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TECHNICAL MEMORANDUM

Date:	August 6, 2013
To:	Mike Wincewicz City of Montesano
From:	Steve Schmitz, PE
Subject:	Summary of Mary's River Mill and WWTP Protection Options
cc:	Mayor Ken Estes, City of Montesano
Project Number:	217-1678-040
Project Name:	Bank Stabilization Project

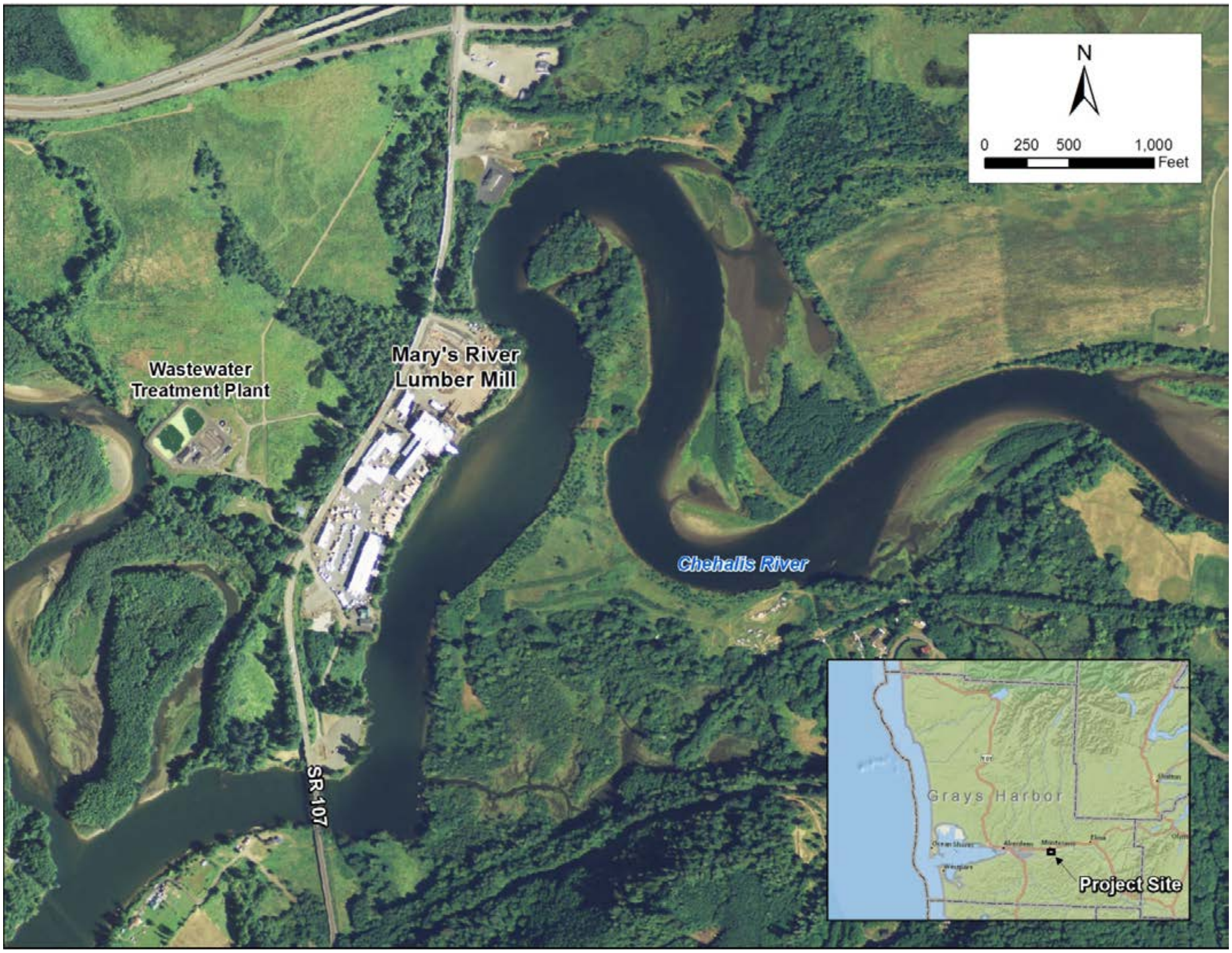
This memorandum summarizes the results of hydraulic, geomorphic, and reach analysis completed on the Chehalis and Wynoochee Rivers, in the vicinity of the Mary's River Lumber (MRL) Mill and the City's wastewater treatment plant (WWTP). Four options for stabilizing the river bank along the mill site where consider, as well as, three alternatives for the protection of the WWTP.

Background

The Mary's River Lumber Mill is located on the north bank of the Chehalis River near Montesano, WA; about 1,400 feet upstream of the SR 107 Chehalis River Bridge. The site is about 13.4 miles upstream from the mouth of the Chehalis River. Due to significant change in the alignment of the Chehalis River near the lumber mill, there is concern about the potential for bank erosion at the mill if a cutoff of the meander bend immediately upstream of the lumber mill were to occur. A meander cutoff could direct high velocity flows at or parallel to the banks adjacent to the mill and cause the thalweg to shift toward the mill, resulting in bank erosion and damage to the mill.

The City is also looking to protect the clarifiers, lagoons, and equipment at its wastewater treatment plant (WWTP) from high flows in the Wynoochee River. During the January 2009 storm event, flood waters reached to within 6-inches of the top clarifiers.

See Figure 1 for Location Map.



- **Figure 1. Location Map**

Summary of Hydraulic Analysis

Historic aerial photographs of the Mary's River Lumber Mill were used to obtain an understanding of how the active channel of the Chehalis River changed through recent history. The historic aerial photographs were obtained from various sources and for years from 1953 to 2011. To characterize the history of channel movement in the vicinity of the lumber mill, the boundaries of the active channel reflected in the historic aerial photographs were identified and compared. The comparison indicates that the bank adjacent to the mill has not experienced significant erosion, while the land across the channel from the mill has been eroding due to the migration of the meander bend. It is apparent that the meander immediately upstream of the mill will be cutoff in the near future. The meander cutoff will likely result in more direct impingement of flows against the bank adjacent to the mill.

Based on the review of historic aerial photographs, it is apparent that the planform of the active channel upstream of the lumber mill is highly dynamic and has changed significantly within the last 58 years. If no action is taken, the observed pattern of channel migration can be expected to continue in the future, resulting in the cutoff of the meander immediately upstream of the lumber mill. As observed from the historic photos, large changes in the channel bank alignment tend to occur as the result of large flood events, such as the 1996 and 2007 floods.

The erosion rate of the meander across from the lumber mill was estimated by measuring the minimum distance along the expected meander cutoff path. Table 2 summarizes: (1) the remaining minimum land distance along the expected meander cutoff path upstream from the mill; (2) the calculated incremental erosion rate, which corresponds to the rate of erosion between two sequential records; (3) long-term erosion rate, which corresponds to the rate of erosion since 1953; and (4) any miscellaneous notes. As shown in the table, the remaining land distance along the cutoff path has decreased from 890 feet to 200 feet over 58 years, the long term erosion rate has been about 12 feet per year since the early 1980’s, and the maximum rate of change (65 feet per year) occurred as a result of the 2006 flood event.

At the current erosion rate of 12 feet per year, it would be about 17 years before the breakthrough occurs. At the fastest rate of erosion of 65 ft. per year it would only be 3 years before the breakthrough occurs. Therefore, the breakthrough would be expected to occur between 3 to 17 years from 2011 (2014-2028).

Table 1. Summary of erosion rates for the ground opposite of the Mary's River lumber mill.

Year	Minimum Distance along Cutoff Path Upstream of Mill	Incremental Erosion Rate (feet/year)	Long Term Erosion Rate (feet/year)	Notes
1953	890	-	-	-
1962	850	4.4	4.4	-
1967	850	0.0	2.9	-
1972	760	18.0	6.8	A relatively large flood event occurred on 1/22/72.
1975	705	18.3	8.4	-
1981	570	22.5	11.4	-
1985	530	10.0	11.3	-
1990	505	5.0	10.4	A relatively large flood event occurred on 1/11/90.
1997	415	12.9	10.8	A significant flood event occurred on 1/9/96.
1999	375	20.0	11.2	-
2005	355	3.3	10.3	In 2002, bank protection measures were installed on the outside of the meander bend immediately upstream of the mill.
2006	290	65.0	11.3	A significant flood event occurred on 1/13/06.
2009	240	16.7	11.6	December 2007, January 2009 events occurred
2011	200	20.0	11.9	-

Scour Estimate

An analysis was completed to estimate the maximum scour depth anticipated near the proposed bank protection. The analysis was conducted assuming that the river had cutoff the meander opposite of mill site.

The design of a resistive bank erosion protection measure must account for potential scour depths anticipated near the structure. Therefore, the scour elevation at the structure was estimated for the 1996, 2007, 2009, 100-, and 500-year flood events. The type of scour anticipated at the structure includes only bend scour. Long-term degradation was not considered because the project site is located within a reach that is typically depositional, and some of the other scour components, such as thalweg migration, are accounted for in the equation used to estimate the bend scour. Bend scour is associated with scour along the outside of a bend caused by transverse or "secondary" currents created by the bend. Material scoured from the outside of a bend is characteristically deposited along the inside of the bends downstream. The results of the scour calculations are summarized in Table 7. It is recognized that the results of the bend scour evaluation are based on assumed conditions. Compared to observed minimum historic profile elevations, the assumed analysis conditions may not represent the most severe scour conditions that could occur. To minimize risk for the revetment design, it is recommended that a maximum scour of elevation -50 ft. NAVD88 be considered.

Table 2. Results of scour calculations.

Event	Scour Elevation (feet, NAVD88)
1996	-41.5
1% exceedance (100-yr)	-41.9
0.2% exceedance (500-yr)	-44.0

<u>Summary of Hydraulic Analysis</u>

Parametrix and WEST Consultants, Inc. (WEST) evaluated changes in the active channel of the Chehalis River through recent historic aerial photography and conducted hydraulic and scour analyses for bank protection measures considered along the mill and at the WWTP. These analyses concluded that the active channel along this reach of the river has moved progressively west since 1953, predominantly in the meander bend located upstream and directly across the channel from the mill (Figure 1). The distance between the meanders in this location has reduced from 890 feet in 1953 to ≈ 90 feet in 2013. The average long term erosion rate has been approximately 11 feet per year, with maximum changes of up to 65 feet of erosion during the major flood event in 2006. This trend makes it apparent that the meander bend will be cut off entirely in the near future, resulting in the river flowing directly toward the mill shoreline. Not only does this represent a significant problem for the mill; this occurrence could also result in increased river velocities at the SR 107 Chehalis River Bridge. Erosion has previously exposed shallow footings of the adjacent bridge piers in this location, which represents a serious threat to the stability of the bridge and the safety of drivers using the bridge.

MARY'S RIVER MILL BANK PROTECTION ALTERNATIVES

Four potential alternatives have been considered for stabilizing the river bank to prevent erosion along the mill site.

Alternative 1 – Full Channel Bypass: This potential solution includes reopening the relic river channel identified on historic aerial photos that reenters the Chehalis River upstream of the mill. This solution would significantly shorten the length of the channel upstream of the SR 107 Chehalis River Bridge, which could decrease the loss of energy the river experiences along its current path. This increase in energy can be mitigated through the use of bank roughing and other engineered structures. Construction of this alternative would result in the removal of approximately 450,000 cubic yards of material. Removal of such a large quantity of material may prove problematic as access to the site is limited. The area designated for the proposed channel is also privately owned property. Through discussions with the property owner, it is apparent that the property could be purchased, but the location of the proposed channel may be a point of contention. The relic channel currently functions as a productive tidal marsh and provides valuable salmonid rearing habitat. Loss of this habitat, approximately 5 acres, would require remediation and increases potential objections from permitting agencies and local stakeholders.

Feasibility

Potential Solution 1 is considered unfeasible because:

- Army Corp objections based on Section 10 of the Rivers and Harbors Act of 1899 prohibits the unauthorized obstruction or alteration of any navigable waters of the US.
- Individual Corp permit would be required for this project, and may take up to two years to obtain.
- Constructability of this option would need to be carefully considered to facilitate removal of such a large volume of material.
- Property is privately owned requiring negotiations and purchase.

Alternative 2 - High Flow Bypass: This potential solution is a variation of the previous option and includes reopening only a small high flow channel to connect the main steam of the river to the relic river channel. This solution would divert a portion of high flows through a created wetland area and channel at the eastern end of the current relic channel. Construction of this alternative would result in the removal of approximately 80,000 cubic yards of material. Overtime the high flow channel may eventually lead to a cut through occurring at this location. As in the previous alternative this property is privately owned and would require purchasing. Furthermore it is not currently possible to estimate the reduction in erosion at the meander due to the high flow bypass. This would require installation of protection measures adjacent to the mill to ensure an adequate level of protection.

Feasibility

Potential Solution 2 is considered unfeasible because:

- Army Corp objections based on Section 10 of the Rivers and Harbors Act of 1899 prohibits the unauthorized obstruction or alteration of any navigable waters of the US.
- Property is privately owned requiring negotiations and purchase.
- Protection measures would still be required at Mary's River Mill to provide an appropriate level of protection.

Construction Cost Breakdown

Item#	Description	Unit	Est Quantity	Unit Price	Amount
1	Mobilization	LS	1	50,000.00	$50,000.00
2	Wetland Channel	CY	28,000	20.00	$560,000.00
3	Diversion Structure	LS	1	100,000.00	$100,000.00
4	Channel Surface Vegetation/Restoration	SY	8500	10.00	$85,000.00

Construction Cost = $795,000.00
Engineering and Contingency (25%) = $198,750.00
Assessed Property Value = $267,645.00
Project Total = $1,261,395.00

Alternative 3- Rip Rap Revetment: This alternative solution involves utilizing a rock riprap revetment to protect the bank along the mill. The riprap revetment considered would be comprised of light loose riprap along the bank and heavy loose riprap along the toe of the embankment. To prevent failure of the structure from undermining, a launchable toe would be placed along the toe of the bank. As erosion occurs below the toe of the revetment, rocks from the launchable toe is undermined and rolls/slides down the revetment slope to stop the erosion. Riprap is typically inappropriate in migrating channels; however the ability for channel migration is already significantly constricted in this reach.

This alternative may qualify for Army Corp Nationwide Permit #13 (NWP #13) Bank Stabilization, but would require additional negotiations with Corp. NWP #13 guidelines state that it is for projects no longer than 500 feet in length along the bank, and projects that qualify for the NWP #13 also are not to exceed an average of one cubic yard per running foot placed along the bank below the plane of the OHWM or high tide line; these requirements could be waived by the district engineer if it is determined that the adverse impacts would be minimal. If a wavier is not granted, the project would require an individual Corp permit which can require a 2+ year process.

Feasibility

Alternative 3 is considered unfeasible because:

- Impact to Department of Natural Resources property no longer under lease to the City.
- Removes existing vegetation and habitat from project area
- Required reconstruction and vegetation of shoreline area
- High construction cost due to amount of “in-water” work.
- Requires waiver to qualify for NWP#13. I
- Timeline for construction would be dependent of fish windows and agency permitting process.

Alternative 4- Sheet Pile Wall:

This alternative will involve armoring of approximately 1,400 linear feet of shoreline at the lumber mill with a sheet pile wall. The sheet pile will be placed landward of the Ordinary High Water Mark (OHWM) so that the waters of the Chehalis River will not be impacted. WEST was retained to conduct a scour analysis as part of considering the feasibility of a sheet pile wall. WEST’s findings indicated that scour elevations for the 100 year flood could be at -50 feet when the meander bend is cut off. Based on recommendations from WEST to armor approximately 1400 feet of the bank, a sheet pile wall approximately 1400 feet long and 60 feet tall would be necessary to fully protect the mill under future conditions. If eventual scour occurs along the sheet pile wall, the City should install log jams and habitat features to restore lost habitat and reduce downstream velocities.

This proposed alternative would require permits from the City of Montesano, including SEPA, shoreline development or shoreline exemption, and critical areas permits. A Construction Stormwater General Permit, issued by the Washington Department of Ecology, would not be required unless the project disturbs a minimum of one acre. If in future, any federal funding is secured for the project, NEPA will be required. If the project is designated a Categorical Exclusion (CatEx), an Environmental Classification Summary (ECS) would need to be completed. If the project does not meet the description of a CatEx, an Environmental Assessment (EA) would be required. Endangered Species Act (ESA) review is required for any project that necessitates a federal permit. If the City of Montesano receives federal funding, the funding source would require ESA review, in which case a biological evaluation (BE) could be required, to evaluate and avoid and/or mitigate effects on listed species and their habitats. In addition, a Certification of Consistency with Washington’s Coastal Zone Management (CZM) Program for Federally Funded Activities would need to be completed, demonstrating that the project either does not impact coastal resources, or if there are impacts, that the activity is consistent with the six laws identified in the CZM Program (Shoreline Management Act, State Environmental Policy Act, Clean Water Act, Clean Air Act, Energy Facility Site Evaluation Council, and the Ocean Resource Management Act). This certification involves a public notice and 21-day public comment period.

Channel Evolution

Exposure of sheet piles by erosion of the bank adjacent to the mill would define a non-erodible barrier to the river. The potential evolution of the channel as a result of this condition would be influenced by specific hydrologic conditions that would occur and the erosion and transport of sediment along the channel. The material eroded from the bank and additional sediment and debris transported from upstream through the new cutoff is deposited in locations of relatively quiescent hydraulic conditions. Typically, this would include flow separation zones surrounding locations of abrupt flow expansion. This would include areas downstream of the cutoff and around the boundaries of any scour hole that formed along the bank in the area of initial flow impingement. As sediment is deposited, new channel topography and flow patterns will become established along the bank adjacent to the Mill. Consequently, the flow pattern and channel topography along the bank adjacent to the Mill can be expected to evolve through time. The magnitude and rate of channel evolution will be dependent on the specific hydrologic sequence that is experienced after the cutoff occurs. If low flows occur, the magnitude and rate of change may be slow, whereas if large infrequent flood events occur, the physical changes adjacent to the Mill may be rapid.

Similarly, the channel cutoff opening could be expected to evolve with time, depending on the magnitude of flow experienced. In general, it would be expected that the size of the cutoff opening would enlarge through time, eventually achieving a width similar to the width of the upstream channel. The enlarged opening and deposition of the material eroded from the cutoff location in areas surrounding the cutoff, would be expected to influence the direction of flow toward the bank adjacent to the Mill. Accordingly, the location of any scour hole and the extent of exposed sheet piling would change through time. Areas initially exposed may buried sediments eroded and transported from adjacent areas.

Overall, the extent and magnitude of potential channel changes that might occur along the channel due to a channel cutoff and potential resultant exposure of sheet piling is highly uncertain but would certainly evolve with time according to the exact location of the cutoff, the specific hydrologic conditions experienced and the locations and rate of sediment erosion and deposition in the cutoff channel, along the bank adjacent to the Mill, and along the channel downstream of the cutoff location.

Feasibility

Alternative 4 is considered the most feasible of the four outlined above because:

- the property is controlled by the project proponent,
- constructible within in timeframe for mill redevelopment
- minimal permitting required since work is landward of OHWM. If federal funding is secured additional permits will be required.
- provides a high level of protection
- provides the opportunity for more environmental benefit such as maintaining habitat and bank roughness in the short term and the opportunity to install additional habitat features in the long term.

Construction Cost Breakdown

Item#	Description	Unit	Est Quantity	Unit Price	Amount
1	Debris Removal	LS	1	10,000	$10,000.00
2	Project Construction Survey and Staking	LS	1	4,000	$4,000.00
3	Erosion/Water Pollution Control	LS	1	5,000	$5,000.00
4	Mobilization	LS	1	100,000	$100,000.00
5	Sheet Pile Wall	LF	1400	3,000	$4,200,000.00

Construction Cost = $4,319,000.00
Engineering and Contingency (25%) = $1,079,750.00
Project Total = $5,398,750.00

WASTEWATER TREATMENT PLANT PROTECTION

The City of Montesano's waste water treatment plant is located adjacent to the Wynoochee River near its confluence with the Chehalis River. During significant floods, there are concerns that the existing dike may be overtopped and cause contamination of the river. Information provided by the City of Montesano, shows that flood waters came within 6-inches of the top of the bank. To protect the plant from future flooding Parametrix and WEST evaluated 100-year and 500-year flood events to determine heights for a proposed wall.

For the 100-year event the modeled water surface elevation is 19.54 feet. Similar results were found for the 2009 event. With the super elevation likely to occur due to the WWTP being at the outside of a sharp bend would add 0.64 feet to the water surface elevation. The 100-year water surface elevation would be approximately 20.2 feet, so the WWTP should be protected to 21.2 feet to provide 1 foot of freeboard (WSDOT standard) for the 100-year event. The anecdotal evidence suggests that the model results are a bit low. Since the 100-year event is about the same as the 2009 event, and the 2009 event was at approximately 20.75 feet (top of berm elevation estimated at 21.25 feet), we recommend raising the berm around the storage ponds to 22.5 feet for 100-year event protection. The 500-year water surface elevation at the WWTP is 22.3 feet with the super elevation included. With one foot of freeboard, the 500-year protection is elevation 23.3 feet. Maximum average channel velocities at the WWTP are 9.52 ft./s for the 100-year event and 9.05 ft./s for the 500-year event (the channel average at the time of the maximum velocity).

Based on this information various wall designs where evaluated to protect the mill for the 500-year flood event. The outcome of this evaluation is that a wall constructed of ecology blocks is the most economical solution. Ecology blocks are precast reinforced concrete blocks. To provide a water tight structure, the blocks would be grouted and caulked to ensure no water penetration. Below is a cost breakdown for this alternative.

Construction Cost Breakdown

Item#	Description	Unit	Est. Quantity	Unit Price	Amount
1	Excavation and ground preparation	CY	300	50.00	$15,000.00
2	CSTC	TON	100	20.00	$2,000.00
3	Precast Conc. Ecology Block	EACH	700	150.00	$105,000.00
4	Grout/Caulking/Gaskets	LF	100	75.00	$7,500.00
5	Mobilization	LS	1	10,000.00	$10,000.00
5	Class 4000 Concrete	CY	50	75.00	$3,750.00

Construction Cost = $143,250.00
Engineering and Contingency (25%) = $ 35,812.50
Project Total = $179,062.50

CONCLUSION

Ongoing erosion of the Chehalis River shoreline is currently threatening the MRL Mill. MRL and City seek to stabilize the bank along this property so that mill operations at the site can continue. This is desirable to maintain an existing use at an existing developed site so new development at another site can be avoided. A meander bend is located upstream of and across from the mill. The distance between the meanders has reduced by 600 feet in approximately 50 years. This trend makes it apparent that the meander bend will be cut off entirely in the near future, resulting in the river flowing directly toward the mill site. Four potential solutions have been considered for stabilizing the bank along the mill site. The fourth potential solution is identified as the preferred due to property ownership issues, the potential for environmental benefits, and in an effort simplify permitting and engineering process. This solution includes construction of a 1400 lf sheet pile wall, landward of the OHWM, along the bank in front of the mill.

In order to prevent sewage interaction with the Wynoochee River the waste water treatment plant should be protected to elevation 22.5 feet for the 100-year event, and to elevation 23.3 feet for the 500-year event. Protection would take the form of an ecology block wall which will provide protection to an elevation of 24.0 feet.

REFERENCES

Pacific International Engineering (PIE) and Pharos Corporation, 1996. *Chehalis River Bank Stabilization Project, Preliminary Engineering Design Report*, prepared for the City of Montesano, Washington.

Washington Department of Transportation, 2005 (July). *Reach Assessment for the SR 107 Chehalis River Bridge at Montesano*, prepared by Robert W. Schanz and Jim Park.

WEST Consultants, Inc., 2008 Technical Memorandum, *Mary's River Lumber Mill Erosion Protection Measure Historical Aerial Analysis and Protection Recommendations.*

WEST Consultants, Inc., 2013 Technical Memorandum, *Hydraulic Analysis at Mary's River Lumber Mill, SR 107 Bridge, and the Wastewater Treatment Plant on the Wynoochee River*

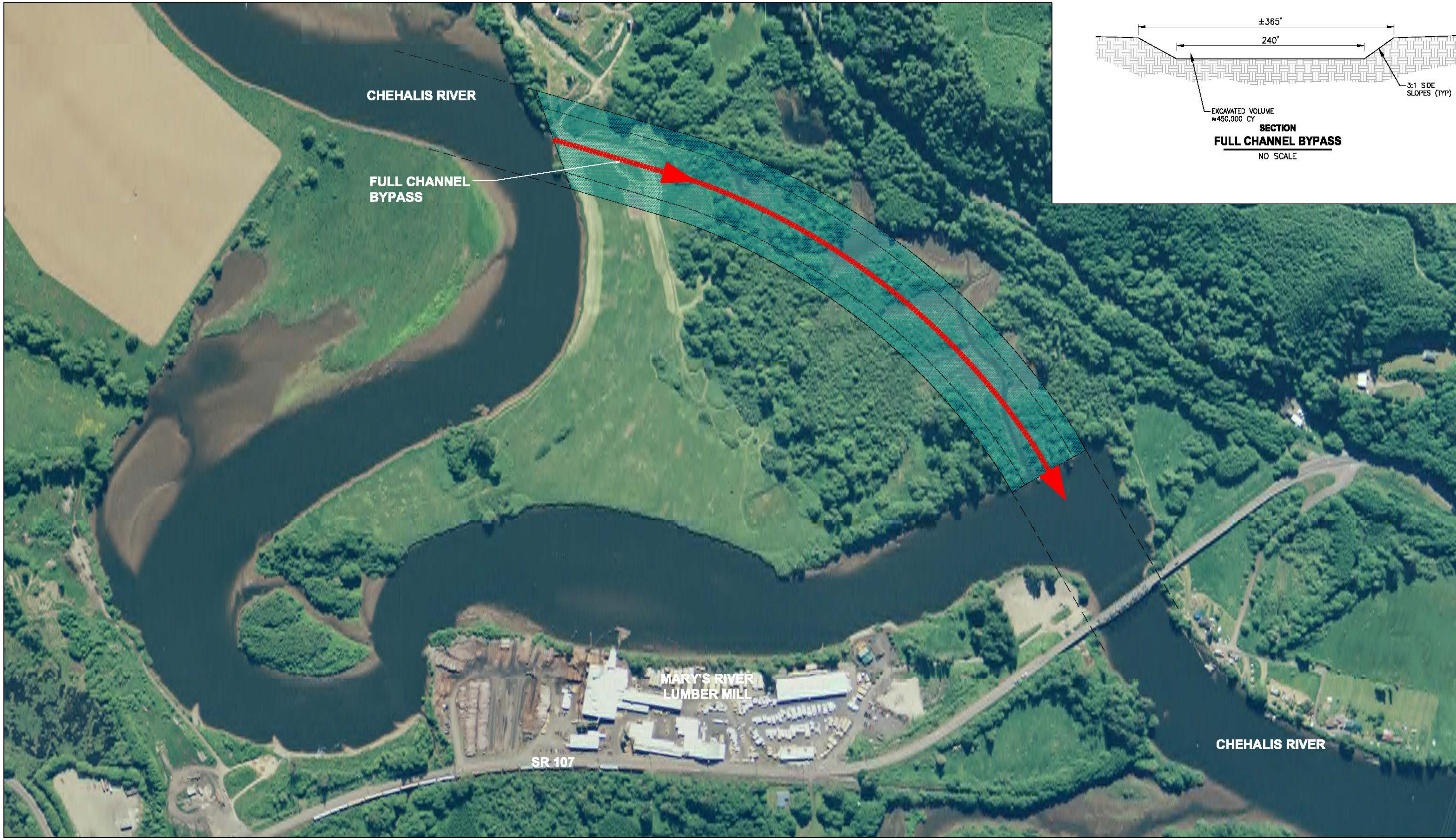
ATTACHMENTS

1. Alternative Solution Figures

2. Waste Water Treatment Plant Proposed Improvements

3. Sheet Pile Installation Phasing

4. WEST Consultants, Inc., 2013 Technical Memorandum



Parametrix

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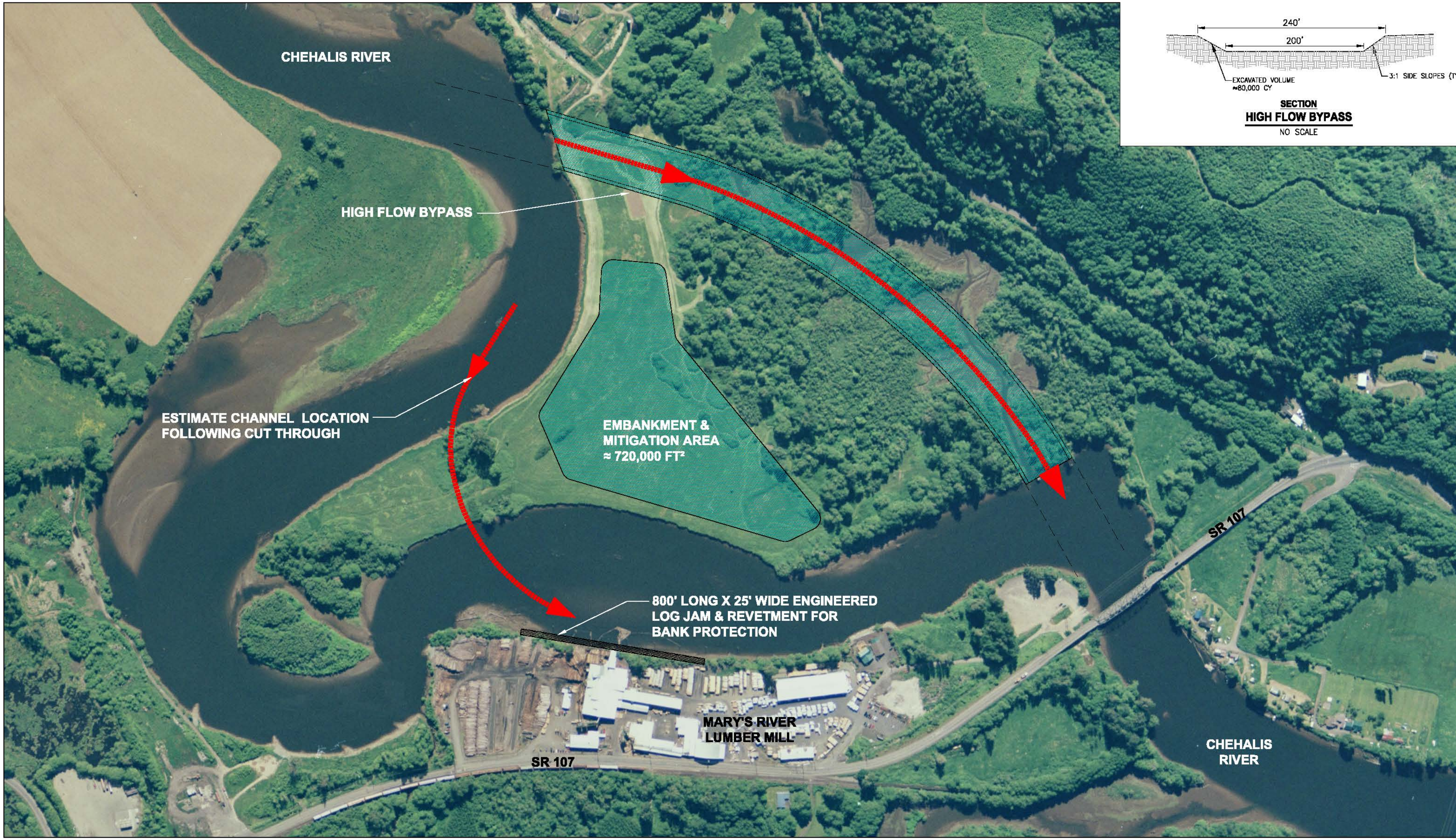
SCALE IN FEET

ALT# 1 - FULL CHANNEL BYPASS
MARY'S RIVER LUMBER
CITY OF MONTESANO



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ALT# 2 - ELG & HIGH-FLOW BYPASS
MARY'S RIVER LUMBER
CITY OF MONTESANO

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ALT# 3 - RIPRAP REVETMENT
MARY'S RIVER LUMBER
CITY OF MONTESANO

Parametrix

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SCALE IN FEET

ALT # 4 - SHEET PILE WALL
MARY'S RIVER LUMBER
CITY OF MONTESANO

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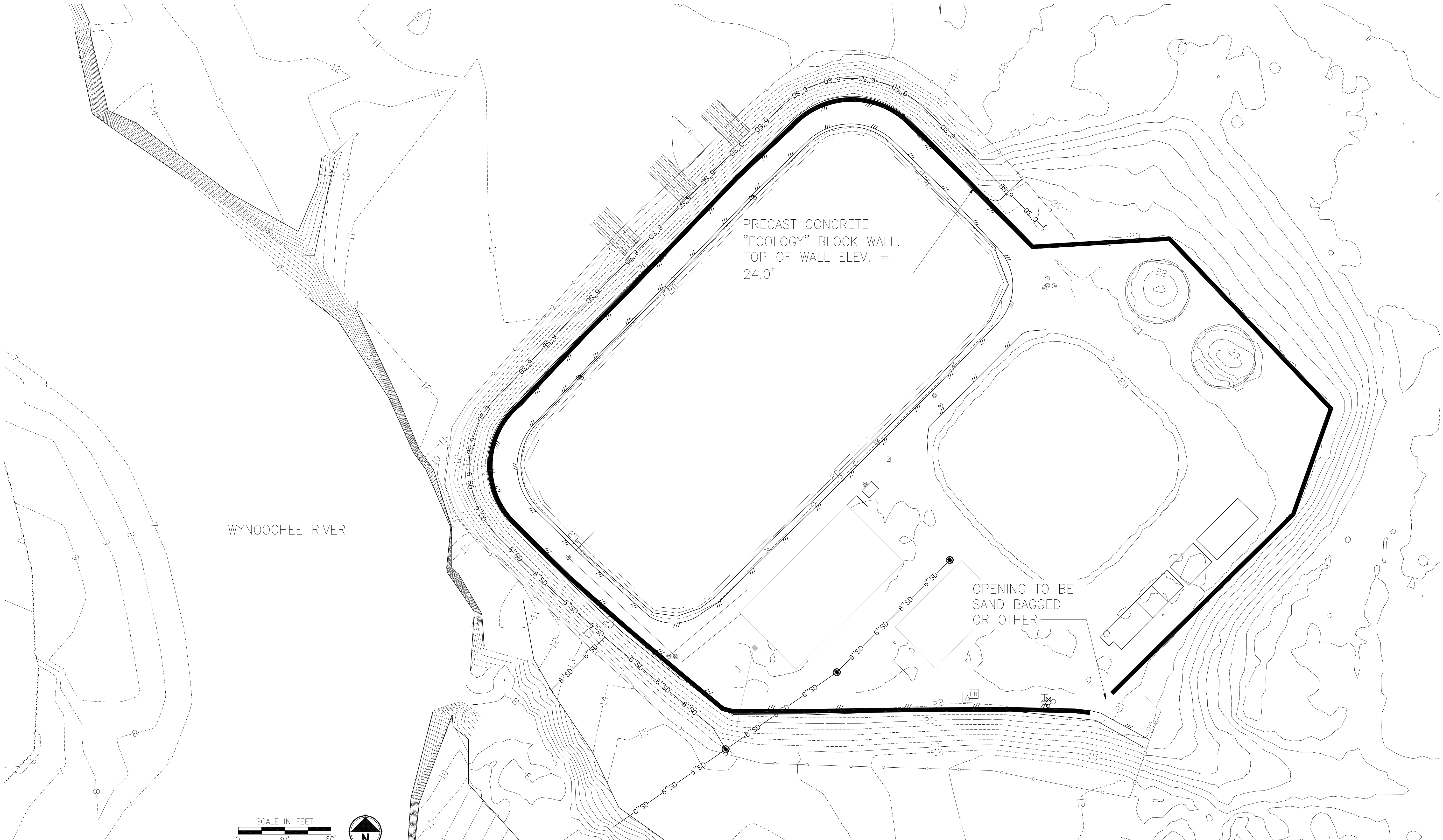

REVISIONS	DATE	BY

DESIGNED S. WAGNER
DRAWN J. BETZVOG
CHECKED
APPROVED

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PROJECT NAME

WASTE WATER TREATMENT PLANT PROPOSED IMPROVEMENTS

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INSTALL 60' LONG STL SHEET PILING
PHASE 1
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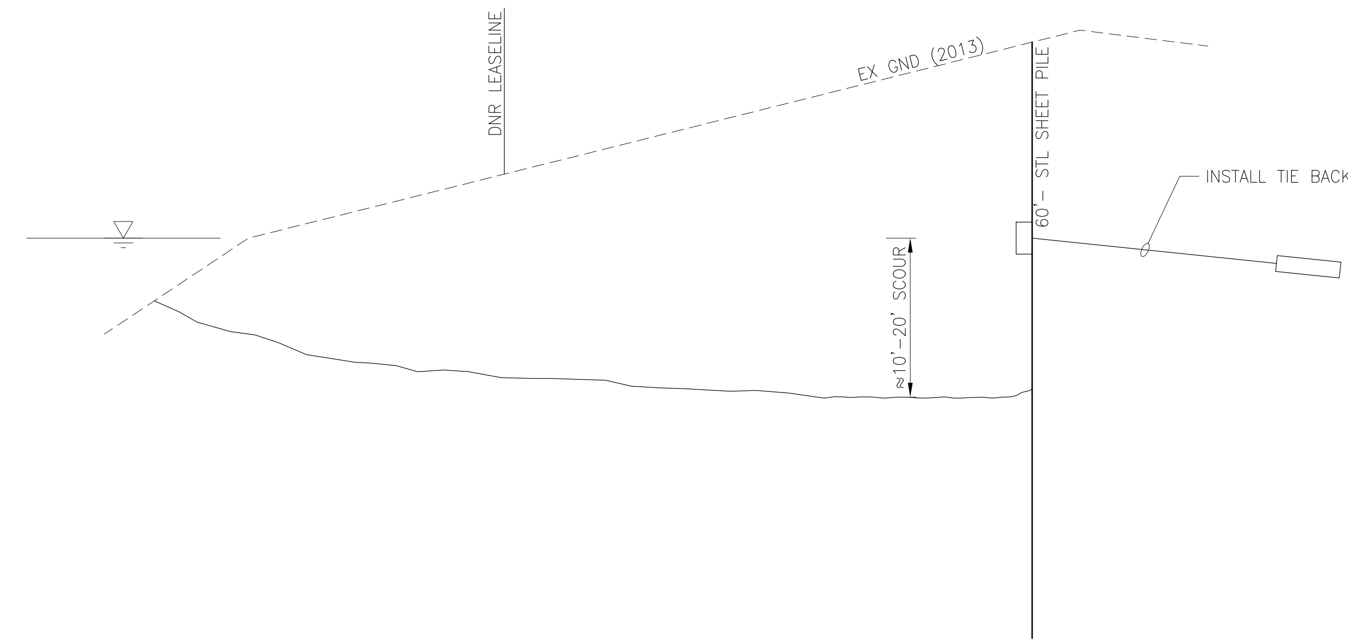

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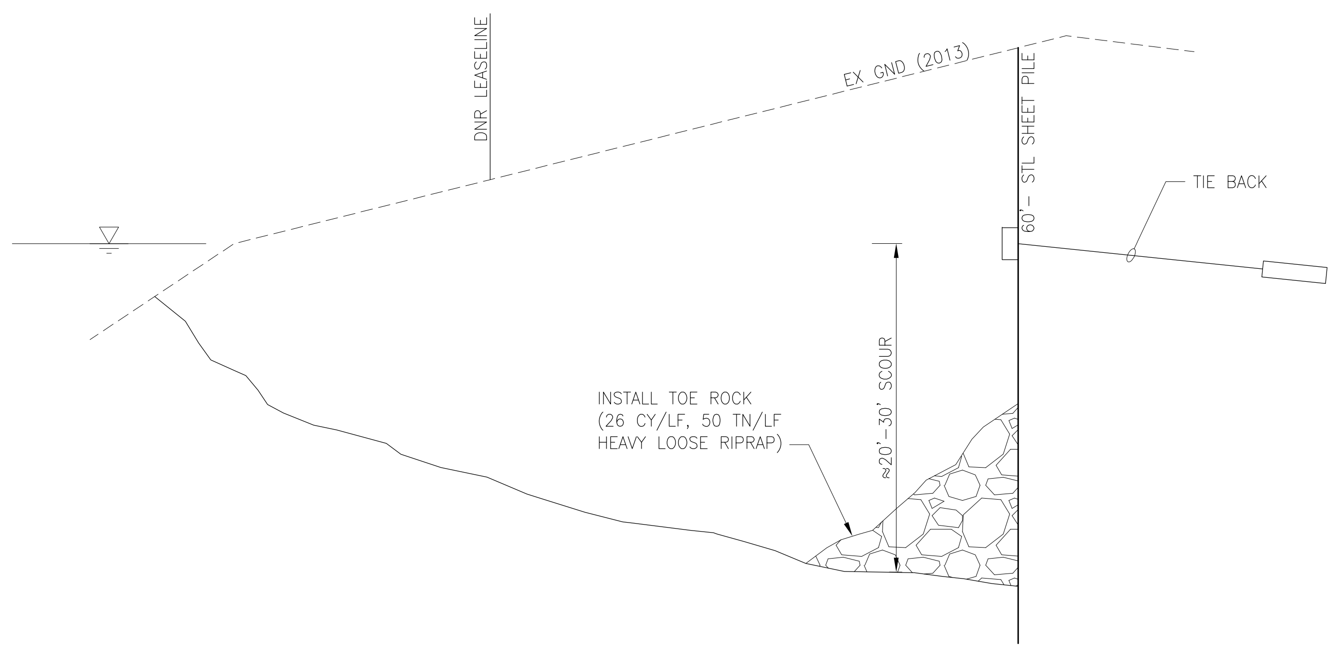

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PHASE 3
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			DRAWN J. BETZVOG
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PROJECT NAME

SHEET PILE INSTALLATION PHASING

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Technical Memorandum

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Name: Steve Schmitz

Company: Parametrix

Date: 4/29/13

From: Raymond Walton, Ph.D., P.E., and John Howard
WEST Consultants, Inc

Subject: **Hydraulic Analysis at Mary's River Lumber Mill, SR 107 Bridge, and the Wastewater Treatment Plant on the Wynoochee River**

Introduction

The Mary's River Lumber Mill is located on the north bank of the Chehalis River near Montesano, WA about 1,400 feet upstream of the SR 107 Chehalis River Bridge. The site is about 13.4 miles upstream from the mouth of the Chehalis River. Due to significant change in the alignment of the Chehalis River near the lumber mill, there is concern about the potential for bank erosion at the mill if a cutoff of the meander bend immediately upstream of the lumber mill were to occur. A meander cutoff could direct high velocity flows at or parallel to the banks adjacent to the mill and cause the thalweg to shift toward the mill, resulting in bank erosion and damage to the mill. Therefore, the City is evaluating options for bank protection. Alternatives being considered include revetment, a Full Channel Bypass, or a High Flow Bypass. Potential impacts to SR 107 due to the alternatives must be considered. The City is also looking to protect the settling lagoons at its Waste Water Treatment Plant (WWTP) from high flows in the Wynoochee River. The location of the project sites are shown in Figure 1.

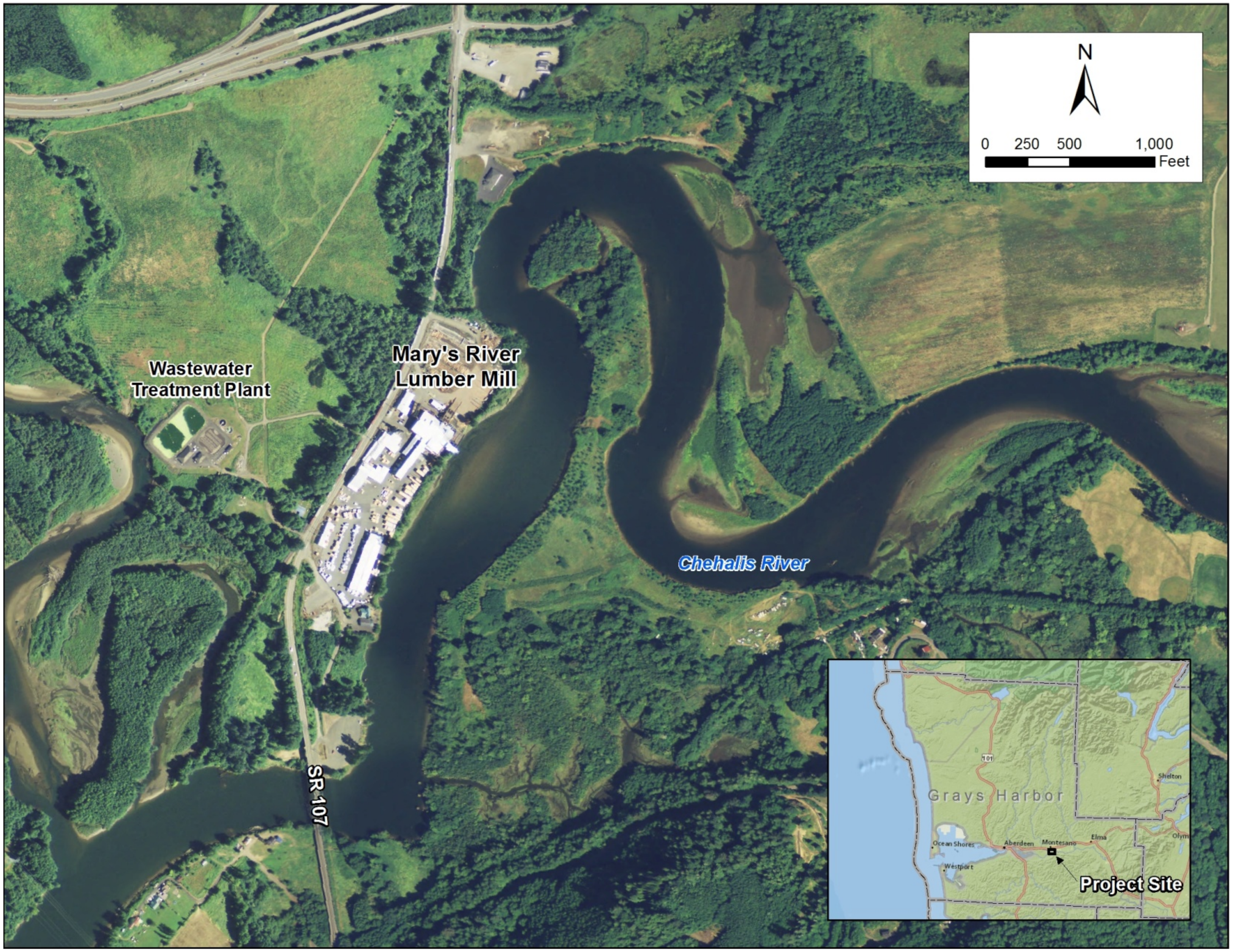

Figure 1. Location Map.

The City contracted Parametrix to design the bank protection for the Mary's River Lumber Mill site. WEST Consultants, Inc. (WEST) was subcontracted by Parametrix to perform the hydraulic, scour and geomorphic analyses in support of the bank protection design. An evaluation of historic aerial photography and hydraulic and scour analyses are documented in this memorandum.

Unless otherwise stated, all elevations within this memorandum are referenced to the North American Vertical Datum of 1988 (NAVD88).

Analysis of Historic Aerial Photography

WEST obtained historic aerial photographs of the Mary's River Lumber Mill vicinity. An evaluation of the photographs was conducted to obtain an understanding of how the active channel of the Chehalis River changed through recent history. The historic aerial photographs were obtained from various sources. Photos were obtained for the years 1953, 1962, 1967, 1972, 1975, 1981, 1985, 1990, 1997, 1999, 2005, 2006, 2009, and 2011.

To characterize the history of channel movement in the vicinity of the lumber mill, the boundaries of the active channel reflected in the historic aerial photographs were identified and compared.

The active channel alignments delineated from each of the historic aerial photographs from 1953 to 2006 are shown in Figure 2. For clarity, the active channel alignments for years 2006 to 2011 are shown in Figure 3. The figures indicate that the bank adjacent to the mill has not experienced significant erosion, while the land across the channel from the mill has been eroding due to the migration of the meander bend. It is apparent that the meander immediately upstream of the mill will be cutoff in the near future. The meander cutoff will likely result in more direct impingement of flows against the bank adjacent to the mill. Observations made from these figures and aerial photographs are summarized in Table 1.

Based on the review of historic aerial photographs, it is apparent that the planform of the active channel upstream of the lumber mill is highly dynamic and has changed significantly within the last 58 years. If no action is taken, the observed pattern of channel migration can be expected to continue in the future, resulting in the cutoff of the meander immediately upstream of the lumber mill. As observed from the historic photos, large changes in the channel bank alignment tend to occur as the result of large flood events, such as the 1996 and 2007 floods.

The erosion rate of the meander across from the lumber mill was estimated by measuring the minimum distance along the expected meander cutoff path. Table 2 summarizes: (1) the remaining minimum land distance along the expected meander cutoff path upstream from the mill; (2) the calculated incremental erosion rate, which corresponds to the rate of erosion between two sequential records; (3) long-term erosion rate, which corresponds to the rate of erosion since 1953; and (4) any miscellaneous notes. As shown in the table, the remaining land distance along the cutoff path has decreased from 890 feet to 200 feet over 58 years, the long term erosion rate has been about 12 feet per year since the early 1980's, and the maximum rate of change (65 feet per year) occurred as a result of the 2006 flood event.

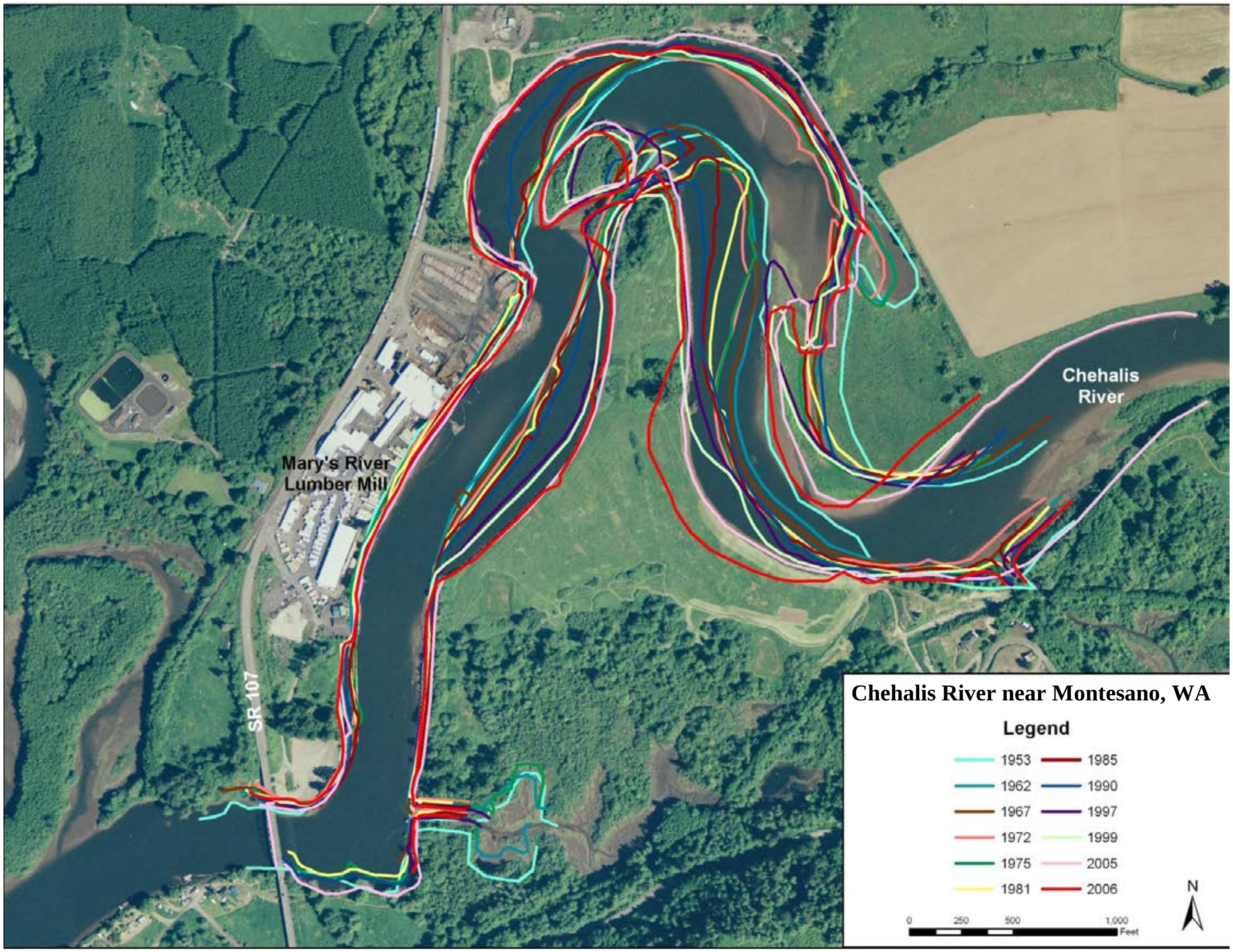

Figure 2. Historic alignments of the active channel for the Chehalis River between 1953 and 2006 (2005 aerial used as background)

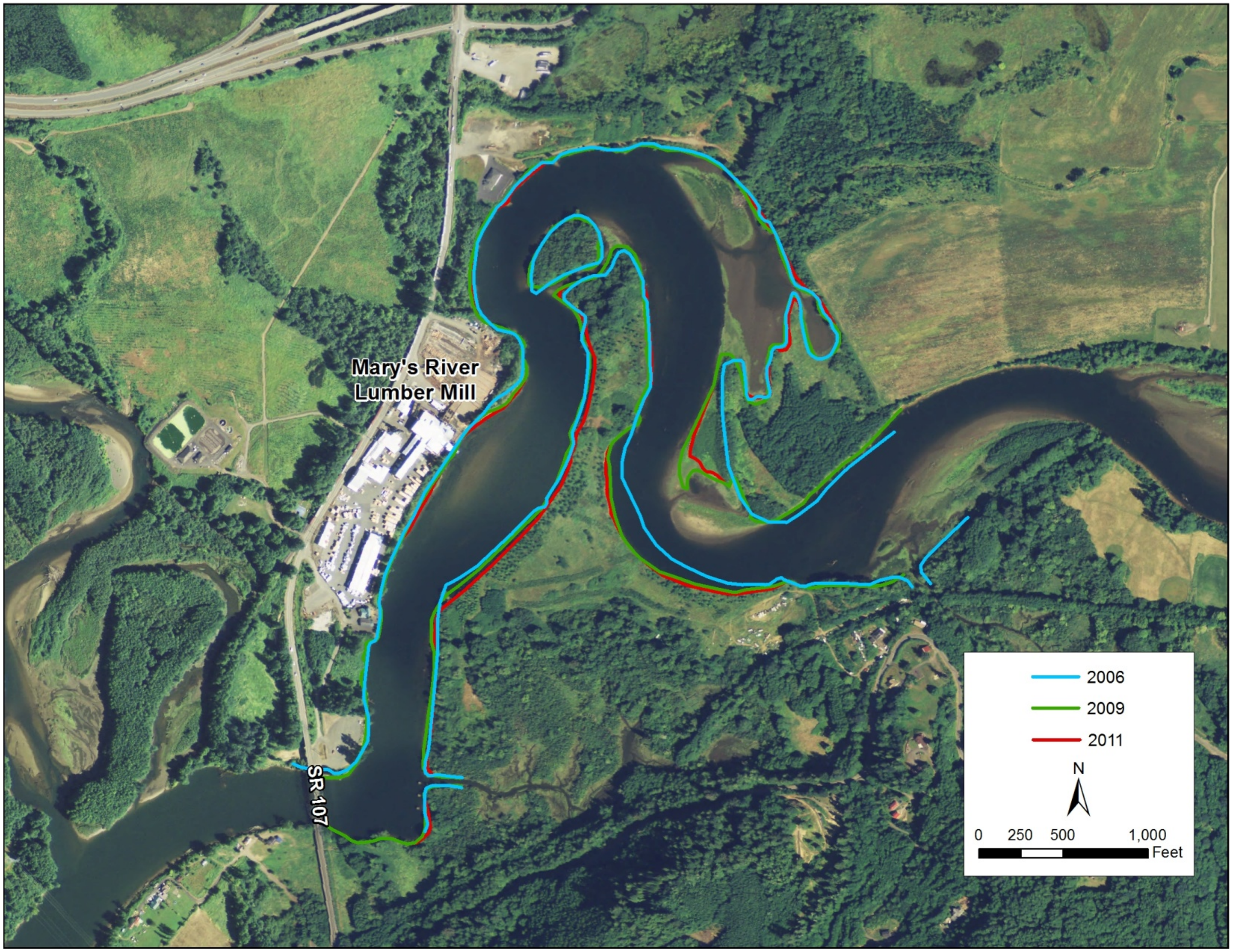

Figure 3. Chehalis River channel alignment for 2006, 2009, and 2011 (2011 background aerial)

At the current erosion rate of 12 feet per year, it would be about 17 years before the breakthrough occurs. At the fastest rate of erosion of 65 ft per year it would only be 3 years before the breakthrough occurs. Therefore, the breakthrough would be expected to occur between 3 to 17 years from 2011 (2014-2028).

Table 1. Summary of observations from historical aerial photograph comparison.

Years	Notes
1953	This aerial photograph covers a large area. There are either barges or floating logs existing in front of the lumber mill. The alignment of the river is fairly straight and has a narrower width than the existing conditions. The photographs indicate alignments of the river or side channels located immediately to the east and southeast of the lumber mill.
1962	This aerial photograph covers an area of the Chehalis River from the SR 107 bridge to about 1.7 miles upstream. In general, the conditions of the Chehalis River in this photograph are similar to the conditions reflected in the 1953 photograph. There are several areas of the river in front of the lumber mill that contain floating logs.
1967	This aerial photograph covers about the same area as the 1962 photograph, and the alignment of the river is similar to the alignment seen in the 1962 photograph.
1972	This aerial photograph covers about the same area as the 1962 and 1967 photographs. There are fewer logs on the river in front of the lumber mill. There is a slight increase in the river width within the meander immediately upstream of the lumber mill.
1975	This aerial photograph covers about the same area as the 1962, 1967, and 1972 photographs and the condition of the river is similar to the condition reflected in the 1972 aerial.
1981	The changes since 1975 include the formation of a small side channel in the point bar of the bend immediately upstream of the lumber mill and no floating logs in front of the lumber mill.
1985	The conditions reflected on this aerial are similar to the conditions reflected on the 1981 aerial.
1990	The changes since 1985 include the outer bank of the meander bend immediately upstream of the lumber mill shifting to the west towards SR 107, and a slight change of the conditions on the point bar of the bend immediately upstream of the lumber mill.
1997	Significant changes are evident in this aerial. The outer bank of the meander immediately upstream of the lumber mill migrating to the west, the bank across from the lumber mill's migrating to the east, the side channel on the point bar immediately upstream of the lumber mill has enlarged, and riparian vegetation cover a larger area of the point bar north of the side channel.
1999	The conditions reflected on this aerial are similar to the conditions reflected on the 1999 aerial.
2005	This aerial covers a large area similar to the 1953 aerial. The changes since 1999 include the installation of stream barbs, which were constructed in 2002, on the outer bank of the meander bend immediately upstream of the lumber mill. The bank across from the lumber mill shifted further to the east.
2006	The only noticeable change reflected in this aerial includes the migration of the outer bank of the upstream most meander further to the west towards the lumber mill.
2009	The east side of the meander breakthrough area eroded significantly. The western side did not change significantly.
2011	Both sides of the meander breakthrough area show erosion continuing.

Table 2. Summary of erosion rates for the ground opposite of the Mary's River lumber mill.

Year	Minimum Distance along Cutoff Path Upstream of Mill	Incremental Erosion Rate (feet/year)	Long Term Erosion Rate (feet/year)	Notes
1953	890	-	-	-
1962	850	4.4	4.4	-
1967	850	0.0	2.9	-
1972	760	18.0	6.8	A relatively large flood event occurred on 1/22/72.
1975	705	18.3	8.4	-
1981	570	22.5	11.4	-
1985	530	10.0	11.3	-
1990	505	5.0	10.4	A relatively large flood event occurred on 1/11/90.
1997	415	12.9	10.8	A significant flood event occurred on 1/9/96.
1999	375	20.0	11.2	-
2005	355	3.3	10.3	In 2002, bank protection measures were installed on the outside of the meander bend immediately upstream of the mill.
2006	290	65.0	11.3	A significant flood event occurred on 1/13/06.
2009	240	16.7	11.6	December 2007, January 2009 events occurred
2011	200	20.0	11.9	-

Hydraulic Analysis

An unsteady flow hydraulic analysis was conducted to obtain the hydraulic characteristics of the Chehalis River in the vicinity of the lumber mill, WWTP, and SR 107. The analysis was conducted using the Corps of Engineers River Analysis System (HEC-RAS Version 4.1.0) standard-step backwater computer program. Recently, an existing HEC-RAS hydraulic model of the Chehalis River was updated using funding from the Chehalis River Basin Flood Authority and Corps of Engineers. The updates included extending the model downstream to Aberdeen and adding the Wynoochee River. WEST Consultants was the lead consultant for this effort. Hydrographic surveys of the Chehalis River completed previously by Parametrix for the study area were combined with 2012 Lidar data obtained from the Puget Sound Lidar Consortium's website (http://pugetsoundlidar.ess.washington.edu/) to create updated cross sections of the river in the vicinity of the mill. The developed cross sections have been added to the existing model to provide necessary resolution in the study reach. The locations of the cross sections in the vicinity of the projects are shown in Figure 4. Ineffective flow boundaries were set in the model to define the active flow area of each cross section. The hydraulic roughness coefficients used in the model were based on calibration to observed data. A roughness coefficient of 0.042 was assumed for the active channel of the river, and values of 0.07 and 0.09 were used for overbank areas.

The downstream end of the model is located in Grays Harbor. The Mary's River Lumber project

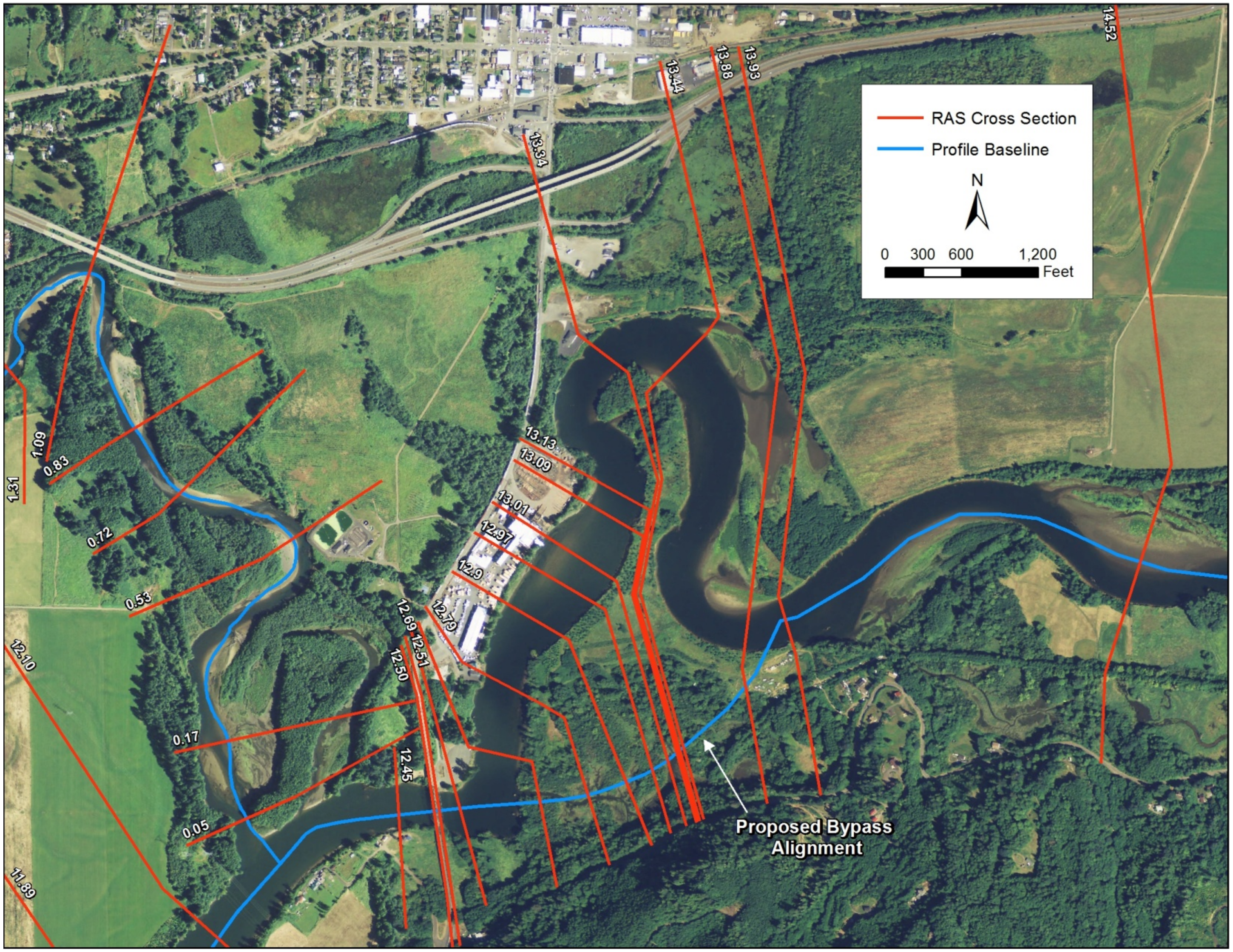

Figure 4. Cross section locations and possible bypass flow path.

area and the SR 107 bridge are tidally influenced. The starting water surface elevation used in the HEC-RAS hydraulic model was the observed tide for the 1996, 2007, and 2009 events. These are the three largest events for the period of record on the Chehalis River. For the 100- and 500-year events, a synthetic sinusoidal tide from mean lower low water (MLLW) to mean higher high water (MHHW) in a diurnal cycle was used (shown in Figure 5). The elevations are based on MLLW and MHHW as defined at the NOAA tide station at Aberdeen (No. 9441187). Maximum water surface elevation, velocity, and shear stress near the project site were extracted from model results for each event. Table 3 summarizes the maximum discharge and tidal condition for each event.

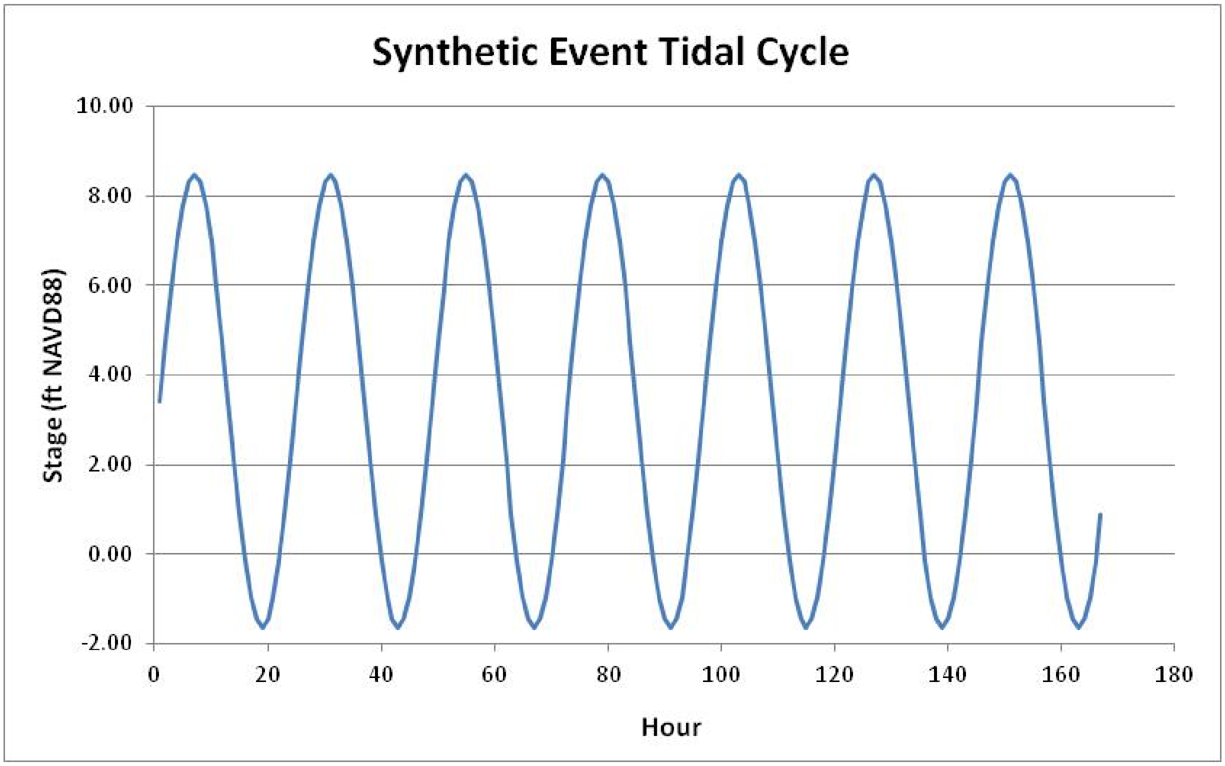

Figure 5. Tidal cycle for synthetic flow events (100- and 500-year events)

Table 3. Discharge and starting water surface boundary condition.

Event	Lumber Mill Vicinity Approximate Maximum Discharge (cfs)	Downstream Boundary Condition
1996	102,170	Observed tide
2007	96,270	Observed tide
2009	81,270	Observed tide
100-year	117,640	Synthetic Tidal
500-year	169,930	Synthetic Tidal

The results from the HEC-RAS model are summarized in Tables 4 and 5. Table 4 summarizes the calculated maximum water surface elevations at the downstream end of the lumber mill, near the main saw of the lumber mill, and at the upstream end of the lumber mill for the various flow and downstream boundary conditions. Table 5 summarizes the maximum average channel velocities and shear stresses for the various flow and downstream boundary conditions (representing the channel average at the time of the maximum value).

Table 4. Maximum water surface elevations for the Chehalis River near the Mary's River Lumber Mill.

Discharge Event	*Approx-imate Discharge (cfs)	Maximum Water Surface Elevation (NAVD88 ft)		
		Downstream End (RS 12.79)	At Saw Structure (RS 13.01)	Upstream End (RS 13.13)
1996	102,170	18.34	18.99	19.13
2007	96,080	17.85	18.48	18.62
2009	82,630	18.20	18.63	18.73
1% exceedance (100-yr)	116,420	19.43	20.11	20.25
0.2% exceedance (500-yr)	168,670	22.82	23.60	23.75

*Discharge is for time of maximum water surface elevation, not necessarily maximum flow.

Table 5. Maximum average channel velocities and shear stresses for the Chehalis River near the Mary's River Lumber Mill (for the breakthrough scenario).

Discharge Event	Discharge (cfs)	Velocity (ft/s)[1]	Shear Stress (lbs/ft^2)[1]
1996	94,690	7.7	1.00
2007	96,030	7.5	0.96
2009	82,160	7.0	0.86
1% exceedance (100-yr)	116,330	8.1	1.10
0.2% exceedance (500-yr)	166,480	9.5	1.50

Notes:

1. Maximum velocity and shear stress are tidally influenced in this area - therefore time of maximum occurrence may not correspond to maximum flow.
2. The velocity and shear stress values represent the channel average at the time of the maximum.

Riprap Evaluation

Calculations were performed to determine the required riprap size for bank protection. The calculations were performed using the guidance provided in Hydraulic Design of Flood Control Channels (USACE, 1994). This method was used due to the correction factor available for the channel bend angle. Other riprap sizing equations were used for comparison purposes – some calculated a similar size and some calculated a smaller size. The riprap size was computed using the following equation:

$$D_{30} = S_f\, C_s\, C_V\, C_T\, d \left[\left(\frac{\gamma_w}{\gamma_s\ \gamma_w} \right)^{0.5} \frac{V}{\sqrt{K_1\, gd}} \right]^{2.5}$$

where D_{30} is the riprap size of which 30% is finer by weight, S_f is the safety factor (2), C_s is a stability coefficient (0.3), C_V is a vertical velocity coefficient (1.22), C_T is a thickness coefficient (1), d is the local depth of flow (19.58) in the same location as V,γ_w is the unit weight of water (62.4 lbs/ft^3), γ_s is the unit weight of stone (165 lbs/ft^3), V is the average channel velocity (6.21ft/s), K_1 is the side slope correction factor (1.18) , and g is the gravitational constant (32.2 ft/s^2). Values listed near the descriptions are for the 100-year event. The D_{50} (converted from D_{30}) for the 100-year event is 1.3 feet, corresponding to heavy loose riprap. Results are summarized in Table 6. The riprap classification for the 500-year event is also heavy loose riprap.

Table 6. Summary of riprap sizing calculations.

Discharge Event	S_f	C_s	C_V	V	d	K_1	D_{50}	WSDOT Riprap Class
1% exceedance (100-yr)	2.0	0.3	1.22	6.21	19.58	1.18	1.3 ft	Heavy Loose

Scour Estimate

An analysis was completed to estimate the maximum scour depth anticipated near the proposed bank protection. The analysis was conducted assuming that the river had cutoff the meander as reflected by the alignment shown in Figure 6**.**

The design of a resistive bank erosion protection measure must account for potential scour depths anticipated near the structure. Therefore, the scour elevation at the structure was estimated for the 1996, 2007, 2009, 100-, and 500-year flood events. The type of scour anticipated at the structure includes only bend scour. Long-term degradation was not considered because the project site is located within a reach that is typically depositional, and some of the other scour components, such as thalweg migration, are accounted for in the equation used to estimate the bend scour. Bend scour is associated with scour along the outside of a bend caused by transverse or "secondary" currents created by the bend. Material scoured from the outside of a bend is characteristically deposited along the inside of the bends downstream. The bend scour elevation was estimated using the equation developed by Zeller (Simons, Li and Associates, Inc., 1985). The Maynord equation was also used to calculate bend scour (Maynord 1996). The Zeller equation was found to agree with a previous scour analysis (WEST 2008) much better than the Maynord equation which predicted less bend scour. Due to the agreement with the previous analysis and the uncertainty in the breakthrough configuration, the Zeller results were used. The results of the scour calculations are summarized in Table 7. It is recognized that the results of the bend scour evaluation are based on assumed conditions. Compared to observed minimum historic profile elevations, the assumed analysis conditions may not represent the most severe scour conditions that could occur (Figure 7). To minimize risk for the revetment design, it is recommended that a maximum scour of elevation -50 ft NAVD88 be considered.

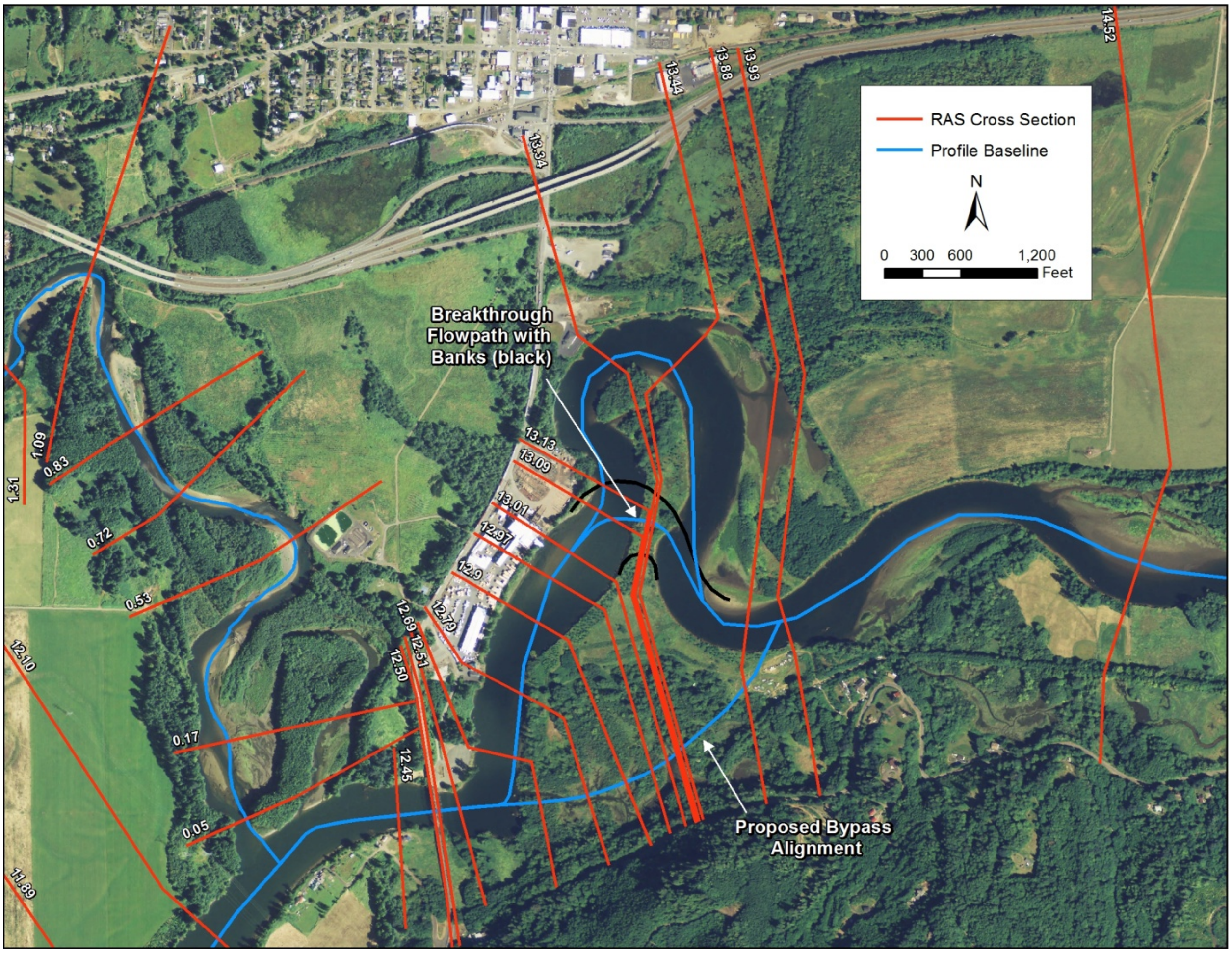

Figure 6. Assumed breakthrough scenario.

Table 7. Results of scour calculations.

Event	Scour Elevation (feet, NAVD88)
1996	-41.5
1% exceedance (100-yr)	-41.9
0.2% exceedance (500-yr)	-44.0

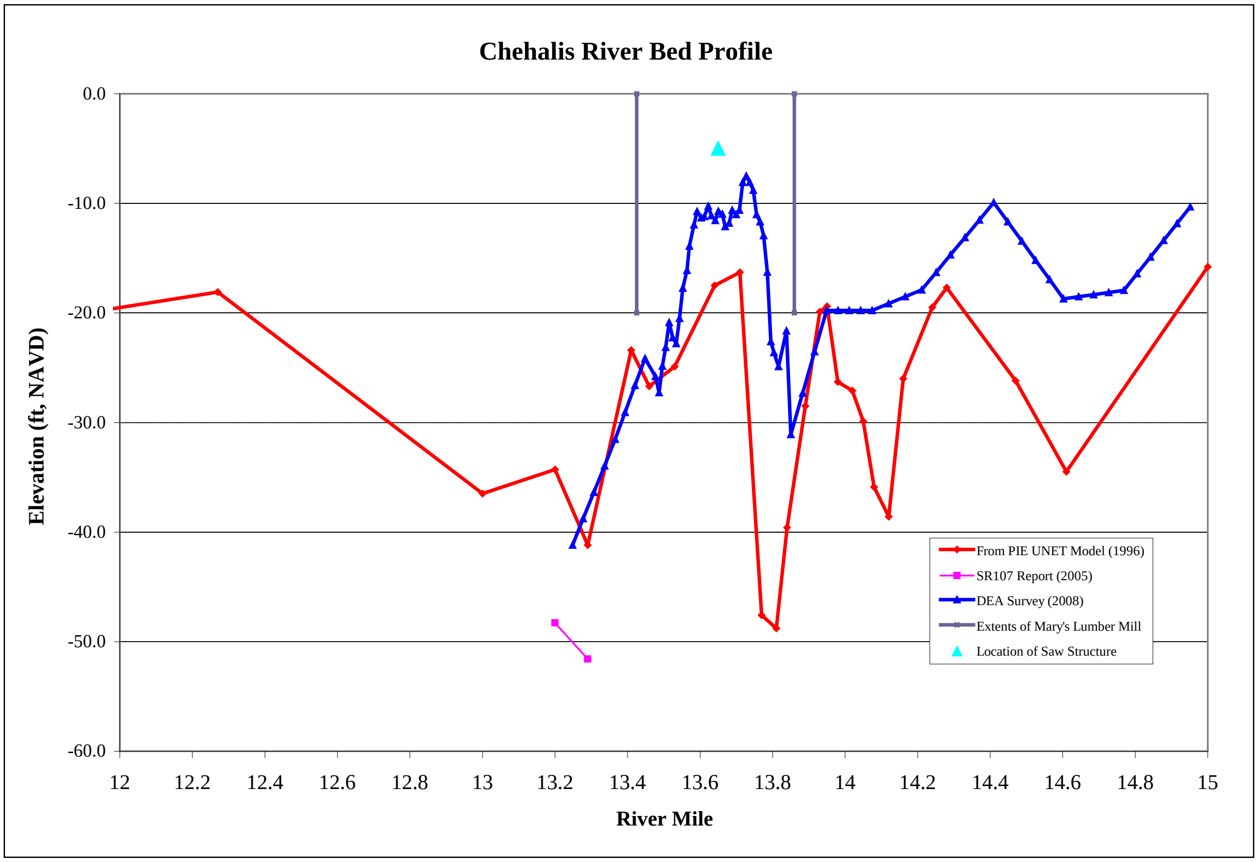

Figure 7. Bed profile of the Chehalis River near the Mary's River Lumber Mill

Recommendations for Erosion Protection Measures

If the Full Channel Bypass is not implemented, the recommended extents of the bank protection measure are shown in Figure 8. In general, the erosion protection measure would be located along the bank from near the upstream extents of the lumber mill to a point approximately 1,700 feet downstream, to tie into existing bank protection. This would cover most of the bank adjacent to the Mill. If the breakthrough did occur, the entire bank length near the lumber mill would be on the outside of the bend, making it susceptible to erosion. Currently, the upstream portion of the bank adjacent to the Mill is on the inside of the bend, and the downstream portion is on the outside of the bend. Potentially, extending the bank protection to tie into existing protection near the downstream end of the mill site could also protect SR 107 from future right bank erosion by keeping the channel better aligned with the bridge opening. If the entire bank is not protected, the protection should start at the upstream end and proceed downstream as far as feasible. Any remaining unprotected bank should be monitored for erosion.

Another alternative would be to protect approximately the upper 800 feet with riprap, and engineered log jams, woody debris, or other protection measures along the rest of the bank adjacent to the mill. The first 800 feet would take the brunt of the impact of the breakthrough. The remaining approximately 900 feet would not be in as severe a bend, and would not be subjected to the most erosive forces due to the breakthrough. This method would create fish and wildlife habitat as well as directing the flow away from the bank.

Details of the proposed erosion control measure are provided in Figure 9. It is recommended that the top of the revetment extend to the top of the bank. The riprap revetment should consist of Heavy Loose Riprap (based on WSDOT specifications, D_{50} of 2.2 feet) along the bank and along the toe of the embankment. Recommended layer thickness is 5.25 feet with a geotextile fabric filter. To prevent failure of the structure from undermining, a launchable toe should be placed along the toe of the bank. The volume and dimensions of the launchable toe are based on the recommendations provided in EM 1110-2-1601, *Hydraulic Design of Flood Control Channels* for an estimated scour elevation -42 feet. The volume per foot of bank protection is 700 ft^3. If the entire 1,700 feet is protected a volume of approximately 44,074 cubic yards would be required. If launchable riprap protection is designed for the historic depth of -50 feet 770 ft^3 volume of riprap would be needed for each foot of bank covered.

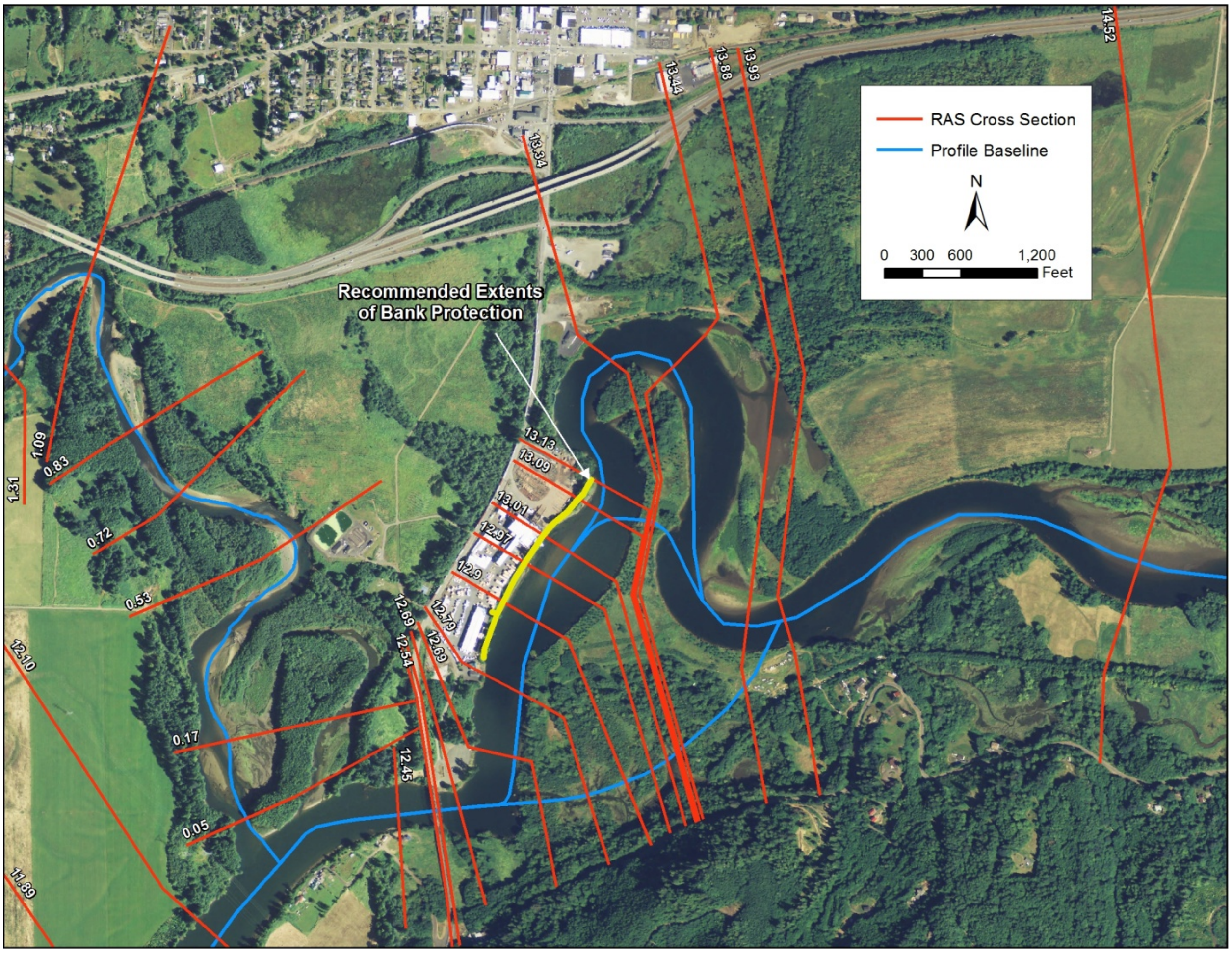

Figure 8. Recommended extents of bank protection.

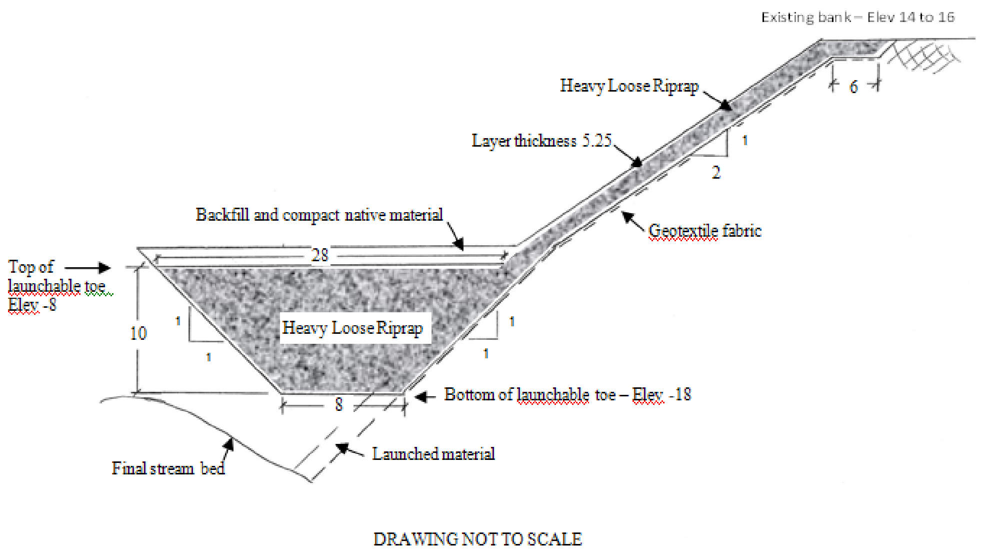

Figure 9. Riprap protection configuration for a thalweg of -42 feet (distances and elevations in feet).

Impacts at SR 107

A change in the Chehalis River flow paths has the potential to alter hydraulic characteristics at the SR 107 bridge. The SR 107 bridge is already experiencing scour around its foundations. The hydraulic characteristics at the bridge for existing conditions were compared to those for alternative conditions to determine any potentially adverse impacts. Alternative scenarios compared to existing conditions included the Breakthrough, a High Flow Bypass, and a Full Channel Bypass. The layout for these alternative configurations is shown in Figure 6.

The High Flow Bypass is similar to existing conditions until the water surface elevation gets above elevation 11 feet near the upstream end of the large meander (RS 13.88). At elevation11 feet and above, flow will split off and follow the bypass channel, as well as proceed down the mainstem of the Chehalis River. The mainstem cross sections were split to create separate mainstem and Bypass Reach cross sections. Lateral structures were used to allow flow to move from the bypass to the Chehalis mainstem, or vice-versa. An assumed channel top width about 240 feet wide (200 foot bottom width) with 3H:1V slopes was cut into the bypass reach along the centerline shown in Figure 6. A typical cross section along the High Flow Bypass Reach is shown in Figure 10. The thalweg along the channel is shown in Figure 11. Table 8 has the details for the High Flow Bypass cross sections. The total volume of cuts is approximately 77,660 cubic yards for the High Flow Bypass.

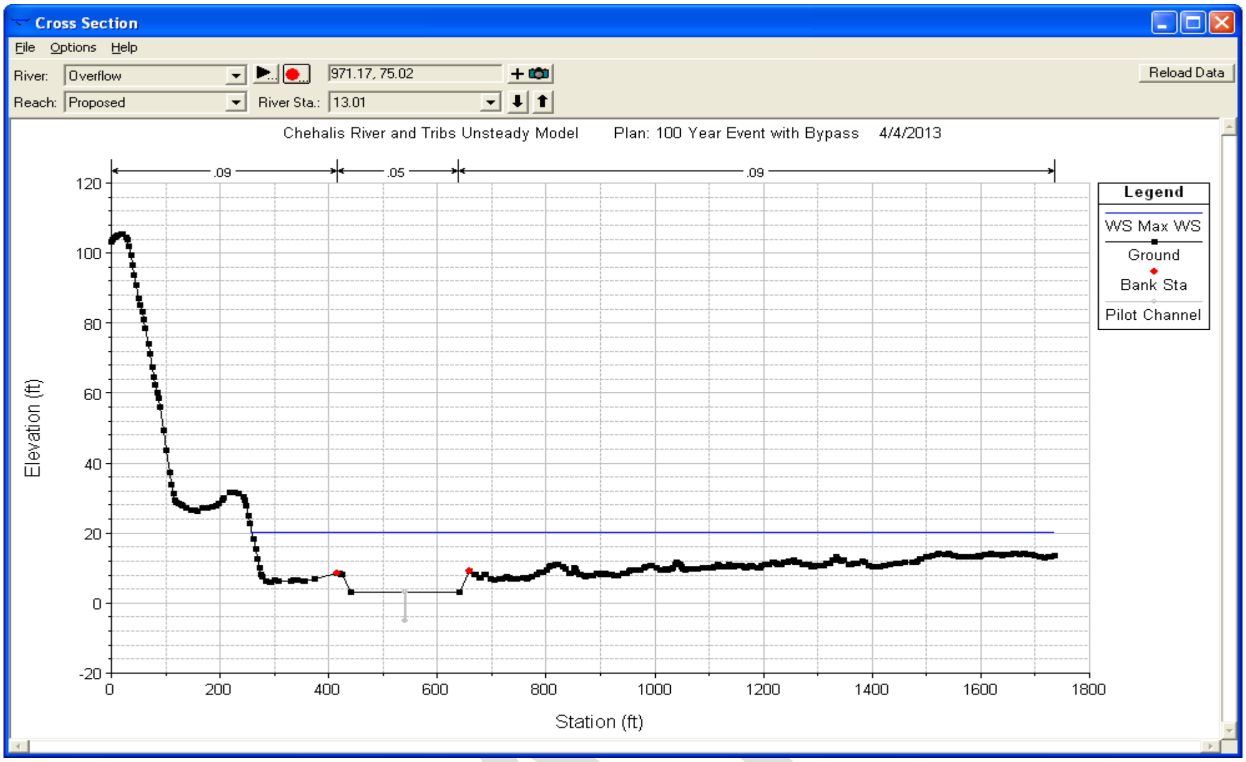

Figure 10. Typical cross section cut for the High Flow Bypass

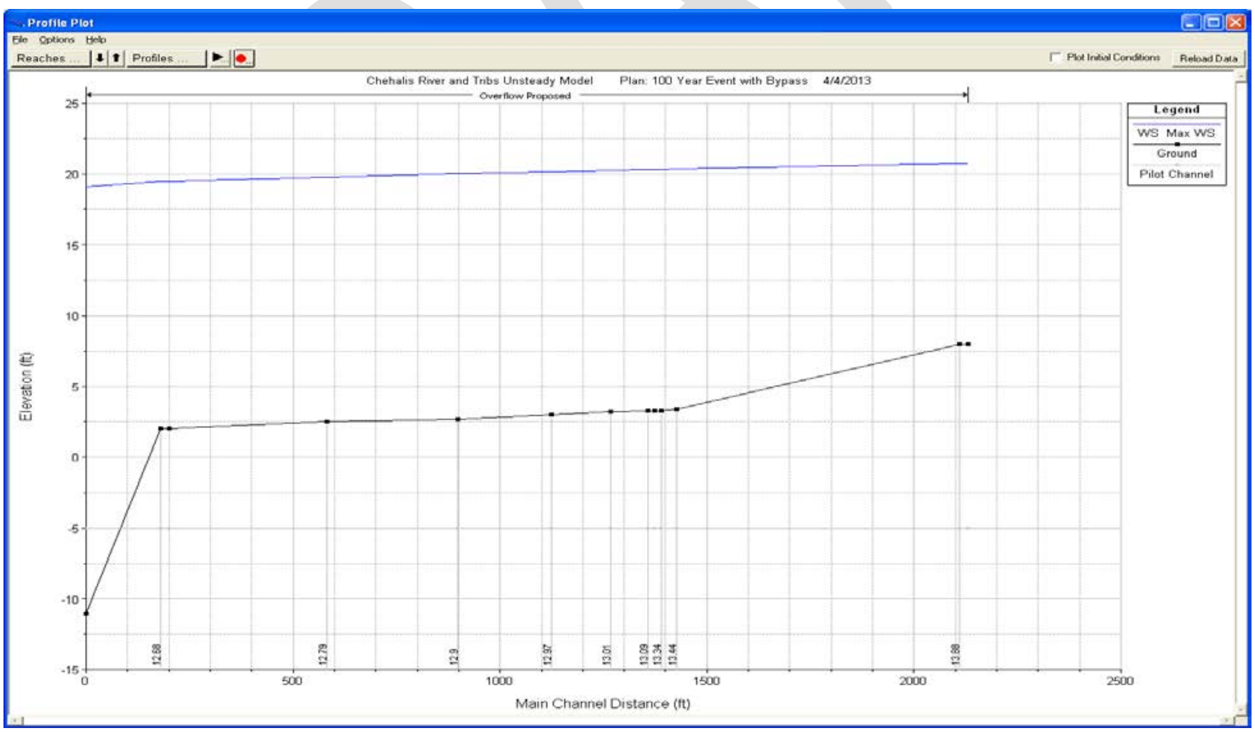

Figure 11. Thalweg used for High Flow Bypass (distance 180 to 2130).

Table 8. Cross section details for High Flow Bypass

RAS Station	Thalweg Elevation	Approximate depth (thalweg to average ground)	Approximate ground elev	Top width	Area of cut (sq ft)
13.89	11	2	12.9	250	363
13.88	11	2	12.9	250	363
13.44	3.4	5.5	8.7	233	1,053
13.34	3.3	5	8.3	235	1,024
13.13	3.3	5	8.3	232	1,003
13.09	3.3	4.8	8.0	229	933
13.01	3.2	3.8	7.0	230	780
12.97	3	6.7	9.7	237	1,509
12.9	2.7	5.4	8.1	232	1,079
12.79	2.5	3.8	6.3	232	843
12.69	2	5.6	7.6	242	1,322
12.68	2	5.6	7.6	242	1,322

In the Full Channel Bypass scenario, a full channel was cut into the bypass, and the mainstem of the Chehalis was routed through the bypass. Main channel and overbank reach lengths were adjusted accordingly. A typical cross section along the Full Channel Bypass alignment is shown in Figure 12. The assumed thalweg followed for the Bypass Reach is shown in Figure 13. The bottom width is 240 feet with the sides rising at a 3H:1V slope until it reaches ground level. Table 9 summarizes the geometry characteristics of the Full Channel Bypass cross sections. Excavation volume for all the cross sections is approximately 443,800 cubic yards. Since the meander adjacent to the Mill would be cut off by the Full Channel Bypass, flow in the large meander would decrease, which would likely cause an increase in sedimentation in that portion of the "old channel".

Model results indicate a minimal change in hydraulic characteristics at the SR 107 bridge due to any of the scenarios. Under existing conditions, the largest velocities occur at the upstream face of the bridge, so comparisons to the hydraulic analysis results for alternative conditions were made at that location. The worst case identified was an increase in the maximum velocity of 0.03 ft/s for the 2007 event with the High Flow Bypass. The largest increase in velocity at any time of all the modeled timeframes was 0.35 ft/s for the 500-year event with the Full Channel Bypass. Properly designed engineered log jams could potentially help reduce any increase in velocities associated with the High Flow Bypass or Full Channel Bypass. Some woody debris was incorporated into the model for the Full Channel Bypass, but more would be required to completely negate any increase in velocity due to the Full Channel Bypass. A benefit to the Full Channel Bypass would be that the approach flow to SR 107 would be better aligned with the bridge opening. Currently, there is a sharp bend upstream of the bridge opening. Table 10 summarizes the changes in velocity due to the different scenarios. It is noted that the comparison results are based on assumed conditions so actual results may be different.

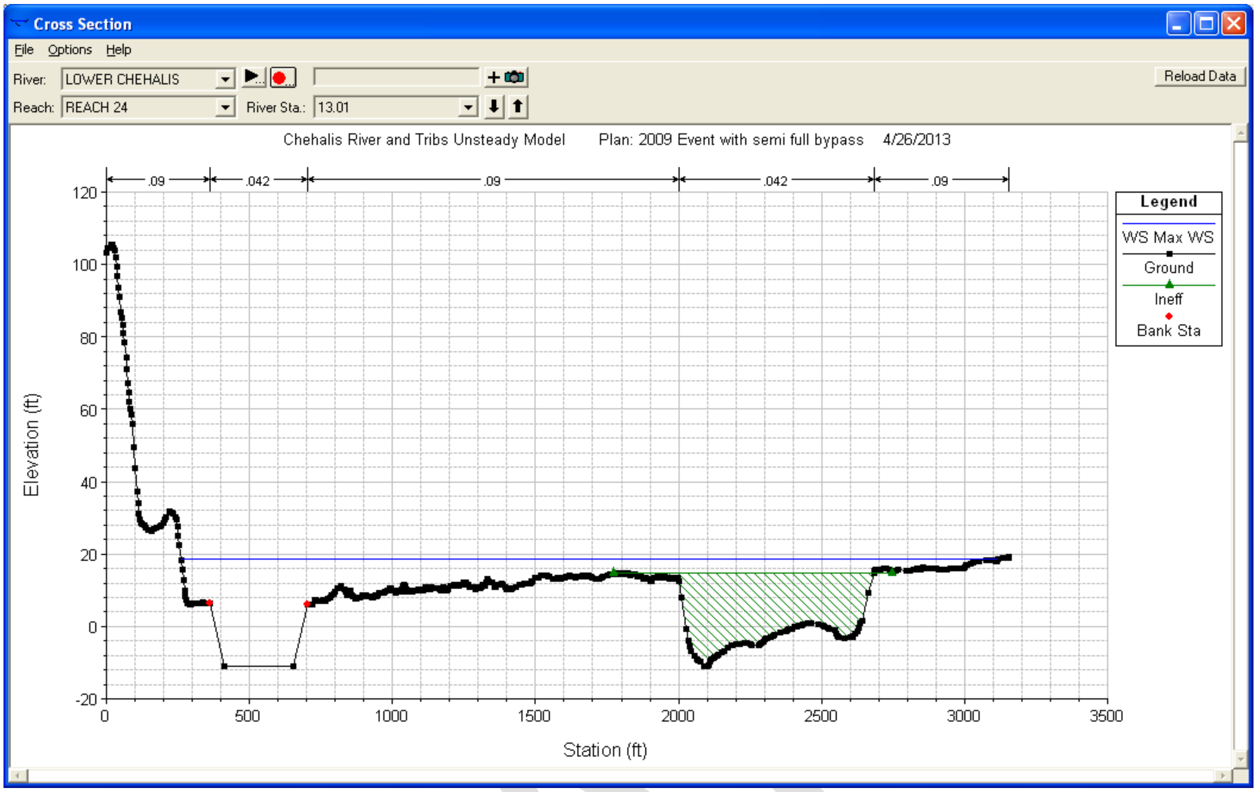

Figure 12. Typical cross section cut for the Full Channel Bypass (old main channel ineffective).

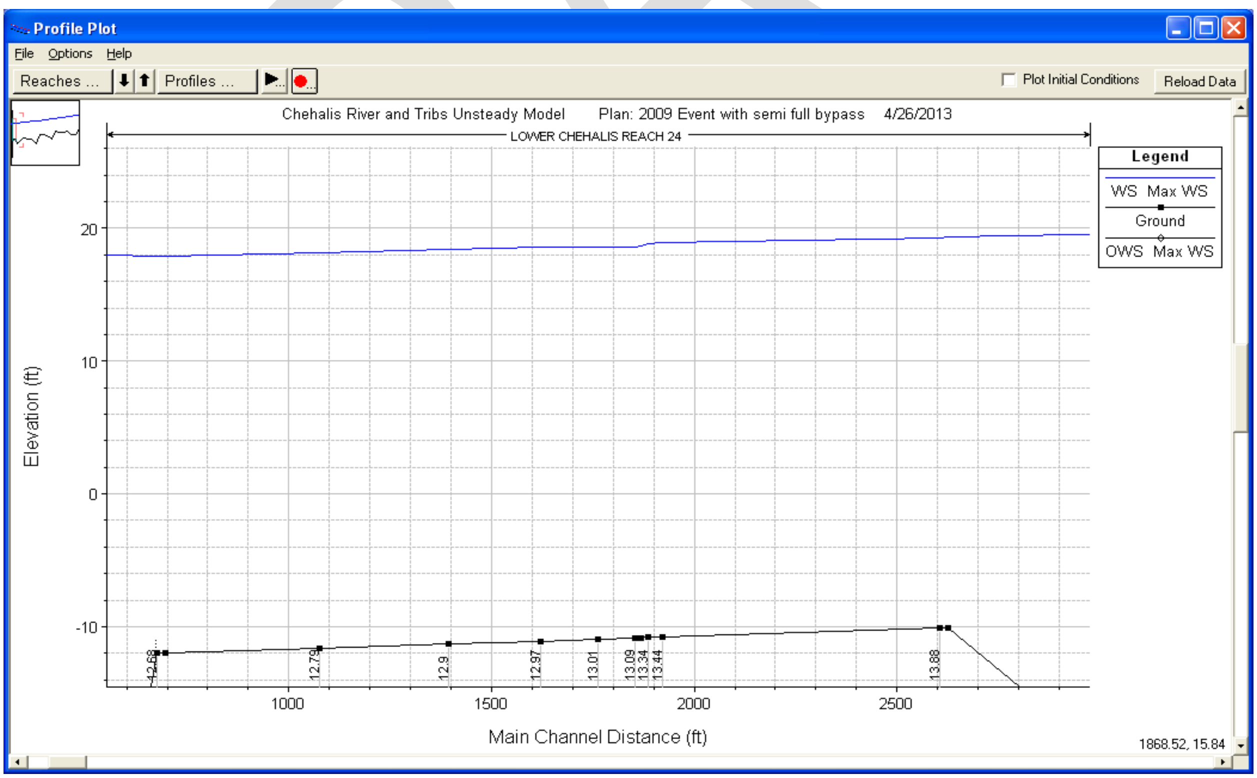

Figure 13. Thalweg for Full Channel Bypass.

Table 9. Cross section details for Full Channel Bypass

RAS Station	Thalweg Elevation	Approximate depth (thalweg to average ground)	Approximate ground elev	Top width	Area of cut (sq ft)
13.89	-10	23.0	13.0	377	5,612
13.88	-10.1	23.0	12.8	377	5,612
13.44	-10.8	20.0	9.0	370	4,880
13.34	-10.8	19.4	9.2	357	4,734
13.13	-10.8	20.3	8.7	359	4,953
13.09	-10.8	19.9	8.3	358	4,856
13.01	-10.9	17.2	7.2	343	4,197
12.97	-11.1	16.4	9.0	336	4,002
12.9	-11.3	21.0	8.2	358	5,124
12.79	-11.6	19.5	6.9	355	4,758
12.69	-12	21.9	8.6	369	5,344
12.68	-12	21.9	8.6	369	5,344

Table 10. Summary of velocity changes compared to Existing Conditions at SR 107 for different scenarios (main channel n value is 0.042 and 0.045, overbanks 0.07 and 0.09 for all scenarios).

Event		**1996**	**2007**	**2009**	**100-year**	**500-year**
Existing Conditions	Maximum Velocity (ft/s)	9.01	8.63	7.77	9.89	12.93
Meander Breakthrough	Maximum Velocity (ft/s)	9.01	8.64	7.78	9.89	12.93
	Increase in maximum velocity (ft/s)	0.0	0.01	0.01	0.0	0.0
	Maximum increase in velocity at any time (ft/s)	0.08	0.09	0.11	0.07	0.10
High Flow Bypass	Maximum Velocity (ft/s)	9.01	8.66	7.79	9.89	12.93
	Increase in maximum velocity (ft/s)	0.0	0.03	0.02	0.0	0.0
	Maximum increase in velocity at any time (ft/s)	0.21	0.10	0.16	0.09	0.10
Full Channel Bypass	Maximum Velocity (ft/s)	9.01	8.63	7.78	9.88	12.94
	Increase in maximum velocity (ft/s)	0.00	0.00	0.01	-0.01	0.01
	Maximum increase in velocity at any time (ft/s)	0.21	0.16	0.21	0.09	0.35

Water Surface Elevation at Wastewater Treatment Plant

The City of Montesano would like to avoid having any sewage interaction at the WWTP with the Wynoochee River during significant flood events. Anecdotal information (from City of Montesano) indicates that the 2009 event came within 6 inches of the top of the bank. For the 100-year event the modeled water surface elevation is 19.54 feet. Similar results were found for the 2009 event. With the superelevation likely to occur due to the WWTP being at the outside of a sharp bend would add 0.64 feet to the water surface elevation. The 100-year water surface elevation would be approximately 20.2 feet, so the WWTP should be protected to 21.2 feet to provide 1 foot of freeboard (WSDOT standard) for the 100-year event. The anecdotal evidence suggests that the model results are a bit low. Since the 100-year event is about the same as the 2009 event, and the 2009 event was at approximately 20.75 feet (top of berm elevation estimated at 21.25 feet), we recommend raising the berm around the storage ponds to 22.5 feet for 100-year event protection. The 500-year water surface elevation at the WWTP is 22.3 feet with the superelevation included. With one foot of freeboard, the 500-year protection is elevation 23.3 feet. Maximum average channel velocities at the WWTP are 9.52 ft/s for the 100-year event and 9.05 ft/s for the 500-year event (the channel average at the time of the maximum velocity).

Conclusions

WEST conducted an evaluation of historic aerial photographs obtained for the Chehalis River near the Mary's River lumber mill in Montesano, WA. The historic channel alignments delineated from the historic photographs are shown in Figures 2 and 3. Observations made from these figures and the aerial photographs are summarized in Table 1.

The information for the last 58 years demonstrates that the planform of the Chehalis River is highly dynamic and the river will eventually cut off the meander bend near the lumber mill in the near future if no action is taken. The erosion rate of the land remaining between the meanders upstream from the lumber mill was estimated using the historic bank alignments obtained from the aerial photographs and the rates are summarized in Table 2.

If a cutoff of the meander bend occurs, the thalweg of the river will shift towards the bank adjacent to the lumber mill and the banks will experience impinging flow, high flow velocities, and shear stresses. These changes will cause bank erosion that could result in damage to mill structures. WEST completed hydraulic and scour analyses in support of a bank protection design for the site. A detail for the bank protection measure is provided in Figure 9.

The Full Channel Bypass Alternative would relieve pressure on the breakthrough area and likely make the bypassed bend aggradational. With the Full Channel Bypass the channel would be better aligned to the bridge opening, eliminating the sharp bend upstream of the bridge opening.

Hydraulic impacts at SR 107 due to Chehalis River modifications are not significant, as seen in Table 10. However, the bridge is already experiencing scour problems. The slight increase in velocity could be mitigated by the inclusion of engineered logjams or other habitat friendly bank protection measures. Whether or not any changes are made to the Chehalis River in the bridge vicinity, scour conditions at the bridge should be monitored and measures should be taken to protect the bridge.

In order to prevent sewage interaction with the Wynoochee River the WWTP should be protected to elevation 22.5 feet for the 100-year event, and to elevation 23.3 feet for the 500-year event.

References

Federal Emergency Management Agency, 1986. *Flood Insurance Study for Grays Harbor County, Washington*.

Pacific International Engineering (PIE) and Pharos Corporation, 1996. *Chehalis River Bank Stabilization Project, Preliminary Engineering Design Report*, prepared for the City of Montesano, Washington.

Maynord, Stephen 1996. Journal of Hydraulic Engineering, *Toe Scour Estimation in Stabilized Bendways.*

Simons, Li and Associates, Inc. *Design Manual for Engineering Analysis of Fluvial Systems*, prepared for Arizona Department of Water Resources, 1985

Washington Department of Transportation, 2005 (July). *Reach Assessment for the SR 107 Chehalis River Bridge at Montesano*, prepared by Robert W. Schanz and Jim Park.

Washington Department of Transportation, 2010 (June). *Hydraulic Manual*.

WEST Consultants, Inc., 2008 Technical Memorandum, *Mary's River Lumber Mill Erosion Protection Measure Historical Aerial Analysis and Protection Recommendations.*

U.S. Army Corps of Engineers, 1994 (June) *EM 1110-2-1601, Hydraulic Design of Flood Control Channels.*