

EXECUTIVE SUMMARY

PROJECT BACKGROUND AND PURPOSE

Pierce County is conducting the Lower Puyallup River Flood Protection Investigation to address significant flood-related issues affecting communities along the Lower Puyallup River. Under federal flood-management guidelines, these communities are facing restrictions on properties within a broad area that is newly defined as floodplain, based on recent floodplain maps developed by the Federal Emergency Management Agency (FEMA).

Federal regulations establish structural criteria that levees must meet in order to be certified as providing 100-year flood protection; the certification must be made by a registered professional engineer or a federal agency with competence in levee design and construction. Levees cannot be certified if they fail to meet any of the criteria, and uncertified levees cannot win accreditation under FEMA's National Flood Insurance Program (NFIP). The NFIP requires that floodplains around levees without accreditation be mapped as though there are no levees at all.

The Lower Puyallup levees were accredited as 100-year levees when flood mapping was last performed in this area (in 1987), but since then, sediments accumulating along the river bottom have raised river water levels so that the tops of the levees are no longer at least 3 feet above the predicted 100-year water levels, which is one of the requirements for federal certification.

The “without-project” analysis is a first step in the process of finding ways to reduce the size of the recently mapped floodplain. This analysis evaluated flood-related conditions along the river as they are today and will be in 50 years if no new flood-protection project is undertaken. The analysis used the most current information available and advanced analytical techniques to assess these without-project conditions. The key findings sought in this analysis were as follows:

- Hydrology—The expected river flows associated with floods up to the 500-year event, based on analysis of more than 90 years of Puyallup River flow records
- Levees—The geotechnical characteristics and physical condition of the levees, as well as the associated likelihood of levee failure
- Sediment Deposition—The characteristics of river sediments and the likely deposition of sediment and resulting rise in river bed levels in the future
- Hydraulics—Likely locations of levee overtopping and breaching, the resulting amounts of flow over the levees, and the corresponding extent of flooding
- Economics—The costs of damage associated with expected flooding.

Development of flood protection measures for the Lower Puyallup River will ultimately require integration of the technical findings of this report with environmental analyses so that the benefits, costs and impacts of a proposed alternative can be fully evaluated. Each alternative will need to fully evaluate potential impacts on environmental, cultural and socioeconomic resources. An appendix to the without-project analysis report describes the existing environmental conditions.

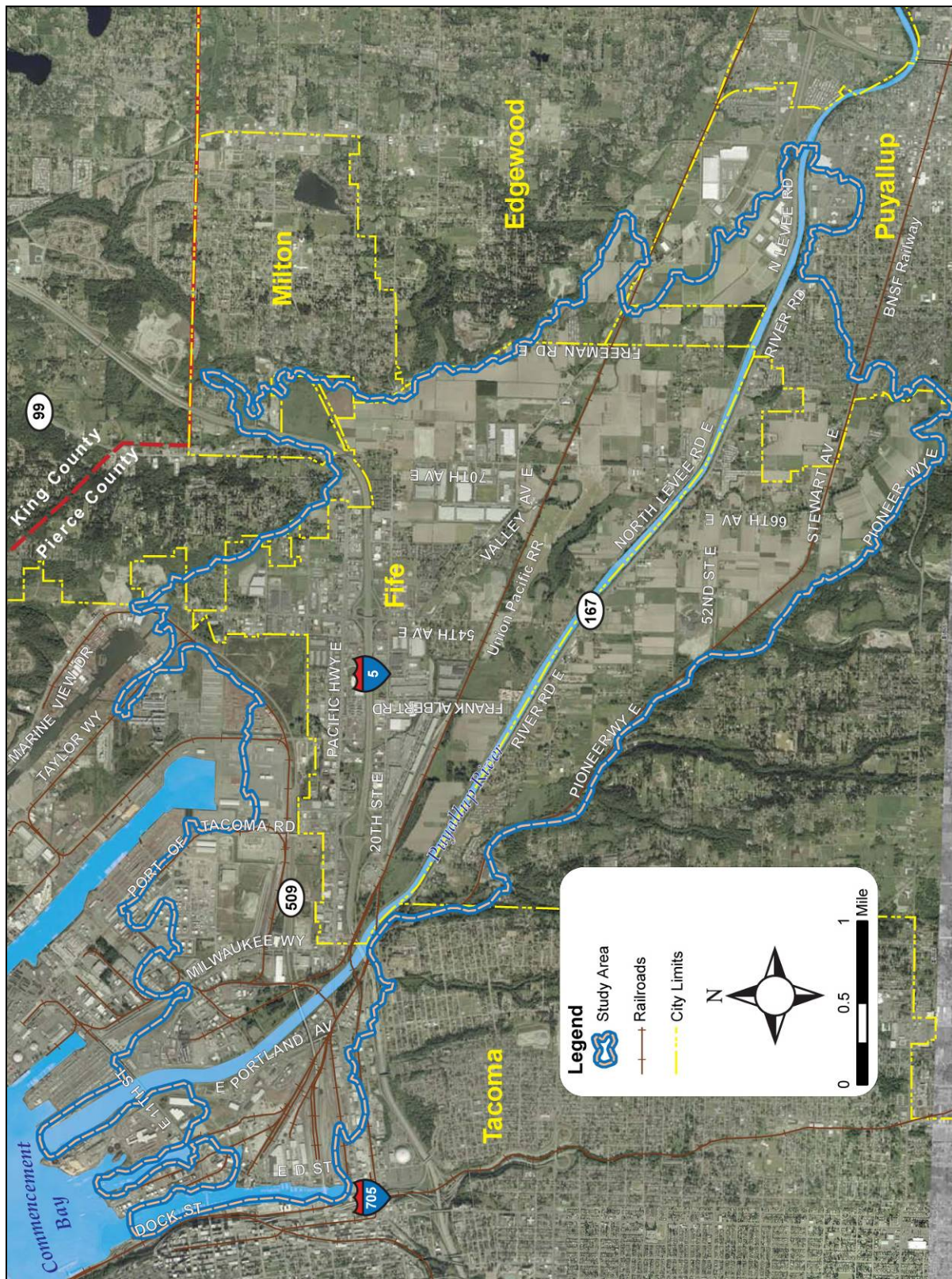


Figure ES-1. Study Area for the Without-Project Analysis

STUDY AREA DESCRIPTION AND HISTORY

The Puyallup River drains the southwest flank of Mount Rainier and is joined along its course by the Carbon and White Rivers, major tributaries that also drain Mount Rainier. The Lower Puyallup is the 8-mile reach of the Puyallup River extending upstream from the river mouth at Commencement Bay to about the Meridian Street Bridge in the City of Puyallup. The study area for the flood-protection investigation is the 500-year Lower Puyallup floodplain mapped by FEMA in 2007, as shown in Figure ES-1.

Levees, constructed between 1914 and 1924, line both banks of the river for the entire length of the study area. In this report, areas on the south side of the Lower Puyallup are referred to as the left bank (looking downstream) and areas on the north side are referred to as the right bank.

Three dams operate within the watershed: the U.S. Army Corps of Engineers' Mud Mountain Dam, completed in 1948, which is operated primarily to control flooding in the Puyallup River downstream of its confluence with the White River; Puget Sound Energy's White River Hydroelectric Project, completed in 1914; and Puget Sound Energy's Electron Hydroelectric Project, completed in 1904.

The most significant recorded floods in the study area occurred in December 1933 and February 1996. The 1933 flood was a major driver behind the 1936 authorization under the Flood Control Act for levee improvements and the construction of Mud Mountain Dam. Flood levels in the Lower Puyallup during the 1996 flood were reported to be at the top of the levees, but control by Mud Mountain Dam prevented overtopping and extensive damage in the study area.

HYDROLOGY

New hydrologic modeling performed for the without-project analysis determined peak flows for the 2-, 10-, 25-, 50-, 100- and 500-year flood events. Calculated peak flows included the peak 1-day-average, 3-day-average and 7-day-average flows, as well as the instantaneous peak, which is the highest flow at any given instant, not averaged over a longer period. The results are shown in Figure ES-2. These peak flows were fitted to flood hydrographs, based on historical storm records, to represent the river flow over the course of the flood event, for use in hydraulic modeling. The flood hydrographs are presented in Figure ES-3.

LEVEES

The levee evaluation performed for this report is preliminary, based on available records, personal communication, and limited field reconnaissance. Detailed geotechnical testing that will be required for use in future decision-making regarding the levees, such as borings or grain size sampling, was not performed. The following sections describe the conclusions of the preliminary evaluation.

Geotechnical Characteristics

Available geotechnical information indicates that the Lower Puyallup levees are generally constructed on fine-grained silt and clay, with deposits of clean to silty sand and gravelly sand. Although these soils appear to be generally consistent over the study area, soil conditions may vary substantially over short distances. Having been constructed using a dragline, the levees themselves likely consist of a mixture of the existing native deposits. The levee embankments and nearby foundation soils may also contain cobbles or boulders and wood piling. A terrace or bench of river-deposited fine sand and silt, 30 to 60 feet wide, exists between the levees and the river channel over most of the study area.

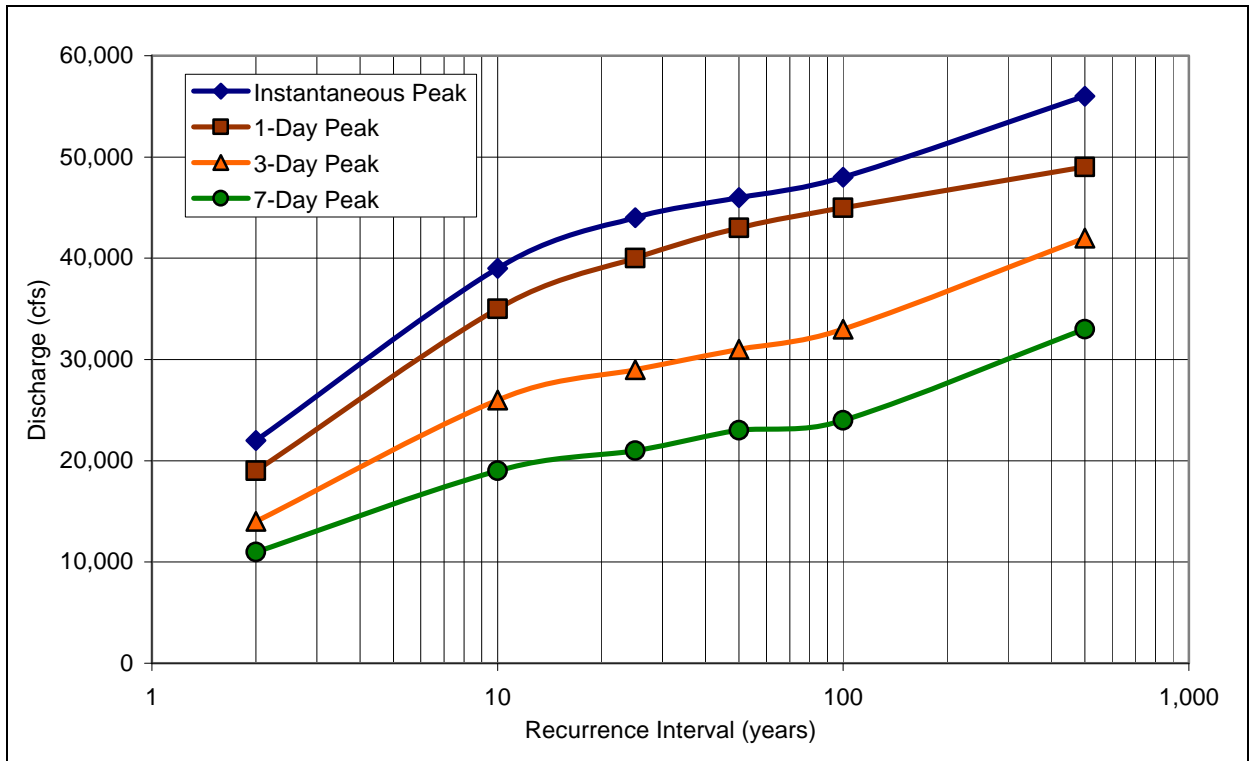


Figure ES-2. Peak Flows Estimated in Without-Project Analysis

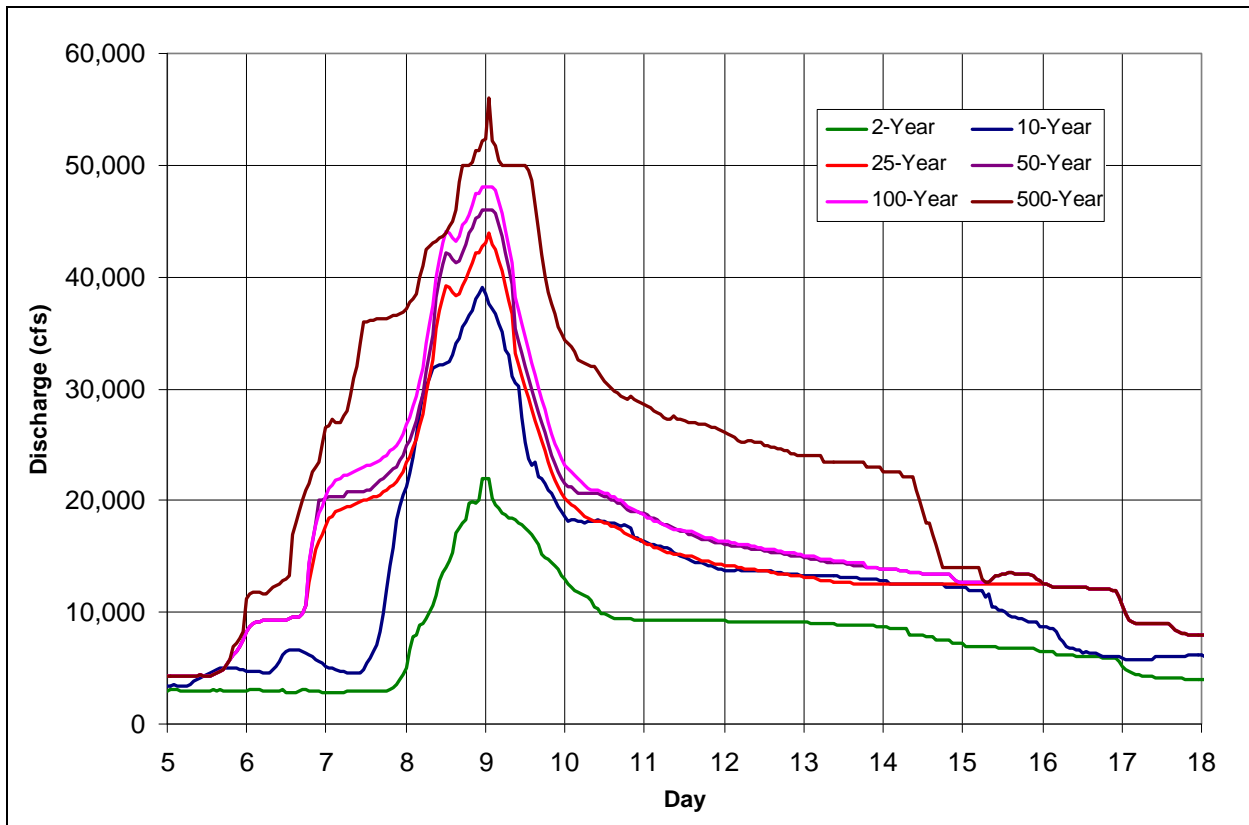


Figure ES-3. Design Hydrographs for the 2- through 500-Year Flood Events

Observed Physical Condition

Historical aerial photos of the levees generally show no evidence of instability or erosion, with the exception of two areas of apparent instability in photos from 1969: on the right-bank levee approximately 0.75 miles downstream of the bridge at 66th Avenue East; and on the left-bank levee approximately 1 mile downstream of SR-161. These features appear as indentations along the river side of the levees, with soil deposits in the river at the base of the indentations. In general, the photographs show a consistent line of trees along the margins of the stream, indicating a lack of significant erosion.

A reconnaissance performed for this study generally found little evidence of significant erosion of the silt bench along the river side of the levees. Although numerous tension cracks and some evidence of erosion were observed along the margin of the silt bench, the bench appears to have maintained its width and a line of trees along the margins of the river. Erosion of the river edge of the silt bench is evident on the right bank near River Mile (RM) 5.3, and Pierce County has deemed this erosion to be significant to the extent that they are pursuing designs and permitting to perform silt bench stabilization work.

The roads on top of the levees show no cracking or set-downs that would indicate levee instability. In scattered locations, concrete panels on the levee slopes are visible; however, in most areas the panels are covered by a layer of soil and vegetation up to 1 foot thick. The most common form of damage to the concrete panels is cracking.

Stability and Seepage Analysis

A rapid-drawdown analysis of selected levee segments indicates that the levees generally have a sufficient factor of safety against failure toward the water side. A steady-state seepage analysis found that the levees have an adequate factor of safety against shallow failures on the land side (those that result in a failure surface in the levee extending 3 to 4 feet back from the top of the slope). Given soil and construction variability, the actual factor of safety for instability in some locations is likely lower than computed for the levee segments analyzed, but it is unlikely to approach 1.0.

Modeling also showed that seepage-induced soil erosion from the levee and the potential for sand boils to occur is low for transient river conditions. The transient river conditions modeled simulated the elevation change associated with the rise and fall of the Puyallup river surface for the design flood event considered, and the time over which the river rises and falls. The results indicate that for uniform soil conditions, failure by seepage for the levees subjected to transient river conditions has a low probability. The potential for seepage-induced instability or piping would be greater if the river were assumed to remain elevated at the design flood elevation until steady-state flow through the levee. The Corps specifies that the sustained elevated river, steady-state condition be considered when evaluating levees for certification. Steady-state seepage was not evaluated for this analysis because the levees were being evaluated for their existing condition, Puyallup river flood flows are controlled by regulation at Mud Mountain dam, a significant river flow history is available, and probable failure point analyses are part of this preliminary levee study.

Probable Failure Point Analysis

Based on subsurface information, levee geometry, past performance, and engineering judgment, the probable failure point (PFP) for the right-bank levee is estimated to be 1 foot below the top of the levee; this is the river water level that has an 85-percent chance of causing levee failure. The probable non-failure point (PNP), which is the river level with a 15-percent chance of causing levee failure, is estimated to be 3 feet below the top of the levee. PFP and PNP were not assigned for the left-bank levee, which is not expected to experience failure.

Erosion and Overtopping

The levees are generally protected from erosion on the river side by the presence of vegetation and concrete panels on the levee embankment and by the presence of the silt bench and riprap adjacent to the river-side levee toe. There apparently has been no significant erosion of the levees since about 1940. If the levees are overtopped during a flood event and the volume and duration of flow are sufficient, the landward surface of the embankment would experience erosion. Once erosion of the sand levees begins, it would quickly progress riverward, breaching the levee. Once breached, breach widths in excess of 50 feet would develop. Overtopping locations and flow rates are described below in the section on hydraulics.

SEDIMENT DEPOSITION

The river-bed sediment is a poorly graded sand, with a median particle diameter of 0.35 mm (medium sand). The quantity of sediment suspended in the river varies with river flow, as shown in Figure ES-4.

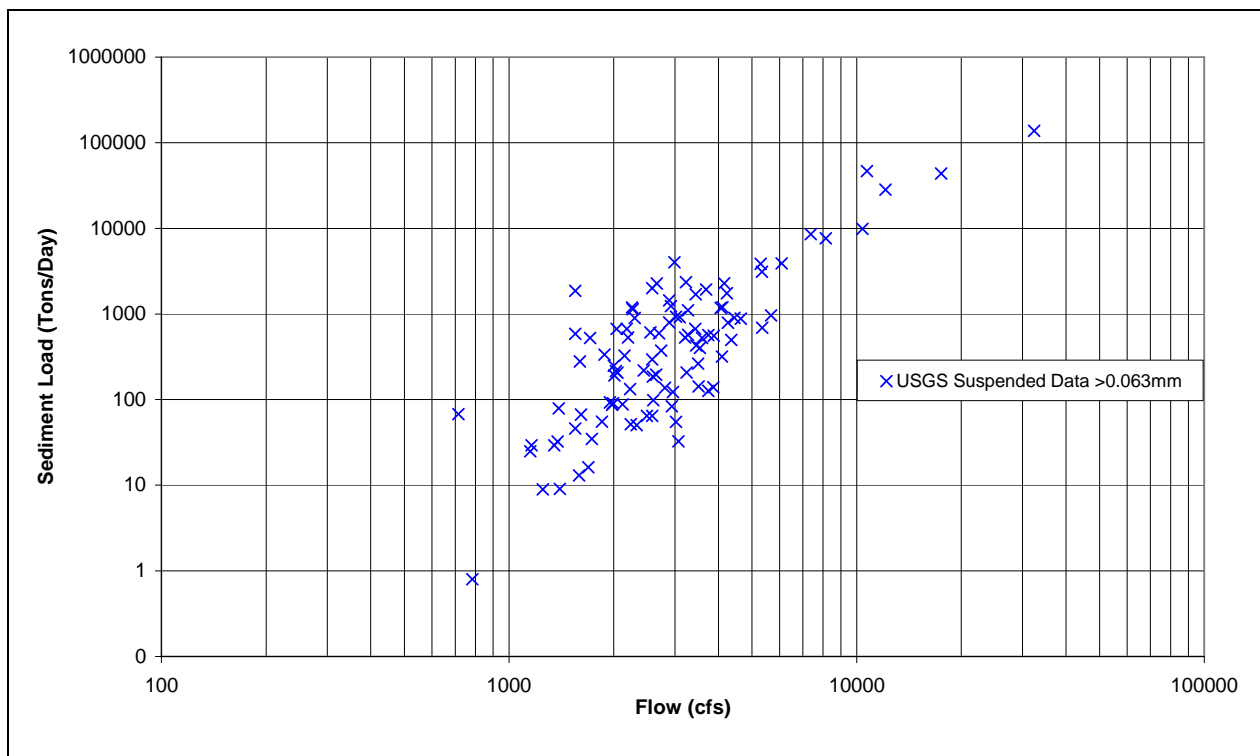


Figure ES-4. Sediment Rating Curve for Puyallup River at Puyallup Gage (12101500), 1978–1994

Sediment modeling of the total accumulated load (the total weight of suspended sediment passing each section of the river) shows little change in the load for the uppermost 2 miles in the study area, indicating that sediment passes through this reach without significant erosion or deposition of the bed material. The load then decreases as the river approaches Commencement Bay, consistent with observations of significant deposition on these lowermost reaches of the Puyallup River.

The sediment model was used to predict river bed levels throughout the study area as sediment accumulates over a 50-year period. The model shows that the Lower Puyallup would trap about 13 percent of all bed material sediment transported into it over the initial 10 years of simulation; but less than 5 percent over the final 10 years. This suggests that without dredging or other major changes to the bed, the channel will progress toward a higher bed elevation.

Over 50 years, the Lower Puyallup’s bed elevation will typically rise 1.5 to 3 feet, with a rise of up to 5 feet in some locations. River bed levels predicted by the sediment model over the length of the Lower Puyallup for the years 2007, 2017 and 2057 are used in the hydraulic and economic modeling performed for the without-project analysis.

The rise in river bed elevation will result in rising river water levels. For example, the 100-year flood elevation would be 2 feet higher in 2057 than in 2007 at River Mile 2.27, and the 500-year flood elevation would be 2.2 feet higher in 2057 than in 2007 at River Mile 2.40.

HYDRAULICS

Overtopping

The location, duration and magnitude of potential levee overtopping was identified using a simulation that accounts for water passing over the top of the levees but assumes that no levee breaches occur. Figure ES-5 shows overtopping levee segments, which are identified by the approximate river mile.

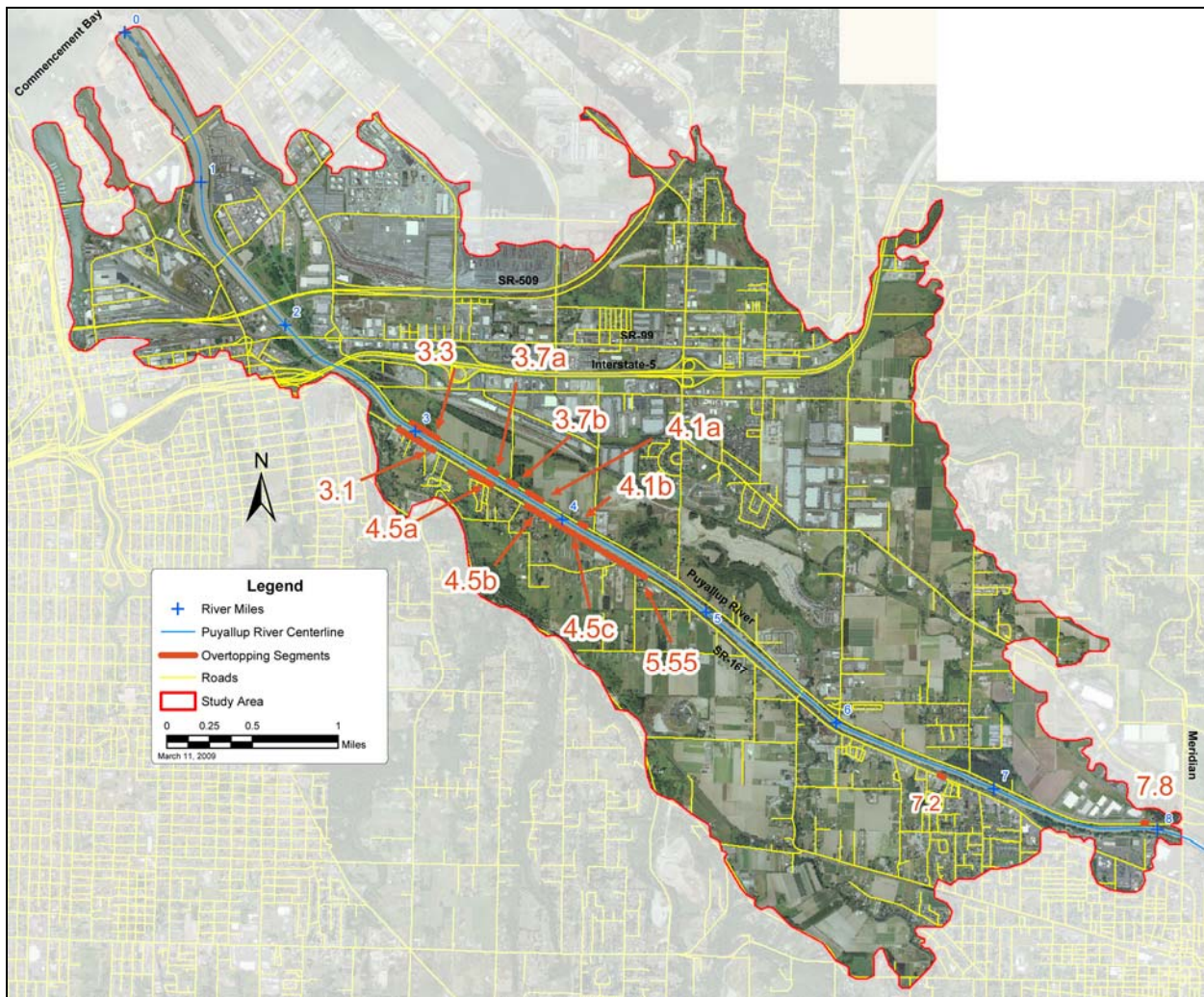


Figure ES-5. Predicted Levee Overtopping Locations

Key results are as follows:

- With the 2007 river bed levels during the 100-year event, the right levee will be overtopped only at Segment 3.3; the overtopping will last for less than nine hours.
- With the 2007 river bed levels during the 500-year event, water will overtop Segment 3.3 for approximately 24 hours and right-bank Segments 3.7a, 3.7b, 4.1a and 4.1b for shorter periods. The most significant left-bank overtopping occurs at Segment 3.1, with a duration of 28 hours; water will also overtop the left levee at Segments 4.5a, 4.5b, 4.5c, 5.55, and 7.2.
- Overtopping is more severe for the raised 2017 and 2057 river bed levels, resulting from accumulated sediment, than for the 2007 bed level. Overtopping would occur at more locations and for floods below the 100-year event.

Levee Breaches

At the locations where the model predicts levee overtopping, assessments were made as to whether a breach is likely. The decision was made to model a breach only at Segment 3.3, but to use a relatively wide breach to include the possibility of a breach developing at Segments 4.1a and 4.1b. Landward of the right-bank levee there is a railroad embankment. The railroad is predicted to be overtopped during the 2007 river bed 500-year flood and it too could fail, so another breach was simulated in the railroad embankment.

Flooding Rate

Hydraulic modeling was used to simulate 43 combinations of river bed level (2007, 2017 or 2057), event recurrence interval (2-, 10-, 25-, 50-, 100- and 500-year flood events), and levee breach condition (no breach, breach at the PNP flow level, and breach at the PFP flow level). Table ES-1 summarizes the peak total discharge out of the Lower Puyallup for various flood conditions, as estimated by the hydraulic modeling.

TABLE ES-1. TOTAL PEAK DISCHARGE OUT OF LOWER PUYALLUP RIVER CHANNEL DURING FLOOD EVENTS						
Location ^b	Total Peak Discharge from Lower Puyallup Channel (cubic feet/second)					
	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
2007 River Bed Level						
No Levee Breach	0	0	220	410	770	3,300
Right Levee Breach at PNP		6,880	8,260	9,600	10,580	14,140
Right Levee Breach at PFP						13,590
2017 River Bed Level						
No Levee Breach	0	0	570	1,310	2,250	8,040
Right Levee Breach at PNP		7,680	10,180	11,490	12,610	16,240
Right Levee Breach at PFP			12,070	11,140	12,810	15,720
2057 River Bed Level						
No Levee Breach	0	230	880	2,000	3,420	11,310
Right Levee Breach at PNP		7,960	10,470	11,870	12,940	17,640
Right Levee Breach at PFP		230	10,130	11,690	12,430	17,110

Based on the hydraulic modeling results, new floodplain maps were generated for three river bed levels (2007, 2017 and 2057) and three levee failure scenarios (no levee failures; failure at the PNP river level; and failure at the PFP river level). Figure ES-6 is a sample of one of the new floodplain maps.

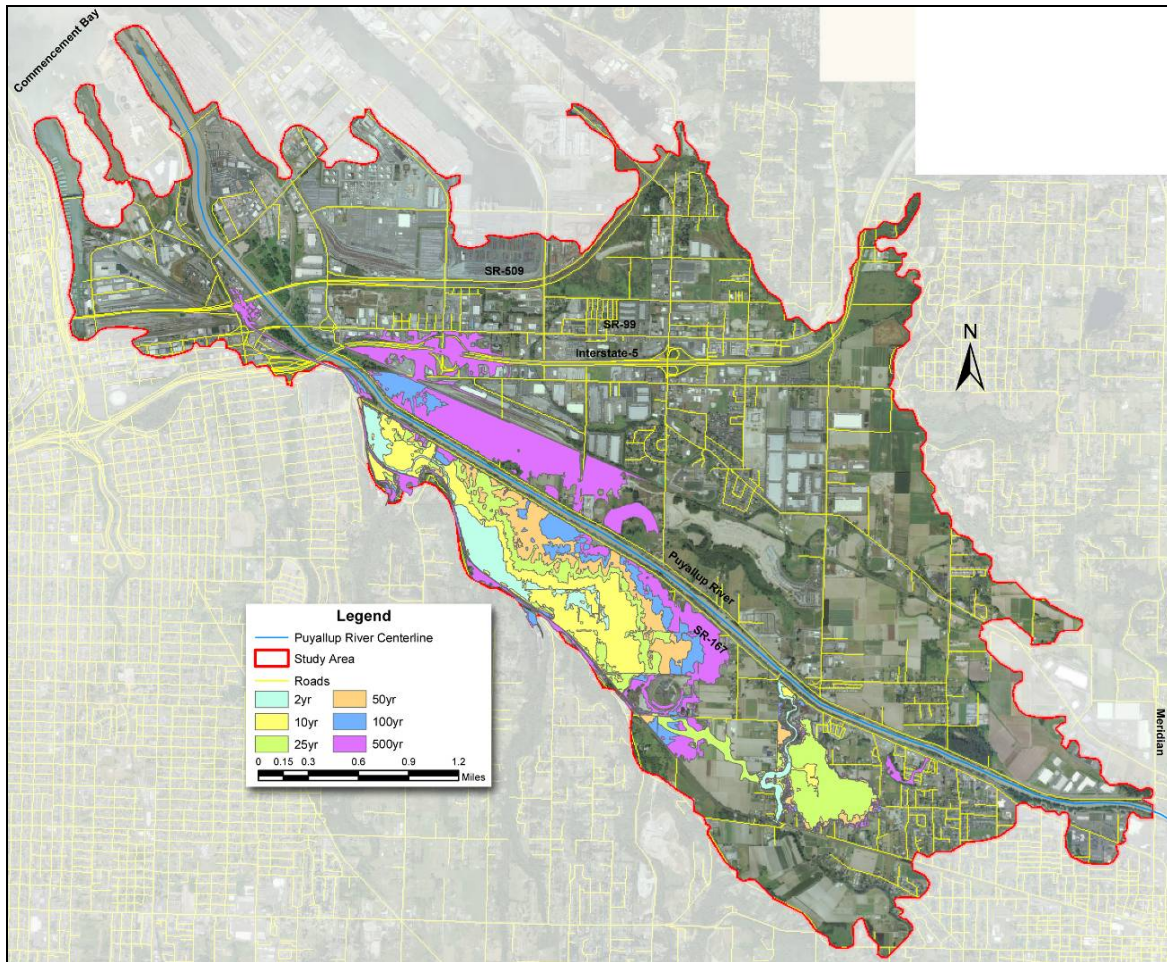


Figure ES-6. Predicted Flooding for 2007 River Bed Levels with No Levee Breach

ECONOMICS

The first step in the economic analysis was to assess the number of structures inundated by flooding, based on the updated floodplain maps, and the depreciated replacement value of those structures. Depreciated replacement value was based on structure condition and is used in the analysis to reflect the actual value subject to damage as opposed to full replacement cost, which would reflect a betterment relative to actual conditions. Subsequent analyses estimated damage costs associated with predicted flooding of the structures and their contents, as well as costs associated with automobile losses; crop, road and railroad losses; cleanup; and temporary relocation and other public assistance. These costs were estimated for the predicted river bed levels for 2007, 2017 and 2057. Table ES-2 summarizes the total estimated costs for all these losses. All costs shown are in 2007 dollars.

TABLE ES-2. TOTAL ESTIMATED FLOOD DAMAGE COSTS						
	Estimated Value of Flood Damage					
	100-Year Event			500-Year Event		
	2007	2017	2057	2007	2017	2057
Right Bank	\$84,367,000	\$96,248,000	\$101,801,000	\$100,379,000	\$106,623,000	\$109,387,000
Left Bank	\$8,570,000	\$10,338,000	\$11,017,000	\$13,355,000	\$15,996,000	\$17,100,000
Total	\$92,937,000	\$106,586,000	\$112,818,000	\$113,734,000	\$122,619,000	\$126,487,000

The final economic analysis combined the estimates of flood damage for each flood event with the likelihood of each event to estimate the expected annual average equivalent damage over a 50-year period. These estimates were developed for the scenario in which the levees fail based on the PNP and PFP established for this study, and for the scenario in which there is no levee failure, only overtopping of the levees due to high river flows. Table ES-3 summarizes the results for these two scenarios. Costs are again shown in 2007 dollars.

TABLE ES-3. 50-YEAR AVERAGE ANNUAL EQUIVALENT DAMAGE WITH AND WITHOUT LEVEE FAILURE			
	Average Annual Equivalent Damage		
	Right Bank	Left Bank	Total
With Levee Failure	\$6,382,000	\$1,227,000	\$7,609,000
Overtopping Only	\$463,000	\$1,296,000	\$1,759,000