

Memorandum

To: Russ Esses, Grays Harbor County
Cc: Wes Cormier, Jay Gordon, Butch Ogden
From: Larry Karpach and Shaina Sabatine
Date: October 16, 2014
Re: Elma-Porter Flood Mitigation Project – Hydraulic Modeling and Analysis (Draft)

Introduction

This technical memorandum describes work performed by Watershed Science & Engineering (WSE) to evaluate options for improvements to Wakefield Road near Elma Washington to reduce upstream flood impacts. Preliminary hydraulic evaluations of other potential local flood damage reduction projects are also presented.

WSE developed a hydraulic model of the reach of the Chehalis River from downstream of Wakefield Road to upstream of Porter Creek Road and used this model to evaluate a broad range of possible project alternatives. The WSE team was initially scoped with developing plans, specifications, and estimates (PS&Es) for a 562 foot expansion of the primary overflow bridge on Wakefield Road (to a total length of 900 feet). The 900 foot length for the proposed bridge expansion was based on preliminary hydraulic analysis (WSE, 2012) and available funding constraints. The refined hydraulic analysis conducted for this study determined that a 900 foot wide bridge would not provide sufficient hydraulic capacity to either mitigate upstream flood problems or allow the road to remain open during a 100-year design event. Therefore, several project alternatives were investigated to provide information to allow the County to decide how to proceed with this project.

In addition to the Wakefield Road alternatives four other potential flood reduction projects were investigated; 1) installing a culvert under South Bank Road near its intersection with Porter Creek Road W, 2) widening the bridge on Dunlap Road over a Chehalis River side channel, 3) removing sediment buildup in the main channel downstream of the Wakefield Road Bridge, and 4) installing flap gates to prevent Chehalis River floodwaters from back-flowing through culverts along Highway 12. The results of these analyses are described below.

Model Development

Previous hydraulic modeling for the lower Chehalis River (WSE, 2012) was performed using HEC-RAS, a one-dimensional hydraulic model. While that model was appropriate for the analyses conducted at that time, the current project seeks to evaluate local effects of the proposed bridge lengthening at Wakefield Road, and to evaluate additional flood reduction alternatives for the reach of the Chehalis River between Porter and South Elma. This reach is extremely complex from a hydraulic perspective; therefore, it was determined that a two-dimensional (2D) numerical hydraulic model was required for this study. The 2D model allows

- Analysis of the complex hydraulic conditions near Wakefield Road where floodwaters exit the main channel and spread across the floodplain, ultimately reaching the overflow bridges

- Simulation of super-elevation of flood levels along the outside edge of the large meander bends in the project reach near Dunlap Road
- Simulation of detailed velocity patterns, as needed for bridge scour analyses
- Production of the data needed for permitting the bridge improvement and evaluation of environmental issues for flood mitigation alternatives

A 2D hydraulic model was developed for an 11.5 mile study reach of the Chehalis River from approximately 1.5 miles upstream of Porter Creek Road to just downstream of Wakefield Road using SRH-2D, a hydraulic modeling program developed by the USBR. The model was extended further upstream and downstream of the study reach an appropriate distance to minimize uncertainty due to boundary conditions. The lateral extent of the model was defined to encompass the 500-year floodplain area as previously mapped by WSE using the HEC-RAS model.

Hydrologic data for the modeling were extracted from the HEC-RAS model of the lower Chehalis River. Flow data from the USGS gage on the Chehalis River near Porter were used for low flow model calibration; however, analysis by WSE indicates that there may be issues with the Porter gage for high flows so the Flood Authority model data were used to represent the 2-, 10-, 20-, 100-, and 500-year flood events. Calibration data for the high flow events of February 1996, December 2007, and January 2009 flood events were also taken from that project.

A bathymetric (underwater) land surface was created using the most recent (2012) LiDAR data and new channel surveys collected by Pacific Geomatic Services, Inc (PGS). The PGS survey included the main channel of the Chehalis River from approximately 1000 feet downstream of the Wakefield Road crossing to 1.5 miles upstream of the Porter Creek Road crossing at Porter, a total river length of approximately 11.5 river miles. The survey was conducted utilizing a meandering zigzag method crossing the river channel in approximate 300' intervals. Every third leg of the meanders crossed the river approximately perpendicular to the channel creating channel cross sections at 600' intervals.

Utilizing the bathymetric data collected, WSE created breaklines representing key channel features (e.g. top of bank, toe of slope, edge of water, thalweg). These feature breaklines were used with the topographic and bathymetric data to create a surface model of the river. This topographic surface was then imported into SRH-2D as the bed elevation layer.

An SRH-2D model of the project reach was created, including the following elements:

- Model boundary- The model boundary is a polygon defining the limits of the model. The upstream and downstream limits of the model were established at a location where flow into and out of the model could be estimated accurately. The upstream and downstream boundaries were set to ensure that the model extents included all areas that could potentially be impacted by flooding.
- Conceptual model- The conceptual model is a collection of breaklines that define important topographic features throughout the model domain. Care was taken to create the conceptual model to ensure that all elevation data necessary to accurately represent key features were included.

- **Mesh-** The model mesh is a collection of nodes and elements at which model calculations are made and was configured to be dense enough to accurately simulate the flood events of interest in this study.
- **Roughness Parameters-** Manning's n values were input as model parameters to define roughness throughout the model domain.
- **Boundary Conditions-** Upstream and downstream boundary conditions were established for each flow scenario using the hydrologic data developed as described above.

The SRH-2D model was calibrated to available high water marks by adjusting the model roughness parameters. Calibration was performed primarily for the December 2007 flood event. The calibration effort made use of flood survey records, aerial photos, and anecdotal information to determine the extent and magnitude of the historical flooding. In addition, in channel roughness values were calibrated using water surface elevation data collected at the time of the bathymetric survey and the corresponding USGS flow data. The results of the model calibration are summarized in Table 1.

Table 1: Calibration Results

Calibration Points				
Description of Point	Flow (cfs)	Observed WSE (ft)	Simulated WSE (ft)	Error (ft)
At USGS Porter Gage	4,150	36.4	35.6	-0.8
	5,150	37.5	36.9	-0.6
	12,300	43	43.7	0.7
	86,500	53.2	53.7	0.5
54 Dunlap Road	86,500	42.7	43.5	0.8
Power Pole on Gordon Property	86,500	43.5	42.9	-0.6
Wakefield Road	86,500	38.2	38.25	0.05
Red Barn	86,500	46.5	45.8	-0.7
Yellow Pump House	86,500	46.5	45.8	-0.7
Power Pole	86,500	46	45.7	-0.3

Hydraulic Modeling and Analysis

The calibrated SRH-2D model was then run for the 2-, 10-, 20-, 100-, and 500-year flood events to provide information on existing hydraulic conditions within the study reach. This provides a baseline assessment of flooding throughout the study reach and in particular at Wakefield Road.

Wakefield Road Bridge Alternatives Analysis

Following the baseline model runs described above the SRH-2D model was run to evaluate the proposed 900 foot bridge opening. The results of these runs showed that the proposed overflow bridge expansion, from 350 to 900 feet, would not have a significant effect on upstream water levels (i.e., there would be little upstream benefit). Furthermore the modeling showed that the proposed expansion would not be large enough to allow the 100-year flood to be passed without road overtopping. As these are the two primary objectives of the proposed project WSE conducted additional analyses to characterize flooding and provide data for

evaluation of a more beneficial alternative. Tables 2 and 3 summarize the results of the alternatives analyses.

As seen in Table 2, expanding the main overflow bridge would result in a reduction in the frequency of overtopping of Wakefield Road from a 25-year event (existing conditions) to approximately a 40-year event. Expanding the bridge to 3600 feet (essentially removing the entire road fill) would reduce the frequency of overtopping to approximately a 90-year event. Table 3 shows the effects on water levels within the study reach of the various alternatives. As seen in Table 3 the alternatives would cause between 0.0 and 0.3 feet of rise in downstream water levels and between 0.3 and 0.6 feet of fall in upstream water levels.

Table 2: Flow Rates and Flood Flow Frequency for Overtopping Wakefield Road

Scenario	Flow Rate (cfs)		Overtopping Return Period	
	First Water on Road	Overtopping	WSE, 2014	WEST, 2012
Existing	50,700	60,400	25-year	18-year
900ft Bridge	56,700	67,300	40-year	30-year
1300ft Bridge	57,300	70,000	50-year	37-year
3600ft Bridge	66,800	77,400	90-year	50-year
1250ft South Bridge	54,000	68,700	45-year	32-year
Widen Main Channel Bridge	53,200	65,200	35-year	25-year

Notes: ¹ The 100-year flood at the Porter gage estimated by WSE based on gage data and a Bulletin 17B Analysis is 79,500 cfs (computed probability)

² The 100-year flood estimated by WEST Consultants for the USACE in 2012 was approximately 89,500 cfs at Porter Gage (expected probability)

³ The 100-year Flood in the Flood Authority HEC-RAS Model being used for the OFM project is approximately 86,000 cfs at the Porter Gage

⁴ USGS Gage Data for Porter Gage for top 6 events in record:

05-Dec-07	86,500
09-Feb-96	80,700
11-Jan-90	60,400
09-Jan-09	58,700
22-Jan-72	55,600
27-Jan-71	49,600

Table 3: Upstream and Downstream Water Levels Associated with Various Bridge Alternatives

Scenario	Water Surface Elevation (feet NAVD) at OFM 100-year Event (86,145 cfs)				
	Airport	Downstream of Wakefield Road	Upstream of Wakefield Road	Near Gordon Property	Upstream of Porter Creek Road
Existing	36.7	38.4	39.8	43.4	54.6
900ft Bridge	36.7	38.5	39.5	43.3	54.6
1300ft Bridge	36.7	38.5	39.3	43.3	54.6
3600ft Bridge	36.7	38.7	39.2	43.2	54.6
1250ft South Bridge	36.7	38.6	39.6	43.3	54.6
Widen Main Channel Bridge	36.7	38.3	39.7	43.3	54.6

Considering the results shown in Tables 2 and 3 additional alternatives were investigated. These alternatives included raising the elevation of Wakefield Road to prevent overtopping during a 100-year event with and without expansion of the overflow bridge. In all of these simulations the elevation of Wakefield Road was assumed to be raised sufficiently high to prevent overtopping at any location for any flow up to and including the OFM 100-year flood (86,500 cfs). Thus any of these alternatives could effectively prevent overtopping (closure) of Wakefield Road. The tradeoff is that some of the alternatives would cause increased upstream water levels. Differences in maximum simulated water surface elevations (as compared to the existing condition) for the 100-year flood event are described briefly below and summarized in Table 4:

- **Existing Conditions Bridge with Raised Road:** 1 to 1.5 foot increase in water surface elevation close to Wakefield Road with 0.5 foot increases extending at least a mile upstream.
- **900 foot Wide Overflow Bridge with Raised Road:** Increases in water surface elevations generally on the order of tenths of a foot. In some areas the rise is as high as 0.5 feet, but there are no structures in these areas. Water surface elevation differences for this alternative are shown in Figure 1.
- **1300 foot Wide Overflow Bridge with Raised Road:** Slight decrease (0.0 to 0.5 feet) in water surface elevations upstream of Wakefield Road with little change downstream.

Table 4: Upstream and Downstream Water Levels with Bridge and Road Raise Alternatives

Scenario	Water Surface Elevation (feet NAVD) at OFM 100-year Event (86,145 cfs)				
	Airport	Downstream of Wakefield Road	Upstream of Wakefield Road	Near Gordon Property	Upstream of Porter Creek Road
Existing	36.7	38.4	39.8	43.4	54.6
Existing with Raised Road	36.6	37.8	41.4	43.9	54.6
900ft Bridge with Raised Road	36.7	38.3	39.9	43.4	54.6
1300ft Bridge with Raised Road	36.7	38.4	39.4	43.4	54.6

Culvert at the intersection of Porter Creek Road and South Bank Road

When flow in the Chehalis River at Porter reaches about 47,000 cfs (based on the USGS Porter gage), the intersection of South Bank Road and Porter Creek Road begins to flood. The roads near this intersection become impassable at higher flows such as the 100-year event (about 80,000 cfs at the Porter gage). Hydraulic modeling by WSE indicates that flow affecting this location initially breaks out of the Chehalis River channel approximately one mile upstream of Porter Creek Road and is conveyed via large floodplain channels until it reaches South Bank Road near Ridings Road and subsequently the intersection of South Bank and Porter Creek Roads. This flow path is shown in Figure 2. WSE was asked to determine whether installing a culvert at this location would provide enough relief to prevent this intersection from flooding.

Analysis of a range of flows in the existing conditions model shows that the intersection first starts overtopping at a river discharge of about 47,000 cfs (approximately a 10-year event). To evaluate the feasibility of a culvert, WSE examined the water surface elevations upstream and downstream of the proposed culvert and the flow overtopping the road at this location in the

10-, 20-, and 100-year events (see Table 5). The modeling shows that Porter Creek Road would see less than half a foot of overtopping during the 10-year and 20-year events as summarized in Table 5. Flows overtopping the road are relatively low in these events, thus a culvert could be designed to alleviate overtopping. During a 100-year event, however, approximately 2900 cfs is flowing in the overbank flow path which is more than can likely be passed through a culvert. In order to accommodate this flow and alleviate flooding over the road during a 100-year event, a bridge up to 100-feet or more in length would likely be required.

Table 5: Hydraulic Model Data at Proposed Culvert Location at the Intersection of Porter Creek Road and South Bank Road

Chehalis Flow (cfs)	Approx. Recurrence	Lowest Road Elevation (feet NAVD)	Water Surface Elevation		Swale Flow (cfs)
			Upstream (feet NAVD)	Downstream (feet NAVD)	
47,200	10-year	51.5	51.7	48.8	70
56,100	20-year		51.9	49.7	350
86,100	100-year		53.2	52.8	2900

Dunlap Road Bridge Expansion

Dunlap Road crosses over a large side channel on the eastern floodplain of the Chehalis River (see Figure 3). The existing bridge opening at this location is considerably smaller than the size of the channel. WSE was asked to determine whether widening the bridge would provide significant flood relief, specifically to the northeast of the bridge where flood waters exit the side channel and overtop the east-west portion of Dunlap Road indicated on Figure 3. The main concern at this location is flooding during relatively frequent flood events (i.e. the 2-year event). Baseline condition modeling showed that the east-west section of Dunlap Road would not flood in events smaller than about a 2-year flood (30,700 cfs at the Porter gage). During larger (less frequent) flood events the entire floodplain is flooded and the main flow path is generally northward. The Dunlap Road Bridge does not have much impact on water surface elevations at these larger flows.

WSE modeled the 2-, 10-, 20-, and 100-year flood events assuming the Dunlap Road Bridge was widened to an approximate 150 foot bottom width. The widened bridge resulted in minor changes in water levels during the 2-year event. Water surface elevations were slightly higher (up to 0.1-ft) west (downstream) of the bridge and slightly lower (up to 0.3-ft) east (upstream) of the bridge. Modeling of the widened bridge alternative showed that water levels near the east-west section of Dunlap Road might be reduced by a couple of tenths of a foot in the 2-year event but the road would still overtop. Water surface elevation differences between the widened bridge scenario and existing conditions upstream of the Dunlap Road Bridge during the 10-, 20-, and 100-year events are negligible (hundredths to thousandths of a foot). In summary, the modeling showed there was no flooding of the east-west section of Dunlap Road at events smaller than a 2-year flow (thus no benefit of the bridge expansion), a very slight water surface reduction at the 2-year flow but no change in the frequency of flooding, and insignificant water surface reductions at higher flows.

Sediment Removal in Main Channel Downstream of Wakefield Road Bridge

A large island of sediment exists in the main channel of the Chehalis River just downstream of the Wakefield Road Bridge. WSE was asked to evaluate whether the removal of this sediment would provide any upstream benefit.

To evaluate this, WSE adjusted the model bathymetry (channel bed) to remove the sediment island and modeled the 2-, 10-, 20-, and 100-year flood events. The results of these runs were compared to the results of the existing conditions model to determine the upstream impacts, specifically near Wakefield Road. The results are as follows:

- **2-year Event** – Water surface elevation decreases of up to 0.4-ft with the greatest benefits in the floodplain near the primary overflow bridge. Water surface elevation decreases of 0.1-ft or more extend as far as 2500-ft upstream of Wakefield Road.
- **10-year Event** – Water surface elevation decreases of about 0.2-ft along the entire length of Wakefield Road on the upstream side. Decreases up to 0.1-ft extend about 3000-ft upstream of Wakefield Road in the floodplain and in the channel as far as 1 mile upstream of the main channel bridge.
- **20-year Event** – Water surface elevation decreases of about 0.2-ft along the entire length of Wakefield Road on the upstream side. These reductions extend as far as 1 mile upstream of Wakefield Road in the right bank floodplain.
- **100-year Event** – Water surface elevation decreases are less than 0.1-ft at any location.

Water level reductions resulting from removal of the sediment island in the main channel downstream of the Wakefield Road Bridge are small. A project to remove this sediment would also be difficult and expensive to permit.

Preventing Backflow through Highway 12 Culverts

Numerous culverts exist along Highway 12 near Elma, WA, most notably the double box culvert on Vance Creek and the single box culvert on McDonald Creek (see Figure 4). These culverts exist to allow flow from creeks and ditches to cross the highway and drain to the Chehalis River. During periods of high flow on the Chehalis River, some of these culverts can flow backwards allowing flood flows to cross Highway 12 from the south to the north. WSE was asked to evaluate flooding on the north side of Highway 12 due to the Chehalis River. A potential project to prevent backflow in these culverts could reduce this flooding

The area north of Highway 12 that is potentially flooded by the Chehalis was estimated by projecting the simulated water surface elevations in the model on the south side of the highway to the north side. WSE used the 100-year water surface elevation results from the existing conditions model to estimate the approximate area that could get wet north of Highway 12 during a 100-year flood. The resulting area is shown in Figure 4. Preventing backflow through the Highway 12 culverts could reduce or eliminate this backwater flooding. However, some flooding might still occur due to local drainage being unable to discharge from the north to the south when Chehalis River water levels are high. A detailed evaluation of the potential to reduce flooding in this area would require a local drainage investigation which was beyond the scope of WSE's work in this project.

Summary

WSE was tasked with analyzing the effects of widening the primary overflow bridge at Wakefield Road and designing a bridge expansion that would reduce upstream flooding and allow Wakefield Road to remain open during higher flow events than is currently possible. WSE's scope envisioned the development of Plans, Specifications, and Engineer's Estimate (PS&Es) for a 562 foot bridge expansion (total opening 900 feet). Detailed hydraulic modeling conducted for this study found that a 900 foot opening would only reduce the frequency of overtopping at Wakefield Road from about a 25-year level to a 40-year level. Modeling also found that there was no length that the overflow bridge could be expanded to that would eliminate overtopping in the 100-year flood event. Furthermore, none of the bridge widening alternatives investigated provided a significant reduction in upstream water levels.

WSE then conducted additional analyses looking at the potential effects of raising Wakefield Road. Raising the road was evaluated with and without an expansion of the overflow bridge. These analyses showed that raising the road above the 100-year flood level, together with a 900 foot bridge opening, would have only minimal effect on upstream water levels. Raising the road together with a 1300 foot bridge opening would actually have a slight benefit on upstream water levels while keeping Wakefield Road from overtopping in the 100-year event.

Considering the analyses presented above, WSE does not recommend proceeding with the original scope of work for the Wakefield Road Project at this time. Instead we recommend meeting with the project stakeholders and discussing our findings and together determining an appropriate course of action for this project.

WSE also undertook preliminary hydraulic analyses of four additional problem areas as requested by the project stakeholders: 1) Porter Creek Road culvert, 2) Dunlap Road Bridge expansion, 3) sediment removal in main channel downstream of Wakefield Road, and 4) backflow prevention along Highway 12 near Elma. The results of these analyses are documented above. WSE recommends discussing these preliminary results with the stakeholders and determining an appropriate course of action for each of these sites.

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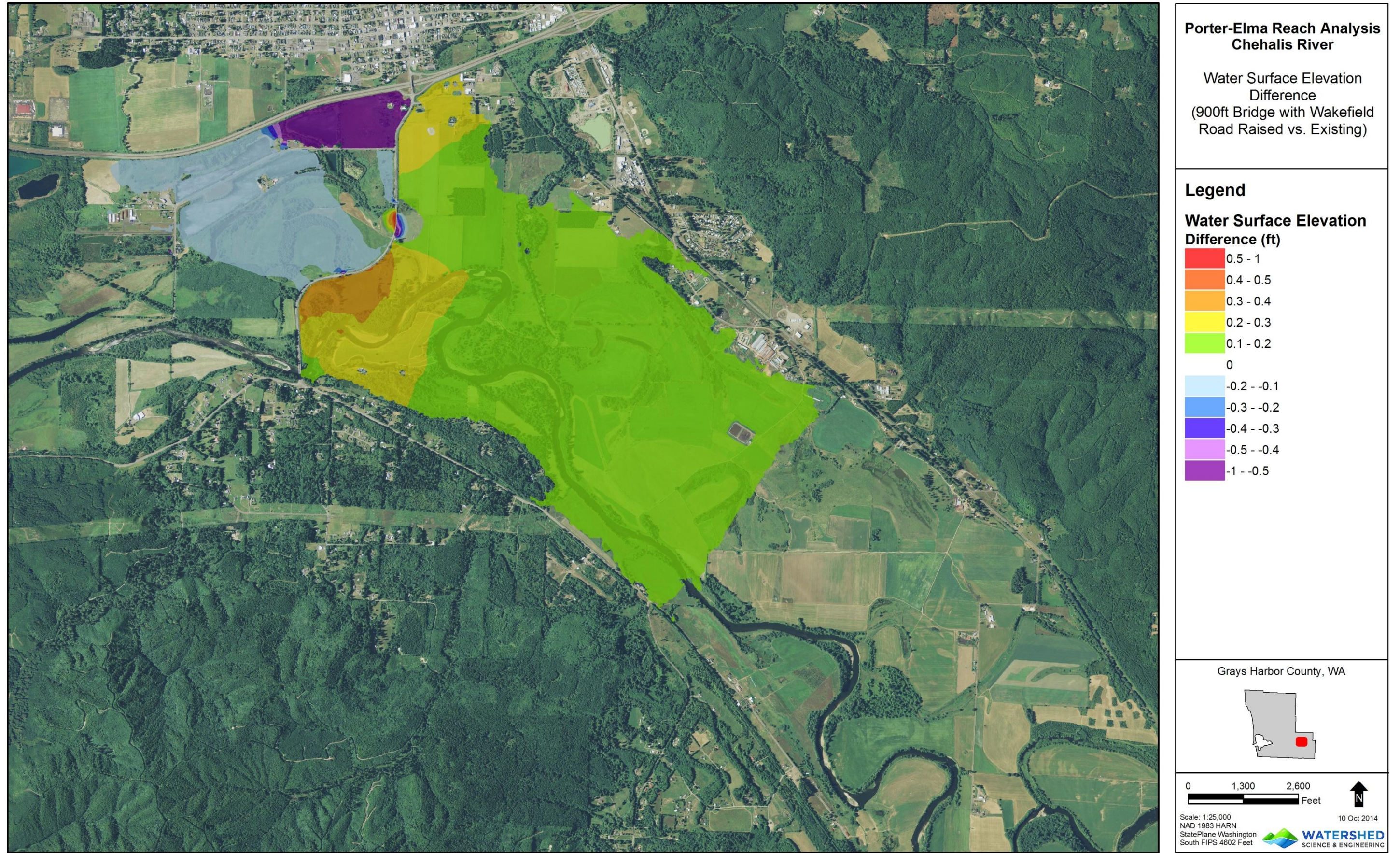
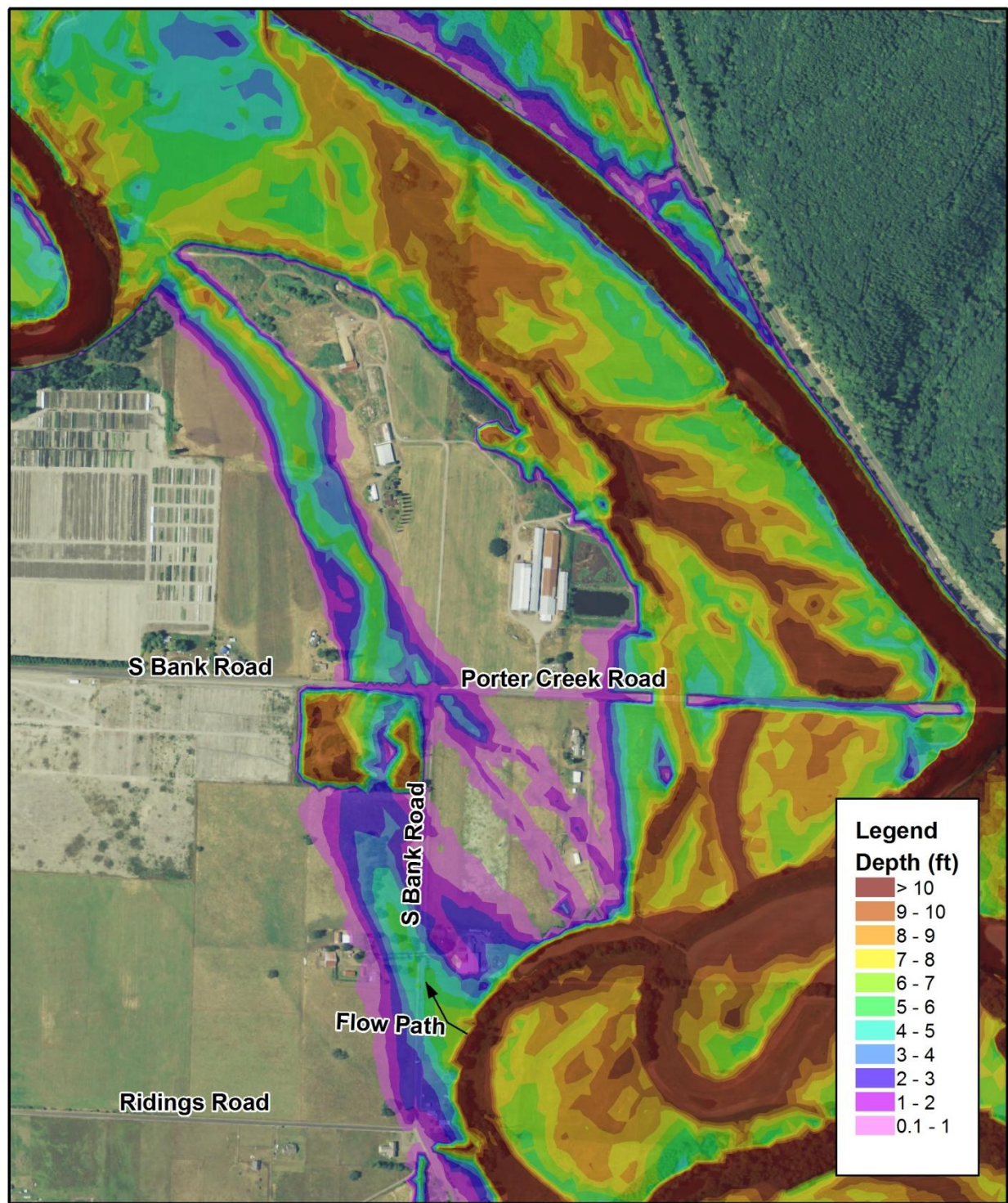


Figure 1: Comparison of Peak 100-year Water Levels in Study Reach

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Grays Harbor County, WA



Porter-Elma Reach Analysis
Chehalis River
Depth: 100-year Event (86,100 at Porter Gage)
at Flow Path Near Porter Creek Road

0 600 1,200
Feet

Scale: 1:10,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

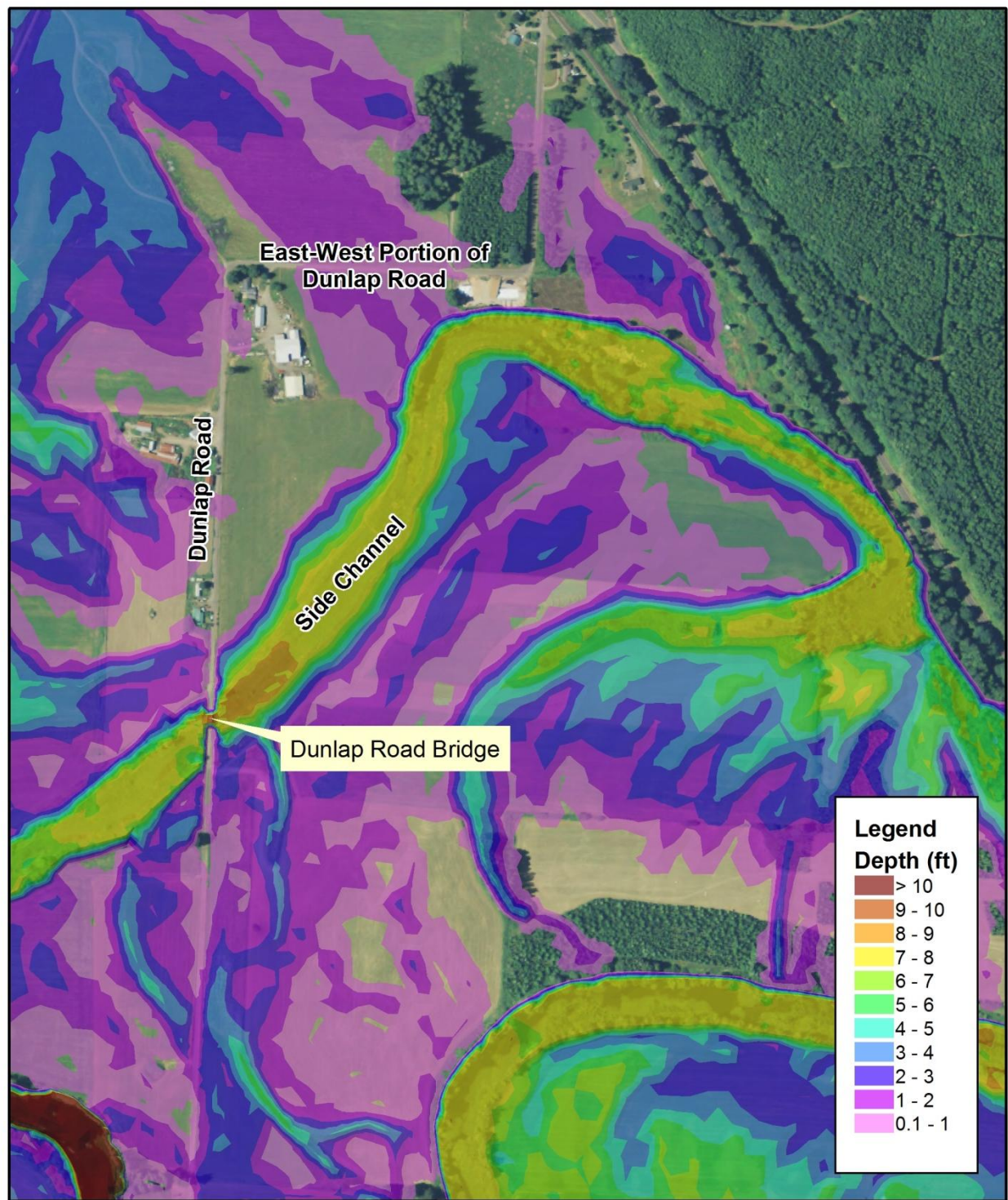


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Figure 2: Flow path from Chehalis River to Porter Creek Road/South Bank Road Intersection

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Legend	
Depth (ft)	
> 10	
9 - 10	
8 - 9	
7 - 8	
6 - 7	
5 - 6	
4 - 5	
3 - 4	
2 - 3	
1 - 2	
0.1 - 1	

Grays Harbor County, WA



Porter-Elma Reach Analysis
Chehalis River
Depth: 2-year Event (30,700 at Porter Gage)
near Dunlap Road

0 440 880 Feet

Scale: 1:7,321
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

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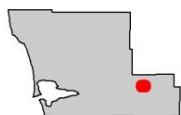


Figure 3: Overtopping of the east-west portion of Dunlap Road near the side channel at Dunlap Road Bridge



Grays Harbor County, WA



Porter-Elma Reach Analysis
Chehalis River
Areas Potentially Inundated North of Highway 12
During a 100-year Event on the Chehalis River

0 690 1,380 Feet



Scale: 1:11,000
NAD 1983 HARN
StatePlane Washington
South FIPS 4602 Feet

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Figure 4: Areas potentially inundated by Chehalis River backflow