

Reach Assessment for the South Fork Newaukum River at SR 508 Milepost 7.3



Work Order MS 5404

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July 2006



Washington State Department of Transportation
Environmental and Engineering Service Center
Environmental Services Office

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INTRODUCTION

This report presents a site and reach assessment to identify solutions to bank failures and road settling on SR 508 at Milepost 7.3 near Onalaska. Bank erosion on the South Fork Newaukum River has initiated ground movement in landslide deposits beneath the road. This has caused the roadbed to settle, and led to a road closure during the January 2006 floods. A rock buttress has been installed as an emergency repair, but a long-term solution is needed that will stabilize the road and minimize impacts to riparian and aquatic habitat. The *Site Assessment* describes conditions in the immediate vicinity of the project site. The *Reach Assessment* examines stream processes upstream and downstream that could influence the long-term stability of the road. Site- and reach-based factors are then considered together to identify alternative solutions to the problem.

SITE ASSESSMENT AND PROBLEM DESCRIPTION

The project site is located on SR 508 near Onalaska, just east of Hyak Road near River Mile 20 (Figure 1). The road approaches Onalaska on the edge of a terrace that forms the northern boundary of the South Fork Newaukum River floodplain. SR 508 is built on landslide deposits at the base of the terrace slope. The river is entrained directly against the leading edge of this landslide, and has eroded a 15- to 20-foot high cut bank below the road. In January 2006 the river undermined the base of the landslide material, causing ground movement and settling beneath SR 508.

The site has a long history of road instability associated with ground movement and riverbank erosion. In the early 1990's attempts were made to stabilize the road by placing lightweight polystyrene blocks and installing a 10-foot trench to intercept seepage (WSDOT, 2000). This held until floodwaters in the 1998-99 rainy season eroded the toe of the slope. The landslide began to move again, creating tension cracks over a 200-foot stretch of road. Three bank barbs were installed in 1999 to reduce erosion and provide some buttressing of the slide. However, inclinometers installed in the slide still showed substantial ground movement in January 2000 (WSDOT, 2000).

Heavy rains fell throughout western Washington in early January 2006, leading to extensive flooding and river erosion. The South Fork Newaukum River at the USGS Gage in Onalaska peaked on January 10 at 2310 cfs, just above the 2-year peak flow. Flows receded slowly over the next two days, but peaked again during another wave of storms on January 13.

The South Fork Newaukum River removed 8-10 feet of bank during this storm, leaving less than 15-feet of terrace between the roadbed and the riverbank. Erosion was concentrated in a 40-foot scalloped section of bank between the second and third river barbs. Large fissures opened up on the terrace, and the road settled several inches overnight. WSDOT closed the road on January 13, and SR 508 was included in the Governor's declaration of emergency for the January 2006 storms. A rock buttress was installed as an emergency repair between the second and third barbs, filling in the scallop and stabilizing the slumping terrace (*see cover photo*). This buttress has

stabilized a 140-foot section of bank, but erosion scallops continue to develop upstream and downstream of the installed rock.

The upstream scallop (between the first barb and the upstream end of the buttress) is about 70 feet long, and has cut 18 feet inland. The scallop lies within a strong eddy that develops as the river bends sharply towards the rock buttress. The bank within the scallop consists of a 15-foot high 1:1 slope covered by horsetails, alder seedlings, and shrubs. During low flows a marshy terrace is exposed at the toe of the slope. Gheer Creek enters the South Fork Newaukum immediately upstream of the first barb and the erosion scallop.

The downstream scallop has developed off the downstream end of the rock buttress, and is caused primarily by loss of roughness and flow acceleration along the face of the rock structure. It consists of an 80-foot section of 10 to 20 foot high bank. The bank is actively eroding, and consists of near vertical slopes with slumped deposits of sandy silt along the toe.

Figure 2 shows typical sections of the bank before and after the emergency repair. On January 12 (before the repair) the river had dropped below its peak flood level, and was flowing at about 1350 cfs at the project site. The eroded bank was about 15 feet high, and consisted of loose sandy silt. Sandy siltstone was exposed at the base of the slope, just above the river water level. Seepage was emerging from subsurface drainage pipes and from the eroded bank along the top of exposed geotextile fabric (*see cover photo*).

The soils within the landslide consist of a mixture of sandy silt with gravel, clayey sands, sandy clays, and elastic silts with sand (WSDOT, 2000). Underlying the landslide debris is a very weak, highly weathered sandy siltstone. The failure surface lies 33 to 45 feet below the highway (WSDOT, 2000). Groundwater in the slide was about 10 feet below the ground surface in January 2000.

REACH ASSESSMENT

The reach assessment focuses on the South Fork Newaukum River between River Mile 18 downstream of the site and River Mile 22 upstream of the site. We also examine watershed-scale conditions where appropriate.

Watershed Conditions and Land Cover

The South Fork Newaukum River drains 52.2 square miles at the project site (Figure 1). It combines with the North and Middle Forks about 20 miles downstream to form the mainstem Newaukum River. The Newaukum River eventually flows into the Chehalis River near Chehalis, and is within the Upper Chehalis Water Resources Inventory Area (WRIA 23).

The river begins at Newaukum Lake in the Cascade foothills. Elevations range from about 440 feet MSL at the site to 3800 feet MSL in the headwaters. Almost the entire upper basin is covered by privately owned industrial forest, with 53 percent as mid-seral coniferous forest (Washington State Conservation Commission, 2001). The lower basin is dominated by hardwood

forest (59%) and non-forest (23%). By 1959 most of the pre-settlement timber in the basin had been harvested, and there is now almost no late seral forest remaining.

The basin contains about 3.6 miles of road per square mile (Washington State Conservation Commission, 2001). Agriculture is concentrated on the valley floor, and covers 17 percent of the Newaukum basin (Envirovision, 2000). Residential and other rural uses cover the remaining non-forested areas. The unincorporated town of Onalaska lies just upstream of the project site. Agricultural land use in the watershed is declining, and many farms and low-elevation forestry operations are being converted to low-density residential uses.

There has been extensive logging and land clearing on the terrace above SR 508. A large clear cut extends to the top edge of the terrace, in soils that were saturated during the January 2006 storms. The logged area is relatively flat, and is separated from SR 508 by a slope covered by a regenerated forest of Red Alder and Western Red Cedar. The cleared area drains down this slope towards SR 508, as well as into ditches along Hyak Road.

Geology and Soils

Figure 3 shows the surficial geology in the vicinity of the project site, based on 100K Department of Natural Resources (DNR) mapping. Low areas next to the river are covered by coarse alluvial soils found in floodplains that are frequently dissected by channels (USDA, 1979). Cloquato silt loam and Chehalis silty clay soils cover the higher floodplains on the south side of the valley.

The valley floor alluvium is about 2000 feet wide at the project site, and is bounded by terraces of alpine glacial outwash. SR 508 lies on the edge of a terrace of alpine glacial outwash from the Logan Hill Formation. This formation extends across much of west-central Lewis County, and is an important regional aquifer (Weigle and Foxworthy, 1962). The top of the terrace is covered by Prather silty loam soils that often perch water in the winter and early spring (USDA, 1979). In January 2006 we observed large areas of ponded water in recently logged areas within these soils.

SR 508 is built on landslide deposits at the base of a slope on the southern edge of the terrace, about 60 feet below the top of the terrace. This slope exposes Miocene sedimentary rock that underlies the Logan Hill glacial outwash (Figure 3). Geotechnical reports for the Onalaska slide describe this material as a very weak, highly weathered sandy siltstone. A shelf of this rock is exposed at the base of the eroding riverbank, at about the Ordinary High Water level of the river. A mantle of loose sandy xerothent soils covers the bedrock and makes up most of the eroding riverbank. These soils often form in colluvium derived from marine siltstone, sandstone, and pyroclastic breccia (USDA, 1979).

Hydrology

The South Fork Newaukum basin receives about 65 inches of mean annual precipitation above Onalaska (USGS Streamstats, 2006). The watershed generally does not maintain a persistent snow pack, and flood events are driven by long winter rainstorms. Rain-on-snow has contributed

to several large historical floods, including the record February 1996 floods. Gheer Creek enters the South Fork Newaukum on the right bank immediately upstream of the site, and is dammed in Onalaska to form Lake Carlisle. This dam is the largest in the watershed, but has little regulatory effect on river flows (Envirovision, 2000).

The USGS operates a stream gage at Jorgenson Road, about 3 miles upstream of the project site (USGS, 2006). The river drains 42.4 square miles at the gage. This gage operated between 1948 and 1978, but was discontinued until the February 1996 floods renewed interest in stream flow data. It now operates as a winter gauge from October through April.

Table 1 summarizes peak flows at the USGS gage and at the project site, estimated from flow statistics and drainage area relationships derived by Sumioka et al. (1998).

Table 1. Flow Statistics for the South Fork Newaukum River

Event	Peak Flow at USGS Gage 12024000	Estimated Peak Flow at the project site (cfs)*
2-year	2270	2751
10-year	3470	4205
25-year	4020	4871
50-year	4410	5343
100-year	4790	5804
Peak on January 10, 2006	2310	2799
Flow during January 12 site visit	1100	1333

* *Region 1: Estimated flow = USGS Gage Flow x (52.24 mi²/42.4 mi²)^{0.92}*

Channel Migration and Floodplain Interactions

Figure 4 shows a valley cross-section at the project site, measured from USGS 1:24K topography. At the project site the South Fork Newaukum River has migrated to the northern margin of its floodplain where it is jammed against a glacial terrace. The 100-year floodplain covers a 400-foot wide band that generally lies within low alder-covered areas next to the channel. The southern side of the valley contains a higher floodplain terrace of alluvial deposits that only floods during extreme events.

2002 aerial photos show three major meander bends in the project reach, including the bend that contains the project site (Figure 5). These bends typically contain a 25- to 30-foot wide wetted channel and 30- to 80-foot wide sediment bars. The meander bends are separated by relatively straight 1000- to 1500-foot pool segments with 40- to 60-foot wide channels and few large sediment bars.

Figure 5 compares channel configurations shown in 1966, 1977, early 1990's, and 2002 aerial photos. The channel stays to the north side of the valley throughout this period, with no major avulsions or channel changes into the southern side of the valley floor. Two major chute cutoffs of meander bends upstream and downstream of the site simplified and straightened the channel

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between 1977 and 1990. The meander bend at the project site migrated northward towards SR 508 between 1966 and 1977, and was almost at the road shoulder by the early 1990's.

The 1966 photo shows large open sediment bars opposite and just upstream of the project site. The area upstream of the project site can be accessed by a road from SR 508, and may have been created by in-channel gravel mining in the 1960's. The area opposite the project site is at the outlet of a secondary channel that in 1966 branched off of the left bank just upstream. By the early 1990's both of these areas had been colonized by alders and shrubs.

The 1966 and 1977 photos show numerous channel scars lacing across the southern side of the alluvial valley (Figure 5). These indicate the river historically migrated across the floodplain on the southern side of the valley. They currently function as shallow overflow swales that only carry water across the high floodplain terrace during very large flood events. Farm tilling has obscured these features in the early 1990s and 2002 photos.

More active secondary channels cut across the low floodplain directly opposite the project site. The coarse soils, immature alder forest, and low elevation in this floodplain area indicate high potential for channel migration. If the channel split or migrated into this area, it would divert energy and flow from the eroding bank at the project site. This realignment would also alter channel characteristics near a residence on the left bank immediately downstream of the project site.

Channel Profile and Sediment Transport

Figure 6 shows the profile of the riverbed in the project reach, derived from USGS 1:24K topography. The river gradient is fairly uniform at about 0.5 percent between the project site and the USGS gage upstream of Onalaska. At the project site the gradient drops to about 0.3 percent.

The presence of large sediment bars indicates most sediment deposition in the project reach occurs within meander bends. The long pool segments that separate these bends tend to function as transport reaches, and contain few large sediment bars. The meander bend that contains the project site is characterized by broad gravel deposits and low floodplain terraces that are frequently dissected by channels. This sediment deposition may be related to changes in gradient and channel capacity as the river transitions into a relatively straight and confined segment downstream of the project. There is also evidence of historical in-channel gravel mining in the 1960's that could have destabilized sediment bars just upstream of the site.

Riparian Condition and Large Woody Debris

Bank erosion and stabilization work have removed all trees and shrubs from a 200-foot length of bank at the repair site. The 1966 photo shows about 80 feet of riparian trees between SR 508 and the riverbank at the project site. This was reduced to less than 60 feet by 1977 and 25 feet in the early 1990s.

Large stands of riparian trees occupy both banks upstream of the project site, and on the right bank downstream of the site. These stands typically consist of young alders on low floodplain

areas, and mixed conifers and deciduous trees on higher banks. Aerial photos show a general increase in the width and density of riparian forests in the project reach between 1966 and 2002, particularly on the left bank just upstream of the project site. About 1500 feet of the left bank downstream of the site remains cleared of trees throughout the photo record to accommodate farms, access roads, and residences. The WRIA 23 Limiting Factors Analysis rated riparian conditions as “fair” from the project site upstream to Leonard Road in Onalaska (Washington State Conservation Commission, 2001). A 2000-foot segment that extends downstream beginning at the project site was rated “poor”.

Surveys conducted in the 1990s show 32 percent of riparian areas in the lower South Fork Newaukum as unforested (Washington State Conservation Commission, 2001). Hardwood forests cover 55 percent of riparian areas, and early- to mid-seral coniferous forest covers 13 percent. Four percent of surveyed stream banks were altered by riprap (Envirovision, 2000).

Surveys in the headwaters of the South Fork Newaukum found low amounts of large woody debris (Envirovision, 2000). In January 2006 wood was largely absent from the eroding bank. However, two rootwads just upstream were having a significant effect on flow patterns. A single rootwad on the right bank just upstream was diverting flow energy away from the project site, although not enough to prevent further erosion.

During the January 2006 flood we inspected logjams downstream of the site near Milepost 5. A log placed by WSDOT to divert river energy away from the road had recruited a significant amount of woody debris. We also saw growth in a mid-channel jam downstream of this location. This indicates there is potential for recruitment of woody debris in the South Fork Newaukum River, although most of the observed debris was less than two feet in diameter.

Water Quality

The Department of Ecology did not include the South Fork Newaukum River on the 2004 303(d) list of impaired waters (Washington State Department of Ecology, 2006), although high water temperatures have been observed (Washington State Conservation Commission, 2001). High fecal coliform levels and high water temperatures are listed as impairments to water quality in the mainstem Newaukum River. Total Maximum Daily Load (TMDL) studies have been developed for water temperature and fecal coliform in the upper Chehalis Basin.

Lake Carlisle in Onalaska has a long history of water quality problems associated with shallow water depths, poor circulation, and high nutrient input. These problems may contribute marginally to high water temperatures and fecal coliform levels in downstream reaches of the Newaukum River.

Fish Utilization and Habitat Availability

The South Fork Newaukum River provides spawning, rearing, and migration habitat for coho salmon, winter steelhead, chinook salmon, and cutthroat trout (Table 2). Gheer Creek and Lake Carlisle produce coho and steelhead, including hatchery coho raised by Onalaska High School (Washington State Conservation Commission, 2001). None of these are listed in the Chehalis

Basin as threatened or endangered under the Endangered Species Act. The U.S. Fish and Wildlife Service lists coastal cutthroat trout as a Federal species of concern (WSDOT, 2006).

The Limiting Factors Analysis for the Chehalis basin WRIAs 22 and 23 identified the Newaukum as a priority subbasin for salmon recovery (Washington State Conservation Commission, 2001). A variety of factors combine to limit salmon production in the basin, including high water temperatures, riparian degradation, low levels of large woody debris, excess sediment delivery from landslides and erosion, channel incision, and loss of side- and off-channel rearing habitat. Bank erosion, livestock access, high road densities, and historic gravel mining have all contributed to sedimentation in the South Fork Newaukum.

The Chehalis Basin Level I Assessment summarized habitat conditions in the South Fork Newaukum based on 1993 surveys and a 1999 watershed analysis (Envirovision, 2000). These surveys identified loss of streamside vegetation from livestock damage, bank erosion, and land clearing activities as a major source of habitat problems. Road erosion and landslides have lead to fine sediment deposition and pool filling.

Table 2. Salmonid Stock Status in the South Fork Newaukum Basin.

Species	Stock	Primary Utilization	2002 SASI Status	ESA Status
Coho (<i>Oncorhynchus kisutch</i>)	Chehalis	Spawning, Rearing, Migration	Healthy	Not Warranted
Winter steelhead (<i>O. mykiss</i>)	Skookumchuck /Newaukum	Spawning, Rearing, Migration	Healthy	Not Warranted
Coastal cutthroat trout (<i>O. clarki clarki</i>)		Unknown	Not Rated	Species of Concern
Fall and Spring chinook (<i>O. tshawytscha</i>)	Chehalis	Spawning, Rearing, Migration	Healthy	Not Warranted

(From WLRIS and SASI databases, WDFW, 2006 and 2002; NOAA Fisheries, 2006)

EVALUATION OF TREATMENT ALTERNATIVES

Mechanisms and Causes of Failure

The mechanism of failure is ground movement within landslide deposits that underlie SR 508. The South Fork Newaukum River is eroding the toe of the slide, and has reactivated lateral movement of the slide towards the river. This toe erosion is caused by stresses generated in a bend of the river, loss of roughness, and reduced vegetative structure on the riverbank. Subsurface flow associated with heavy rains further contributes to instability of the landslide material.

Project Objectives

The objectives of this project are to:

- Stabilize the landslide material that underlies SR 508
- Stabilize the riverbank adjacent to SR 508
- Reduce frequency of maintenance and bank repairs
- Minimize changes in flood elevations and erosion patterns that could affect nearby properties
- 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.
- Provide mitigation for unavoidable impacts to aquatic and riparian habitats.

Treatment Alternatives

Chapter 5 of the Integrated Streambank Protection Guidelines (WDFW, 2003) provides matrices that aid in the selection of alternatives. The matrices for site and reach conditions rate Roughened Rock Toes, Log Toes, and Bank Reshaping as good treatments for reducing erosion and stabilizing the riverbank. However, WSDOT's geotechnical analysis indicates that a more substantial structure equivalent to the existing rock buttress is needed to prevent lateral movement of the landslide beneath SR 508. Alternatives that provide the needed structural stabilization of the landslide are considered below.

Alternative 1 - No Action (leave Rock Buttress in place). This alternative would leave the rock buttress that was installed as an emergency action in place. This buttress was constructed by filling an erosion scallop with large rocks, covering a 140-foot stretch of bank between the second and third barbs. Geotechnical analysis indicates that this will provide adequate support for the toe of the landslide. The structure is also sufficiently robust to resist localized river erosion. However, this alternative causes negative impacts to riparian function, cover, and habitat complexity and diversity along a 140-foot segment of bank. This alternative would also not address erosion scallops that are forming upstream and downstream of the rock buttress. As these scallops enlarge, they could eventually undermine the buttress, threaten the stability of the road, and cause further loss of riparian habitat.

Alternative 2 - Rock Buttress Combined with Log Structures in Erosion Scallops. The rock buttress would remain in place to support the toe of the landslide, and log structures would be constructed within the erosion scallops upstream and downstream of the buttress (Figures 7 & 8). At the upstream scallop the log structure would consist of interlocking logs anchored to pilings. Rock and soil would cover portions of the structure to provide ballast and a terrace for riparian planting. Most of the structure would be constructed on the mud and marsh terrace that has formed within the eddy at the toe of the bank. Rootwads would intrude out into the eddy, providing flow deflection and roughness.

The steep slope and deep water at the downstream scallop provide less room for reconstruction of a planting terrace. The structure here would therefore consist of a log cribwall anchored to

pilings. Interlocking logs and rootwads would provide roughness and structural reinforcement to the bank. The structure would intrude outward no further than the tip of the buttress, to avoid further intrusion and potential deflection of river flow towards downstream properties. Riparian plants would be installed at the top of the slope, and in spaces within the crib wall. The slope above the downstream scallop includes a step 10-15 feet high that is almost vertical. It may be necessary to lay this slope back somewhat in order to establish stable vegetative cover on the slope.

The log structures would combine to provide riparian function, cover, and habitat complexity and diversity for 150 feet of reconstructed riverbank. Additional mitigation could be created by anchoring rootwads along the toe of the rock buttress. However, we do not recommend this approach for the following reasons:

- The rootwads would further impinge into a river that has already been substantially confined by the rock buttress. This would increase the footprint of the project, and could potentially push flow towards downstream private properties on the left bank.
- Placement of the rootwads would require temporary removal of rock from the buttress, and could damage its structural integrity.
- Isolated rootwads extending out into the main flow of the river would have limited habitat value, especially when compared to the more complex log structures that could be built in the scallops upstream and downstream of the buttress.

In selecting the preferred project alternative for this site it is important to select an appropriate balance between deflection and diffusion functions in light of the need to check potential downstream channel response. The structures proposed are limited in terms of protrusion into the channel and deflective function, they will function more as an energy diffuser / dissipater than a deflector (such as a barb might provide). A structure that operates of principles of flow diffusion will also provide superior habitat function than a deflector structure as it will create more in the way of quiescent aquatic habitat areas. The structures proposed will provide good flow-through characteristics and energy diffusion. Some deflective function will also be provided however this will be checked by the complex shape of the structure, and by limiting its protrusion into the thalweg of the river.

Alternative 3 - Roughened Rock or Log Toe combined with Sheet Pile Wall. The rock buttress would be removed, and a structural sheet pile wall would be constructed to stabilize the landslide. The wall would be buried behind the riverbank just below the SR 508 road shoulder, and would allow riparian planting and reconstruction of the riverbank in front of the wall. A combination of rock and log toe treatments would be used to reinforce the reconstructed riverbank.

This alternative could minimize habitat impacts by providing log structures along the toe of the reconstructed bank, and by planting riparian vegetation on slopes and terraces above the toe treatment. However, geotechnical analysis indicates that the sandy siltstone that underlies the landslide material is too hard for sheet pile installation. This alternative is therefore not constructible.

CONCLUSIONS

The project site has a long history of landslide movement and riverbank erosion that damages SR 508. This has led to frequent closures of the primary access road to Onalaska and other rural communities in eastern Lewis County. Repairs to the eroding bank have been costly and damaging to aquatic and riparian habitats.

A rock buttress was installed as an emergency action to prevent road failure during a series of flood events in January 2006. The road failures were caused by riverbank erosion that reactivated lateral movement within historical landslide deposits. Geotechnical analysis indicates a substantial rock buttress is needed to permanently stabilize the landslide material. Bank treatments that only address toe erosion are not sufficient to prevent movement of the landslide.

Table 3 summarizes the risks and benefits associated with two treatment alternatives. The existing rock buttress (Alternative 1) provides the structural support needed to prevent further movement of the landslide. It has also caused substantial impacts to aquatic and riparian habitats. Erosion scallops immediately upstream and downstream threaten the edges of the buttress and could eventually impinge on SR 508. To address habitat impacts and protect the ends of the buttress, we recommend installing log structures in the erosion scallops (Alternative 2). These structures will create riparian and refuge habitat that substantially mitigates for the impacts of the rock buttress.

Table 3. Risk Analysis of Treatment Alternatives.

Failure Mode	Alternative 1 – Rock Buttress		Alternative 2 – Buttress with Log Structures		Explanation
	Consequence	Likelihood	Consequence	Likelihood	
Landslide Movement	Very High	Low	Very High	Low	Rock Buttress provides substantial geotechnical stabilization
Scallop erosion advances to SR 508	Very High	High	Very High	Low	Without log structures the scallops will continue to advance towards SR 508.
Scallop erosion undermines edges of structure	High	Moderate	High	Low	Log structures provide roughness and structure to resist edge erosion
Scour undermines toe of structures	Moderate	Low	High	Moderate	Log structures are more susceptible to scour than the simple rock buttress
Aquatic and Riparian impacts are not mitigated on-site	High	Very High	High	Low	Log structures provide substantial mitigation of impacts caused by the buttress

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Consequence ratings: range from “Very High” (road failure, or project permitting will require extensive off-site mitigation) to “Very Low” (structure functions as intended without intervention, and provides full mitigation of impacts).

Likelihood Ratings: range from “Very High” (will almost certainly occur) to “Very Low” (will almost never occur).

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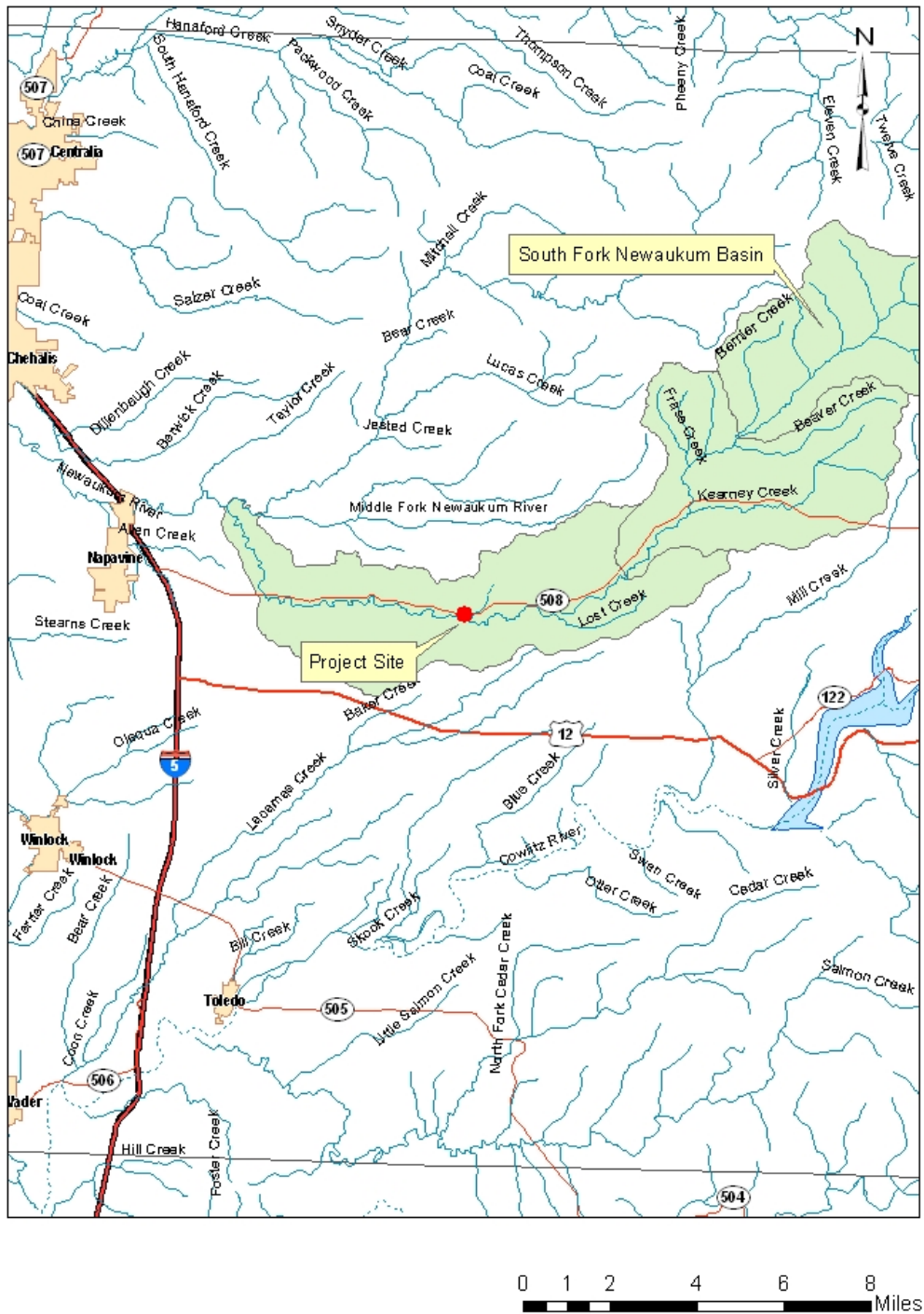


Figure 1. Location of the South Fork Newaukum Watershed

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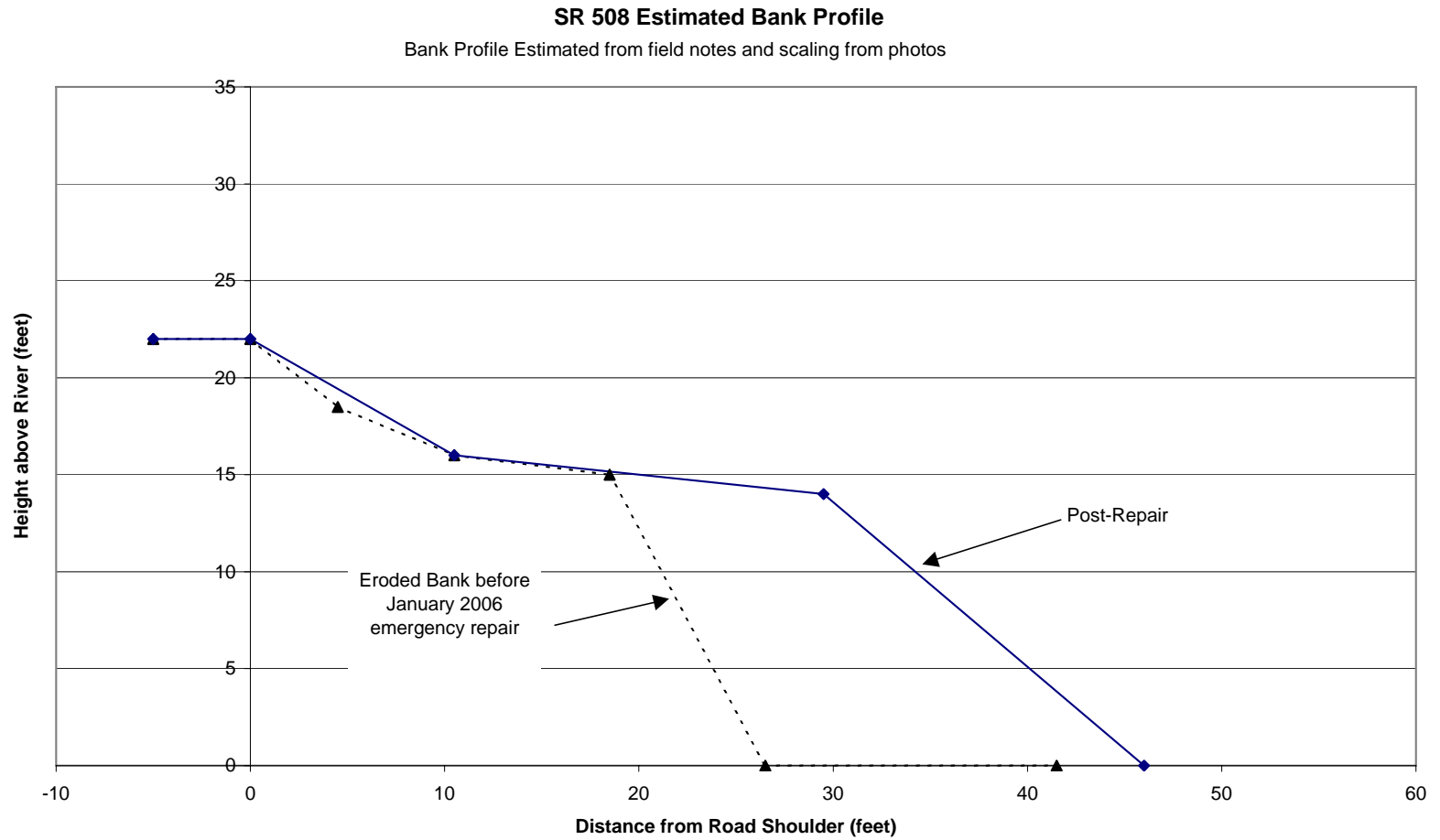


Figure 2. Estimated Riverbank Profiles at the Erosion Site

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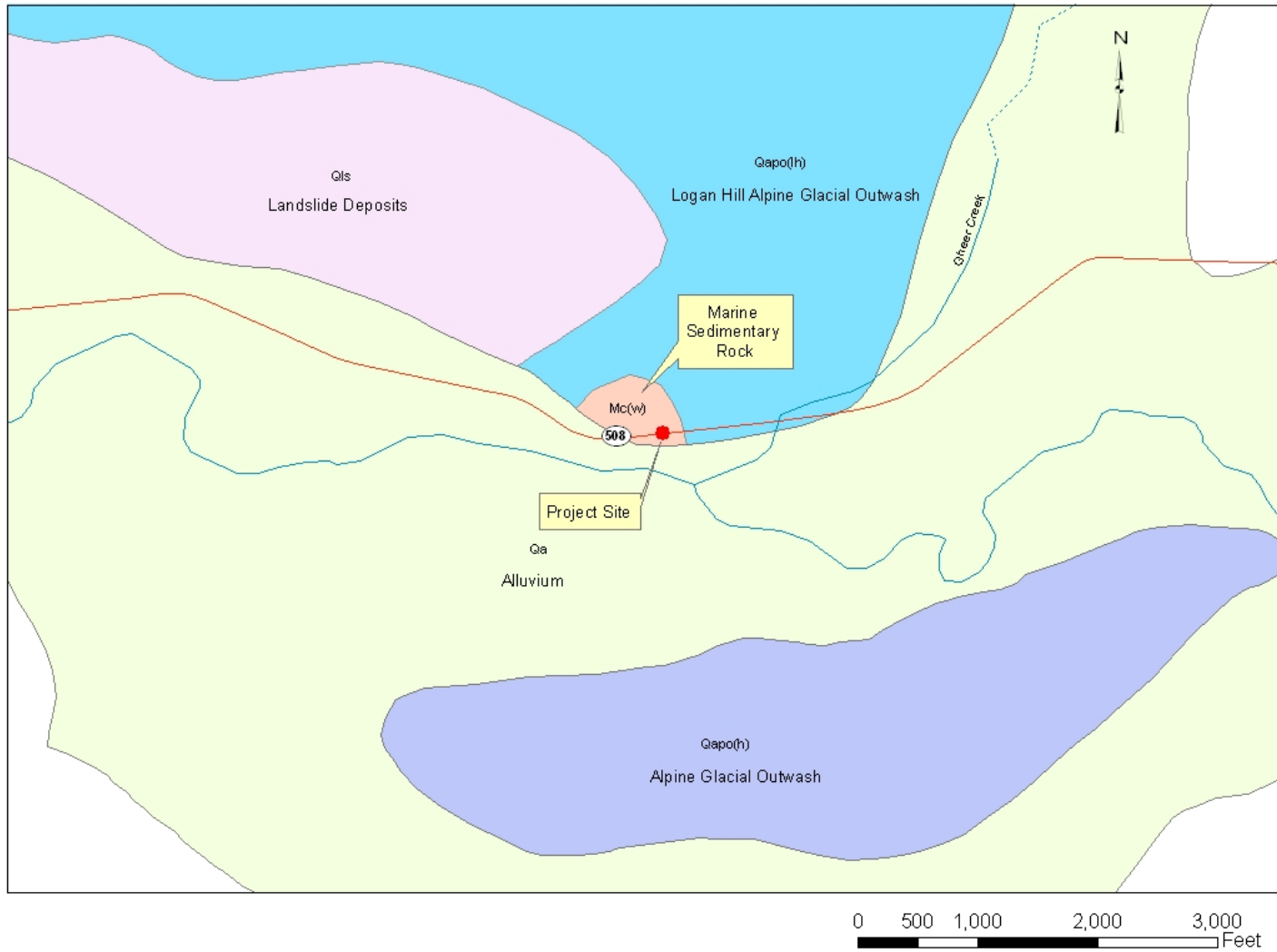


Figure 3. Surficial Geology near the Project Site

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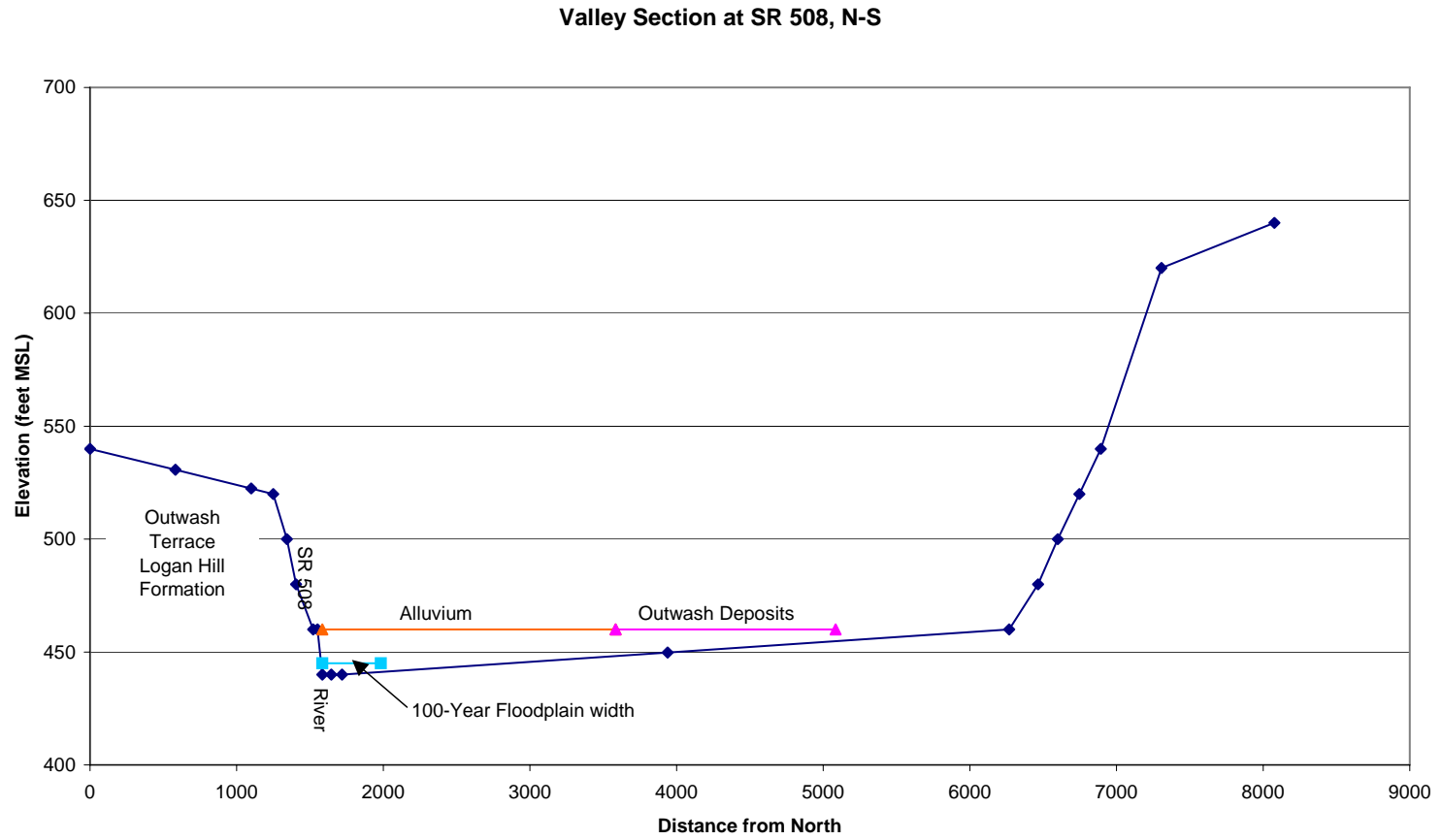


Figure 4. Cross Section of the South Fork Newaukum River Valley at the Project Site

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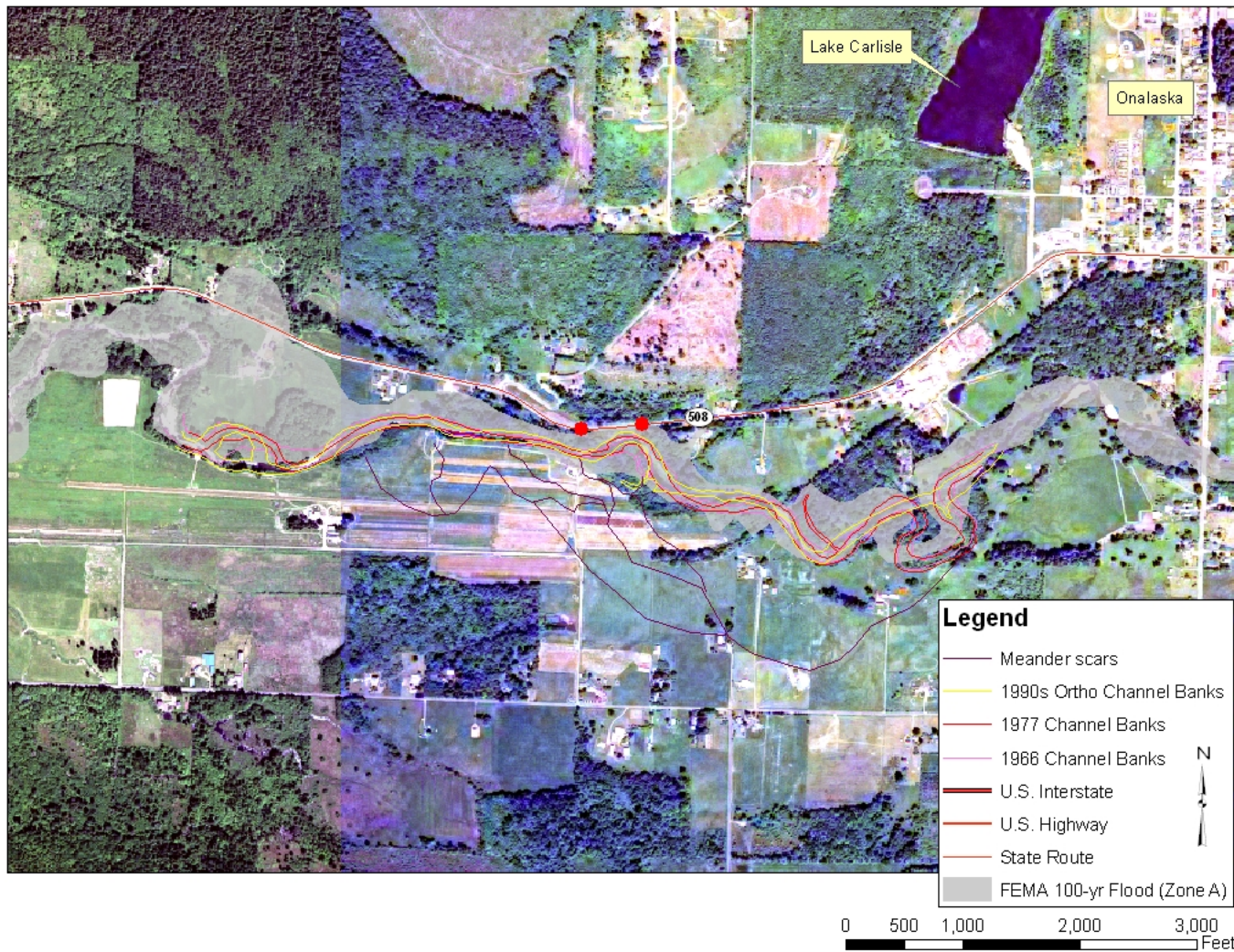


Figure 5. Channel Migration Patterns Observed in Historical Aerial Photographs

Reach Assessment for the South Fork Newaukum River at SR 508 Milepost 7.3

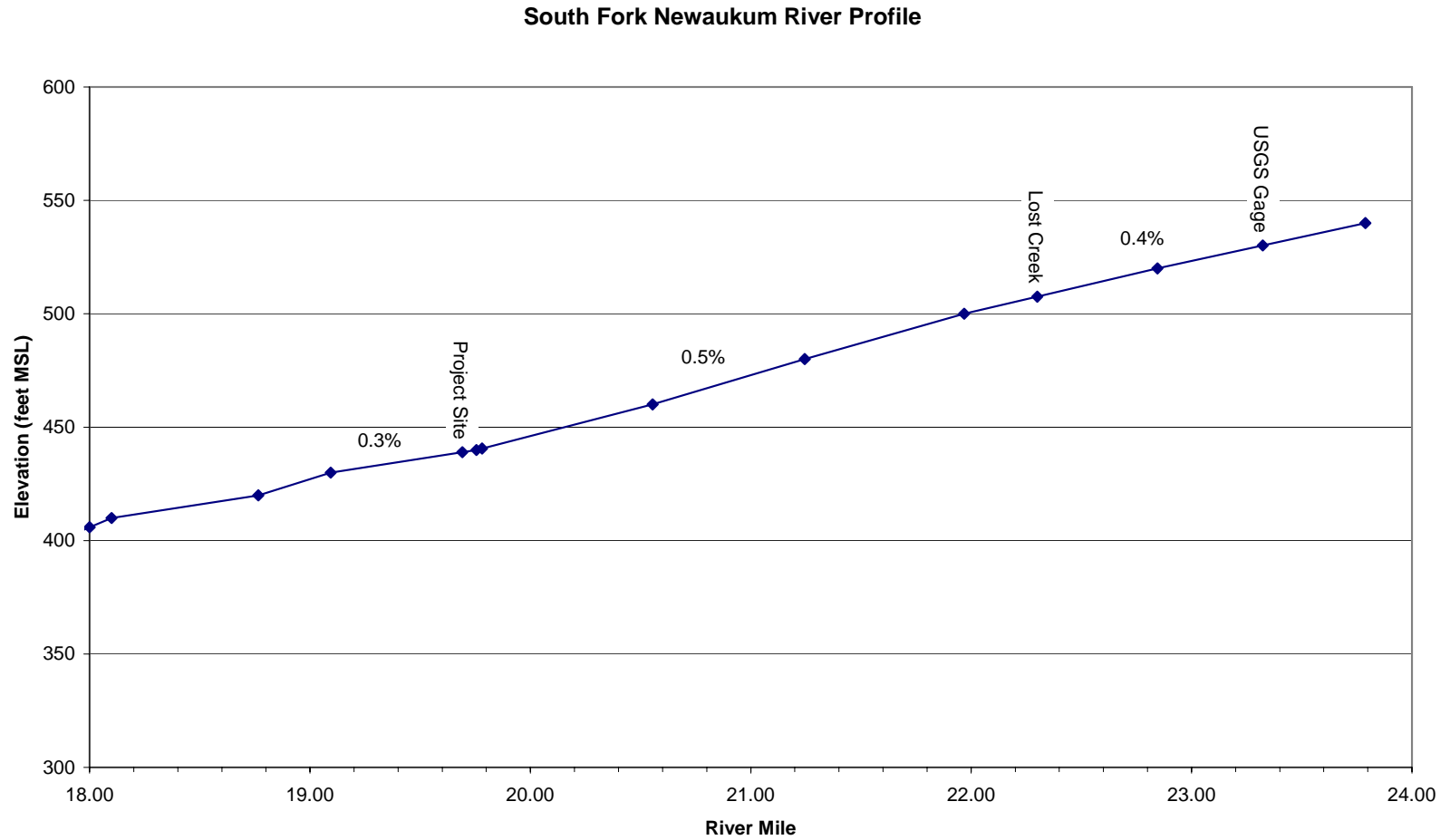
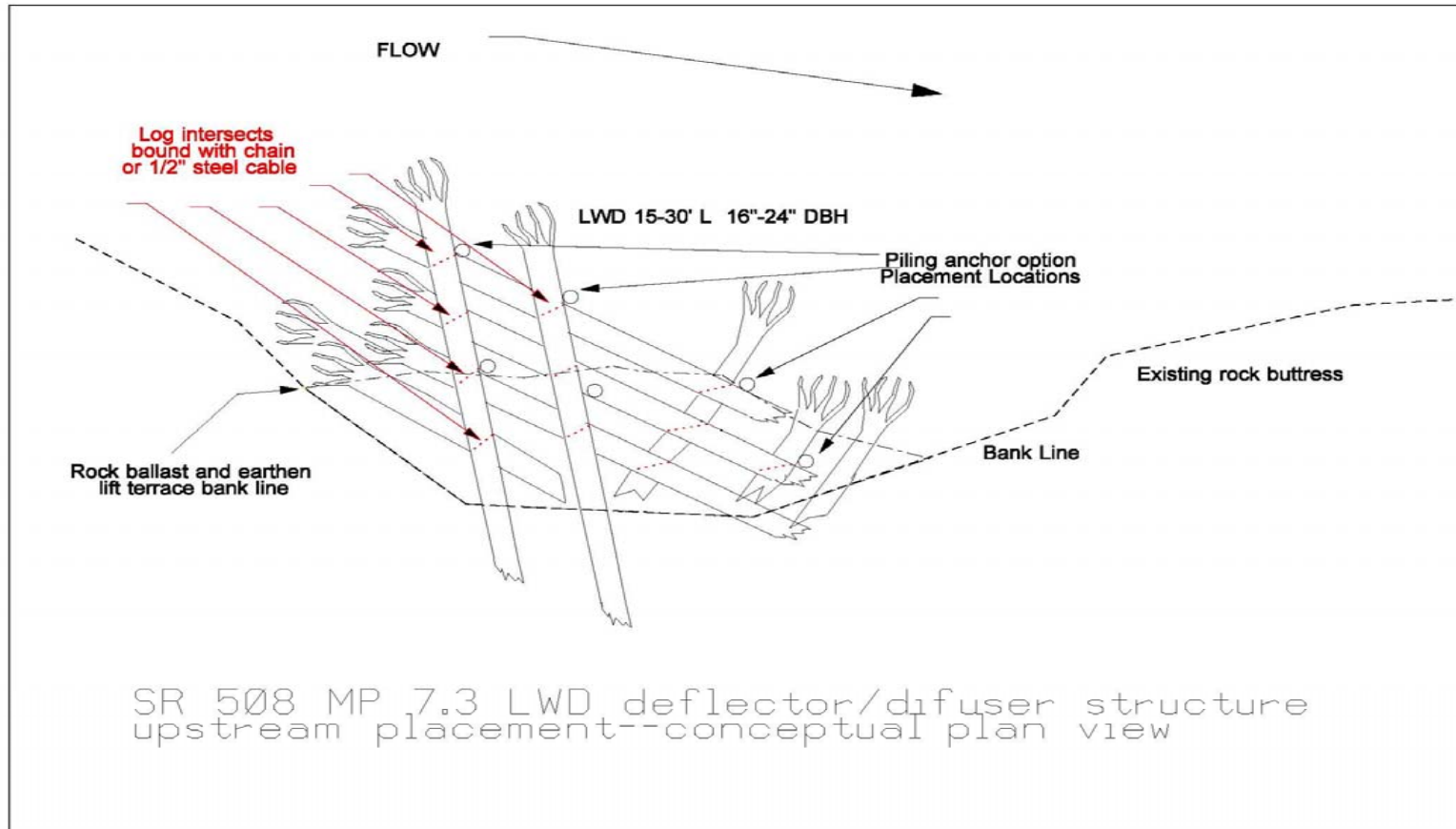


Figure 6. Profile of the South Fork Newaukum River Bed in the Project Reach

Reach Assessment for the South Fork Newaukum River at SR 508 Milepost 7.3



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Figure 7. Log Structures to Address Bank Erosion and Habitat Impacts

Reach Assessment for the South Fork Newaukum River at SR 508 Milepost 7.3

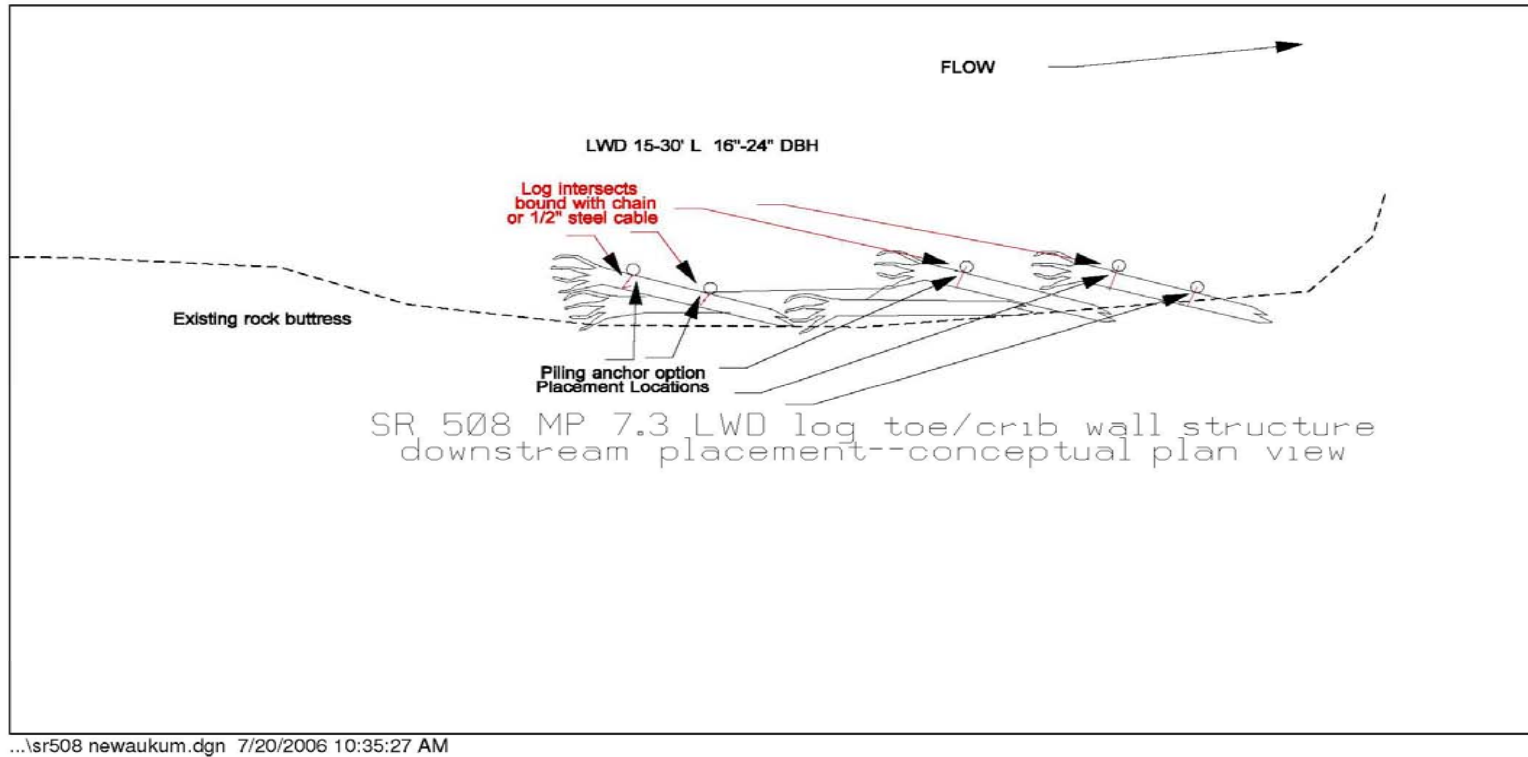


Figure 8. Log Structures to Address Bank Erosion and Habitat Impacts