Reach Assessment for the SR 107 Chehalis River Bridge at Montesano

Work Order XL-2008

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INTRODUCTION

This report presents a site and reach assessment to identify solutions to bank failures that are threatening the safety of the SR 107/Chehalis River bridge in Montesano. The ***Site Assessment*** describes conditions in the immediate vicinity of the bank failures. The ***Reach Assessment*** examines river processes upstream and downstream of the project site that could influence the long-term stability of the bank. Site- and reach-based factors are then considered together to identify alternative solutions to the erosion problem.

This Site/Reach Assessment is prepared following guidelines described in chapters 2-5 of the Integrated Streambank Protection Guidelines (ISPG). The ISPG is published by the Washington State Aquatic Habitat Guidelines Program (2003). This is a consortium of public agencies including the Washington State Department of Fish and Wildlife, the Washington State Department of Ecology, the Washington State Department of Transportation, U.S. Army Corps of Engineers, and the U. S. Fish and Wildlife Service. The ISPG site/reach assessment is analogous to the Level 1 geomorphic assessment described in FHWA's HEC 20.

It is important to understand that ISPG is mainly a problem identification and methods selection framework. It is not a "cookbook" approach to solving streambank protection problems. The guidelines represent an attempt to standardize detailed geomorphic, hydrologic and habitat related reconnaissance for a wide variety of riverine channel stability considerations.

The ISPG also is not a regulation (See ISPG Preface page ii – "information in these guidelines is not a substitute for the law"). It is utilized here as a structure for the presentation of supporting environmental documentation pertaining to the proposed project. It is anticipated that the outcome of this approach will result in a project proposal that will protect the bridge and public safety, meet permit requirements, and provide environmental enhancements to this reach of the river.

PROJECT OBJECTIVES AND DESIGN CRITERIA

The aim of this project is to prevent further erosion of the left riverbank immediately upstream of the SR 107/Chehalis river bridge. Erosion of this bank could expose the shallow footings of the adjacent bridge piers, which would pose a serious threat to the stability of the bridge and the safety of the driving public. The specific objectives of the project are to:

- Stabilize the left bank to protect existing infrastructure.
- Avoid changes in river flow conditions that could increase flooding, bank erosion, or riverbed scour within the project reach.
- Avoid and minimize impacts to riparian and aquatic habitat.

Based on information developed in the site and reach assessment below, the following design criteria are necessary to meet these objectives:

- Bank stabilization measures shall be stable and withstand scour during flows up to the 100-year flood.
- Bank stabilization measures shall minimize additional confinement of the river channel, to avoid increasing velocities, bed scour, and bank erosion in this reach.
- Bank protection structures shall not exacerbate potential loading of debris against downstream bridge piers.
- Bank stabilization measures shall not increase 100-year flood elevations upstream
- Treatments shall avoid and minimize impacts to riparian function, cover, spawning, complexity and diversity, and flood refugia to the greatest extent practicable. Where practicable, techniques that enhance riparian function will be considered.

SITE ASSESSMENT

The project site is located on the left (south) bank of the Chehalis River at River Mile 13.2, on the upstream side of the SR 107 bridge at Montesano (Figure 1). Toe slope failures have eroded two 300-foot wide scallops into the left bank upstream of the SR 107 bridge. The first of these scallops is centered about 200 feet upstream of the bridge, and has cut into the bank to a point that is now in line with the sixth set of wood piers (about 175 feet inland of the concrete abutment pier on the left bank).

The project site is located within a 90-degree bend that directs flow from a 1500-foot straight river segment at the eroding bank. Within this straight reach the Mary's River lumber mill is protected by a combination of rock riprap and woodpile bank treatments. These have confined flow and reduced roughness, resulting in higher velocities directed at the project site.

Figure 2 shows a profile of the eroding bank at the center of the first scallop. The upper section of bank is nearly vertical and extends about 8 feet from the top of the bank. At about Mean Higher High Water level the bank transitions into tidal mud and slopes at 2.5:1 down to the low tide level. This profile is typical of eroding channels in tidal environments, where the upper section of bank slumps off in vertical chunks that are reworked by daily tidal flows to create a gentler slope on the lower bank.

Aerial photos from 1964, 1979, 1990, and 2003 provide a historical record of the erosion problem (Figure 3). In 1964 and 1979 the beginnings of the erosion scallops can be seen, and the deepest part of the first scallop is about 90 feet inland of the bridge abutment pier (Pier 2). Little change can be seen in the bank between 1964 and 1979. Between 1979 and 1990 the bank lost about 20 feet in the first scallop and 30 feet in the second scallop, but trees remained along most of the bank. Erosion becomes more severe between 1990 and 2003, with a loss of most trees and up to 40 feet of bank in the deepest part of the first scallop. Much of this may have occurred during the 1996 flood event, which is generally the largest flood of record in the Chehalis basin.

The riverbank and adjacent floodplain are made up of fine-grained alluvium deposited by floodwaters within a relatively low-gradient section of the Chehalis River. The upper section of the eroding bank is made up of Chehalis silt loam, a very deep well-drained floodplain soil with moderate permeability (USDA, 1979). Upstream riverbank samples collected by PIE (1996) had median particle diameters (D_{50}) of 0.04 to 0.18 mm. Soils in the upper profile are soft and loose, but become dense and more resistant to erosion at depths of 10-15 feet. Low areas inland of the eroding bank are covered by Rennie silt clay loam, a deep poorly-drained soil associated with relic river channels. The WDFW boat ramp and the mill on the opposite bank are underlain by udorthent soils that typically form in sandy and loamy river dredgings. Bore logs for a nearby private well show clays down to 66-feet depth, gravels and glacial deposits below 66-feet, and sandstone at 172-feet depth (Washington State Department of Ecology, 2005).

The floodplain at the project site is covered by grasses and scattered trees. Willows and shrubs line the bank directly adjacent to the bridge. No trees remain along the deepest portions of the erosion scallops. Scattered residences line the left bank of the Chehalis for about 1500 feet downstream of the SR 107 bridge. A WDFW boat ramp occupies the right bank directly opposite the project site. Mary's River Lumber Mill lines the right bank upstream of the boat ramp. Vacant parcels on the right bank upstream of the mill (near RM 14) are zoned by the City of Montesano for industrial development. Rock riprap and a series of barbs were installed between 2002 and 2003 to protect this area from erosion on the outside of a migrating river bend.

The SR 107 bridge was completed in 1958 (as-built date on X-sections). SR 107 crosses the Chehalis floodplain and approaches the main bridge deck on spans supported by wood pilings. The main bridge deck is supported by solid concrete abutment piers at waters edge on each bank (Piers 2 and 3), and two pairs of concrete columns about 58 feet inland from each bank (Piers 1 and 4). The bottom footing for the left bank pier (Pier 2) is at -20 feet NGVD, about 19 feet below ground and 26 feet above the river thalweg (Figure 4). The bottom footing for the inland Pier 1 is at 0 feet NGVD, about 10 feet below ground and 46 feet above the river thalweg.

The left bank abutment Pier 2 is placed on a point of remnant riverbank that intrudes into the current river channel. This point has been hardened with a riprap blanket that extends below Mean Lower Low Water up to the top of the bank. The riprap consists of 2" to 24" diameter rock, with a median diameter similar to that of light loose riprap. In the 1964 aerial photo the abutment pier was a relatively minor intrusion into the river channel. However, as the upstream erosion scallops deepened in subsequent decades the hardened point and pier became a more severe obstacle to flow. The pier and surrounding rock now intrude over 175 feet into the channel (relative to the deepest part of the erosion scallops), causing vortices that accelerate the upstream toe slope failures.

Figure 4 shows cross sections of the river at the bridge from various bridge surveys. These cross-sections extend over the riprapped base of the pier, and do not include the unarmored eroding section of bank. When the bridge was built the channel had a top width of 390 feet and a thalweg elevation of -27 feet NGVD. Later bridge surveys show a substantial amount of fill placed in the right bank channel, probably to construct the WDFW boat ramp. This reduced the top width of the active channel to about 300 feet. The river responded to confinement by the bridge piers and the boat ramp by scouring a new thalweg down to -46 feet NGVD (19 feet deeper than the as-built thalweg). The channel thalweg has since stabilized, with little change observed between the 1995 and 2003 elevations.

WSDOT bridge surveys and hydraulic modeling results from PIE (1996) were used to estimate shear stresses at the project site. Shear stresses will be largest on the outside of the river bend, which has a radius of curvature of about 300 feet. Using bend correction factors from ISPG, shear stresses on the outside of the river bend could range from 0.4 lbs/ft^2 at bankfull flow to 0.7 lbs/ft^2 during major floods. Charts in FHWA (1988) indicate that unvegetated banks of Chehalis Silt Loam are eroded by shear stresses greater than 0.1 lbs/ft^2.

REACH ASSESSMENT

Watershed Conditions and Land Cover

The Chehalis River drains 1,780 acres upstream of Montesano. The Satsop River is the largest tributary below Porter, draining more than 300 square miles. The Wynoochee River drains more than 155 square miles, and enters the Chehalis immediately downstream of the SR 107 bridge.

Eighty-three percent of the Chehalis basin above Montesano is covered by forestry, most of which is heavily managed private and state forestland (Envirovision, 2000). Agriculture covers 11 percent of the basin, and is concentrated on valley floors and floodplains. Urban land covers only 2 percent of the basin, and is concentrated in small cities scattered along I-5 and US 12.

Recent aerial photos show agriculture as the dominant land cover on the lower Chehalis floodplain. Recent clearcuts and forest cover hillslopes on both sides of the river valley. Urban development within the City of Montesano is generally confined to terraces and hillslopes north of US 12, outside of the Chehalis River floodplain. Comparison of aerial photos from 1964 and the 1990's shows little change in the extent of urban development in Montesano.

Geology and Soils

The Chehalis River flows through a broad alluvial valley bounded to the south by steep slopes of marine sedimentary rock and to the north by terraces of glacial outwash (Figure 5). The alluvial valley floor is generally 8500 to 9500 feet wide, but narrows down to about 6000 feet wide at the SR 107 bridge. At the project site the river has meandered to within 600 feet of the southern edge of the alluvial valley. The deep alluvial deposits contain an unconfined aquifer with a high level of connectivity to the Chehalis River (Envirovision, 2000).

During the last ice age the lower Chehalis River was a major drainage channel for meltwater from glaciers that covered the Puget Sound lowlands. The river is believed to have been as large as today's Columbia River (Alt and Hyndman, 1984). The glacial meltwater carried coarse outwash gravel that was deposited on terraces along the margins of the valley. These terraces now underlie much of US 12 and the City of Montesano north of the project site.

The glaciers receded 10,000 to 15,000 years ago, and sea levels rose 300 feet. This inundated Grays Harbor, and converted the lower reaches of the Chehalis River to a tidal estuary. The lower Chehalis responded to rising sea levels and smaller river flows by filling the historical meltwater channel with fine-grained alluvium. This created today's smaller river that migrates slowly across a broad, flat valley.

Most of the soils on the valley floor are very deep, well-drained silt loams with moderate permeability, including Chehalis, Cloquato, Humptulips, and Newberg silt loams (USDA, 1979). Low areas and relic channels contain Rennie silt clay loam, a deep, poorly drained soil with slow permeability.

Hydrology and Flow Conditions

In most years the Chehalis basin does not have a significant snowpack, and flood flows are generated primarily by runoff during rain events. Average annual rainfall ranges from 59 to 75 inches along the lower Chehalis valley, and from 98 to 123 inches in the Satsop and Wynoochee basins (Envirovision, 2000). Flows during dry periods are derived from groundwater. A dam on the Skookumchuck River has minor effects on flows in the lower Chehalis River (Envirovision, 2000). A COE dam has a substantial effect on flows in the Wynoochee River (FEMA, 1986).

The Chehalis River at Montesano is tidally influenced, with a typical daily tidal range of 8 to 10 feet. PIE (1996) identified the following tidal elevations at Montesano:

Tide	**Elevation (feet MSL)**
Highest Tide	10.20
Mean Higher High Water	5.11
Mean Lower Low Water	-5.02
Lowest Tide	-7.80

Tidal influence extends upstream to the Satsop River, above River Mile 18 (FEMA, 1986). Tidal flooding at the bridge is generally confined to low areas near channels, including a complex of wetlands along a remnant channel that enters the Chehalis just upstream of the project site. The Chehalis River Surge Plain lies about 2.5 miles downstream of the bridge, and is the largest tidal surge plain wetland in Washington State. This complex of forested wetlands is protected by a 2,643 acre Natural Area Preserve managed by the Washington State Department of Natural Resources.

Major flood events occur when storm surge tides coincide with large rainfall events and high river flows. The lower Chehalis River's 100-year floodplain covers most of the alluvial deposits on the valley floor, and is about 5500 feet wide at the SR 107 bridge (FEMA, 1986). Floodwaters can be as deep as five feet on the floodplain during major storms (PIE, 1996).

Table 1 summarizes peak flood flow statistics for gages on the lower Chehalis and its major tributaries, based on data presented by Sumioka et al, 1998. These statistics reflect gage records through 1996, and include the two highest flood events on record (February 1996 and January 1990).

Table 1. Flow Statistics for USGS Streamgages in the Lower Chehalis Basin

Event	Chehalis at Porter	Chehalis below Satsop R.	Chehalis at Montesano	Satsop at Satsop	Wynoochee at Montesano
2-year flow (cfs)	29,100	NA	NA	24,700	16,400
10-year flow (cfs)	46,100	NA	NA	38,200	25,200
25-year flow (cfs)	55,500	NA	NA	44,400	29,400
50-year flow (cfs)	62,900	NA	NA	48,800	32,400
100-year flow (cfs)	70,700	NA	NA	53,000	35,400
Drainage Area (mi^2)	1,294	1,761	1,780	299	155
River Mile	33.3	18.0	13.2	2.3	5.9
Tidal?	No	Yes	Yes	No	No

Figure 6 shows median monthly streamflows estimated at Montesano by Envirovision (2000) from upstream gage data and unit runoff estimates. The Chehalis River is over-allocated, and existing water rights exceed available streamflows from May through September (Envirovision, 2000).

PIE (1996) used the following flows to characterize flood conditions near the SR 107 bridge:

100-year Flood:	78,000 cfs
Major Flood:	81,760 cfs
Moderate Flood:	49,056 cfs
Typical Winter High Flow:	30,600 cfs
Bank full flow:	30,000 to 40,000 cfs (depending on tide)

PIE used these flows to develop a HEC-2 step-backwater model of the reach beginning at the bridge (RM 13.2) and ending upstream of the City of Montesano bank stabilization project (RM 14.61). The model showed that tides have a minor influence (less than 0.5 feet) during major flood events, but have a more significant (over 4-feet) effect on more frequent flood events. Velocities in this reach were highest at the bridge, where the channel is most constricted. Average velocities at the bridge ranged from about 4 fps during typical winter high flows to 7 fps during a major flood.

Sediment Transport and Scour

Because of the river's low gradient, most of the sediment carried by the lower Chehalis is fine-grained silt and sand. Riverbank samples collected by PIE (1986) had median particle diameters (D_{50}) of 0.04 to 0.18 mm. Just before entering the Chehalis the Wynoochee flows into a large pond that first appears in the photo record in the early 1970's. This pond appears to capture most of the coarse sediment from the Wynoochee before it enters the Chehalis.

The river segment between the mill and the Wynoochee River (including the project site) functions primarily as a transport reach. At low tide there are few visible sediment bars or islands between the upstream end of the mill (3000 feet upstream of the bridge) and the mouth of the Wynoochee (1500 feet downstream of the bridge). Sand bars form on the insides of meander bends upstream of the mill. The outsides of these bends are generally eroding, with near vertical banks of fine-grained alluvium.

Figure 7 shows the profile of the riverbed in the project reach, derived from WSDOT bridge surveys and cross-sections surveyed by PIE (1996). Note that this profile predates construction of the City of Montesano bank stabilization project. The overall gradient in this reach is almost flat, with a natural bed elevation of between –15 and –20 feet NGVD. At constrictions the river scours deep holes in the riverbed to below –45 feet NGVD. This has occurred at the SR 107 bridge, at the upstream end of the lumber mill, and just upstream of the oxbow above the City of Montesano bank stabilization project. Bridge surveys show that the depth of the scour hole at the bridge has changed little since 1995.

Channel Migration and Avulsion

Figure 8 overlays river channel alignments from the 1964, 1979, 1990, and 2003 aerial photos. With the exception of the erosion of scallops along the left bank, the general alignment of the river at the bridge has changed little since 1964. Changes are more significant upstream near the Mary's River lumber mill. From 1964 through 2003 the meander bend upstream of the mill migrated westward towards SR 107, with the largest changes occurring after 1979. In 2002 the City of Montesano installed a series of rock barbs and a riprap blanket to stabilize the outside of this meander bend. The upstream end of the lumber mill was also armored with rock to tie into the Montesano project. During our site visit in May 2005 these bank protection measures were still in place, and there was no evidence of new migration of the outside of the bend. However, these bank protection measures have combined to direct flow against the bank opposite the mill. This bank is now eroding rapidly, and has retreated up to 190 feet since 1990.

The erosion of the left bank opposite the mill has implications for future channel changes in the project reach. This erosion has narrowed the isthmus on the inside of the meander bend to less than 400 feet, and is concentrated at the mouth of a historic cutoff channel. If this continues, it is likely that the river will shift into this channel, cutting off the meander bend upstream of the mill. This channel change would direct erosive flows against the mill, and would significantly shorten the length of the channel upstream of the project.

Historic survey maps from the 1860's show that the river once occupied the relic channel that enters the river just upstream of the SR 107 bridge erosion scallops. A landslide shown on DNR geology maps (Figure 5) may have closed off this channel at the upstream end and forced the river into the tight meander bend that it now follows upstream of SR 107. The relic channel is now a tidal marsh, and has generally remained stable throughout the historic photo record. In the current river alignment there does not appear to be much risk of avulsion or chute cutoff into the relic channel. However, a chute cutoff opposite the mill would tend to increase erosion within the 90-degree bend upstream of the bridge, which in turn could increase the risk of a future avulsion into the relic channel/tidal marsh. This would straighten out the river's approach to the bridge by eliminating the existing 90-degree bend, but would also shorten the river's flow path upstream of the bridge. A shortened flow path would decrease energy losses and could increase velocities at the bridge.

Riparian Condition and Large Woody Debris

Aerial photos from 1988 along 14 miles of the lower Chehalis show 9 percent of the riparian area to be intact, 45 percent to be altered, and 28 percent to be absent (Envirovision, 2000). Most floodplain areas in the project reach have been cleared, and riparian vegetation is generally restricted to narrow bands of deciduous trees along the streambank. Erosion and land use activities have removed all trees from large sections of both banks.

In May 2005 we observed woody debris racked against rock structures and pilings at the mill and on the downstream end of the eroding bank opposite the mill. A logjam was visible on a sand bar upstream of the City of Montesano bank stabilization project. Otherwise, large woody debris was mostly absent from the project reach.

Water Quality

Water temperatures and fecal coliform counts frequently exceed state standards in the Chehalis River at Montesano (Envirovision, 2000). Envirovision (2000) also found high total phosphorus and inorganic nitrogen yields at this station. The lower Chehalis River is on the state's 1998 303(d) list for fecal coliform and temperature.

Fish Utilization

The following information describes fish distribution and stock status in the project and action area. The project site is in a tidally influenced area of the Chehalis and Wynoochee rivers. Substrate in the project area is not conducive to spawning, but the area is assumed to be used for migration and rearing of various salmonid species.

Salmonid Distribution and Status in the Lower Chehalis River Basin

Within WRIA 22 there are seven fall chinook stocks, one summer chinook stock, and one spring chinook stock identified in the Salmon and Steelhead Stock Inventory (SASSI) report. The seven fall chinook stocks are designated as separate stocks based upon geography that include the: Humptulips, Hoquiam, Wishkah, Wynoochee, Satsop, Johns/Elk/South Bay Tributaries, and Chehalis fall chinook (WDF, WDW, and WWTIT 1993 and 2005).

Two stocks of fall chum are identified in WRIA 22 that include the Humptulips and Chehalis. The status of Chehalis chum is healthy. However, it is noteworthy that the distribution of chum has decreased over time (Phinney and Bucknell 1975, as cited in Smith and Wenger 2001).

The Chehalis and nearby drainages produce more coho smolts (575,000 in 1999) than any other system along the Washington Coast, and in 1999 was the third largest producer of wild coho smolts in Washington State (Seiler 2000, as cited in Smith and Wenger 2001). Seven stocks of coho salmon are listed in the SASSI report, using the same geographic categories as fall chinook. All of these stocks are considered composites of hatchery and wild fish, with significant hatchery influence. All stocks are considered healthy with the exception of the Wishkah coho that are considered depressed (WDF, WDW, and WWTIT 2005)

Two summer steelhead trout stocks are identified in SASSI; one in the Humptulips, and the second stock in the remaining areas of the Chehalis drainage. Stock status is considered unknown for both stocks (WDFW and WWTIT 2005). Seven stocks of winter steelhead trout are listed in the SASSI report. Three of the seven stocks are considered depressed, one stock is considered unknown, and three are considered healthy. The Chehalis and Wynoochee stocks are two of the three stocks considered healthy (WDFW and WWTIT 2005).

While WDFW lists a bull trout/Dolly Varden stock in the Chehalis drainage (WDFW 1998), documentation regarding the presence of the stock is scant. Six records document the presence of low numbers of bull trout within the Grays Harbor estuary (Jackson 2000, as cited in Smith and Wenger 2001), and it is possible that these fish temporarily dipped into the estuary or are strays from the more robust stocks located north of Grays Harbor. Recent evidence of bull trout presence outside of tidally-influenced areas is lacking. In the eleven years that WDFW has operated the juvenile smolt trap in the Chehalis River, no native char have been reported (Jackson 2000, as cited in Smith and Wenger 2001). Also, smaller scale smolt trapping has occurred in various tributaries to the Chehalis River, with no records of bull trout presence. Records for adult returns to a trap in the Wynoochee River since 1968 were examined, and no evidence of char were found (Jackson 2000, as cited in Smith and Wenger 2001). The low gradients in the Chehalis drainage are not considered to be ideal habitat for bull trout, and while historically, bull trout might have inhabited limited areas of the Chehalis drainage, their current existence within this region is questionable (Smith and Wenger 2001).

Table 2. Salmonid Stock Status in the Lower Chehalis River Basin.

Stock	Primary Utilization	2002 SASSI Status	ESA Status
Coho (*Onchorhyncus kisutch*)	Migration	Healthy	NA
Summer steelhead (*O. mykiss*)	Migration	Unknown	NA
Winter steelhead (*O. mykiss*)	Migration	Healthy	NA
Chum (*O. keta*)	Migration	Healthy	NA
Cutthroat trout	Migration	Unknown	NA
Fall and Spring chinook (*O. tshawytscha*)	Migration	Healthy	NA
Bull Trout/Dolly Varden (*Salvelinus confluentis*)	Migration/foraging/overwintering?	Unknown	Threatened

(Salmonscape 2005; Phinney et al. 1975; WDFW and WWTIT 1993; WDFW 2005)

Salmonid Distribution and Stock Status in the Wynoochee Sub-Basin

The project site is approximately 0.2 RM above the confluence of the Wynoochee River. The lowest mile of the Wynoochee River is tidally influenced. The Wynoochee River historically had runs of fall chinook salmon, a small run of spring chinook, coho salmon, fall chum salmon, and winter steelhead trout. Summer steelhead trout were initially stocked in the Wynoochee sub-basin, and have established a self-sustaining population that has not been supplemented for over 20 years (Randy Aho, Aberdeen Lake Hatchery, personal communication, as cited in Smith and Wenger 2001).

Table 3 summarizes the SASSI 2002 salmon and steelhead stock status in the Wynoochee River sub-basin. All of the stocks with status data are considered healthy except for fall chinook stock, whose status is depressed (WDFW and WWTIT 2005).

Table 3. Salmonid Stock Status in the Wynoochee River Basin.

Stock	**Primary Utilization**	**2002 SASSI Status**	**ESA Status**
Coho (*Onchorhyncus kisutch*)	Migration	Healthy	NA
Winter steelhead (*O. mykiss*)	Migration	Healthy	NA
Cutthroat trout	Migration	Unknown	NA
Fall chinook (*O. tshawytscha*)	Migration	Depressed	NA
Bull Trout/Dolly Varden (*Salvelinus confluentis*)	Migration/foraging/ overwintering?	Unknown	Threatened

(Salmonscape 2005; Phinney et al. 1975; WDF, WDW, and WWTIT 1993; WDFW and WWTIT 2005)

MECHANISMS AND CAUSES OF FAILURE

The mechanism of failure is toe erosion of the left bank. Shear stresses during storm events on the Chehalis River erode the silt loams and fine-grained alluvium that make up the toe of the riverbank. This causes the upper bank to slump and collapse into the river. The base of the left bank abutment piers intrudes into the river channel, creating vortices that accelerate the erosion of scallops into the left bank upstream of the bridge.

The site-based causes of the toe erosion include erosion along a bend, reduced vegetative structure, and channel smoothing. The site is located within a sharp 90-degree bend in the river that directs flows from a 1500-foot long straight river segment at the eroding bank. Most of the bank has been cleared of riparian vegetation, and the remaining pasture grasses and scattered alders provide little reinforcement. Woody debris is largely absent from this reach of the river. Riprap and other hard bank treatments at the mill and bridge reduce roughness and confine flow.

The underlying reach-based condition is meander belt migration that is artificially confined by the bridge, the mill, and upstream bank protection structures. Upstream bank protection measures have reduced roughness and redirected the energy of the river against unprotected sections of bank opposite the lumber mill and at the SR 107 bridge. These bank protection measures may also induce chute cutoffs that would change the river's alignment and increase erosive forces at the bridge.

ALTERNATIVES CONSIDERED

Repair alternatives need to address the following factors that contribute to bank erosion:

- Shear stresses created by high river flows within a 90-degree bend
- Erosional vortices created by the hardened left bank bridge approach
- Loss of vegetative structure and roughness on the eroded banks
- Smoothing of channels in the project reach by bank protection measures and loss of vegetation
- Confinement of the river by the bridge, the WDFW boat ramp, the Mary's River Lumber Mill, and the City of Montesano bank stabilization project
- A deep river channel with scour holes that cut down to –46 feet NGVD. This will make it difficult to provide stable foundations for in-stream structures.
- Potential future changes in river alignment due to chute cutoffs in the upstream meander bend

In developing repair alternatives two functions must be considered. First, the repair must provide protection to the bridge pier itself. Second, the repair must address ongoing channel migration that threatens to flank the bridge if left unchecked. The following repair alternatives should be considered:

- The ISPG selection matrices point to Buried Groins, Roughness Trees, Rock or Log Toes, and Engineered Log Jams (ELJ's) as potential solutions.

- Buried Revetment or Groins with roughness elements -- This would involve burying a rock revetment or series of groins in the bank behind the erosion scallops. Rootwads and woody debris could be anchored into the buried rock to provide roughness and bank reinforcement. The buried structures would tie into a riprap blanket and roughened rock toe around the base of the bridge piers.

- Roughness Trees – Trees placed along the base of the bank would provide roughness and bank reinforcement, but would be subject to undermining and dislodgement by local scour within the erosion scallops. However, wood placement could be a component of the buried rock structures described above, using the rock and buried bank to anchor wood elements.

- ELJ's, barbs-- Because the reach is confined to the extent that it has deepened considerably, structures that further impinge on the active channel are inadvisable in this location. The existing channel depths (down to –46 feet NGVD) pose serious problems for the foundations of instream structures. Additionally, the potential for recruitment of additional LWD immediately upstream of the bridge could further exacerbate channel constriction at the site if it results in an increased ELJ size over time. Recruited LWD could also be loaded onto the pier under flood conditions if high flows mobilize recruited wood to calve off of the ELJ immediately above the bridge

- Riprap Revetment -- ISPG indicates that this method is inappropriate in migrating channels. However, most of the project reach is heavily armored to protect existing infrastructure, thus drastically limiting the extent to which channel migration can take place. The preclusion of channel migration has become the long-term environmental baseline throughout the project area. Those sections of bank within the reach that remain unarmored both at the bridge and upstream across from the Mary's River Mill are now eroding considerably as a result of redirection and concentration of erosive flows. Because the area of erosive channel migration above the bridge is in the process of flanking the bridge, channel migration in this location cannot be accommodated.

- Removal/relocation of boat ramp – The WDFW public access boat ramp across the channel from the scour critical piers of the bridge appears to impinge flow, driving the thalweg toward the left bank. Removal of this structure would increase the effective channel cross section at the bridge. This could be beneficial by centering the thalweg beneath the bridge, as well as reducing velocity shear within the channel cross section.

- Flow diversion into relic channel -- PIE (1996) studied an alternative that involved redirecting the river into the relic channel just upstream of the project. This would soften the angle of attack on the bank by eliminating the 90-degree bend. However, it would not address local scour and could increase velocities in this reach by shortening the river flow path. This alternative would require extensive in-channel work, and would result in complex impacts on upstream and downstream reaches. Obtaining permits for this option would be very difficult due to impacts on rearing habitat in the relic channel.

PREFERRED ALTERNATIVE

This report presents a geomorphic analysis and lays out alternatives and design considerations for the design team. The next logical step is to use this information to collectively decide upon a preferred alternative for the repair of the SR 107 Chehalis river bridge. The information presented here indicates that some alternatives are problematic from a constructability, environmental, or hydraulic standpoint. Other alternatives have definite utility here but may need to be combined with more than one technique to implement a complete repair.

The combination of lateral and vertical instability problems at this site makes selection of a preferred alternative challenging. The preferred alternative should include the following elements.

1. It is critical that the face and toe of the pier be protected where the depth of the channel poses a threat. The depth of the channel also poses constructability challenges. Placement of heavy loose rip-rap around the pier is the easiest approach in this instance. In addition, this method replicates the original pier protection and may be easier to permit if it is a footprint "replacement" rather than a "new" footprint feature. Rip-rap armoring around the pier should be kept to the minimum necessary so as to avoid exacerbation of the channel constriction.

2. The bridge is located at the narrowest channel cross section of the entire reach. This has resulted in high velocity flows that have deepened the channel considerably, increasing the scour threat top the bridge. Increasing the channel cross section by relocating the boat ramp and re-shaping the right bank near the bridge is strongly recommended. A viable site for the boat ramp to be relocated to exists on the right bank just downstream from the bridge

3. Although it was identified as a secondary concern, lateral migration of the channel into the left bank may continues to bein the future. If so, it may be advisable to place hard point(s) in the erosion scar upstream of the bridge to check lateral migration that is in the process of flanking the bridge. Adding roughness features to the hard point(s) would be very beneficial in terms of countering erosive forces in this location. Another alternative would be to install a buried revetment or avulsion sill parallel to the bridge approach.

This Reach Assessment indicates that the reach based factor behind both the lateral and vertical instability problems at the bridge stem from channel constriction. In achieving the objective of protecting the bridge, it is imperative that the repair alternative selected avoids exacerbation of the constricted channel conditions prevalent at the site. In light of this, protection measures that are buried in the bank incorporating rock and /or wood roughness features (such as buried revetments or buried groins) to counter the tendency of the river to flank the structure are recommended.

Lastly, the potential for avulsion through the isthmus that separates the upstream meanders must be considered in terms of anticipated project performance under changing geomorphic conditions. Changes in velocity and angle of attack resulting from such changes should be anticipated. Because of this large in-stream structures with a tendency to split flows should be avoided as performance of such structures would be difficult to predict. In addition, structures of this type would tend to exacerbate channel constriction problems.

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FIGURES

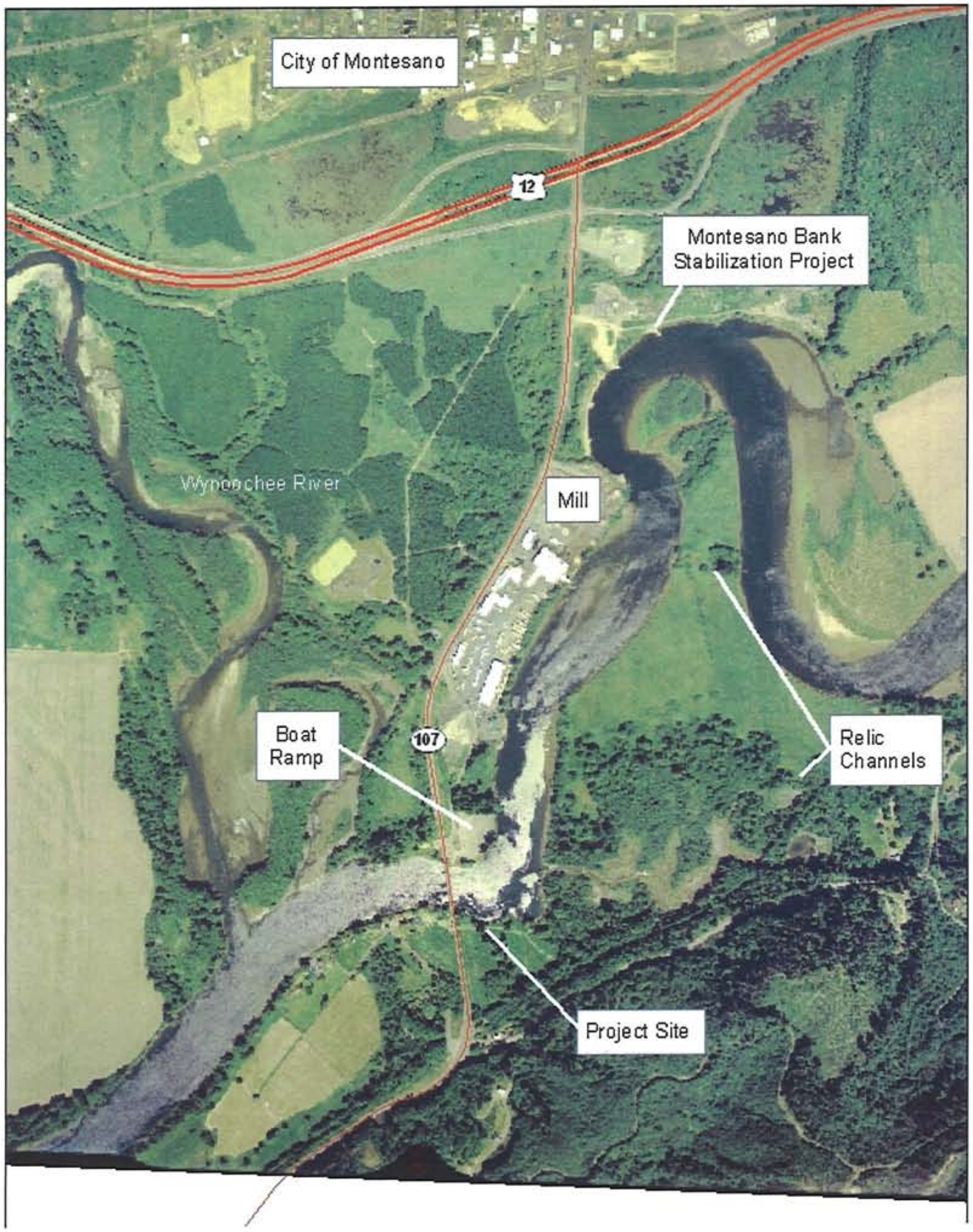

Figure 1
Location Map

Base: 2003 Color Photo

0 500 1,000 2,000 3,000 Feet

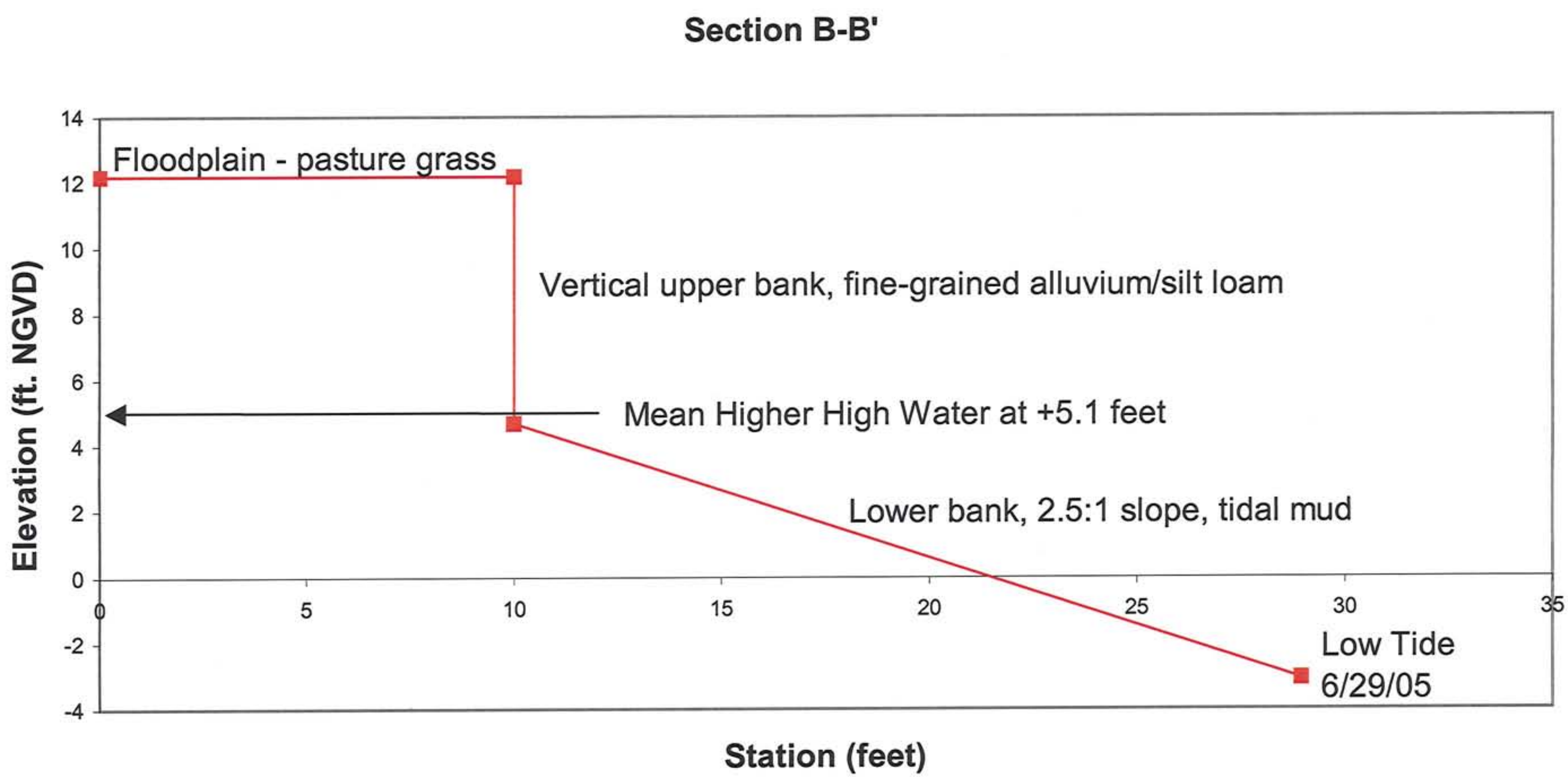

Figure 2. Profile of the Eroding Bank 200' Upstream of the SR 107 Bridge

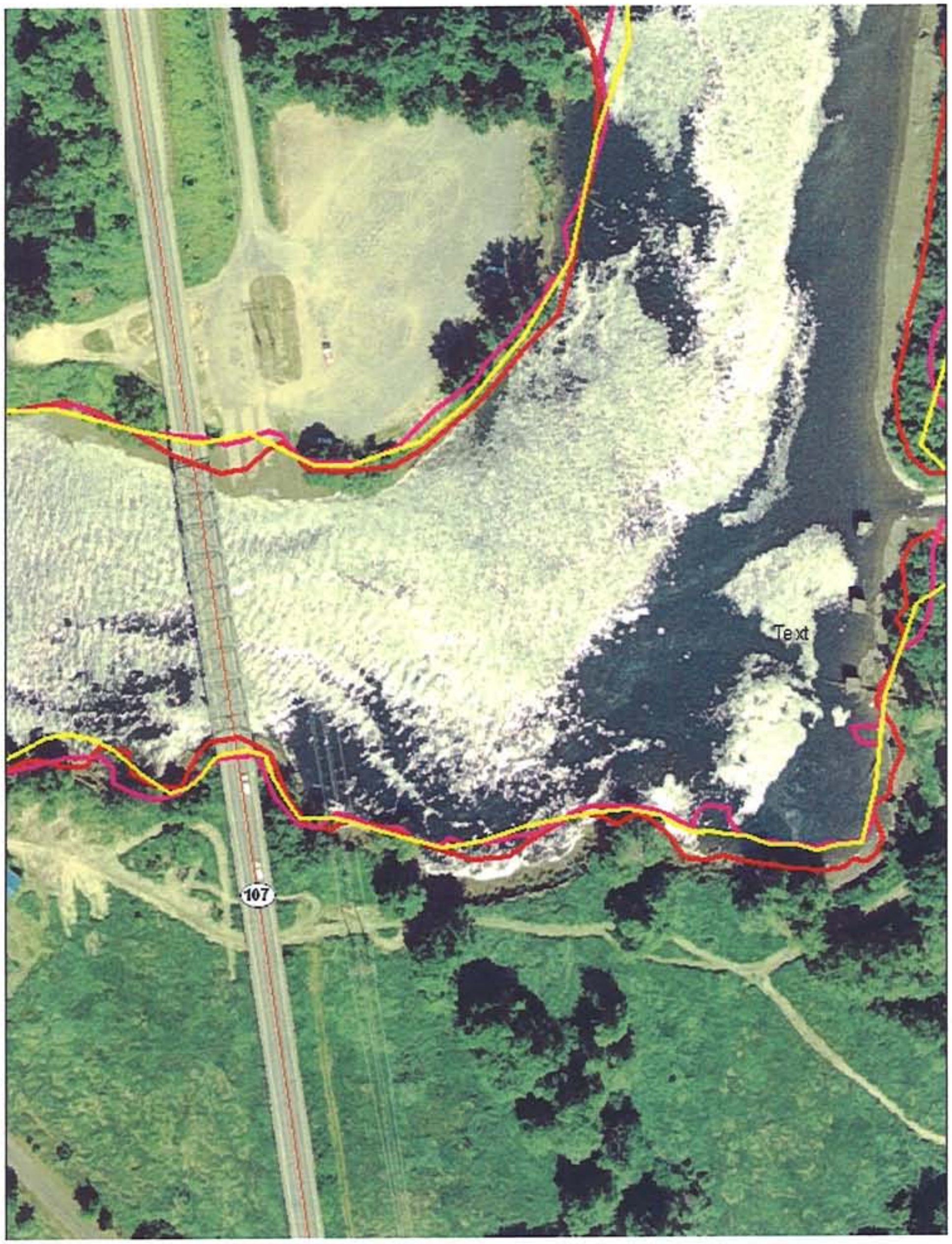

Figure 3

Photo Record of Bank Erosion

Base: 2003 Color Photo

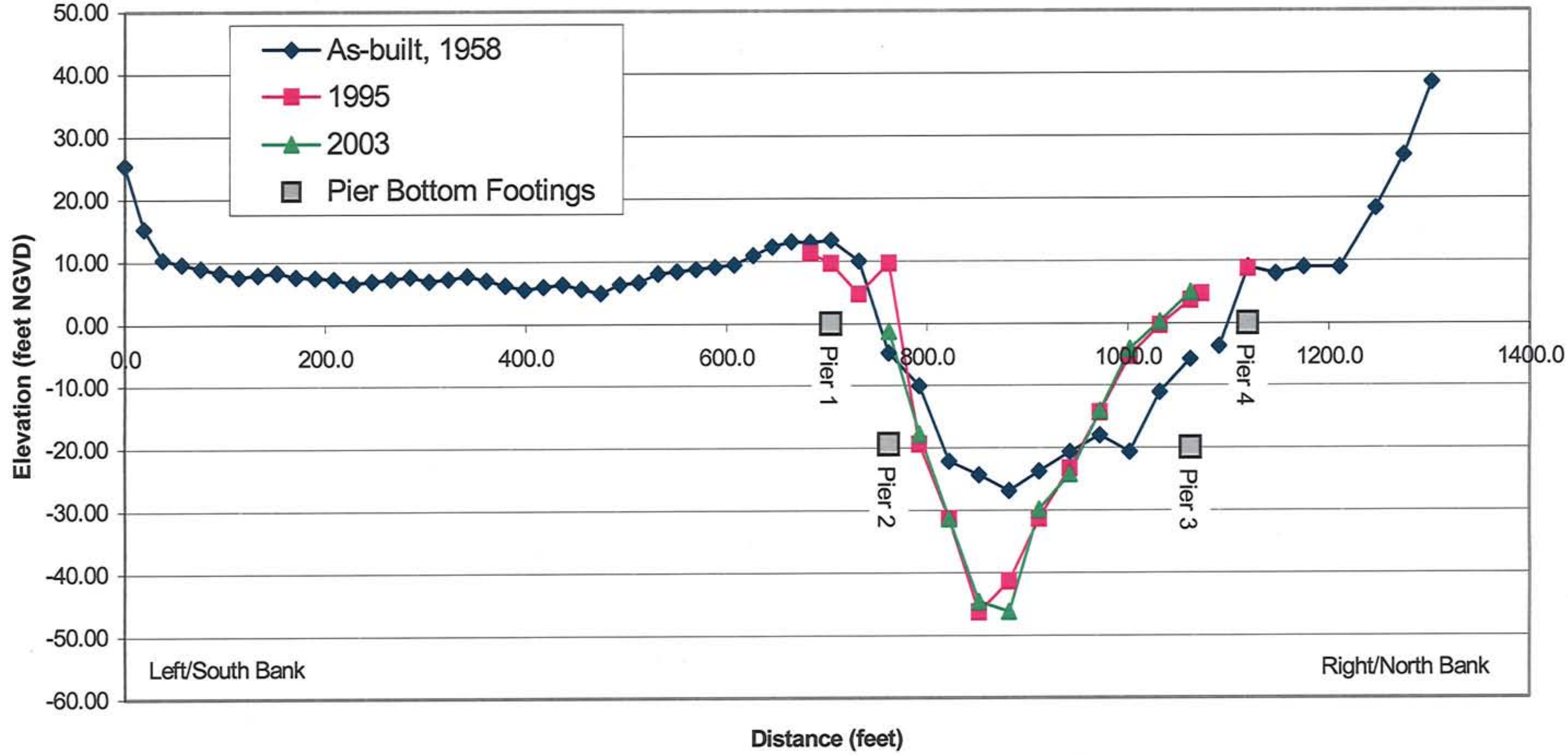

Figure 4. Bridge Survey Cross Sections at the SR 107 Bridge

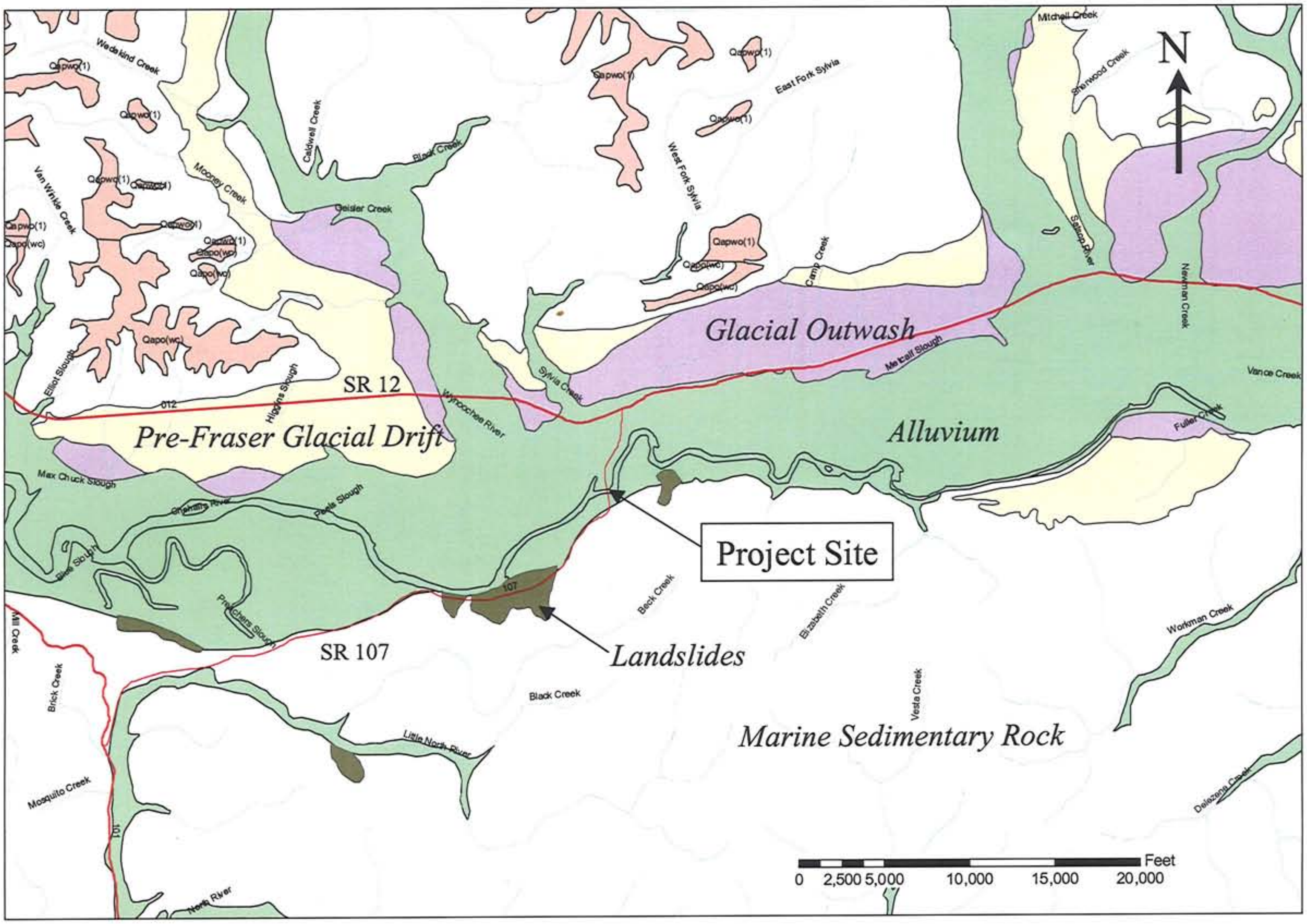

Figure 5. Regional Geology

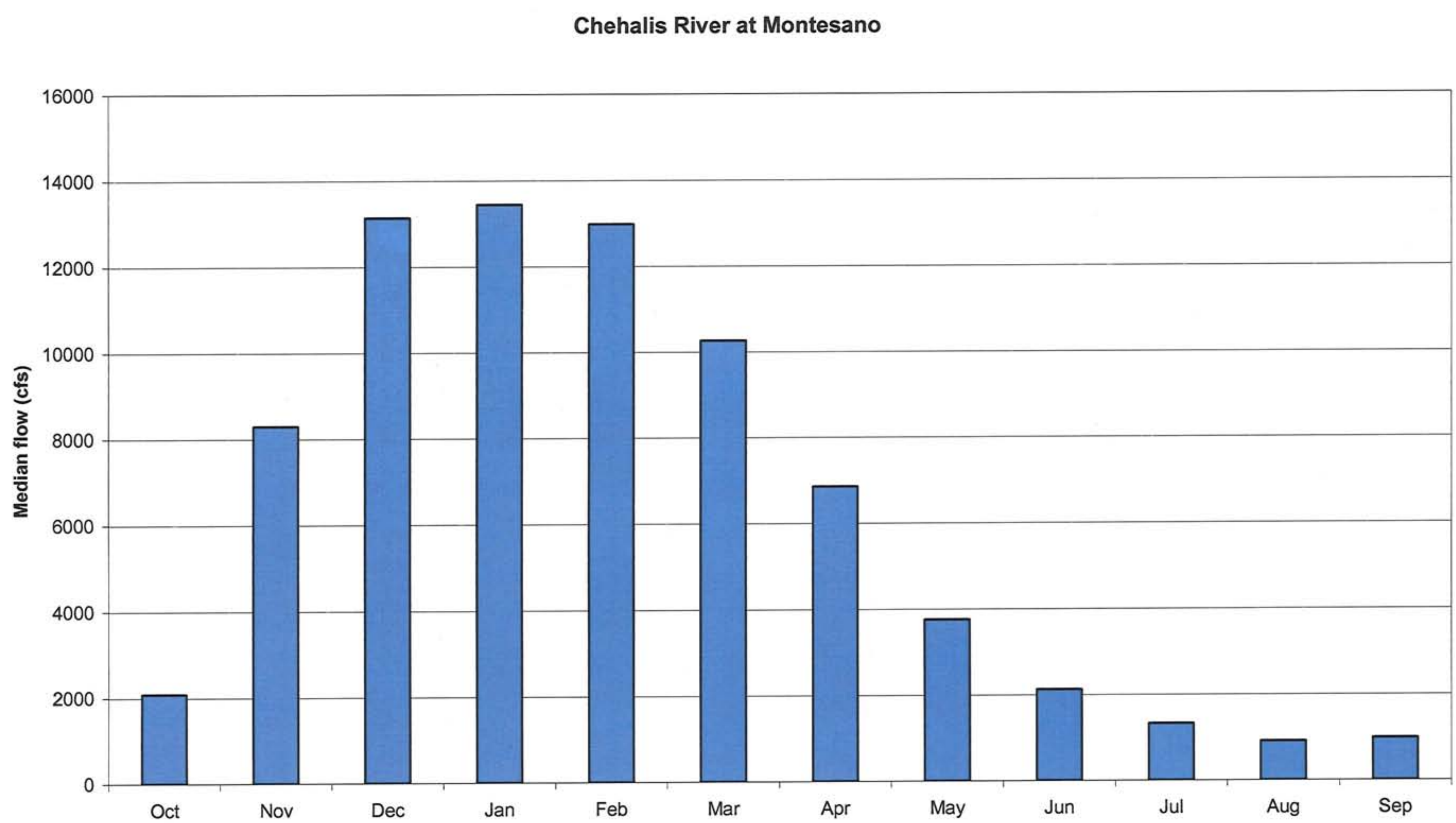

Figure 6. Median Monthly Flows at Montesano (from Envirovision, 2000)

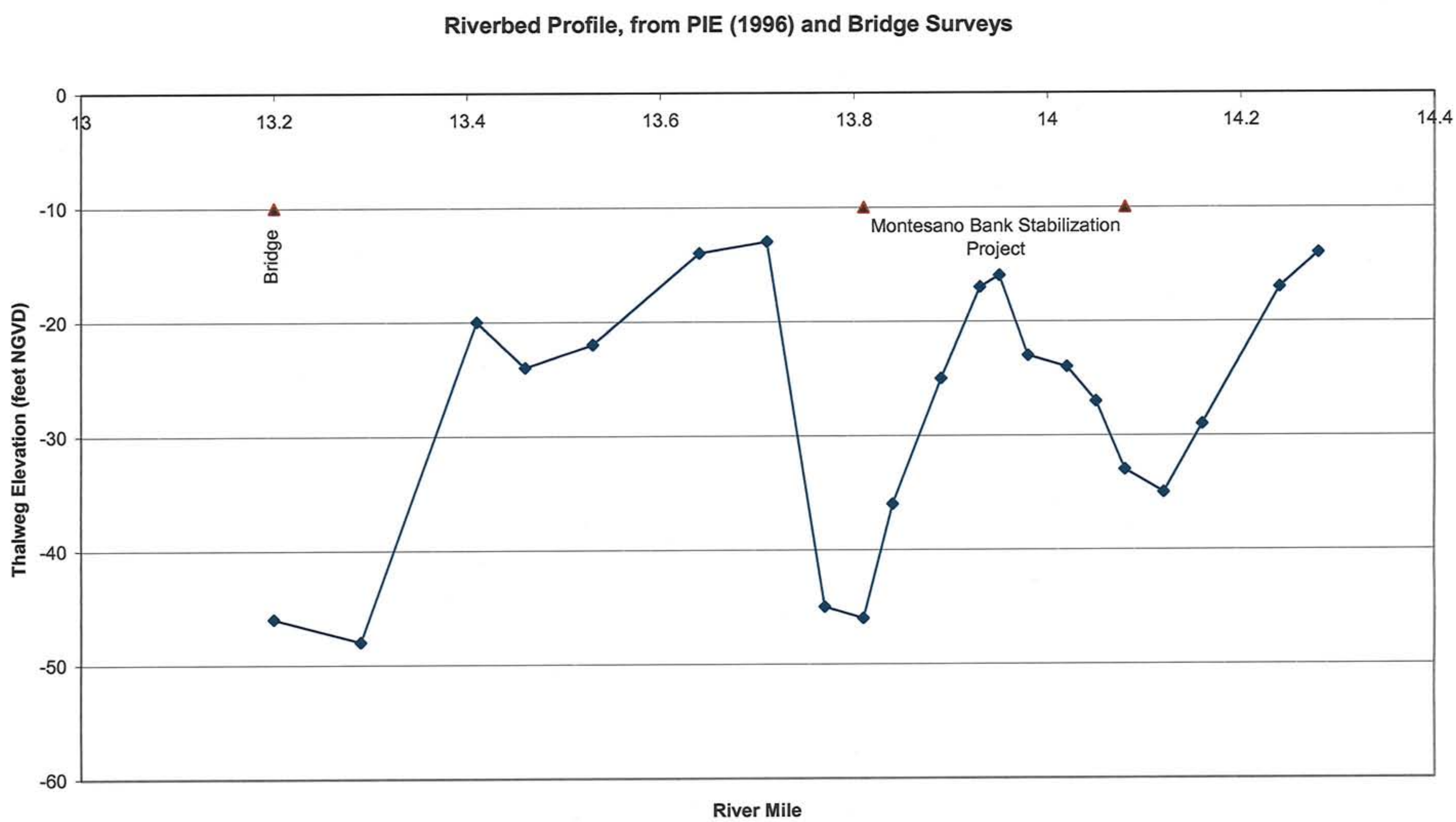

Figure 7. Riverbed Profile Upstream of the SR 107 Bridge

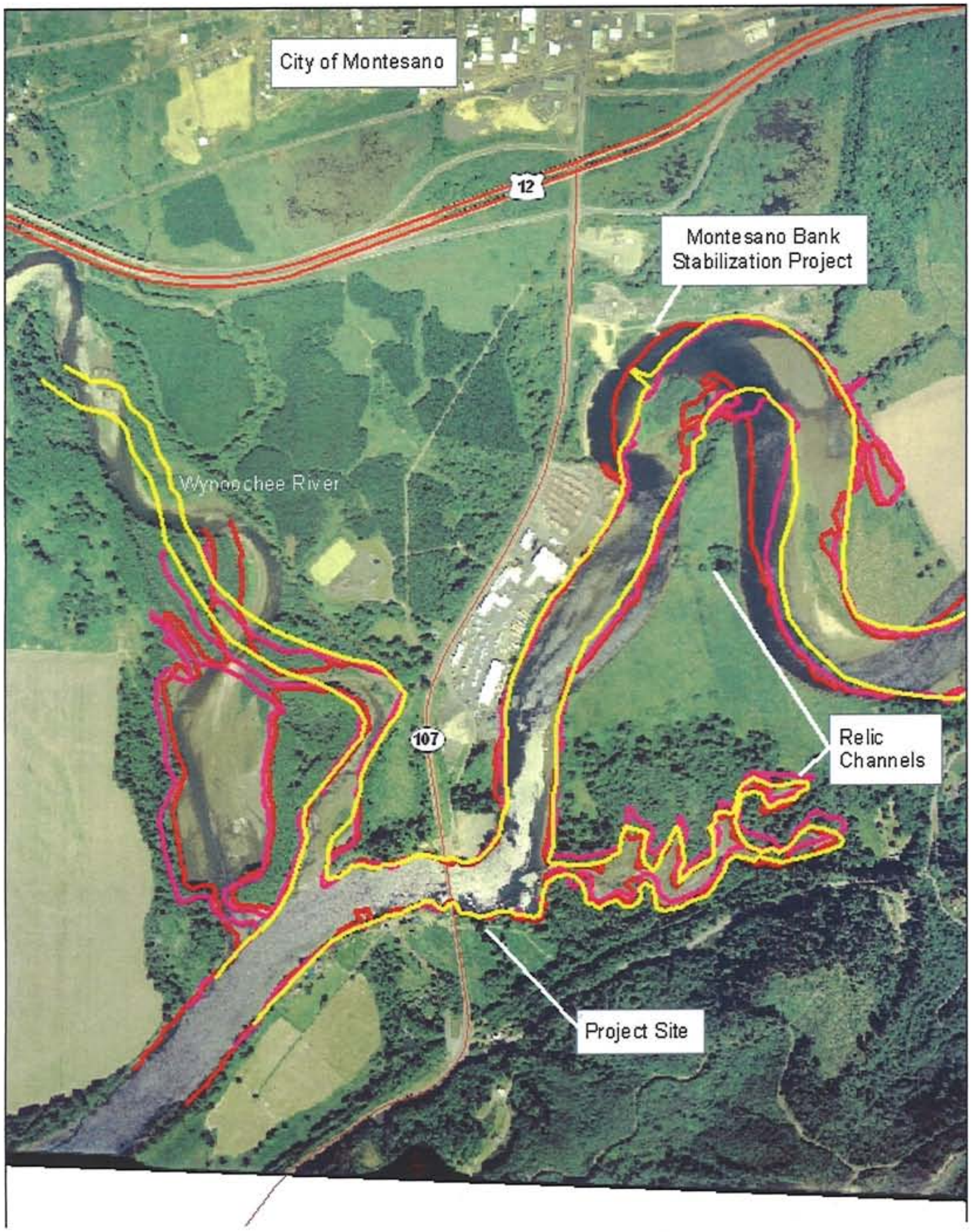

Figure 8
Historic River Alignments

Base: 2003 Color Photo