trucks, for a total volume of 29,700 vehicles. Of the passenger vehicles,

- 6,000 cars are headed through to Portland

- 6,000 cars have destinations in the portion of the Centralia area that will be inaccessible during the flood and thus will disappear (i.e., these trips cannot be made during the flood)

- 10,000 cars have destinations that will be accessible in the northern portion of Centralia and can divert via routes such as SR 507.

For the 7,700 trucks,

5,300 trucks are headed through to Portland

500 trucks have destinations in the portion of the Centralia area that will be inaccessible during the flood, and thus will disappear

1,900 trucks have destinations that will be accessible in the northern portion of Centralia.

### **From Kelso, Heading North**

At Kelso on I-5, roughly 15,500 cars and 7,500 trucks travel in each direction on a normal late Fall weekday. Even during the 2007 closure, 8,000 cars and 1,700 trucks remained on I-5 at this point. Those vehicles are assumed to be destined for points south of the closure and are subtracted from the total.

Consequently, combined through-traffic and internal/external traffic volumes to and from the south are 7,500 cars and 5,800 trucks, for a total volume of 13,300 vehicles. Of those vehicles,

6,000 cars are headed through to Tumwater and points farther north

300 cars have destinations in the portion of the Centralia area that will be inaccessible during the flood, and thus will disappear

1,200 cars have destinations that will be accessible in the southern portion of Chehalis and will divert along roads such as the Jackson Highway.

For the 5,800 trucks,

5,300 trucks are driving through to Portland

300 trucks have destinations in the portion of the Centralia area that will be inaccessible, and thus will disappear

200 trucks have destinations that will be accessible in the southern portion of Chehalis.

### **Local Traffic within the Closure**

I-5 at Centralia carries an AADT of roughly 70,000 vehicles. Given the through-volumes and internal/external volumes shown above, this means that roughly 17,000 “local” vehicle trips use I-5 in the closure area in each direction. (The actual number of trips is likely higher than this because some trips occur in the southern portion in addition to the trips measured at the peak traffic volume point at Centralia. The use of the 70,000 AADT statistic as the measure of trip making is therefore assumed to be conservative.)

Estimates of local truck traffic, based on truck data from traffic counters on I-5 in Tacoma, suggest that the fraction of local trips generated within the Centralia and Chehalis area that are truck trips is small. Consequently, local trips were assumed to consist of 16,340 car trips and 660 truck trips.

## **DETOUR ROUTES**

As shown in Figure 2, two major detour routes are available for I-5 traffic between the greater Portland and greater Puget Sound metropolitan regions,<sup>12</sup> with variations in both of those routes. The historical detour for traveling between Portland and the Puget Sound region has been to travel east of the mountains via I-84. Two alternatives then exist. The shorter route takes US 97 (SR 97 in Washington) north to I-82 just south of Yakima, follows I-82 to I-90, and then takes I-90 west to Seattle. The longer route follows I-84 all the way east until Hermiston, Oregon, before turning north on I-82. The SR 97 route has more hills and a lower speed limit, and is often one lane in each direction. It is therefore more susceptible to slower speeds, especially for loaded trucks, which may be unable to easily pass slower vehicles. However, in good conditions, the SR 97 route is roughly 75 minutes faster than the longer route through Hermiston. The I-84 to I-82 route has a higher speed limit and multi-lane roadways for the entire detour, but it requires an extra 120 miles of travel.

The SR 97 route adds 134 miles to the trip between Seattle and Portland. Travel time via a car or unloaded truck in uncongested conditions adds just under 2.5 hours<sup>13</sup> to the Portland to Seattle trip. (These values will change somewhat depending on the destination of the trip in the Seattle area. Trips with destinations south of Seattle will require more time and mileage than a direct I-5 trip.<sup>14</sup>) Loaded trucks are unlikely to travel as quickly as cars on this detour because heavy trucks go slowly over hills, and SR 97 has multiple hills, including five truck climbing lanes between the Oregon border and Yakima on SR 97. Detouring vehicles will also be stuck behind slower moving vehicles until they find passing opportunities on the one-lane sections of the roadway (gaps in oncoming traffic matched with safe passing zones). Loaded trucks are therefore expected to travel at speeds considerably below the near free flow speeds used to estimate the “uncongested” travel time for the detour. Vehicles detouring may also need to stop for driver rest breaks and added fuel.

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<sup>12</sup> The detours are described for travel from the south to the north. The same routes can be used for travel north to south.

<sup>13</sup> More details on the estimated travel times are included in the last chapter of this report describing the model assumptions.

<sup>14</sup> Note that the travel time assumption is likely somewhat too slow for anyone who drives straight through with no stops. However, many drivers will need to stop either to rest or for gas.

The detour route through Hermiston adds 254 miles to the trip between Portland and Seattle and almost 3.75 hours of travel time in uncongested conditions. While a trip via this route also includes hills, vehicles are less likely to experience difficulties passing, and because the roads are larger and more strategically important to the state, the weather conditions that result in I-5 flooding are *less likely* to significantly affect travel here.

However, the same weather patterns that cause the I-5 flooding are also quite likely to affect these cross mountain detour routes. In fact, in 2009 when I-5 was closed for 48 hours, I-90 was also closed because of avalanches and snow clearing activities. The result was that no detour was possible around the mountains for the 2009 I-5 flood event.

To reflect the effects of slow, loaded truck travel over the hills on these detours combined with the likely effects of bad weather, a second set of travel times was computed for these detours. These travel times were based on the 95<sup>th</sup> percentile travel times measured for these trips in the Inrix travel time database. No car trips were assigned to these slower speeds. Two-thirds of the detoured trucks were assigned to these slower speeds.

Because of the long distance and extended travel times imposed by the cross-mountain detour routes, WSDOT has developed a “truck only emergency detour.” This detour route leaves I-5 onto eastbound US 12, south of Chehalis.<sup>15</sup> It then turns north on SR 7. The detour then splits, with northbound and southbound trips using different roads: one on SR 7 and the other using SR 161. Both SR 7 and SR 161 connect with SR 512, which provides access back to I-5.

The SR 12 to SR 7/SR 161 to SR 512 to I-5 detour is 91.5 miles long. It replaces a 64-mile trip on I-5. If the trip can be made at the speed limit, the detour requires roughly 115 minutes, 55 more minutes than a car making the I-5 trip. However, because of the combination of weather, local car traffic, and truck use of roads with insufficient roadway geometry, this route is not expected to operate at the speed limit for much of the day. Instead, it is expected to operate as if it were heavily congested for much of each day. When congested, I-5 requires twice the normal time to traverse this corridor. Thus, the assumed trip time for most trucks using this detour is twice the free flow travel time, or 230 minutes (just under 4 hours). Of all trucks using this detour, it is assumed that 80 percent will operate at these lower speeds, And 20 percent will travel at the speed limit.

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<sup>15</sup> The southbound trip follows these same roads in the opposite order.

The SR 12 to SR 7/SR 161 detour cannot open to traffic until 24 hours after the I-5 closure. Consequently, no traffic will follow this detour on the first day of any I-5 closure. All first day detour traffic must travel via I-90 and I-82.

Because of the significant geometric constraints on SR 7 and SR 161, once this route has been opened, WSDOT will limit the number of trucks that can use this detour. WSDOT will manually restrict access to this detour by staffing specific entry points along SR 7 and SR 161. WSDOT will provide access only to “priority truck shipments.” WSDOT is charged with determining how to define a priority truck movement, but the intent is to make sure emergency and time-critical medical supplies and material needed for emergency repairs have access to this route.

WSDOT’s initial estimate of roadway capacity was that the northbound truck movement will handle 250 trucks per hour, and the southbound movement will handle only 100 trucks per hour. However, concerns about the safety of the detour under these truck volumes have resulted in the potential for the corridor capacity to be reduced to 50 trucks per hour in each direction.

Alternative cost estimates have been developed for both of these detour capacities; however, the primary cost estimate assumes a restriction of 50 trucks per hour. The effects of allowing 100 trucks per hour southbound and 250 trucks per hour northbound are explored as part of the sensitivity analysis chapter.

Any truck trip that is not considered to be a “priority shipment” must use the longer detour over I-90, via I-82, if it will travel between Seattle and Portland. For this cost estimate, it was assumed that truck drivers will know in advance whether they may use the SR 12 to SR 7/SR 161 detour. Therefore, no truck was assumed to drive north from Portland to the SR 12/SR 7 intersection, and then be turned around and sent back to I-84 to travel around the mountains.

For internal/external trips, an example detour was built that assumed a trip from the Tumwater area to northern Centralia. The trip would detour via Tenino on SR 508. The detour was assumed to add 15.5 miles and roughly 36 minutes to each internal/external trip. Part of the added time was assumed to be due to congestion, as smaller back roads become congested because of high volumes. A similar detour with similar travel time and distance penalties was assumed for accessing Chehalis from the south using SR 12 and the Jackson Highway.

Finally, an example “local detour” was created for trips that use I-5 but that would normally remain within the Centralia/Chehalis area. This detour would increase trip distance (per trip) by 1.7 miles and require an extra 20 minutes to complete.

## **BEHAVIORAL ASSUMPTIONS**

Behavioral assumptions for cars were based on a survey of motorists observed traveling I-5 during February 2014. A mail out/mail back survey was used to determine the number of trips using I-5, by trip purpose, that respondents took during the previous week. They were also asked to indicate, for their last trip, the action they would take if I-5 were closed for more than one day.

Respondents who made more than four trips on I-5 in the previous week were used to estimate “local” behavior. Respondents who made three or four trips were used to estimate internal/external trip behavior, and respondents who made two or fewer trips were assumed to represent through-trip behavior. Table 1 shows the behaviors reported.

**Table 1: Travel Behavior in Response to Flooding by Trip Frequency**

<b>Stated Behavior If A Flood Disrupted Their Last Trip on I-5</b>	<b>Number of Trips Made on I-5 the Previous Week</b>		
	<b>0, 1 or 2 trips</b>	<b>3 or 4 trips</b>	<b>5+ trips</b>
Reroute	30.7%	38.5%	51.7%
Use a Different Destination	6.9%	11.9%	7.9%
Abandon the Trip	16.8%	14.8%	16.4%
Postpone the Trip	38.5%	31.1%	20.6%
Use a Different Mode	4.7%	0.7%	0.5%
No Response	2.4%	2.2%	2.9%

The responses in Table 1 fit the general pattern expected. Individuals making local trips are likely to know of ways around local flooding –if they exist—and will therefore be better able to reroute around flooded roads. They will also be aware that few alternative modes exist in the Centralia/Chehalis area. Therefore, reported rerouting for this group was relatively high in comparison to what are assumed to be internal/external and through- travelers, and reported potential use of alternative modes was relatively low. Conversely, individuals who use I-5 infrequently and are therefore more likely making through-trips reported that they would be less likely to reroute (given the time and cost of going over the mountains) and more likely to both postpone their trip (if it was not of high value) or pay to take an airplane (if it was of high value). Moderate users of I-5 reported behaviors more like long distance travelers than local travelers, although the lack of modal alternatives and the lack of detour routes remain apparent for internal/external trips.

Behavioral responses were also compared by trip purpose. Table 2 shows how reported behavior changed in relation to both trip purpose and the number of trips made on I-5 during the previous week.

**Table 2: Travel Behavior in Response to Flooding by Trip Purpose and Trip Frequency**

	<b>Work</b>	<b>Shop</b>	<b>Recreation</b>	<b>Other</b>
<b>Infrequent trip makers (0, 1, or 2 trips per week) – Long Distance Cohort</b>				
Reroute	29.2%	34.0%	28.2%	33.6%
Different Destination	4.4%	12.8%	7.7%	6.6%
Abandon the Trip	15.3%	21.3%	17.9%	15.6%
Postpone the Trip	41.6%	31.9%	44.4%	32.0%
Different Mode	9.5%	0.0%	1.7%	4.1%
<b>Frequent Trip Makers (5 or more trips per week) – Local Cohort</b>				
Reroute	59.3%	30.2%	44.0%	39.7%
Different Destination	6.5%	25.6%	0.0%	4.8%
Abandon the Trip	15.7%	11.6%	28.0%	17.5%
Postpone the Trip	18.1%	32.6%	28.0%	19.0%
Different Mode	0.4%	0.0%	0.0%	1.6%
<b>Modest Trip Makers (3 or 4 trips per week) – Internal/External Cohort</b>				
Reroute	48.9%	37.1%	37.5%	27.8%
Different Destination	4.3%	28.6%	6.3%	8.3%
Abandon the Trip	21.3%	5.7%	18.8%	13.9%
Postpone the Trip	25.5%	28.6%	37.5%	38.9%
Different Mode	0.0%	0.0%	0.0%	2.8%

The behavior reported in Table 2 was used to estimate trip behavior for passenger vehicles (cars) for travel on I-5. The fraction of trips by trip purpose for the last reported trip was also used to estimate the fraction of trips on I-5 by trip purpose.

The project budget did not allow collection of definitive behavior details for truck trips. However, interviews with trucking firms helped to support and refine the findings obtained by reviewing historical traffic volume trends measured during the 2007 and 2009 I-5 closures.

During the 2007 closure, traffic declined on I-5 at both Kelso (20 miles south of the closure) and South Tumwater (12 miles north of the closure). Table 3 illustrates the size of those volume declines during the first two full calendar days of the closure. (I-5 was partially opened late during the third full calendar day of the closure. The closure started in the evening of a Monday.)

**Table 3: Vehicle Volume Decline Measured during Full-Day Road Closures on I-5**

	<b>Cars</b>	<b>Single unit Trucks</b>	<b>Multi-Unit Trucks</b>
<b>North of the Closure</b>			
Normally expected traffic	27,120	2,530	5,450
Tuesday DECLINE in volume	14,973	1,367	4,495
Wednesday DECLINE in volume	12,180	968	4,965
<b>South of the Closure</b>			
Normally expected traffic	15,200	1,740	5,570
Tuesday DECLINE in volume	6,354	835	4,576
Wednesday DECLINE in volume	6,211	691	4,918

Table 4 shows the increases in volumes that occurred on these same two days on I-90 at Cle Elum. The third full day after the closure is also shown because diversion traffic was still obviously present on I-90 throughout that entire day, even though a single lane of I-5 was opened in each direction to slow moving trucks late on Thursday.

**Table 4: Changes in Volume on I-90 (B04) during the Four-Day Closure on I-5**

Day	Westbound			Eastbound		
	Change in Car Volume	Change in Small Truck Volume	Change in Multi-Unit <sup>16</sup> Truck Volume	Change in Car Volume	Change in Small Truck Volume	Change in Multi-Unit Truck Volume
Tuesday	439	163	1757	960	207	2266
Wednesday	180	167	2977	688	160	2657
Thursday	145	152	2476	351	136	2027

A comparison of tables 3 and 4 shows that just about half of the multi-unit trucks that make through-trips on I-5 re-route over the mountains if I-5 is closed. Roughly 42 percent of the total I-5 multi-unit truck traffic re-routes across the mountains. This is one-third of the total pre-closure weekday truck traffic. (Fewer single-unit trucks appear willing to reroute over the mountains in comparison to larger, multi-unit trucks.) Another one-third of the I-5 truck traffic normally observed at both Kelso and South Tumwater simply disappears, and the final third continues to use I-5 to make deliveries outside of the closure area. The “disappearing” truck traffic is assumed to be split evenly between truck trips that are not made and truck trips that are rerouted between entirely different origin/destination pairs. That is, stores/companies in southern Washington and northern Oregon normally supplied by Seattle warehouses and businesses either will not be resupplied during the flood, or they will be served by trucks operating out of warehouses in Oregon. (It is assumed that no truck traffic changes mode.)

Measured traffic volumes show that only about 3 percent of the car traffic that normally uses I-5 at Kelso detours across the mountains and uses I-90 to reach I-5. (This is about 7 percent of the car volumes “lost” due to the road closure.)

### **Route Choice on the Detour Route**

Table 5 shows the increase in truck volumes for the average day during the two days of full closure of I-5 in 2007. The count locations on I-90 (B-04) and north of Yakima on I-82 (R48) showed very similar increases, as almost any vehicle making the detour crosses both of these count locations. The P09 count location is on I-82 south of the Tri-Cities. The volume estimate from P09 provides a good estimate of the volume of vehicles that divert via I-84 to I-82. The remaining diverting vehicles

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<sup>16</sup> “Large” trucks include all combination and multi-trailer trucks. They do not include single-unit trucks. Single-unit trucks are included in the “Truck Volume” statistic.

can be assumed to take the SR 97 detour. The assumptions used in the travel cost model that were based on the five tables presented in this section are as follows.

**Table 5: Changes in Volume per Day on Monday and Tuesday of the 2007 I-5 Closure**

Location	Car Volume Increase	Single Unit Truck Volume Increase	Combination Unit Truck Volume Increase
B04: Westbound <b>I-90</b> near Cle Elum	460	165	2360
R48: Northbound <b>I-82</b> North of Yakima	1130	240	2260
P09: I-82 South of Tri Cities	220	20	270

**For TRUCKS.** On the basis of the above statistics, the assumption is that roughly 11 percent of the cross-mountain diversion will go via I-84 to I-82. The remaining 89 percent of the diverting traffic will use the SR 97 cut-off to I-82. It is further assumed that one third of the SR 97 traffic will not be loaded and will thus take the “uncongested” travel time. The other two thirds will take the congested travel time. For the trip via the Tri-Cities, two thirds of trips are assumed to travel under uncongested conditions, and one third will travel under congested conditions. (This distinction is meant primarily to estimate the effects of hills, the need to stop for rest breaks, and the effects of additional urban traffic congestion on overall truck speeds.)

It is assumed that when the US 12 to SR 7/SR 161 detour opens, that route will be fully utilized. The most recent estimate is that this route’s truck capacity will be limited to 50 trucks per hour. Therefore, roughly 1,200 trucks will use this route. If the 100 truck per hour capacity estimate is used, then 55 percent of all “normal” weekday through-truck traffic will use the emergency detour. If 250 trucks per hour can be accommodated, then all through-trucks will be accommodated during the course of the day. Under this last scenario, no trucks will divert over the mountains.

What is not well known is the degree to which the availability of the emergency detour will change the percentage of trucks that are willing to detour. The emergency detour will be, in theory, limited to “emergency” or “high priority” truck loads. Many through-movements are not in those categories but will want to divert. The initial assumption is that only a modest increase (approximately 10 percent) in total detour truck travel will occur because of the new route. Of the truck traffic willing

to make a detour, 43 percent will take the “emergency detour,” with the rest splitting between the SR 97 option (89 percent of the remainder) and the Hermiston option (11 percent).

**For CARS.** On the basis of the survey results described in Table 2, 29 percent of long distance work trips and 32.6 percent of personal trips are assumed to reroute. This slightly over-estimates passenger vehicle volumes observed in 2007 but is assumed to be a reasonable estimate. Of the through-traffic that diverts across the mountains, 82 percent is assumed to use the SR 97 detour route. The remainder will pass through Hermiston. No through-cars are assumed to use US 12 and SR 7, in large part because through-traffic is assumed to be unaware of this route, and WSDOT will not broadcast its availability. (The cars that do use this route are assumed to be internal/external traffic, with drivers who are familiar with the back roads of the area.) All cars using the SR 97 and I-82 (Hermiston) detours are assumed to travel in uncongested conditions.<sup>17</sup>

### **PERSON TRAVEL BY TRIP PURPOSE**

As noted above, personal (car) travel on I-5 is divided into local travel, internal/external travel, and through-movements/volumes. Responses from the mail survey were used to estimate the fraction of each of these vehicle volumes related to business or personal trips. Local trips were divided into commute, other business trip, shopping, and recreational categories. Internal/external and long distance trips were divided only into business and personal trips. The following estimates were used in the cost model:

Local trips:

- 49.5 percent commute trips
- 16.1 percent other business trips
- 21.4 percent shopping trips
- 12.9 percent recreational trips

Internal/external trips:

- 35.9 percent business trips
- 64.1 percent personal trips

Through- (long distance) trips:

- 33.2 percent business trips
- 66.8 percent personal trips.

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<sup>17</sup> The “uncongested travel times” are slightly slower than the speed limit to allow for some drivers to stop for gas or to rest.

## **COST OUTCOMES**

WSDOT estimates that flooding of I-5 will last for 123 hours (five days and 3 hours). It will result in an expected additional travel cost of \$11,872,000. Those costs include \$8,508,000 for additional time and mileage for individuals who must travel to take detours to reach their destinations. Another \$1,614,000 in costs is associated with abandoned trips (that is, trips that would have been made, but either could not be made or were not made because the effort required exceeded the value placed on them by the travelers). The remainder includes costs incurred by the need to take alternative modes (primarily air travel), costs associated with shifting to alternative destinations, and costs associated with choosing to postpone a trip from a preferred time of travel until some time after the flood has receded.

All of these behaviors are associated with a cost. They all represent a loss to travelers, who would have preferred to drive on I-5 as part of their originally planned itinerary. None of the costs presented in this report include estimates of the value of the economic activity lost as a result of trips cancelled or delayed. That is, when a trip is abandoned (not made)—because the individual or company’s valuation of that trip is not higher than the cost of one of the available trip alternatives—then the research team assigns a dollar value to the traveler’s decision. However, a value is not assigned to the activity itself. For example, if a couple were going on an overnight vacation trip and that trip was prevented by flooding of I-5, a value would be assigned to the travelers’ trip to account for their inability to travel. However, an estimate of the economic loss caused by the fact that they did not pay for a hotel at their intended destination is not computed, nor is an estimate of any other economic losses from preclusion of their planned spending at their intended destination. The costs applied to each of these travel decisions are discussed in the Assumptions chapter presented at the end of this report.

The costs presented in this section are based on travel volumes for a closure that starts on a Monday in the late autumn. This replicates the 2007 and 2009 closures. Closures that involve weekend days will have different volumes (higher car volumes but lower truck volumes), which will change the value of the time lost because of the closure. The effects of including a weekend in the closure cost estimate are discussed in the Sensitivity Tests section later in the report.

Because the primary truck detour will not be available for the first 24 hours of the closure, travel behavior on that first day is expected to be quite different than during the remaining four-plus days of the closure. As a result, the costs associated with the first day and all remaining days will also differ. These estimates also assume the lowest emergency truck detour capacity: 50 trucks per hour in each direction, over each 24-hour period. The computed costs for these important days and directions are shown in Table 6.

**Table 6. Total I-5 Closure Travel Cost Summary**

	<b>Direction</b>	<b>Cost</b>	<b>Cost / Day</b>
Day 1	NB	\$1,243,000	
	SB	\$1,243,000	
Day 2 – 5	NB	\$4,693,000	\$1,136,000
	SB	\$4,693,000	\$1,136,000
<b>Total</b>		\$11,872,000	

### **Cost Associated with Cars Versus Trucks**

On weekdays, cars make up about 80 percent of I-5 traffic leading into the area closed by flooding. However, despite the higher car volumes, the value of truck trips is perhaps the most important factor in the cost estimation process. There are several reasons for this. 1) The value of trips (both hourly rate and the cost per mile) is higher for trucks than for passenger cars. 2) A large portion of the truck trips comprises long distance trips, which have a high detour cost, while a much larger proportion of car trips involve shorter distances, and are thus assigned smaller travel costs. 3) In comparison to truck trips, for a much larger portion of long distance car trips, travelers abandon their trip rather than choosing to detour. 4) The current cost estimate spreadsheet assumes that the value of abandoned and destination shifted trips is lower than the cost of taking the available detours, so that the high abandonment of long distance car trips reduces the overall value of car trips. The travel costs (and costs associated with the loss of travel opportunity) associated with the 123-hour closure for cars and trucks are shown in Table 7.

**Table 7. Total Travel Cost by Original Mode of Travel**

	Direction	Costs Associated with Cars	Costs Associated with Trucks
Day 1	NB	\$409,000	\$834,000
	SB	\$409,000	\$834,000
Day 2 - 5	NB	\$1,847,000	\$2,846,000
	SB	\$1,847,000	\$2,846,000
<b>Total</b>		<b>\$4,512,000</b>	<b>\$7,360,000</b>

**Costs Estimated by Behavior Due to the Closure**

As noted earlier in this report, travelers will react to the closure of I-5 in different ways, depending on the type of trip they were planning to take and the options that remain to them after I-5 has been closed. The costs associated with detours are relatively easy to estimate. Costs associated with abandoning trips or shifting destinations because the planned destination is not accessible (or cannot be served by the regular freight depot) are more nebulous. Consequently, to clarify the relative importance of these behaviors, Table 8 shows the number of estimated trips associated with each of these behaviors. Table 9 then shows the costs computed for each of these activities. These tables give a sense of how the total costs reported above were constructed. This will allow easier critical review of the cost totals. The sensitivity of these outcomes is explored in the Sensitivity chapter of this report.

**Table 8. Estimated<sup>18</sup> Number of Trips by Type of Behavior Resulting from the Closure**

	Trips Made Via Detours	Trips Abandoned	Trips Postponed	Trips That Shifted Mode	Trips That Changed Destination
Trips Per Day					
Day 1	32,000	22,600	17,200	800	5,500
Days 2-5+	33,000	19,300	15,900	800	8,000
Total Number of Trips for Days 2 – 5+					
Days 2-5+	135,900	79,800	65,600	3,100	33,000
<b>Total</b>	166,900	102,400	82,800	3,800	38,500
<b>Total Number of Trips Modeled</b>			<b>394,400</b>		

<sup>18</sup> The number of trips are rounded to the nearest 100 trips.

Table 8 shows that only about 42 percent of trips normally occurring on I-5 in the Centralia/Chehalis area are estimated to occur via alternative routes when I-5 is closed. Nevertheless, over 70 percent of the estimated “travel costs” of the closure will be due to the costs caused by additional miles and time for detouring. If higher values are assigned to trips not taken or trips shifted to alternative, less desirable destinations, then the total value of the I-5 closure could increase substantially.

**Table 9. Estimated Costs by Type of Behavior Resulting for the Closure**

		All Travel Costs Due to Detours	All Trip Abandonment Costs	All Costs Associated With Trip Postponement	Costs Associated with Mode Shifts	Costs Associated with Destination Changes
Day 1	NB	\$903,000	\$199,000	\$61,000	\$53,000	\$21,000
	SB	\$903,000	\$199,000	\$61,000	\$53,000	\$21,000
Day 2-5	NB	\$3,351,000	\$608,000	\$181,000	\$220,000	\$308,000
	SB	\$3,351,000	\$608,000	\$181,000	\$220,000	\$308,000
<b>Total</b>		<b>\$8,508,000</b>	<b>\$1,614,000</b>	<b>\$484,000</b>	<b>\$547,000</b>	<b>\$658,000</b>

Table 10 shows the cost per trip not made for each of type of passenger vehicle trip. Table 11 shows those costs for trucks.

**Table 10. Assumed Cost Per Person Per (Car) Trip Not Made on a Detour**

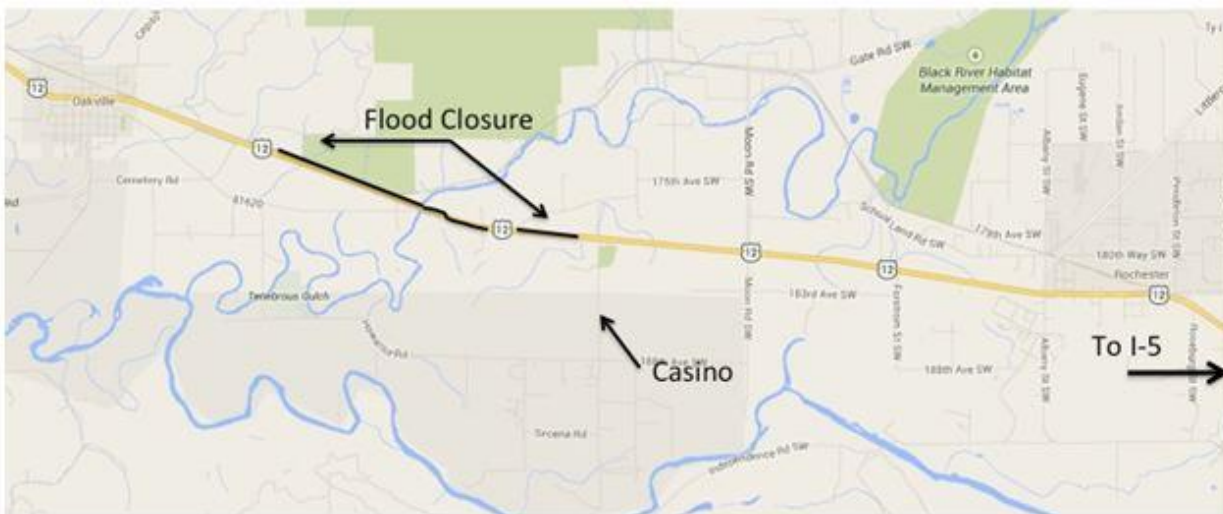
	Local Trips				Internal / External Trips		Through-Trips	
	Commute	Business	Shopping	Recreation	Business	Personal	Business	Personal
Cost per abandoned trip	\$4	\$7	\$4	\$4	\$9	\$9	\$23	\$18
Cost per delayed trips	\$2	\$4	\$2	\$2	\$6	\$6	\$14	\$11
Cost per trip diverted to new destination	\$4	\$7	\$4	\$4	\$9	\$9	\$23	\$18
Cost of trip that shifted modes	\$1	\$1	\$1	\$1	\$1	\$1	\$184	\$184

**Table 11. Assumed Cost Per Truck Trip Not Made on a Detour**

	Local Trips	Internal / External Trips	Through Trips
Cost per abandoned trip	\$8	\$26	\$42
Cost per delayed trips	\$5	\$16	\$26
Cost per trip diverted to new destination	\$8	\$26	\$42

### III. US 12 FLOOD CLOSURE IMPACTS

WSDOT estimates that during the 100-year flood, US 12 will be closed for 152 hours (six days and eight hours). The primary closure will occur east of Oakville and west of Anderson Rd (also known as County Line Rd). The closure will limit access to the Chehalis Indian (Lucky Eagle) Casino from the west. It will not limit access to the Casino from the east (e.g., I-5) where I-5 will still be open to traffic from the north (Olympia/Tumwater). Therefore, it is assumed that traffic to the Casino from the Olympia/Tumwater metropolitan area will not be affected by the closure. (Traffic to the Casino from Centralia/Chehalis will be lost because of the closure of I-5. These traffic losses are incorporated into the I-5 estimate.) Figures 3 and 4 below provide a visual overview of the closure and the detour routes available for traffic currently using US 12.



**Figure 3: US 12 Closure Area**



**Figure 4: Detour Routes for Traffic Currently Using US 12**

It is assumed that there will be no usable eastbound alternatives to US 12 for traffic generated within the closure area. To get to destinations east of the closure, this traffic will have to go west to Elma (there are local roads that connect to Oakville) and—if desired—either go around Capitol State Forest via SR 8 to reach I-5, Olympia, and the rest of the Puget Sound region, or follow US 12 west to Montesano and then use SR 107 and US 101 to reach Oregon and other points south of the I-5 closure.

It is assumed that the majority of traffic on US 12 affected by the closure will be through-traffic heading between Elma and the coastal communities to the west and I-5 and the Centralia/Chehalis area to the east. A modest percentage (20 percent) of the traffic is generated between Oakville and Anderson Road. This traffic will likely have “local” work, shopping, and recreational interests in Centralia/Chehalis, which is the closest major urban center. These trips will be either abandoned as a result of the flood conditions restricting access to Centralia/Chehalis, or redirected to other destinations either in Elma (e.g, for grocery shopping) or Olympia (for trips requiring access to major medical facilities or other services found in major urban centers).

## **TRAFFIC VOLUMES PRESENT**

Traffic volumes on US 12 west of I-5 change significantly, depending on location. AADT near—but west of—the ramps to/from I-5 is roughly 12,000 vehicles. Volumes stay at or above 11,000 AADT until Anderson Rd (MP 38.8). Volumes then drop, with only 6,500 AADT remaining west of Anderson Road. Traffic continues to decline moving west, reaching 4,900 AADT at Oakville (MP 34.9). It then remains low until reaching the outskirts of Elma, where it jumps to 15,000 AADT and finally to 20,000 AADT within the city.

The 2012 Annual Traffic Report listed the truck percentage as 13 percent west of Oakville. A check of truck volumes via WSDOT's SRWeb video images showed that trucks comprised 20 percent of daytime, weekday traffic on US 12. This fits relatively well with the statistics in the Annual Traffic Report, as well as the classification data from WSDOT's permanent traffic recorder (R075), which is located on US 12 east of I-5. Well over two-thirds of the trucks observed in the video review carried wood products. Trucks were evenly split among log trucks, chip trucks, and finished lumber. Only a few trucks observed in the SR Web video were from other industries (e.g., oil tanker, tow trucks). There does appear to be a big plant nursery to the west of the "town" of Porter. Porter is about halfway between Oakville and Elma.

The truck percentage on US 12 on the east side of I-5 (where WSDOT has a vehicle classification counter) varies between slightly less than 10 percent and 20 percent. Truck percentages on weekdays were typically in the high teens in Fall and Winter 2013. Truck percentages on weekends were typically in the high single digits. These changes in truck percentages are typically a result of a decrease in truck volumes rather than a significant increase in car volumes, which appear to be fairly constant across different days of the week. Truck volumes on weekends are less than half of those found on weekdays. Car volumes are generally 200 to 400 vehicles per day lower on Sundays than on weekdays. Saturday volumes are similar to the average day of the week. Both Saturday and Sunday truck volumes are generally one-third to one-half of the average weekday volume.

There is no significant, consistent change in truck percentage from one season to the next on US 12.

With the closure between Anderson Rd to just east of Oakville, costs were estimated for only the traffic that would move between Oakville and Anderson Rd. That is 6,500 total vehicles (3,250 per direction) per day. Truck volumes were estimated as the 900 trucks (450 per day in each direction) on weekdays and half that number of trucks on weekends.

No data were available for day-of-week, time-of-day, or seasonal patterns. They were assumed to be negligible for these analyses.

## **US 12 DETOUR ROUTES**

There are no current local detour routes that serve traffic using US 12 between Oakville and I-5. US 12 travelers who start their trips west of the closure and need to reach points east of the closure must instead travel westward to Elma before turning eastward on SR 8 and US 101 to Olympia. For the majority of the 152-hour closure, these travelers will still not be able to reach either Centralia or points south of Centralia via this route. While travelers may be able to reach the southern portions of the state by following US 12 west to the coast, then US 101 south, SR 4 to Longview, and finally I-5 to their destination, it is assumed that these detours will be too long for most travelers. (The one-way trip from Elma to southern Chehalis would change from roughly 37.5 miles traveled in 46 minutes, to a trip of 167 miles in 192 minutes—assuming no increase in congestion or storm-related slowdowns on US 101 or SR 4.) For log and lumber trucks, this added time requirement will allow only one round-trip per business day between Elma and areas south of Chehalis, instead of as many as four round-trips. Consequently, it is assumed that the vast majority of trips bound for portions of the state south of the I-5 closure will simply be abandoned for the duration of the closure.

Trips headed from the Oakville area to portions of Centralia/Chehalis that are flooded will simply be impossible. Trips headed from Oakville to those portions of Centralia that can still be reached from the north will be made only by traveling through Olympia (via Elma). The majority of day-to-day shopping and freight needs will therefore be met by a detour (and destination change) that goes either to Elma (e.g., for grocery shopping) or through the longer detour to Olympia.

Trips that start or end west of Elma and are headed to Centralia/Chehalis will not need to “backtrack” to Elma to reach SR 8. Their detour will consist only of the added travel distance from Elma to Olympia and then south on I-5 to points just in or just north of the Centralia/Chehalis area. Many of these trips will not be made because their destinations in the Centralia/Chehalis area will not be accessible because of flooding. Other travelers will make this trip once the I-5 closure ends but before the US 12 flooding recedes.

The assumption is that much of the lumber industry will not function during the closure because of inability to reach mills and/or trees as a result of the poor road conditions. Cut lumber is likely to continue to be shipped and will reroute if alternative routes are available, but at most one quarter of these trucks will detour.

## **DETOUR ROUTE AND BEHAVIORAL ASSUMPTIONS**

On the basis of the traffic volumes reported by WSDOT on US 12, the following are the assumptions made and used in the flooding cost estimation: 26 percent of traffic (1,700 vehicles per day) affected by the flood on US 12 will start or end a trip in Oakville or points to the east of Oakville but west of the flood closure. The remaining 74 percent of trips (4,800 vehicles per day) affected by the closure will start/end their trips at Elma or west of Elma.

Half of the traffic starting or ending near Oakville will be abandoned. Half of all of the trips made by this population will be personal trips that change destination and travel to Elma. The remaining trips will be work-oriented trips that will take the Olympia detour. (The abandoned trips are assumed to be those trips with unreachable destinations in Centralia/Chehalis.) This means that on weekdays roughly 425 trips will be made via these two detours. Of the 425 trips made to Olympia, 14 percent (60 trips) will be truck trips.

For the trips starting or ending in, or west of, Elma, 80 percent will be abandoned, mostly because they cannot reach their intended destination in the Centralia/Chehalis region, but also partly because of the length of the detour required to reach the destinations that are still accessible. The remaining 20 percent of the traffic will be willing to take the available detours. Half will travel to/from locations south of Chehalis. The other half will shift their destination to one that can be reached via Olympia. All of the trips made to the south will be work-related (high value) trips. In both cases 14 percent of the trips are assumed to be made by trucks.

Note that these assumptions are different than the assumptions used for I-5. The survey results used as a guide for determining I-5 travel behavior are not directly applicable to US 12.

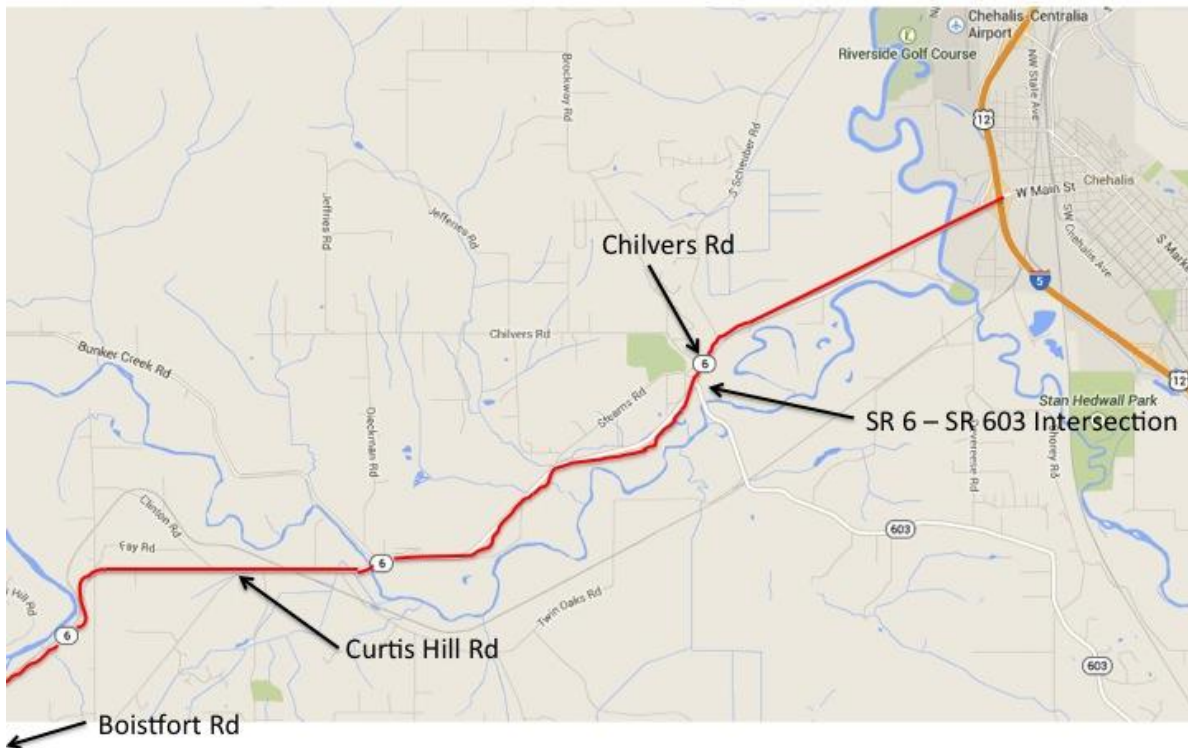
## **OUTCOMES**

Flooding of US 12 for 152 hours (six days and 8 hours) results in an expected additional travel cost of \$340,000. Those costs are divided into \$206,000 for additional time and mileage, as individuals who do need to travel will have to take very extensive detours to reach their destinations. Another \$134,000 in costs is associated with abandoned trips (that is, trips that would have been made, but either could not be made or were not made because the effort required exceeded the value placed on them by the travelers).

Of the just under 41,200 trips that would have used US 12 over the 152-hour period, this analysis concluded that only about 11,500 trips will still be made. The remaining 29,700 trips will be abandoned. Note that the above computations place a value of roughly just over \$3.20 per personal trip and \$9.00 for a truck trip for abandoned trips. This is based on the value of 80 percent of the lowest detour cost modeled. If a higher value is assigned to abandoned trips, then the cost of abandoned trips due to the flooding of US 12 flooding will be higher.

## IV. SR 6 FLOOD CLOSURE IMPACTS

WSDOT predicts that during the 100-year flood, SR 6 will close for 51 hours (two days and 3 hours). The closure will occur in multiple places on SR 6, as this road parallels the Chehalis River and crosses over the river several times. In addition, some of the roads that collect and deliver traffic to (or accept traffic from) SR 6 cross the river and are subject to flooding. Figure 5 shows the portion of SR 6 that is closest to Chehalis and that carries the most significant traffic volumes.



**Figure 5: SR 6 Near Chehalis**

There are very few alternatives to SR 6. However, other roads exist that allow people who would otherwise use SR 6 to travel. For example, SR 603 can be used to reach Napavine to the south, and then from Napavine to reach I-5. However, during the flood event, this alternative will not be accessible to traffic on SR 6 because portions of SR 603 where it meets SR 6 will also be underwater. However, using SR 603 to the south will provide a detour for residents who live along the SR 603 corridor and would otherwise travel north on SR 603 to reach SR 6 and then turn east to reach destinations in Chehalis or Centralia.

Similarly, to the west of SR 603, the only alternative to SR 6 appears to be a detour on Boistfort Rd (or Curtis Hill Rd) to reach Wildwood Rd, which can be taken all the way south to SR 506 and then to Vadar. “Curtis” is the location of (what appears from the aerial photograph to be) a lumber mill. While the same flooding issues that affect the eastern end of SR 6 are likely to also affect SR 6 in this area, like SR 603, the Boistfort Rd/Wildwood Rd detour will serve a valley that would otherwise generate traffic that would be using SR 6. If they need to travel, it is assumed these travelers will follow this detour.

No traffic is assumed to go east/west on SR 6 because of the multiple flood points.

It is also assumed that residents north of SR 6 will not be able to travel during the flood event, with the exception of a small fraction of residents who live west of S. Scheuber Rd. This small group of individuals will be able to reach the medical complex in the southwestern suburbs of Centralia via Scheuber Rd. They are assumed to be an inconsequential number of travelers. All other users who live north of SR 6 in the general vicinity of Chehalis are assumed to be stuck in their houses until the flood waters recede and all trips they would have otherwise made are assumed to be abandoned.

## **TRAFFIC VOLUMES**

Traffic data were taken from the WSDOT Annual Traffic Report. Starting at I-5, traffic volumes on SR 6 are around 11,000 AADT. Traffic volumes then decline by 2,600 vehicles at Chilvers Rd, and by another 1,800 vehicles at Twin Oaks Rd. Finally, volumes drop to 3,100 vehicles by Curtis Hill Rd. AADT is 3,500 west of Curtis Hill Rd.

No truck volume data are available for State Route 6 from the WSDOT Annual Traffic Report. A quick count of cars and trucks passing the WSDOT video van used to collect the SRWeb video indicated that the percentage of trucks on SR 6 during the day is 8.8 percent between I-5 and Boistfort Rd. To account for lower truck traffic at night, a value of 6.7 percent was used for the cost analysis for the flood closure at the highest volume sections of SR 6. A value of just over 8 percent was used for through-traffic. (These estimates probably slightly over-estimate the daily percentage, as over 90 percent of the trucks observed are log trucks, which will only operate during the business day, and mostly during daylight hours.)

No data were available for day-of-week, time-of-day, or seasonal patterns.

## **DETOUR ROUTE ASSUMPTIONS**

The following assumptions were used: Half of traffic getting on SR 6 near Chilvers Rd will come from the north and will have no rational detours available during the flood event. The other half of that volume (1,300 vehicles) will come from the south and can take advantage of the SR 603 detour. (It is 2.5 miles to Chehalis from Chilvers Rd, but since trips will start in the valley south of SR 6, the detour model assumed a 5-mile average trip distance versus a 7-mile trip to Napavine via SR 603.)

Similarly, half of the traffic adding to SR 6 at Twin Oaks Rd will come from the north and therefore have no viable detour during the flood. The other half of the Twin Oaks traffic will come from the south and can access SR 603 via local roads (Pleasant Valley Rd, Haight Rd, and Carroll Rd). This detour will be the twice the length of the SR 603 detour. Because this trip will use local roads, travel speed will be half of the normal speed. The detour trip is assumed to be 8 miles (5 miles on SR 6).

The vast majority of the traffic joining SR 6 at Curtis Hill Rd will come from the south and be able to take the detour via Wildwood Rd to Vadar.

The 3,500 vehicles using SR 6 west of Curtis Hill Rd will be unable to reach Chehalis. Travelers will meet daily needs by traveling west to Pe Ell. Long distance travel will be either abandoned or head west to meet US 101 at the coast, and then go either south to Astoria/Portland or north to Aberdeen/Elma/Olympia.

## **BEHAVIORAL ASSUMPTIONS**

In modeling travel behavior for SR 6 versus that for I-5 travel, there were a number of major differences in assumptions.

The first major assumption was that all traffic starting north of SR 6 will be essentially without travel options and must therefore abandon all trips on SR 6 for the duration of the flood event.

The second assumption was that there will be no alternative mode available, so all travel that was assumed to occur has been assigned to the detour option. Similarly, since Chehalis and Centralia will not be reachable via SR 6 or I-5, and no other options will exist for trips that would use SR 6, all detoured trips will have to choose an alternative destination. (As noted above, these alternative destinations are Napavine and Vadar. For simplicity's sake, the alternative destination option was been zeroed out in the analysis spreadsheet, and all trips were simply assigned to the appropriate detour so costs could be computed based on the time and mileage associated with those detours.

Finally, all postponed trips were assigned to the abandoned trip category. As a result of these assumptions, the model assumed that approximately just one-quarter of trips will be made, with the rest

abandoned (This may over-state the willingness of those individuals to travel, as many businesses are likely to be closed.)

These same fractions were applied to truck trips. The majority of SR 6 truck trips observed in the SR Web video were log trucks. It is not clear whether these trucks will be able to reach their destinations via the available detours, but for this analysis one-quarter were assumed to be able to travel.

## **OUTCOMES**

**Flooding of SR 6 for 52 hours will result in an expected additional travel cost of \$114,000.**

Those costs are divided into \$29,000 for additional time and mileage, as individuals who do travel will need to take back roads to reach their destinations, and \$85,000 in costs associated with abandoned trips (that is, trips that would have been made but either could not be made or were not made because the effort required exceeded the value placed on them by the travelers).

Of just under 24,000 trips that would have used SR 6 over the 52-hour period (assumed to be weekdays), this analysis assumes that only about 4,200 trips will still be made. The remaining 19,800 trips are assumed to be abandoned. Note that this values abandoned trips at just under \$4 per trip (80 percent of the cost of the smallest detour available, which means that a personal trip is worth ~\$1.50 and a truck trip is worth \$18.00). If a higher value is assigned to abandoned trips, the cost of the SR 6 flooding will also be higher.

(Note that the value of the abandoned car trips is fairly low because the distances involved with many of the trips via SR 6 are fairly short. Many of these trips will be postponable until the flood subsides. Truck trips are valued higher in part because of the longer estimated detours.)

## **V. GENERAL ASSUMPTIONS USED IN THE MODEL**

This chapter presents the assumptions that were used in the adopted travel cost model. All of these assumptions can be readily changed in the spreadsheet model.

## **SUMMARY OF KEY STATISTICS**

The following statistics are used in the cost estimation model and play important roles in the development of those estimates. This section summarizes those key statistics. Additional detail is provided later in this chapter.

## **Value of Time and Mileage**

The value of time statistics used in the primary cost estimates were taken from the USDOT's value of time guidance.<sup>19</sup> These estimates are shown in Table 12. The WSDOT study of the Skagit River Bridge closure<sup>20</sup> used slightly lower values of time (\$11.42 per person-hour for automobile travel and \$24.44 per person-hour for truck travel). The WSDOT Skagit River value is very similar to the USDOT "local, non-business trip" statistic. The following values of time were used in the primary cost analysis.

**Table 12: Value of Time Recommended by USDOT and Used in the Primary Cost Estimate**

<b>Individuals</b>	
Local, Non-Business Trips	\$12.00 / hour
Intercity Personal Trips	\$16.70 / hour
Business Trips	\$22.90 / hour
<b>Trucks</b>	
All trips	\$24.70 / hour

The value associated with specific detours was then computed by using the assumed distance and travel time associated with each detour. The cost of the detours was computed as the added time and mileage associated with each detour.

The cost of mileage for passenger cars and trucks was initially taken from the WSDOT Skagit River Bridge diversion study. These were \$0.20/mile for cars and \$1.10/mile for truck. However, the passenger car estimate was increased to \$0.21, which is the value published in the *2013 AAA Cost of Driving* report for a medium sedan. Like the corresponding value for trucks, this includes the estimated unit cost of fuel, maintenance, and tires.

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<sup>19</sup> September 21, 2011 memorandum from Polly Trottenberg, Assistant Secretary for Transportation Policy, available as of April 10, 2014 at: [http://www.dot.gov/sites/dot.dev/files/docs/vot\\_guidance\\_092811c.pdf](http://www.dot.gov/sites/dot.dev/files/docs/vot_guidance_092811c.pdf)

<sup>20</sup> I-5 Skagit River Bridge – Estimate of the Direct Cost of Closure, WSDOT Freight Systems Division, WSDOT Budget and Financial Analysis, August 2013

**Table 13: Cost of Added Mileage Driven Used in the Primary Cost Estimate**

Passenger Vehicles	\$0.21 / mile
Truck Trips	\$1.10 / mile

### **The Cost of Trips Not Made**

One of the most difficult tasks in making this estimate was to assign a cost to the travel that would NOT be made because of flooding. This is not the economic cost of the activity that does not occur (i.e., we did not estimate the loss of economic benefit from shopping trips that would not occur), but an estimate of the value of the trip to the traveler. That is, travelers would prefer to be traveling, so there is a net negative value caused by their inability to make the desired trip.

Four different types of travel behavior can occur other than taking a detour to reach an originally planned destination. These behaviors are

- abandoning the trip altogether (the trip is simply not made)
- diverting the trip to another destination so that the closed road is no longer needed and the detours are not used either
- delaying the trip until sometime after the closed road is reopened
- taking an alternative mode to the original destination.

In all cases but the mode choice alternative, travelers are assumed to value these trip choices lower than the cost (time and marginal mileage costs) of the detour options, or else the traveler would choose to take the detour.<sup>21</sup>

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<sup>21</sup> An exception to this is the case in which one vehicle expected to make multiple trips using the closed road during the flood closure period, and the time and distance required by the detour prevents that vehicle/driver from making those intended trips.

In addition to voluntary abandoning of trips, abandoning trips happens in two other cases. In one case, travelers may abandon trips simply because they cannot be made. This will be the case on SR 6 for trips beginning and ending from the residential areas north of SR 6. These housing areas will be cut off from shops and places of work because SR 6 is the only road to those destinations. A second case is that some truck trips may be abandoned simply because trucks are not available to make the trip. This can happen when the detour route is particularly long. For the US 12 closure, this could occur if a log truck needed to deliver logs from a forest site near Elma to a mill south of Chehalis. Normally a truck could make this trip (one way) in an hour and thus make two or three trips during a workday. However, if the only route between Elma and south of Chehalis involves driving down the coast on US 101, the detour distance and trip duration will limit a truck and driver to one round-trip per day. Unless the logging company has multiple unused trucks and drivers, even if the value of the log delivery warrants the use of the detour, for many small firms, there will be insufficient trucks and drivers to make all three round-trips. Therefore, it would be assumed that at least two trips to the mill will be abandoned.

For the primary travel cost estimate, **abandoned trips were estimated to be worth 80 percent of the added cost of the minimum detour route for a given trip.**

An alternative to abandoning a trip is to change its destination. For personal trips this may mean shopping at a different grocery store (in some cases, a store in a different city). For truck trips, this may entail a complete shift in the shipping patterns of some goods. For example, trips normally served by a warehouse in the Portland metro area might be served by a warehouse in the Puget Sound region. This change in trip origination implies additional costs to the companies (or else those stores would have already been served by those distribution centers). Specific costs involved include the added time and mileage associated with those trips, plus management time to plan and implement the change in freight delivery/pick up destination plans.

For the primary travel cost estimate, **“diverted” trips were estimated to be worth 80 percent of the added cost of the minimum detour route for that trip.**

Many trips are simply delayed until the road opens. During short closures, both trucks and passenger vehicles typically wait out the closure. This occurs when the detour options are more onerous than the duration of the delay. During the 2009 closure of I-5, most trucks simply waited for I-5 to re-open because I-90 was also closed, and the closure lasted for only two days. For short closures, the cost of the delay can be estimated as the hourly rate (see above) times the length of the closure (maximum of 10 hours per day). However, this type of estimate over-states the value of long closures. For a long closure, the trip is often indefinitely postponed. That is, the traveler does not sit beside the road waiting

to resume traveling; instead, the trip is postponed until the conditions are right. The traveler might wait one entire month before making the rescheduled trip. The traveler is productive during the time between the closure and the trip's resumption. Therefore, the delay is not perceived as a function of the duration of the closure.

Because the 100-year I-5 closure will be a long one, for the primary travel cost estimate, **delayed trips were estimated to be worth half of the added cost of the minimum detour route for that trip, rather than being estimated as a function of the duration of the closure.**

The availability of alternative modes is heavily dependent on the types of trips that are affected by the road closure. For the Chehalis River flood, long distance trips (Seattle to Portland and longer) can be served by air travel. (Rail travel will be disrupted by the flood.) It is not expected that bus travel between the cities will add capacity, nor is it entirely certain that these services will not also be disrupted for the duration of the road closure because of the cost and labor issues associated with the long detour routes. Consequently, most high value, long distance travel will take place via air. **The cost of travel for these long distance movements was set equal to the round-trip airfare for the trip between Seattle and Portland purchased on short notice.** This underestimates the cost of longer trips (which will require more expensive airfare, or will also involve the need to rent a car to reach the final destination). However, that cost will be offset by the fact that some travel will not require air travel in both directions.

Most local trips within the Centralia/Chehalis area will be disrupted. Portions of at least four of the five Lewis transit routes will be under water. It is not known whether Lewis County Transit will implement some flood condition transit service. If so, then that will be an option for local travel within the Centralia/Chehalis urbanized areas, but little travel is expected to occur via bus. **The fare for local bus use was set at the cost of a one-way trip, \$1.**

## **Other Statistics**

To compute the time cost of a detour, it is necessary to understand the average occupancy of cars operating on the closed section of I-5. **The assumed car occupancy was 1.1 persons per car.** This is the value used in WSDOT's Skagit River Bridge study. It is also similar to commonly used vehicle occupancy values in urban areas, which are typically in the 1.1 to 1.3 range.

**For trucks, vehicle occupancy was assumed to be 1.0.** This value also comes from the Skagit River Bridge study.

## **DETOUR COMPUTATIONS**

The time and mileage computations for flood detours were computed by using a combination of Google Maps and Inrix roadway performance information. Google maps provides a simple way to compute basic roadway distances and expected travel times from almost any point to any point, along with the ability to create specific paths. The Inrix dataset, purchased for use by WSDOT, allows travel time reliability to be analyzed on state routes. Travel time reliability is important because it provides an estimate of travel times under congested conditions.

During the flood conditions being studied, detour routes will frequently operate at speeds well below their normal conditions, both because the bad weather that causes the floods is likely to impact the performance of other roads and because heavy detour volumes are likely to reduce speeds on those routes. This was seen in the 2009 closure of I-5, when the same weather system that caused the Chehalis River to flood also created avalanche conditions on Snoqualmie pass, forcing I-90 to close. Finally, even in uncongested conditions, heavy trucks do not operate at the same speeds as cars, especially on hilly terrain. On interstates in Washington, trucks also have a lower speed limit than cars. Consequently, trucks are expected to take longer to make some trips than cars.

The estimates of the congested travel times used in the analysis were based primarily on professional judgment given the data provided by Inrix. For the emergency truck detour using US 12, SR 7, and SR 161, a doubling of the free flow travel time was selected for three reasons: 1) added congestion is expected on that corridor (including the inability to easily pass on the two-lane road), 2) trucks have difficulty passing each other in opposite directions on some curves, and 3) a large amount of debris (tree branches, leaves) and water is expected on the roadway surface as a result of the storm.

## **SIZE OF THE EMERGENCY TRUCK DETOUR**

A major assumption underlying a large portion of the costs is the estimated number of trucks that will be willing to detour when I-5 is closed. The estimates used for the primary cost were based on observed behavior from the 2007 closure. During that closure, which occurred when I-5 traffic volumes were quite similar to those currently on I-5, roughly 2,500 trucks per day in each direction of travel diverted via I-90 and I-82. The other trucks normally using I-5 disappeared from the traffic stream. This means they either abandoned their trip, or trucking patterns were changed such that deliveries that would normally have used I-5 did not use either I-90 across the mountains or I-82. (A review of traffic north of Seattle suggests that truck volumes between Seattle and the Canadian border declined slightly.) This suggests that many of those truck trips simply did not occur during the four-day closure. These trips also were not made during the days immediately after I-5 was re-opened to traffic. Consequently, for this study, total truck detour volume per day was assumed to be equal to roughly the volume per day observed in 2007.

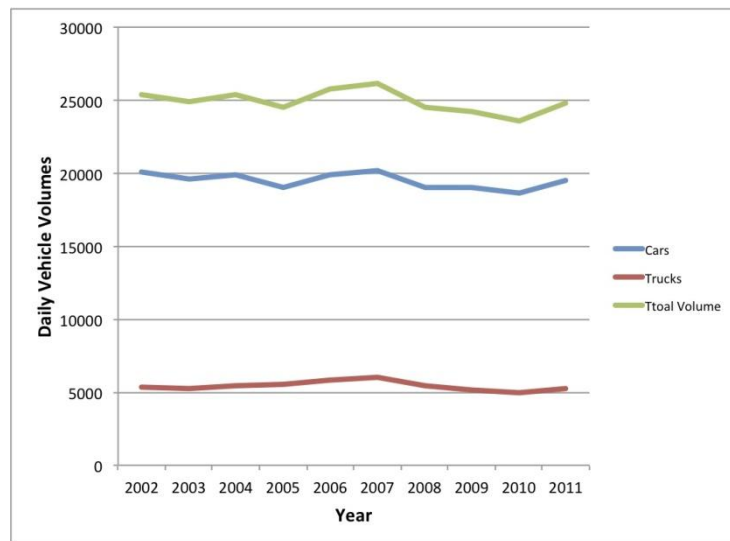
Note that for the two-day closure of I-5 in 2009, no trucks detoured. (No viable detour was available because of the simultaneous closure of I-90 over Snoqualmie Pass.) In the 2009 case, however, the closure appears to have been short enough that the vast majority of trucks simply waited out the closure and traveled on I-5 during the five days immediately following the re-opening of the roadway. In 2009, car volumes did not rebound after the road was re-opened. In fact, car volumes declined on I-5 during the entire week following the closure. This continuing decline in car volumes was not modeled in the costs for this study's closure of I-5. In the longer closure of 2007, car volumes returned to normal levels shortly after the roadway was re-opened.

## **CAR AND TRUCK VOLUMES USED**

One of the most important assumptions in the cost model is the volume of cars and trucks affected by the flood closures. Analysis of truck and car volume patterns on I-5 indicated that while volumes grew steadily for many years, for the past twelve years they have plateaued (Figure 6). Figure 7 shows this same lack of growth on I-5 south of Tumwater. Consequently, the traffic volumes used in the current flood analysis were 2013 volumes. These volumes are assumed to represent traffic conditions in the near future (the next five years) quite well. If the time horizon of the analysis is extended further than five years from now, it is distinctly possible that both car and truck volumes will grow, especially if the population of the Puget Sound region grows as expected.

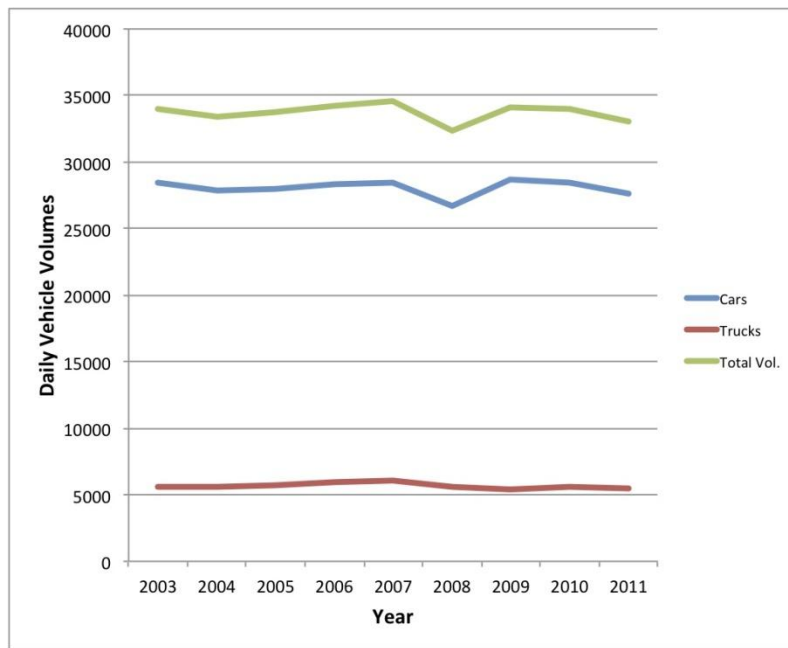
Traditionally, increased population growth would be expected to increase both passenger car traffic on I-5 and the number of trucks needed to deliver goods that serve that population. However, this pattern has not held true for the decade 2000 to 2010, when increases in population of roughly 10 to 20 percent occurred in all of the counties along I-5 without corresponding increases in traffic volume.

The budget for this project did not include a specific forecast of future traffic volumes. Consequently, current volumes were used to estimate the cost of the flood closures. The impact of possible future traffic growth on those estimates is discussed in the next chapter, which examines the sensitivity of the travel estimates to the primary input assumptions.



**Figure 6: Average Daily Traffic Volumes, Northbound on I-5 at Kelso<sup>22</sup>**

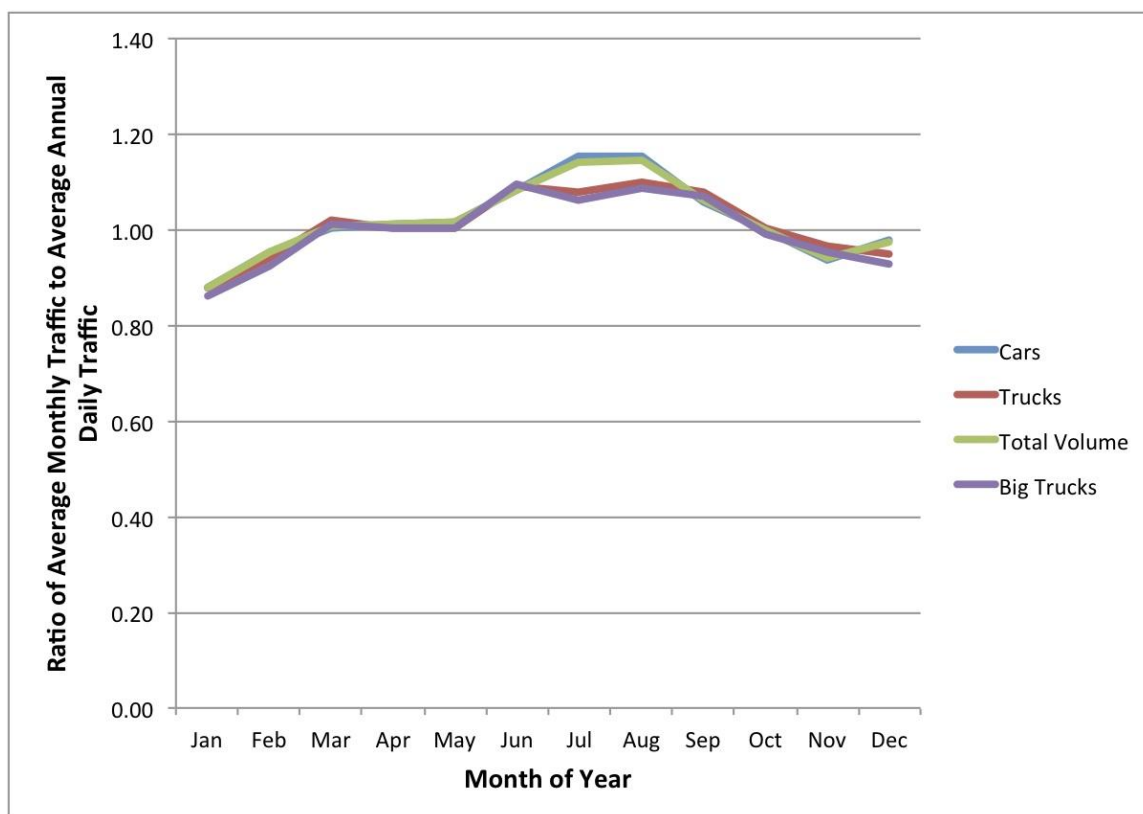
<sup>22</sup> Volumes presented in this figure are simple averages of the available data at WSDOT's permanent counter P8.



**Figure 7: Average Daily Traffic Volumes Southbound on I-5 South of Tumwater<sup>23</sup>**

Two other factors are relevant to the traffic volumes that will be affected by a flood related closure: these are the time of year in which the flood occurs and the days of the week of the closure. Figure 8 illustrates typical changes in average daily traffic volume by month of year. This curve shows that the late fall and winter months—when weather conditions are most likely to result in flooding—experience the lowest traffic volumes of the year. This is true for cars, total trucks, and heavy trucks. Volumes from November and December 2013 were used to indicate actual volumes that would be affected by the flood. If the 100-year flood occurs in the summer, the primary estimate of flood costs will under-estimate the actual volumes affected and therefore will under-estimate the total cost to travelers of the closure.

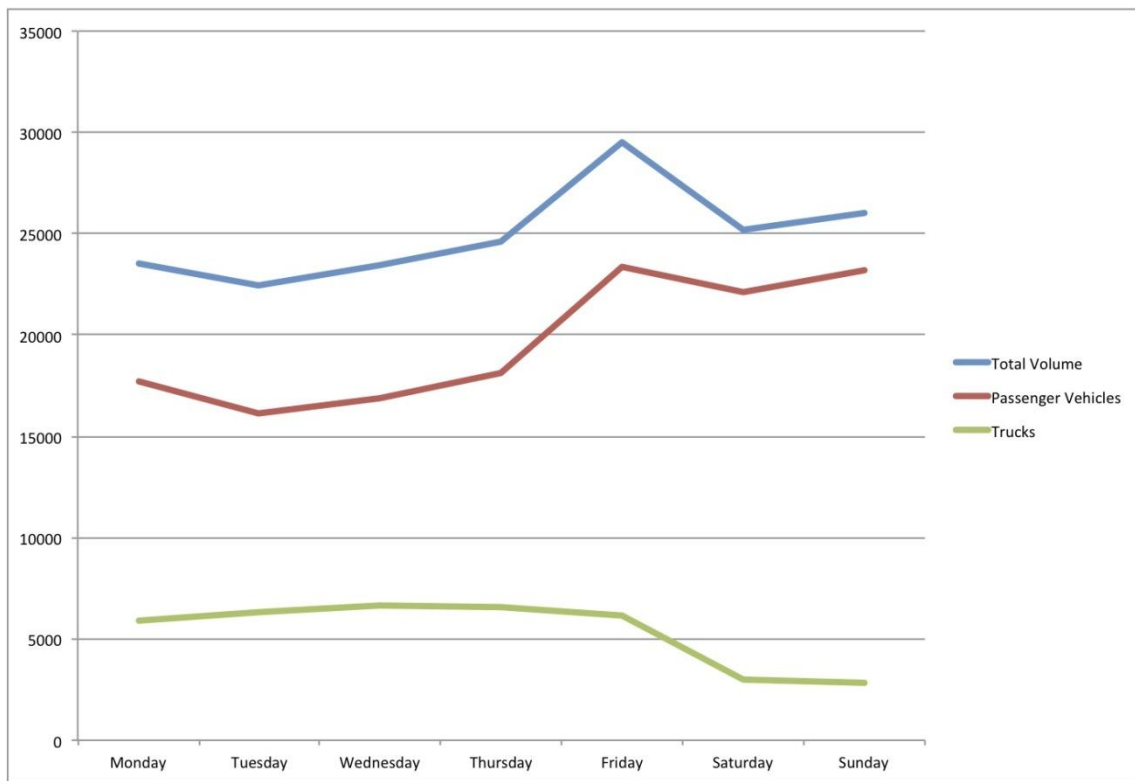
<sup>23</sup> Volumes presented in this figure are simple averages of the available data at WSDOT's counter R097. These values do not attempt to account for minor biases in the totals due to missing days of data. The effects of this bias can be seen in the 2008 estimate because data from May, June, and July – which are months with high car volumes—are missing. The result is a decrease in the mean traffic volume estimate computed with a straight average.



**Figure 8: Seasonal Traffic Volume Patterns on I-5, Northbound, South of Tumwater<sup>24</sup>**

Day of week patterns also affect the volumes changed by a flood. In rural areas along I-5, passenger car volumes are typically higher Friday through Sunday than Monday through Thursday. Conversely, truck volumes on the five weekdays tend to be almost double the volumes observed on Saturday and Sunday. Figure 9 illustrates these trends by using average day-of-week volumes, northbound on I-5 just north of Kelso. On more urban segments of I-5, truck patterns are similar to those in rural areas, but car volumes are lower on weekends than on weekdays because of the high commuter volumes on weekdays. Since both the two closest WSDOT counters north (R019) and south (P8) of the closure area show rural patterns, the rural patterns were used in this study for estimating traffic volume patterns.

<sup>24</sup> In Figure 8, the term “Big Trucks” represents the combined volume of combination and multi-trailer trucks. The term “Trucks” includes both these types of trucks and single-unit trucks.



**Figure 9: Average Day of Week Volumes on I-5 Northbound at Kelso**

What these patterns indicate is that if the flood occurs on a weekend, fewer trucks will be affected than on a weekday, but more cars (and total volume) will be affected. For a flood that lasts five days, such as the forecast 100-year flood, it is likely that the closure will affect both weekdays and weekends. The primary cost estimate assumes that the flood will occur on late Sunday night or early Monday and thus cover only weekdays. This will result in the highest number of trucks being affected, and because the value associated with disrupting truck travel is higher than that for cars, this assumption will result in the highest estimate of costs associated with the closure.

The effects of the flood occurring over a weekend and/or during the summer are explored in the Sensitivity chapter.

## **VI. SENSITIVITY TESTS**

This chapter presents the results of key sensitivity tests. The cost estimates provided in the previous chapters were based on a large number of assumptions. Those assumptions are discussed in the previous chapter. Changing those assumptions will affect the dollar values associated with travel disruptions caused by the flooding. This chapter discusses the impacts of changes to those key assumptions so that readers can determine their relative confidence in the primary estimates of the travel costs presented in Chapter 4.

The key areas of sensitivity testing described below include the following:

- the value of time
- the speeds and level of congestion assumed to occur on the routes used for detours
- the values associated with trips that are NOT made via the expected detours as a result of flooding
- the percentage of personal trips made for work/business purposes versus those being made for personal reasons
- the fraction of cars and trucks willing to detour
- the effects of flood closure during the weekend or the summer
- growth in traffic volumes on I-5.

### **VALUE OF TIME AND ADDED MILEAGE**

The USDOT value of time was used to compute the costs for the primary estimates. These estimates are slightly higher than the estimates that WSDOT used for the Skagit River bridge detour study. If the WSDOT costs are used (\$11.42/hr for “local, non-business trips,” and \$0.20/mile for passenger car mileage, and \$24.44/hr for the value of time for trucks, instead of \$12.00/hr, \$0.21/mile, and \$24.70/hr, respectively) then the computed costs for the detour drops by 3.5 percent, from \$11,872,000 to \$11,455,000.

This suggests that it is essentially irrelevant which of these two sets of base cost values is used, as neither significantly changes the outcomes of the analysis.

### **CHANGING THE SPEED ASSOCIATED WITH “CONGESTED” DETOURS**

If the “congested” travel time on the emergency truck detour is assumed to be 1.5 times the uncongested travel time for the trip instead of 2.0 times the free flow travel condition, the expected cost

of the entire I-5 closure drops 1.6 percent, from \$11,872,000 to \$11,685,000. (Note that cars are assumed to not use the emergency truck detour. This is because the detour will not be signed, no trips other than the emergency truck movements will be encouraged, and WSDOT has suggested that it may use manned check points to limit access to these roads to local residents to maintain safety. While some locals will use this detour, it is assumed that few long distance trip makers will know about, or be able to take advantage of the availability of these roads.)

If all trucks using the emergency truck detour operate at the estimated free flow speed, then the total costs for the I-5 closure will drop to \$11,498,000.

If all three of the long distance detours are assumed to operate under free flow conditions (meaning that loaded trucks operate at the speed of cars and no congestion is caused by detouring vehicles), then total estimated costs for the long distance detours for both cars and trucks will drop further, producing a total estimated cost of \$10,746,000.

This suggests strongly that the fraction of trips made under congested conditions, at least for this multi-day closure scenario, play only a modest role in determining the total travel cost of the closure of I-5.

### **CHANGING THE VALUE ASSOCIATED WITH TRIPS NOT MADE**

If the value of abandoned, diverted, or long-term postponed trips is 60 percent of the minimum applicable detour cost (holding constant all of the other original assumptions), rather than 80 percent, then the total value of the flood closure decreases to \$11,304,000. This is a roughly 5 percent decrease from the primary estimated cost of the I-5 flood closure.

### **SHIFTING TRIP PURPOSES**

The National Household Travel Survey (NHTS) taken in 2009 indicated that in general only 16 percent of trips are work related. In our survey, the percentage of I-5 trips that were work related was much higher. Over 50 percent of local trips on I-5 were reported to be work related. 36 percent of internal/external trips were work related, and 33 percent of long distance trips were reported as work related. These percentages were used in the cost estimate. This makes sense in that many social and recreational trips are taken without need for access to major freeways. However, the survey may overstate the fraction of trips using I-5 that are work related.

If the estimated fraction of trips that are work related is halved, and those trips are distributed to the other travel purposes in proportion to the survey responses, then the total cost of flooding will be reduced because personal trips are valued at lower rates than business or work trips.

This reduction in estimated work travel and corresponding increase in personal travel will result in the total estimated cost of the flood closure dropping by 2.6 percent, to \$11,564,000.

### **CHANGING THE FRACTION OF TRUCKS AND CARS WILLING TO DETOUR**

The primary cost estimate was based on an estimate of 50 trucks per hour in each direction for the capacity of the emergency truck detour, starting at the second day of an I-5 closure. The primary cost estimate for this closure assumed 2,777 total trucks detouring, a slight increase over the truck volume observed in the 2007 flood closure (2,500 trucks per day per direction). Of those trucks, 43 percent will use the emergency truck detour starting on day two. The remainder will use the traditional I-90 detour. Of those trucks using the I-90 detour, 89 percent will use US 97 to reach I-82. The remaining trucks will use I-84 to reach I-82.

Early estimates of the emergency truck detour's capacity were 100 trucks per hour southbound and 250 trucks per hour northbound. Given these estimates, the northbound capacity of the emergency truck detour can carry all I-5 trucks, but the southbound capacity will not allow for all of trucks to use the detour. Given these estimates, it can be assumed that northbound, no through-trucks currently using I-5 will change behavior, other than to use the emergency truck detour. (That is, all through-trucks will use this detour. No trucks will abandon their trips or divert their trips to other destinations.) Southbound, it is assumed that 81 percent of the normal truck volume (4,300 trucks) will continue to make the through-trip, and 55 percent of those trucks will be able to take the emergency truck detour. The remaining trucks are assumed to use I-90 and travel over the mountain passes. (It is not clear whether these assumptions are realistic, as a decrease in trucks moving south may limit the number of trucks available to carry goods northward.)

Under these assumptions, the total estimated cost of the I-5 flood closure decreases slightly to \$10,970,000. The changes that result from these differing assumptions is a decrease (\$450,000) in the costs attributed to time and mileage associated with detours, as well as a decrease of \$220,000 in the costs associated with abandoned trips and a similar amount (\$220,000) associated with trips that must serve or be served by alternative destinations.

If a much lower cost is attributed to abandoned trips (e.g., 50 percent of the detour cost instead of 80 percent), then adding capacity to the emergency detour route—subsequently increasing the total number of trucks using one of the detours—will actually make the total cost of the flood more costly than if no detour were provided and thus limit the number of trucks selecting to detour rather than abandon the trip entirely. It is for this reason that a value of 80 percent of the minimum detour cost was selected as the value of an abandoned trip.

The U.S. Army Corp of Engineers' National Economic Development report, *Flood Risk Management*, IWR Report 2013-R-05, published in June 2013 states, "The cost of traffic disruptions caused by flooding is equal to the value of the resources required to use alternative modes of transportation or routes for the disrupted traffic. This can include increased fuel costs, increased wear and tear on equipment, and the value of the time spent in longer routes." If this is taken literally, then the cost of the disruption to traffic should be computed based on the assumptions that all disrupted travelers can, and do, take the available detours to reach their intended destinations. If all planned trips are assumed to use the available detours—and the emergency truck detour capacity is set at 50 trucks per hour in each direction, starting on the second day of the disruption—then the estimated I-5 traffic cost of the 100-year flood will be \$20,576,000.

## **USE OF WEEKEND OR SUMMER CAR AND TRUCK VOLUMES**

This section describes the effect on estimated travel costs on I-5 due to the 100-year flood if that flood occurs over a weekend. The major effect is that traffic volumes will be different. On weekend, truck volumes decline significantly, while car volume increase modestly. Weekend trips are also taken for different purposes (e.g., less work related travel takes place), and therefore travel behavior may be different. The assumptions used to account for these differences in the cost estimate are given below. The computed costs are then presented in the next subsection.

### **Weekend Volume Assumptions Used**

As noted in the previous chapter, truck volumes on I-5 on the weekend are roughly half of those found during weekdays. Estimated typical weekend volumes based on data from WSDOT's counters are described in the following sections. Of the 2,000 through-trucks that use I-5 in each direction on a weekend day, 90 percent are expected to detour. (It is assumed that the vast majority of weekend truck traffic needs to keep moving.)

For passenger vehicles, it is assumed that 90 percent of travel on the weekends is not business related. (For local trips, the added fraction of trips that was classified as not work-related was split proportionately between shopping and recreational trip purposes.)

### **From South of Tumwater, Heading South**

At South Tumwater on I-5, roughly 29,200 cars and 3,200 trucks travel in each direction on a normal late Fall weekend day. At this point, 2,600 cars and 200 trucks exit before the closure (based on observations at WSDOT counter R019). These vehicles are assumed to be destined for points north of the closure and are subtracted from the total.

Consequently, combined through-traffic and internal/external traffic volumes to and from the north are 26,600 cars and 3,000 trucks, for a total volume of 29,600 vehicles each weekend day. Of those vehicles,

- 9,000 cars are driving headed to Portland

- 7,600 cars have destinations in the portion of the Centralia area that will be inaccessible during the flood and thus will disappear (i.e., these trips cannot be made during the flood)

- 10,000 cars have destinations that will be accessible in the northern portion of Centralia and can divert via routes such as SR 507.

For the 3,000 trucks,

- 2,000 trucks are headed through to Portland

- 200 trucks have destinations in the portion of the Centralia area that will be inaccessible during the flood, and thus will disappear

- 800 trucks have destinations that will be accessible in the northern portion of Centralia.

### **From Kelso, Heading North**

At Kelso on I-5, roughly 20,000 cars and 2,800 trucks travel in each direction on a normal late Fall weekend day. At this point, 8,000 cars and 200 trucks are assumed to be destined for points south of the closure and are subtracted from the total. Consequently, combined through-traffic and internal/external traffic volumes to and from the south are 12,000 cars and 2,600 trucks, for a total volume of 14,600 vehicles. Of those vehicles,

9,000 cars are headed through to Tumwater and points farther north

700 cars have destinations in the portion of the Centralia area that will be inaccessible during the flood and thus will disappear

2,300 cars have destinations that will be accessible in the southern portion of Chehalis and will divert along roads such as the Jackson Highway.

For the 2,600 trucks,

2,000 trucks are headed through to Seattle

300 trucks have destinations in the portion of the Centralia area that will be inaccessible during the flood and thus will disappear

300 trucks have destinations that will be accessible in the southern portion of Chehalis.

### **Local Traffic Within the Closure**

WSDOT does not have a permanent counter located within the Centralia/Chehalis urban area. As a result, there is no good estimate of how weekend traffic differs from weekday traffic within the closure area. It is assumed that locally generated weekend car volumes are similar to those found on weekdays and therefore are roughly 17,000 vehicles/day. Local truck traffic generated within the closure area on the weekends is assumed to be negligible.

### **Cost Differences for Weekend Travel**

Given the above weekend travel assumptions, the total travel cost for the five-day, 3-hour closure will be \$10,717,000. This calculation includes three days of weekday travel and assumes that the initial closure occurs on a weekday. (This is an important assumption because this means that the emergency truck detour will be available for both weekend days.)

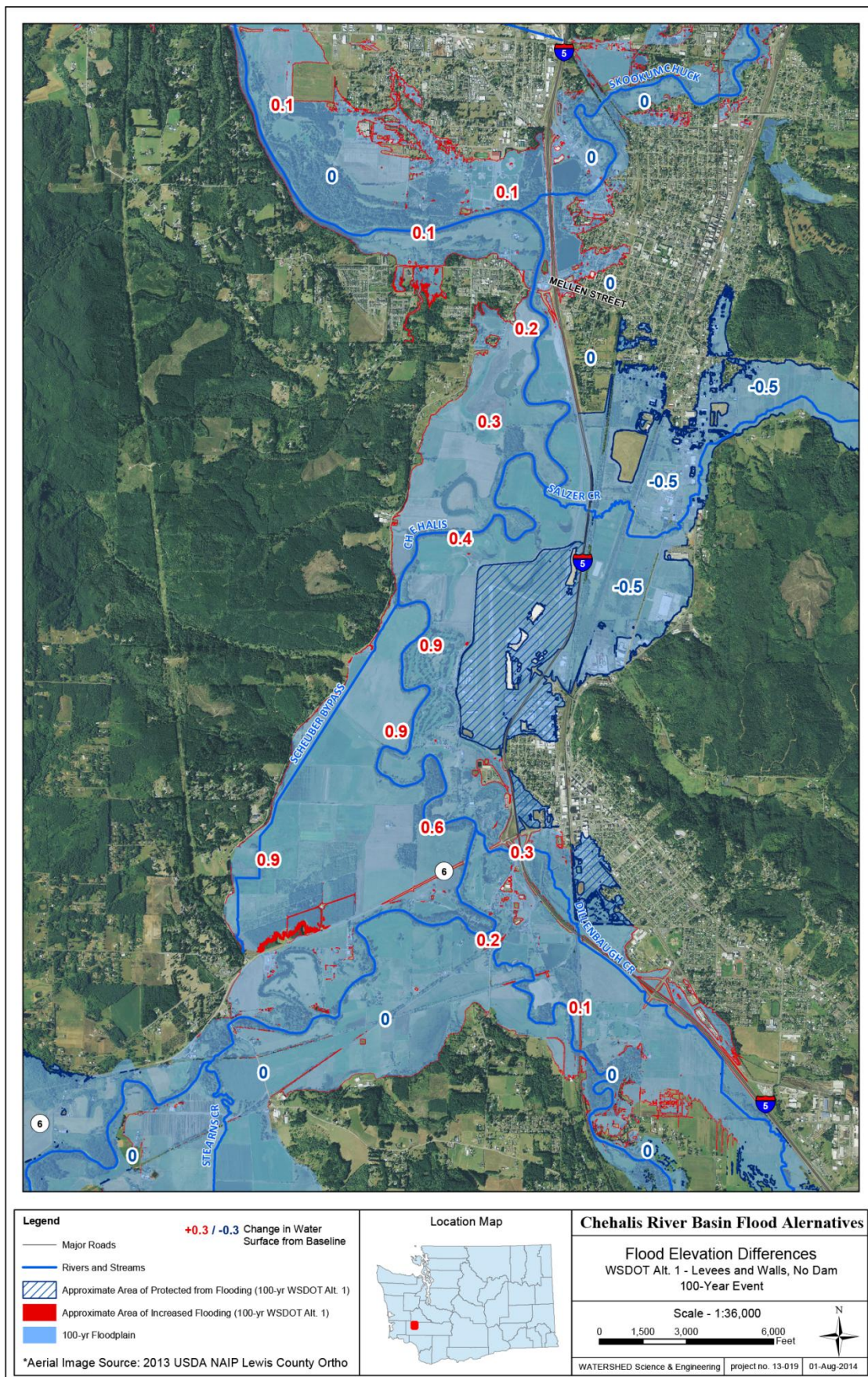
### **THE EFFECT OF TRAFFIC VOLUME GROWTH OVER TIME**

To examine the effects of possible traffic growth on I-5, the researchers increased volumes by 20 percent uniformly to through-trip, internal/external trips, and local trips and to both truck and car volumes. No changes were made in diversion rates or trip purposes from the primary cost computation. All of the added through-trucks were assumed to take the cross-mountain detour, since the emergency truck detour would already be at capacity.

The computed costs resulting from this 20 percent increase in traffic rose 23 percent: \$14,570,000 versus the original estimate of \$11,872,000. Thus, as volumes increase (a decreasing percentage of which can take the less expensive emergency truck detour), costs also increase, but slightly faster in percentage terms than traffic volumes. This is because all of the additional through-trips that are predicted to detour will have to take one of the long detours, thus making the cost per trip higher than that of the initially estimated trips.

## **Appendix B: Alternative 1: I-5 Levees and Walls- Flood Relief Maps**

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# **Appendix C: Alternative 1: I-5 Levees and Walls – Technical Memorandum**

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## MEMORANDUM

**Date:** November, 2014  
**To:** Washington State Office of Financial Management and Governor's Chehalis Basin Work Group  
**From:** Washington State Department of Transportation  
**Re:** Alternative 1: Levees and Walls – Additional Design and Technical Considerations

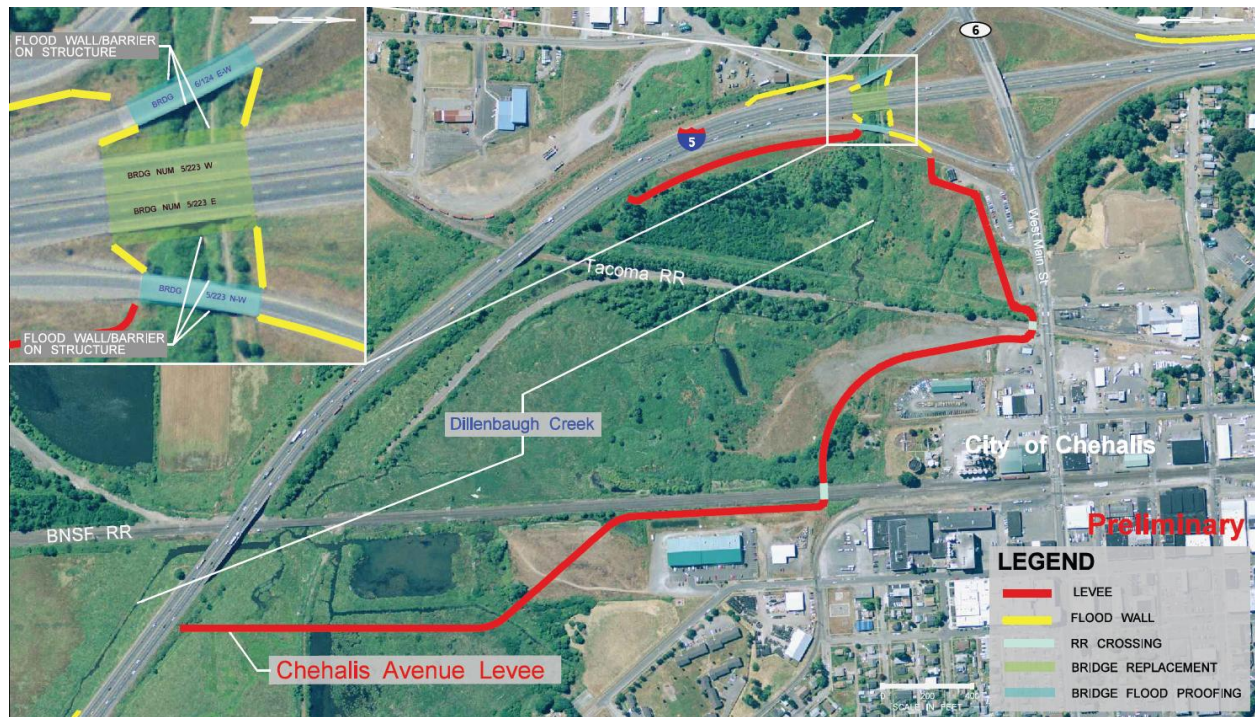
### DESIGN CONSIDERATIONS FOR LEVEES AND WALLS

This memorandum describes additional considerations that were undertaken during analysis of Alternative 1. In addition to decisions about the overall approach to flood damage reduction and aquatic species restoration in the basin (i.e., decisions about a dam, small projects, and the rest of the package), there are a number of other key design considerations WSDOT must take into account during analysis of Alternative 1. The key areas considered are described from south to north.

#### **Chehalis Avenue Levee**

In Alternative 1, a new mile-long Chehalis Avenue Levee (CAL) would be constructed away from I-5, where impacts to property would be minimized and additional infrastructure would be protected (see Figure 1). The construction of CAL involves several design considerations including: addressing the potential for stormwater behind the levee, determining how to cross the Burlington Northern Santa Fe and Tacoma railroad tracks, the presence of a Superfund site, and impacts to wetlands in the project area.

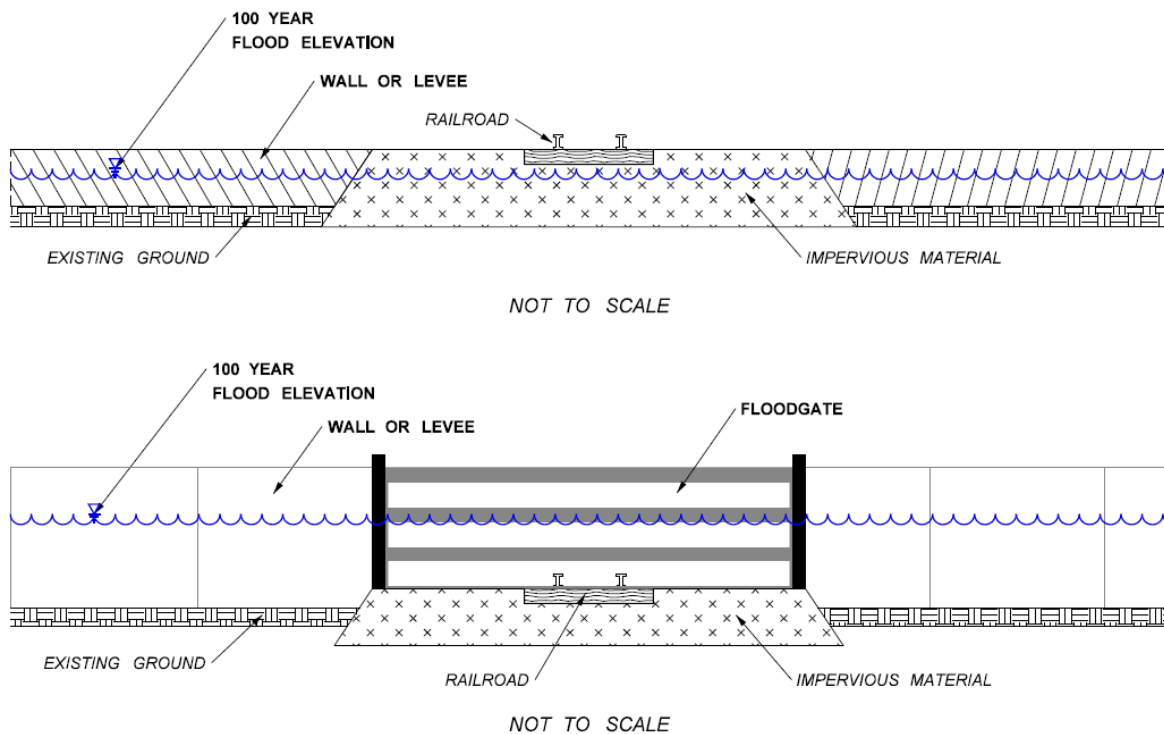
Figure 1: Chehalis Avenue Levee



Stormwater outfalls must be considered because while the levee would keep water from moving north across Main Street and into the area during flooding, there would be five points along the levee where surface water from the City of Chehalis discharges. The location of the levee is designed to allow for this surface water discharge without creating localized flooding.

Another design consideration for CAL is how to cross railroad tracks. One option currently being evaluated for the Burlington Northern Santa Fe (BNSF) crossing includes running a wall or levee parallel to the railroad up to the point where the railroad elevation is 3 feet above the 100-year flood level, and also ensuring that water is not allowed to penetrate through the rail bed. One option for crossing the Tacoma railroad tracks entails running a wall or levee perpendicular to the railroad connecting to a floodgate that would only close across the tracks during a flood event and would extend 3 feet above the 100-year flood level. At the locations where CAL crosses railroad tracks a layer of impervious material would be added to the ballast to halt flood waters (see Figure 2).

Figure 2: Dillenbaugh Creek Railroad Crossing Cross-Sections



A Superfund site where hazardous materials were addressed in the past has been identified that runs through the middle of the currently proposed alignment of CAL. A cap currently exists on the property and there are certain restrictions on land uses. If CAL moved forward, WSDOT would coordinate with all appropriate agencies to ensure compliance with all appropriate requirements of the site.

Finally, WSDOT would have to mitigate any impacts to wetlands in the CAL project area.

In lieu of constructing CAL, the floodwalls on the east side of I-5, and the modifications to the Dillenbaugh Creek ramp bridge crossings, a design option utilizing closures for the openings under I-5 is being considered. This would entail building a combination of levees and closure gates or tide gates west of I-5 at the BNSF/Dillenbaugh opening, the Tacoma Rail opening and the Dillenbaugh Creek opening. These would only be used in a flood event. In this scenario, Dillenbaugh Creek would flow in its existing channel as it does today, except during flooding. See Figure 3 for more detail.

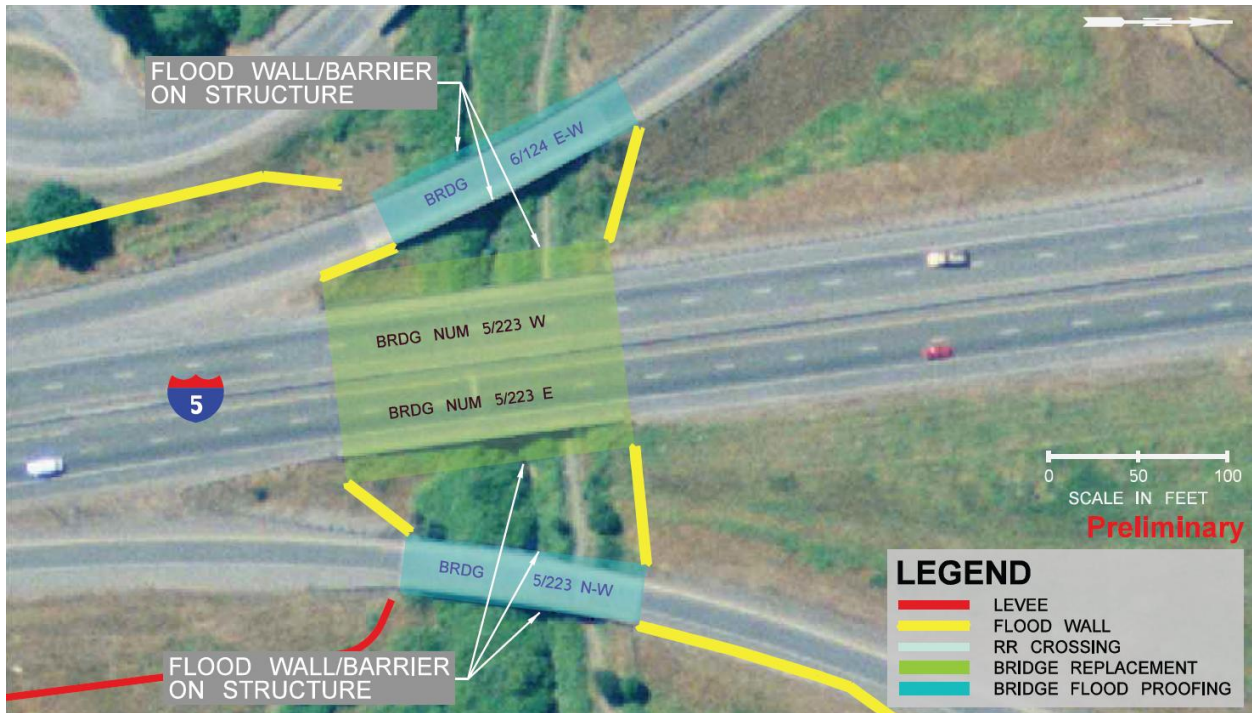
Figure 3: Alternative Design Utilizing Closures for the Openings under I-5



### Dillenbaugh Creek Area Bridges

In Alternative 1, floodwaters are anticipated to be higher than the I-5 mainline bridge over Dillenbaugh Creek and the ramp bridges. Replacement of the I-5 bridge over Dillenbaugh Creek is recommended because reliable flood proofing of the existing structure is not feasible, and a future widening of I-5 would necessitate replacement, as concluded by a recent structural analysis. The ramp bridges at the intersection of I-5 and SR 6 could be modified to provide flood protection by increasing barrier height along with other minor modifications. Floodwalls between the ramps and mainline bridge would be needed to ensure continuity in flood-proofing. In addition, the opening under the replacement bridge would need to be large enough for flood-related hydraulic needs and Dillenbaugh Creek. Figure 4 provides a detailed figure of the Dillenbaugh Creek area improvements. If the Dillenbaugh Creek realignment small project is constructed, which is described later in the report, much of this work will not be necessary.

Figure 4: Dillenbaugh Creek Area Improvements

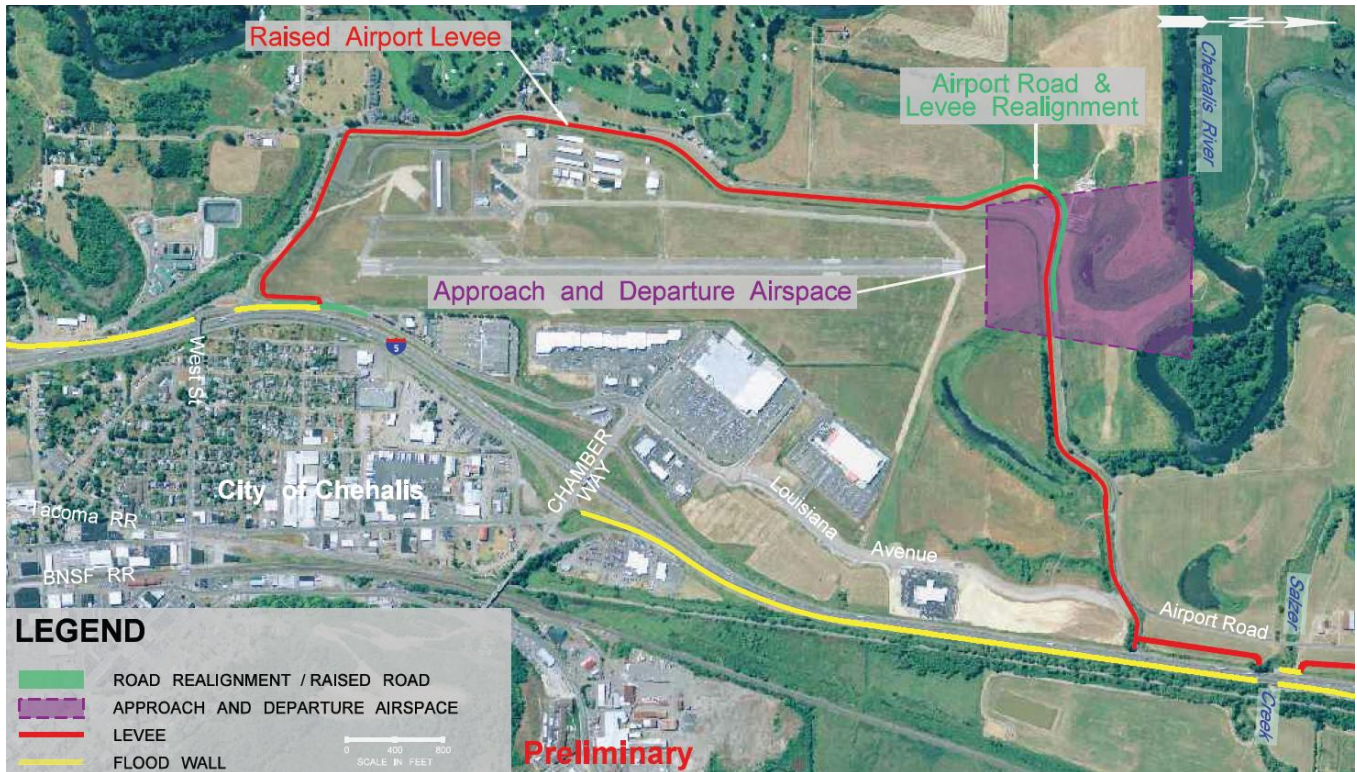


### Chehalis-Centralia Airport Levee

The Chehalis-Centralia Airport is owned and maintained by the City of Chehalis. Lewis County in conjunction with the airport has planned and implemented portions of a multi-phase project to enhance the airport levee. The airport levee improvement project involves widening the existing levee to create a base that will better accommodate raising the 2.3 miles of earthen levee to an elevation 3 feet above the 100-year flood level.

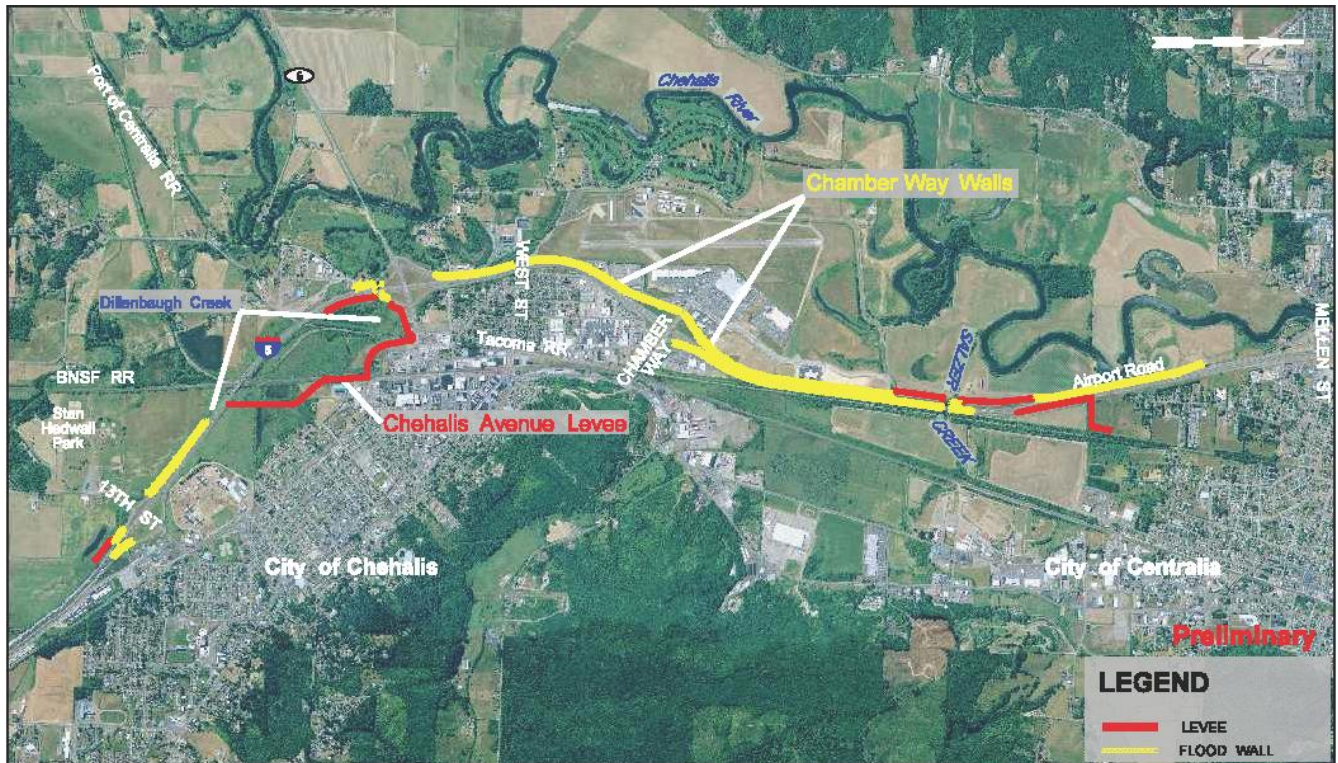
Any effort to raise the airport levee will need to consider the airport's approach and departure airspace (see Figure 5). In order for planes to safely land and take off, the approach airspace for the airport cannot have any obstructions. However, if Alternative 1's proposed improvements to the levee are built 3 feet above the 100-year flood level, they may encroach on the airspace on the north end. In addition, Airport Road would require reconstruction where the alignment is changed for approach and departure clearances; WSDOT is currently working on different design configurations to avoid any airspace encroachment.

Figure 5: Approach and Departure Airspace near Chehalis Airport Levee



Based on WSDOT's current analysis, the most cost effective way to protect I-5 and adjacent infrastructure from flood waters in this area is to raise the airport levee and extend the levee on the south end (see Figure 5). However, hydraulic models show that protecting the airport from floodwaters could result in higher flood levels on properties west of I-5 and outside of the levee. Another option for I-5 protection in this stretch of the project area would be building a floodwall along I-5, as seen in Figure 6.

Figure 6: Floodwall along I-5 near Airport Levee



### Salzer Creek

In Alternative 1, flood waters are anticipated to be higher than the I-5 bridge over Salzer Creek. Replacement of the Salzer Creek bridge is recommended because reliable flood proofing of the existing structure is not feasible, and a future widening of I-5 would necessitate replacement, as concluded by a recent structural analysis.

## OTHER PROJECT CONSIDERATIONS

This section describes other project considerations for Alternative 1 including structural, geotechnical and right-of-way acquisition.

### Structural and Geotechnical

WSDOT evaluated the need for modifications to existing bridges between 13th and Mellen Street to make them flood-resistant, including site-specific structural and geotechnical review. Information from existing soils was gathered and analyzed to provide a preliminary understanding of effects on design features and cost estimates. Since widening I-5 to 3 lanes in both directions through this area is needed, but currently unfunded, all evaluation of flood protection features considered a future widening project to maximize the potential public infrastructure investment.

Results of geotechnical analyses indicate that the soils in the area are generally silty and that the groundwater table is high—water is generally 5-15 feet below the natural ground surface. There is limited ability for the soil to store extra water during a flood event. As with any design effort, settlement of features is considered, and not anticipated to be large. Analysis reflects that bridges will require deep foundations. Preliminary design of

levees and floodwalls accounts for the effects of flood waters being held back by these features as well as residual flow of water through soil under the features.

### **Right-of-Way Acquisition**

WSDOT identified parcels potentially impacted by the current design of structures (walls, levees, ramps, bridges, etc.) for Alternative 1. Market data was assembled for the purpose of estimating the costs of parcels requiring acquisition.

## **POTENTIAL IMPACTS TO NATURAL RESOURCES**

Alternative 1 would have impacts to wetlands and could have impacts to cultural resources due to the fill and excavation necessary. Most wetland impacts would be mitigated at WSDOT's North Fork Newaukum Mitigation Bank. Any adverse effects to cultural resources would be addressed through consultation with interested parties.

There are no Endangered Species present in Dillenbaugh Creek or Salzer Creek. WSDOT would continue to work with the Washington Department of Fish and Wildlife (WDFW) to determine how to address and minimize any impacts to fish passages at these locations.

The natural resource impacts anticipated for Alternative 1 are essentially the same as those that would occur from anticipated (pending funding) future widening of I-5 to six lanes; therefore, these environmental impacts likely will occur regardless of whether Alternative 1 is constructed.

## **POTENTIAL IMPACTS TO ALTERNATIVE 1 FROM SMALL PROJECTS**

### **Dillenbaugh Creek Realignment**

Dillenbaugh Creek realignment is the small project that would have the most impact on the scope and extent of I-5 levees and walls. Flooding occurs along I-5 and within the City of Chehalis during high-flow events due to overbank flooding of Dillenbaugh Creek and backwater flooding of the Chehalis and Newaukum rivers. The project, proposed by the City of Chehalis, includes realigning Dillenbaugh Creek from the undercrossing at Rice Road through Stan Hedwall Park.

To be effective as a flood reduction project, realigning Dillenbaugh Creek would also need to close the openings under I-5 to prevent backwater from flowing under I-5 to the east toward Chehalis. The openings that would need to be temporarily closed during a flood event, listed from north to south, are:

- Dillenbaugh Creek crossing at the southbound I-5 on-ramp at the SR6/Main Street interchange
- Tacoma Rail crossing
- Dillenbaugh Creek and BNSF crossing
- Existing culvert crossing under I-5, just north of the 13th Street exit

If the Dillenbaugh small project is constructed, it affects the design of Alternative 1 in a number of ways: it eliminates the need for CAL on the east side of I-5, flood-proofing the existing ramp bridges over Dillenbaugh, and two walls on the east side of I-5. Protection would be needed only on the west side of I-5. If determined

necessary, a small culvert with a flood gate would be installed to accommodate the City's drainage to prevent backwatering.

### **SR6 Flow Bypass and Road Raise**

State Route 6 (SR 6) presently ponds Chehalis River floodwater on the south side of the road during high-flow events until the water eventually overtops the road, resulting in closure of SR 6. During previous events, SR 6 was closed for approximately 1.2 miles east of Scheuber Road due to overtopping by floodwater. The intent of the proposed project is to keep SR 6 open during a 100-year flood event on the Chehalis River while not altering current flood levels or the distribution of flood flows. The proposed project includes raising the profile of SR 6 to provide 1 foot of freeboard above the existing simulated 100-year water surface elevation. The project would involve raising approximately 1.5 miles of SR 6 up to 4 feet in elevation. Additionally, two new bridges are proposed along the newly raised portion of SR 6 to convey flow under the road to prevent an increase of water surface elevations on the south side of the highway associated with raising the road. The existing SR 6 embankment beneath the bridges would remain intact to maintain the current distribution of flood flows on the north and south sides of SR 6. As a result of raising the road, it would be necessary to raise multiple intersections, accesses, and private driveways.

### **Main Street**

Flooding occurs over West Main Street in the City of Chehalis during high-flow events on Dillenbaugh Creek and the Chehalis River. This flooding prevents access to I-5 at the SR6 – Main Street (Exit 77) interchange. The project, proposed by the City of Chehalis, is to install approximately 660 feet of temporary floodwall structure along the south side of Main Street above the 100-year flood level to maintain access between Chehalis and I-5 during high-flow events.

The proposed floodwall structure would be installed in-line with the existing sidewalk. During flood events, this temporary floodwall would be assembled of posts, floodwall beams, and braces, such that when the beams are laid horizontally and held in place by the posts and braces the flood waters would be retained. Once flood levels have receded, the structure would be taken down and stored. The existing rail line would not be able to operate while the floodwalls are installed. Accesses to local businesses from Main Street would also be closed while the floodwalls are in place.

An existing 36 inch corrugated metal pipe (CMP) culvert crosses under Main Street. The team proposes to retrofit this structure with a backflow device, such as a tide gate, to prevent the flow of water to the north side of Main Street during flood events. Note that the project sponsor, not WSDOT, would be responsible for assembling these structures in a flood risk scenario.

If the Main Street small project is constructed, it would replace or eliminate the need for the portion of CAL that runs parallel with Main Street.

### **Salzer Creek Backwater Control**

The east side of I-5 is flooded by overbank flooding of Salzer Creek and backwater flooding from the Chehalis River. The current opening under I-5 is submerged during the simulated 100-year flood event. An existing private road is located within the opening under I-5. The project, proposed by Lewis County, is to install a backwater control structure in Salzer Creek to prevent backwater flooding under I-5. The control structure would be

installed immediately downstream of the Salzer Creek and I-5 crossing and would theoretically tie into WSDOT's Alternative 1. The existing opening under I-5 is proposed to be closed with an unknown length of sheet pile wall, 50 feet of a temporary floodwall structure, and a 100 foot sheet pile closure structure. Note that the project sponsor, not WSDOT, would be responsible for assembling these structures in a flood risk scenario.

If the Salzer Creek small project is constructed, it would increase water surface elevations on the west side of I-5, which would necessitate higher levees and walls, and it would reduce the need for potential levees and walls on the east side of I-5.

## Appendix D: Economic Analysis of I-5 Project

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## MEMORANDUM

**Date:** September 24, 2014  
**To:** Washington State Department of Transportation  
**From:** Anne Falcon and Amber Nyquist, EES Consulting, Inc.  
**Re:** Economic Analysis of I-5 Project and Airport Levee

### Introduction

The Washington State Department of Transportation (DOT) asked EES Consulting (EES) to analyze the flood reduction impacts of the I-5 Project when combined with the airport levee and to provide an Input-output (IO) analysis for the two projects. The IO analysis estimates the economic development resulting from the proposed projects. DOT asked for the economic impacts for costs avoided during both for a one-time 100-year event as well as expected annual damage over a 100-year study period.

As part of the Chehalis Basin Flood Mitigation Hazard study, economic analyses and IO analyses are being conducted for the Comparison of Alternatives (COA) study. However, the analyses presented in this memo are based on different assumptions compared with the COA. Therefore, the results presented in this memo cannot be compared with the results presented in the COA study. Mainly, the cost per day of a closure on I-5 is assumed at the low end of the cost range developed by DOT whereas the COA assumes the average of the range estimated by DOT.

### Impacts

The I-5 Project (flood walls and berms) and Airport Levee result in changes to flooding patterns in the basin. In particular, some buildings experience less flooding and some may experience more flooding. The net effect is that damages to structures are decreased when both projects are implemented. In addition, the projects have a small negative impact on crop damages since the number of agricultural acres that are flooded increase slightly. Finally, the I-5 Project results in fewer freeway closures reducing detour or trip delay costs when compared with the Baseline. DOT estimates that the I-5 Project would avoid \$11.6 million in travel costs during a 100-year event.

The economic impacts modeled in the IO analysis include the following:

- Changes in flood damage on structures and contents
- Avoided I-5 closure and associated detour costs
- Avoided clean-up costs
- Impacts on agriculture (crops only)
- State's share of avoided Emergency Aid

A summary of the methodologies for estimation the project impacts are provided below for the one-time 100-year event as well as the expected annual impacts over a 100-year study period.

## 100-YEAR EVENT IMPACTS

The impact of the I-5 Project plus Airport Levee on damages from a 100-year flood event was modeled in HAZUS based on hydrology data developed for the DOT.<sup>25</sup> Hydrology data for the 100-year event for a without project condition (Baseline) and a with-project condition were modeled in HAZUS. The impact of the project is the difference between the I-5 Project plus Airport Levee model and the Baseline. For more information on HAZUS and its output, please refer to the COA study.<sup>26</sup>

## EXPECTED ANNUAL IMPACTS

Similarly to the impact analysis for a 100-year event, the expected annual impacts are estimated based on the difference in damages between the I-5 Project plus Airport Levee Scenario and the Baseline Scenario. The expected annual impacts are calculated based on the damages and flood return probability for five flood events: 2-year, 10-year, 20-year, 100-year, and 500-year. The impacts for these events, and event probabilities, result in a damage curve (a curve representing impacts at each flood return interval). Triangular integration is conducted to determine the area under the curve, or the expected annual damage. The net present value of the expected annual damage is discounted at 1.63 percent (real discount rate) over the 100-year study period.<sup>27</sup>

## PERSPECTIVE

The project impacts are modeled from a state perspective. Therefore, any transfers of wealth or income between regions within the state are not modeled. For example, avoided business interruption costs within the basin are not modeled in the IO analysis since the lost income and wages would be recouped by businesses in other parts of the state. In addition, the impact of the I-5 closure on businesses outside of the Chehalis Basin has not been estimated. Therefore, any business losses incurred due to delays in product shipment via I-5 are not included in the analysis. As a result, the impacts of the I-5 Project are likely underestimated.

## RESULTS

The impacts of the I-5 Project plus Airport Levee are compared with the project costs. Table 1 presents the economic analysis results before IO modeling is included. The first analysis is based on expected annual impacts based on modeling for the four flood events. The second analysis compares the I-5 Project impact in a 100-year event with the project costs. On an expected annual basis, the I-5 Project plus Airport Levee have negative net benefits.

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<sup>25</sup> Hydraulic modeling conducted by Watershed Science and Engineering (Seattle, WA) based on the basin HEC-RAS model.

<sup>26</sup> EES Consulting and HDR Inc. Chehalis Basin Flood Hazard Mitigation Comparison of Alternatives Analysis. Draft August 8, 2014.

<sup>27</sup> EES Consulting and HDR Inc. Chehalis Basin Flood Hazard Mitigation Comparison of Alternatives Analysis. Draft August 8, 2014. Appendix A.

**Table 1: I-5 Project plus Airport Levee Economic Analysis (\$2014), Millions**

	<b>Expected Annual Impact</b>	<b>One-Time 100-Year Event</b>
Structure Content Inventory	\$30.3	\$5.4
Emergency Aid	\$20.2	\$5.6
Clean-up Costs	\$9.8	\$1.2
I-5 Delay	\$16.2	\$11.5
Agriculture	(\$0.1)	\$0.1
Total Impact	\$76.4	\$23.9
Project Cost (Capital, O&M, IDC), 100-year NPV	\$106.8	\$106.8
Net Benefit	(\$30.4)	(\$83.0)
Benefit/Cost Ratio	0.7	0.2

## IO Modeling

The impacts in Table 2 are modeled in the IO analysis. From a state perspective, project costs are not included in the IO modeling since the funds needed for the project would be spent elsewhere in the state if not in the Chehalis Basin. Table 2 summarizes how the impacts are incorporated into IMPLAN. Note that avoided vehicle damages are not included in the IO analysis

**Table 2: Impacts and IMPLAN Modeling**

<b>IMPACT</b>	<b>IMPLAN MODELING</b>
Changes in Flood Damage (structure, content, inventory)	Residential: household income change Non-Residential: Industry changes (top 15 industries in Lewis, Thurston, and Grays Harbor Counties)
Avoided I-5 Closure	Industry Income Changes (Trucking)
Avoided Clean-Up Costs	Household income changes or proprietor income changes
Agriculture Impacts	Changes in industry sales (crop farming)
State share of avoided Emergency Aid	Changes in industry sales (relief services)

The IO analyses was conducted using the Washington State IMPLAN model. Impact categories are modeled separately as well as together to show the relationship between each type of impact and economic growth. The I-5 Closure cost, \$11.5 million for a 100-year event, is based on the TRAC study.<sup>28</sup> The methodologies for estimating all other impacts are based on the COA study.

<sup>28</sup> Hallenbeck, Mark E., Dr. Anne Goodchild, and Jerome Drescher. Travel Costs Associated with Flood Closures of State Highways near Centralia/Chehalis, Washington. Washington State Transportation Center. Draft June 2014.

## RESULTS: 100-YEAR EVENT

Table 3: IO Results 100-Year Event, \$2014

	DIRECT IMPACT	VALUE ADDED	MULTIPLIER	TOTAL IMPACT	EMPLOYMENT (FTE)
Avoided Emergency Aid	\$1,813,000 <sup>1</sup>	\$2,204,000	2.2	\$4,017,000	43
Avoided Damages (Structures)	\$5,516,000	\$4,344,000	1.8	\$9,860,000	46
Avoided Clean-Up Costs	\$1,196,000	\$732,000	1.6	\$1,928,000	8
Avoided I-5 Closure	\$11,516,000	\$11,614,000	2.0	\$23,130,000	144
<b>Total</b>	<b>\$20,041,000</b>	<b>\$18,894,000</b>	<b>1.9</b>	<b>\$38,935,000</b>	<b>241</b>

1. State share only (25%).

## RESULTS: NPV EXPECTED ANNUAL IMPACTS

Table 4: IO Results Expected Annual Impact over 100 Years, \$2014

	EXPECTED ANNUAL IMPACT, 100-YEAR NPV	VALUE ADDED	MULTIPLIER	TOTAL IMPACT	EMPLOYMENT (FTE)
Avoided Emergency Aid	\$5,045,700 <sup>1</sup>	\$6,133,200	2.2	\$11,178,900	119
Avoided Damages (Structures)	\$30,324,000	\$23,642,000	1.8	\$53,966,000	250
Avoided Clean-Up Costs	\$9,808,000	\$5,845,000	1.6	\$15,653,000	61
Avoided I-5 Closure	\$16,214,000	\$16,376,000	2.0	\$32,590,000	186
<b>Total</b>	<b>\$60,065,700</b>	<b>\$51,996,200</b>	<b>1.9</b>	<b>\$113,387,900</b>	<b>616</b>

1. State share only (25%).

Table 5 shows the results of the economic analysis when both direct (Table 1) and indirect impacts (Tables 2 and 3) are included.

Table 5: Economic Analysis Results with IO Impacts, \$2014

	I-5 Project Only Expected Annual Impact	I-5 Project Only 100-Year Event
Direct Impact	\$76.4	\$23.9
Value Added	\$52.0	\$18.9
<b>Total Impact</b>	<b>\$128.4</b>	<b>\$42.8</b>
Project Cost (Capital, O&M, IDC), 100-year NPV	\$106.8	\$106.8
Net Benefit	\$21.6	(\$64.1)
Benefit/Cost Ratio	1.2	0.4

## Discussion

The economic impacts above are subject to some model limitations. Specifically, the timing over which these impacts occur is not specified. In addition, the impacts are estimates based on current economic conditions and would change as shifts in industries occur or as interdependence between industries transforms over time. In addition, neither changes in labor productivity nor changes prices are modeled.