

**Site and Reach Assessment  
Evaluation of Treatment Alternatives**

**SR 530/Sauk River Chronic Environmental Deficiency Site**



**Kevin Lautz, P.E.  
Hydrologist**

**Robert W. Schanz, P.E.  
Hydrologist**

**James D. Park  
Hydrologist**

**Watershed Management Program**

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

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## INTRODUCTION

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The Washington State Department of Transportation (WSDOT) established the Chronic Environmental Deficiency (CED) program as a strategy to provide for highway improvements to specific locations where repeated maintenance and preservation activities create unacceptable environmental impacts. Projects identified as chronic environmental deficiency problems are prioritized using an environmental retrofit index, which gives special weight to protection of fish habitat (WSDOT, 2002).

This report presents a Preliminary Site and Reach Assessment conducted for a Chronic Environmental Deficiency (CED) site located along the right bank of the Sauk River on SR 530 between Darrington and Rockport. This Site and Reach Assessment is prepared as per Chapters 2-5 of the Integrated Streambank Protection Guidelines (ISPG), and to present technical design recommendations. 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 similar to the Level 1 geomorphic assessment described in Hydraulic Engineering Circular (HEC) 20 (Federal Highway Administration, 1995), and includes a much more in depth consideration of aquatic habitat impacts (chapter 4). This report includes both site and reach assessments with a focus on geomorphic and habitat implications.

It is important to understand that ISPG is primarily a tool for problem identification, and provides screening matrices to help select the most suitable stream bank protection techniques. 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 has no regulatory authority over projects, but rather provides guidelines for project implementation. It is utilized here as a structure for the presentation of supporting environmental documentation pertaining to the proposed project. ISPG concepts that are applicable to the project objectives are incorporated here. It is anticipated that the outcome of this approach will result in a project proposal that meets the necessary requirements to protect the bridge and public safety, provides environmental enhancements to this reach of the river, and is likely to gain approval from regulating agencies.

*Note:* This preliminary Site and Reach Assessment is a precursor to a full Site and Reach Assessment, and any conclusions and recommendations contained herein should be considered preliminary and subject to revision pending completion of a full Site and Reach Assessment.

## **METHODS**

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This Site and Reach Assessment included a review of relevant aerial photos, ground photos taken at the site, topographic maps, geology maps and reports, fish distribution data, and hydrologic data. Sources of information include:

- aerial photos taken in 1989, 1994, 1998, and 2003;
- ground photos taken immediately after bank damage occurred in November 2003, and during our site visit in April 2004.
- 24K USGS topographic maps (Rockport and Darrington quadrangles, 1979) of the area;
- a geologic map and accompanying report for this area (Tabor et al. 2002)
- peak flow information available on-line from USGS ([www.usgs.gov](http://www.usgs.gov))
- fish distribution information available from the Washington Department of Fish and Wildlife fish distribution database;

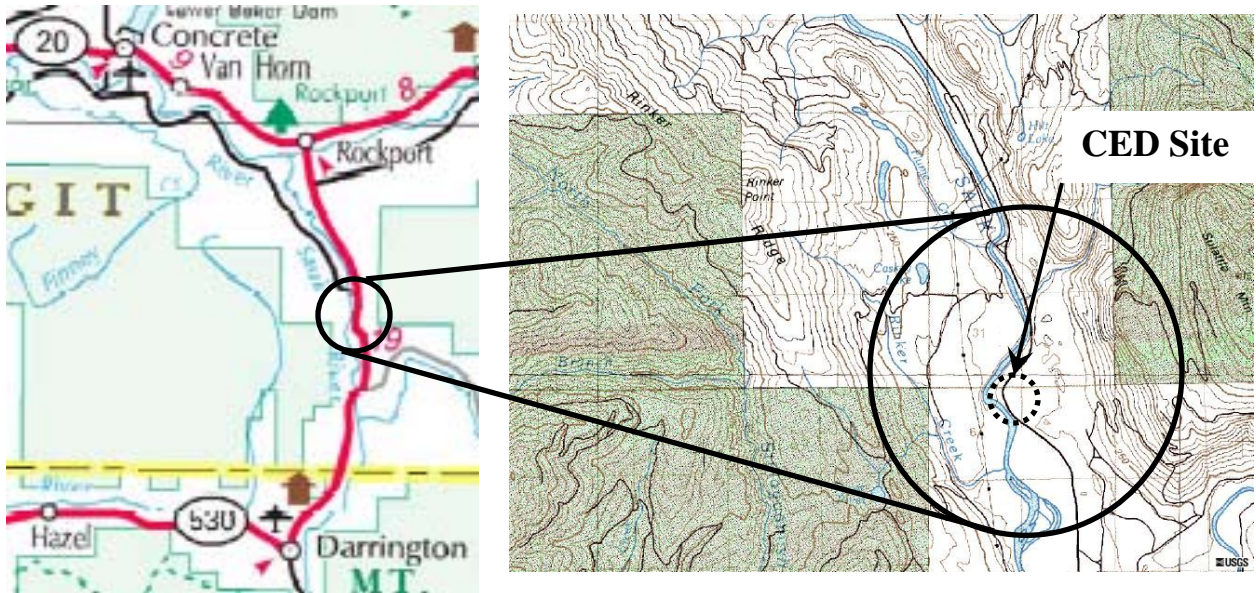
A site visit was conducted to visually evaluate current geomorphic and hydrologic conditions. This evaluation was conducted from the top of the right bank, adjacent to the paved portion of the roadway; access to the river and floodplain for more detailed evaluation was precluded by high winter flows. Geomorphic features were diagrammed and photographed for later office study. Background information on the site was provided by a regional maintenance coordinator (Mark Cornwall) who accompanied the analyst on the site visit.

## **PROBLEM DESCRIPTION**

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This CED site is located along the right bank of the Sauk River on SR 530 near MP 59.3, approximately eight miles south of the town of Rockport (Figure 1). The site has been subject to episodic streambank erosion since the early 1990's, attributable almost exclusively to its location relative to an actively migrating river. Two attempts at stabilization using "hard" (riprap) approaches have been attempted, most recently in November 2003 (Figure 2). While these attempts have been moderately successful at forestalling catastrophic failure of the roadway, there is concern by WSDOT regional staff that maintaining the roadway in its current alignment will require substantial amounts of additional stabilization work, with no guarantee that roadway failure will not occur. In addition, the presence of Endangered Species Act-listed fish and the location of the site in a Wild and Scenic River corridor indicate that permitting for additional hard and/or in-channel stabilization may be difficult, if not impossible, under all but emergency conditions.

**Figure 1.** Location of chronic environmental deficiency site.



**Figure 2.** Installation of riprap at SR 530 CED site (November 2003).



## **SITE ASSESSMENT**

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This CED site is approximately 300 feet in length and consists of the SR 530 roadway and a hardened (riprapped) embankment which extends at a 1:1 slope to the Sauk River approximately 20 ft below the roadbed elevation (Figure 3). Before the fall of 1993 the top of the river bank was 50 feet from the road at the upstream end of the site, and 110 feet from the road at the downstream end. In October 2003 an early season flood eroded the bank to a near-vertical bluff extending to within one to three feet of the paved portion of the roadway (Figure 4).

This portion of SR 530 is constructed on an alluvial terrace that is currently exposed along the outer bend of a river meander. The current embankment hardening was constructed at two different times; the upstream half was constructed in the early 1990's in response to channel changes that occurred during the November, 1990 third-highest flood-of-record, and the downstream half in response to channel changes that occurred during the October, 2003 flood-of-record.

The primary site-based mechanism of bank/roadway failure is most likely toe erosion caused by impinging flows occurring during last fall's peak flow event (see the Reach Assessment for more detail). The location of the site along the outside of the meander bend and smoothing of the channel by the original riprap installed immediately upstream are also likely to be contributing factors.

A shift in the channel alignment induced by last fall's event has caused the main thread of the river to impinge on the bank at a 45° angle of attack (the previous channel alignment had been nearly parallel to the bank) along the outside of a meander bend (Figure 5). This particular configuration guarantees that the largest erosional forces (shear stress and fluid momentum) in this reach will be exerted on the site. Two potential adverse outcomes for the streambank and roadway prism may be foreseen:

- (1) Impinging flow will tend to spiral downward and in a downstream direction after it contacts the bank, forming a scour hole and possible undercutting of the bank. Visual evidence of scour hole formation (flow deceleration, "boiling" from upwelling currents) was seen at the time of the site visit, but no estimation of the depth of the hole could be made because of turbidity.
- (2) The inability of the flow energy to dissipate along the bend because of the lack of roughness and deformability of the hardened bank will tend to cause the erosional forces to propagate immediately downstream, with the potential for an increase in bank erosion at the downstream transition from riprap to unarmored bank.

It is not possible to determine, with the available information, what flow magnitude is necessary to cause either of the adverse outcomes described above; consequently, it is not possible to accurately determine the risk of these outcomes occurring in the future. It should be noted that the two damage-causing events in this location were the first- and third-highest flood events of record for this river, with exceedance probabilities on the order of one to two percent in any year.

**Figure 3.** SR 530 CED site looking downstream.



**Figure 4.** Streambank damage at SR 530 CED site (date of photos 11/19/2003).



## REACH ASSESSMENT

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### *Definition of Project Reach*

The project reach for geomorphic analysis (Figure 5) extends from the confluence of Rinker Creek and the Sauk River at approximately RM 10, downstream to the next meander bend below the project site (approx. RM 9). This reach encompasses approximately one meander cycle.

### *Hydrology/Watershed Conditions*

The analysis site is located on the Sauk River nine miles upstream of its confluence with the Skagit River. The Sauk basin includes the Suiattle and Whitechuck Rivers, and drains the western slopes of Glacier Peak. The Suiattle River enters the Sauk about four miles upstream of the project site. The Sauk basin is steep and mountainous, with heavy rainfall and an extensive winter snowpack (Figure 6). Several glaciers on the west slope of Glacier Peak flow into Sauk River tributaries. No major regulations or diversions exist in the basin.

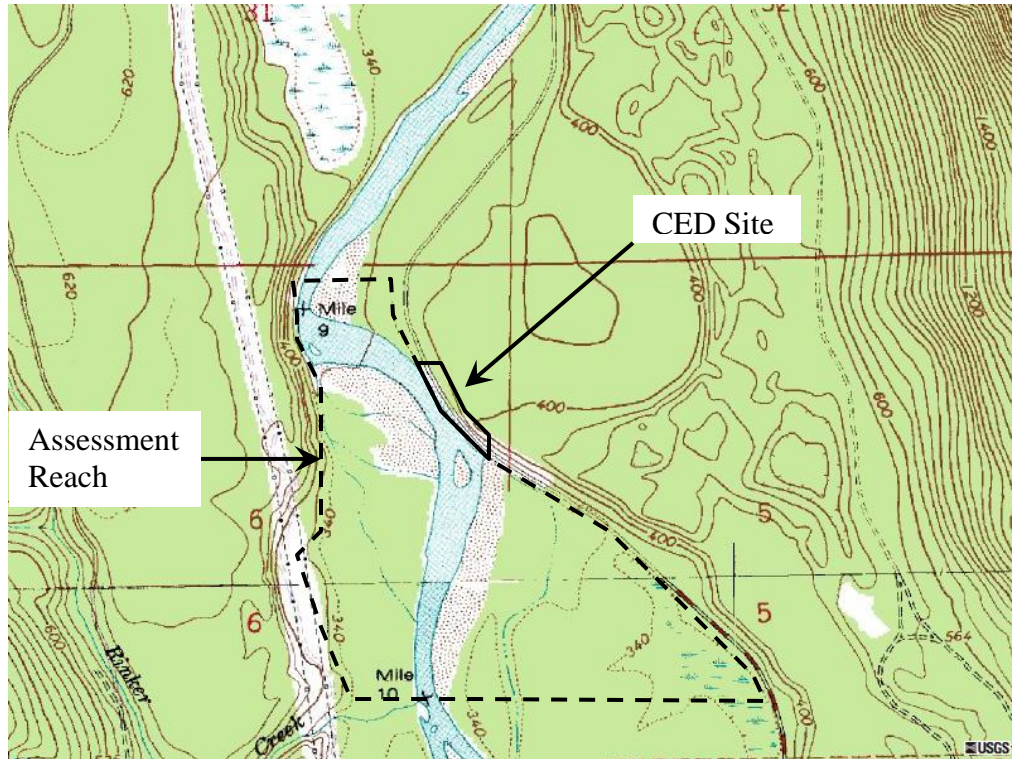
Land cover is primarily forest, with significant (about 15%) amounts of glacial/alpine open areas. Much of the upper watershed is classified as wilderness area, but most of the lower watershed has been harvested at least once. There is a small amount of residential development, mostly in and around the town of Darrington, as well as in sporadic patches along the river between Darrington and Rockport.

The US Geological Survey operates a stream gage four miles downstream of the site (Sauk River near Sauk, WA – USGS ID 12189500), with a drainage area of 714 square miles and a flow record extending back to 1928. The mean annual flow at the gage is about 4300 cfs. The highest mean monthly flows are in the snowmelt season, with nearly 8000 cfs in June. Floods are usually generated by heavy rainfall and rain-on-snow events in November and December. Over the last 70 years, all flows above 50,000 cfs occurred between October and February. During low rainfall years the annual peak flow may occur during spring snowmelt; in these years, the annual peak flow will generally be less than 20,000 cfs. Table 1 provides flood frequency statistics for this gage (WSDOT, 1997).

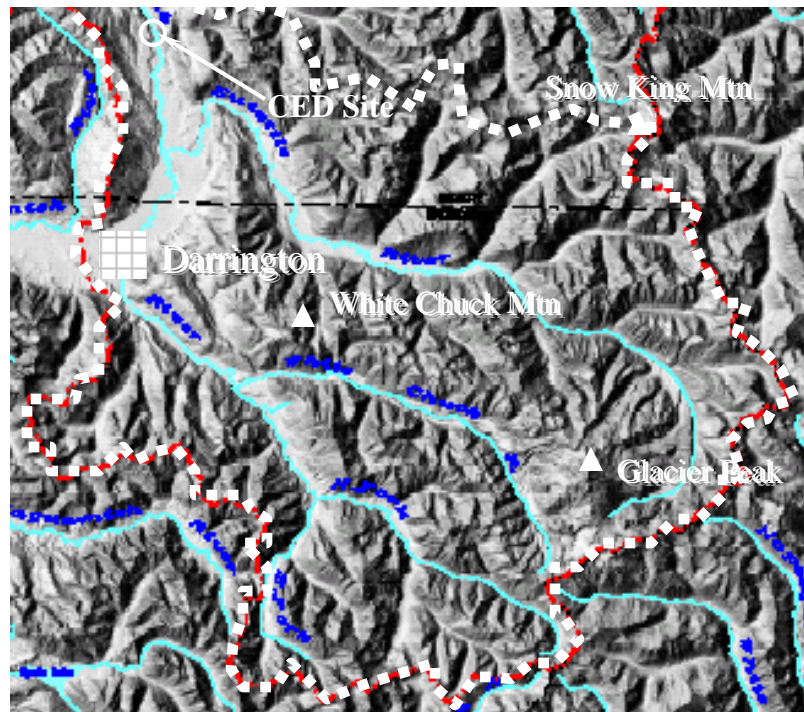
**Table 1.** Flood frequency statistics for USGS Gage 12189500 (Sauk River near Sauk, WA).

<b>Recurrence Interval (years)</b>	<b>Annual Exceedance Probability</b>	<b>Peak Flow (cfs)</b>
2	50%	30,100
10	10%	57,700
25	4%	73,700
50	2%	86,500
100	1%	100,000

**Figure 5.** SR 530 CED assessment reach.



**Figure 6.** Sauk River Watershed above CED site.



The highest flow on record (112,000 cfs) occurred during an unusually heavy rainstorm on October 20, 2003 (USGS, 2003). Prior to that, the largest recorded flow was 98,600 cfs in December 1981.

The Skagit Watershed Council (2000) characterized the hydrologic condition of Sauk River sub-basins by analyzing road density and the extent of hydrologically immature vegetation. Most headwater basins were rated as “functioning with low risk of impairment”. The lower tributaries, including the project reach, were generally rated as either “likely impaired” or “functioning but sensitive to land use”.

### ***Geology/Geomorphology***

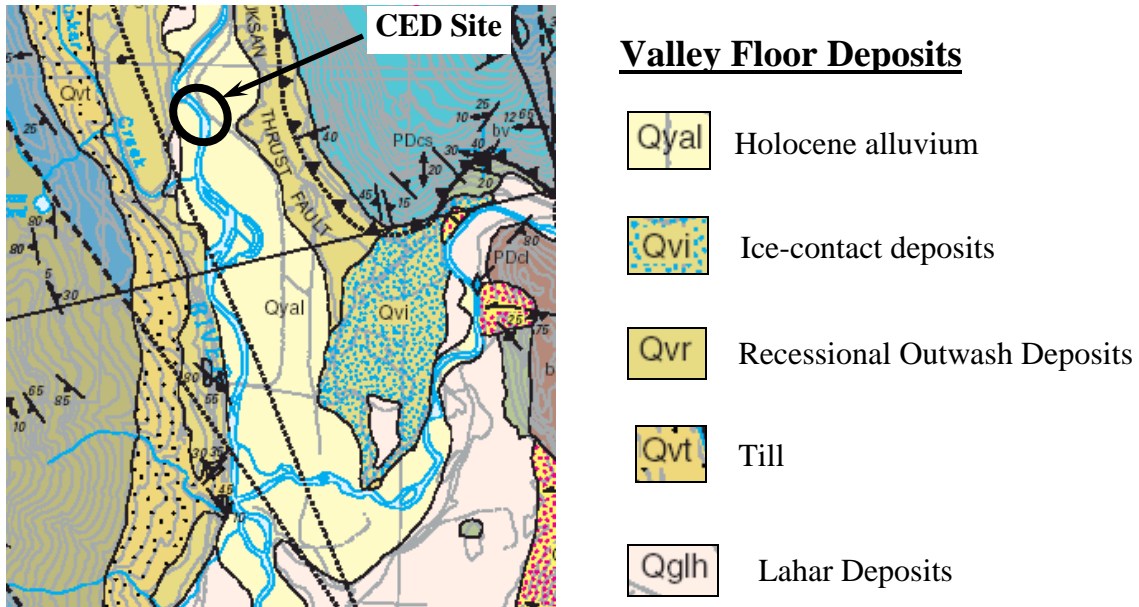
The Sauk River basin is made up of steep, mountainous terrain underlain by a complex mélange of metamorphic, marine sedimentary, and volcanic rocks. The valley floor for the Sauk River is comprised of recessional outwash deposits from the most recent continental glaciation, and lahar (mudflow) deposits from past eruptions of Glacier Peak; these deposits occur as high terraces, or have been reworked since the last glaciation into the alluvium which constitutes the lower terraces and active floodplain (Figure 7). Lateral migration of the channel has exposed terrace deposits immediately above and below the site to form “feeder” bluffs 40 to 60 feet high; these are capable of contributing large quantities of sediment to the river as they are eroded. Erosion of one such bluff on the left bank just upstream of the site caused the loss of a Seattle City Light power line tower during the 1990 event, and may put one or more an additional towers at risk unless measures are taken soon to stabilize the bluff or shore up the tower foundation.

The assessment reach is located in a transition zone between an unconfined (floodplain width = 4000-6000 feet) depositional reach near the Suiattle River confluence and a steeper, moderately confined (floodplain width = 1000 feet) segment of river downstream. Within the assessment reach, the valley narrows and terraces confine the floodplain to between 1400 and 1800 feet wide.

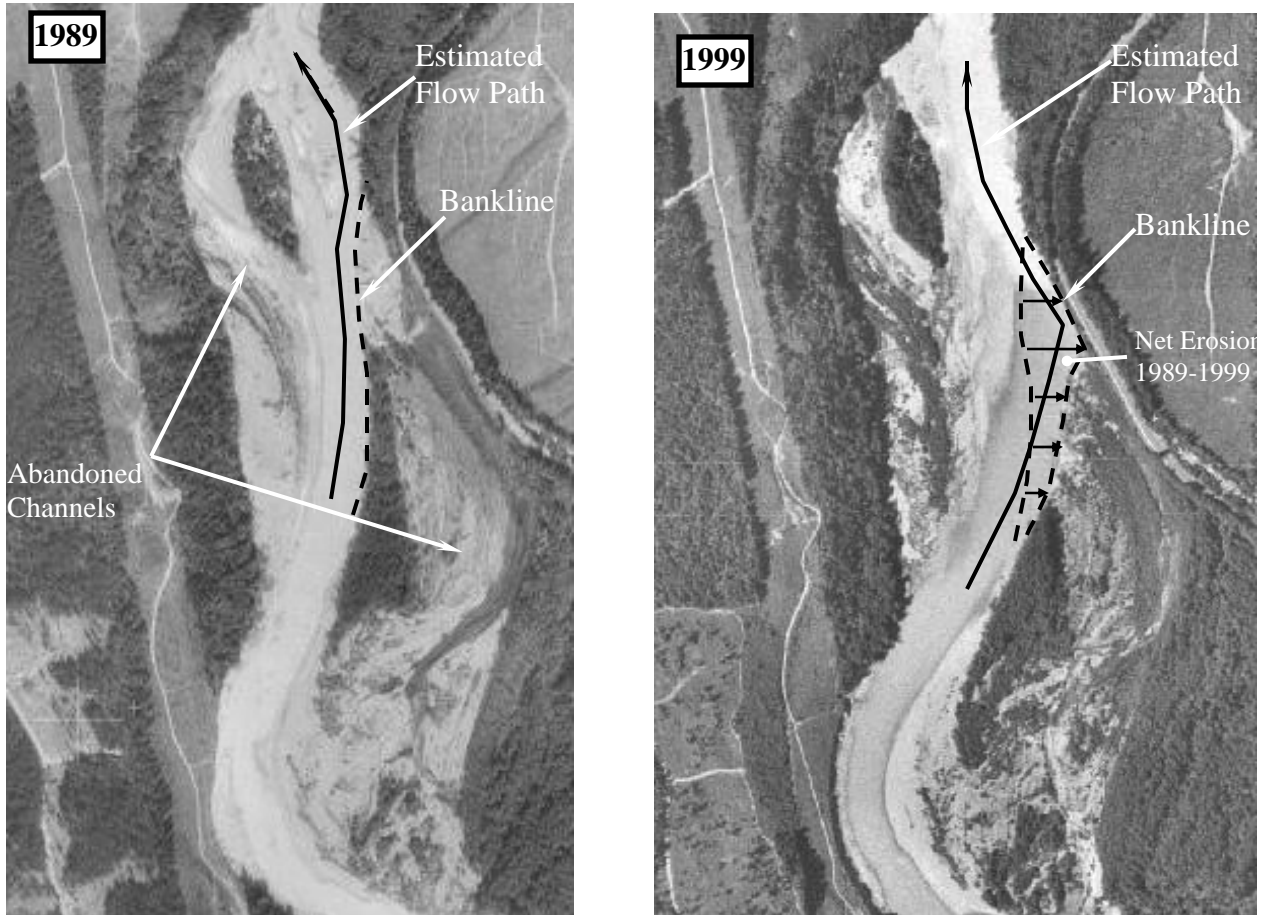
At the Suiattle River, the river gradient is about 10 feet per mile, and sediment input from the Suiattle exceeds the Sauk’s transport capacity. This creates a complex network of braided and anastomosed channels upstream of the Suiattle confluence. Below the Suiattle confluence, the river channel network begins to simplify into one major channel with occasional flow splits around sandbars and islands. The river steepens to a gradient of 18 feet per mile within the project reach. Sediment supply is naturally high due to erosion of alluvial and glacial deposits by the actively migrating channels upstream.

Abandoned channels exist on either side of the river both immediately above and below the site (Figure 8), and the relatively young age of riparian vegetation within and along the margins of these channels indicate that abandonment was recent. This avulsion is confirmed by the most recent 1:24K USGS topographic map (Rockport quadrangle, 1979), which shows the main thread of the channel occupying the alignment of the current relic channels in the vicinity of the CED site. A review of aerial photos since 1989 indicate a lateral advance in the outer meander bend toward the CED site. In addition, the channel planform has shifted such that main thread of

**Figure 7.** Valley floor geology in the vicinity of the SR 530 CED site.



**Figure 8.** Aerial view of assessment site and reach showing channel changes and abandoned channels.



the channel, which previously had run nearly parallel to the project site, is now impinging more directly on the site (angle of attack approximately 45°). Several wide, shallow lateral bars were observed in the assessment reach immediately above the CED site; these, along with the aforementioned evidence of recent avulsion and lateral migration of the main channel, suggest a moderate degree of horizontal and vertical instability within this reach. Relative to its geomorphic setting within the watershed (high sediment supply, low gradient, moderate confinement), the assessment reach is tending toward equilibrium. However, the reach immediately upstream of the site is a depositional zone subject to rapid channel changes and avulsions into abandoned channels during high flow events. These avulsions can change the angle at which the river impinges on the CED site, and increase the risk of future bank erosion. The observed lateral migration and potential for avulsion during large peak flow events are considered to be reach-based mechanisms for bank failure at the CED site.

### ***Riparian Condition***

Riparian forests in and near the assessment reach reflect the occurrence of regular disturbance typically found in geomorphically active floodplains. Stands are dominated by alder of various ages, with younger trees occurring near the apex of point bars and along the margins of relic channels, and older trees found on islands and along portions of the floodplain not recently accessed by the river. A substantial portion of the floodplain has been denuded by last fall's large flow events.

### ***Large Woody Debris***

Almost no in-channel large woody debris (LWD) was observed near the project site; if any significant quantities existed, they were likely flushed out by last fall's large flow event. Several rafts of LWD were observed on point bars and are not available to provide aquatic habitat. Recruitment potential from the floodplain within the reach is low, due to the lack of mature conifers considered to provide functional LWD. Some recruitment from "feeder" bluffs (exposed terraces) may provide some functional wood in the near future if enough erosion of these bluffs occurs.

### ***Fish Utilization and Habitat Availability***

The assessment reach is utilized by seven species of salmonids (Table 2). Other fish species found include sculpins (*Cottus* spp.), largescale sucker (*Catostomus macrocheilus*), and mountain whitefish (*Prosopium williamsoni*).

Habitat is available for spawning and rearing in the assessment reach. Pool tailouts were observed in several locations, though no redds could be seen from the observation point along the roadway. The observed evidence of vertical and horizontal channel instability noted above (see Geology/Geomorphology) may reduce the quality of spawning habitat for mainstem spawners due to the propensity for redd scour. One side channel located immediately above the CED site has been identified as a high quality spawning area for chum salmon (Mark Cornwall, pers. comm.), probably due to the presence of hyporheic upwelling. This and other side channels form potentially high quality rearing habitat for coho and steelhead juveniles during the winter

and spring while they remain “watered up”. A scour hole forming at the base of the project site may provide good holding habitat for steelhead, spring chinook, and bull trout adults provided there is sufficient depth and an influx of cover (e.g. LWD).

**Table 2.** Salmonid utilization and Endangered Species Act status for the Sauk River.

<b>Species/Run</b>	<b>Utilization</b>	<b>ESA Status</b>
Spring Chinook ( <i>Onchorhynchus tshawytscha</i> )	Spawning	Threatened
Summer Chinook	Rearing	Threatened
Coho ( <i>O. kisutch</i> )	Rearing	Candidate
Chum ( <i>O. keta</i> )	Spawning	N/A
Pink ( <i>O. gorbuscha</i> )	Spawning	N/A
Sockeye ( <i>O. nerka</i> )	Rearing	N/A
Bull Trout/Dolly Varden ( <i>Salvelinus confluentis</i> )	Rearing	Threatened
Summer Steelhead ( <i>O. mykiss</i> )	Spawning	Not warranted
Winter Steelhead		
Rainbow Trout (resident)		

## EVALUATION OF TREATMENT ALTERNATIVES

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Objectives (i.e. desired outcomes) for redressing the chronic environmental deficiencies and associated site- and reach-based causal mechanisms identified for this site include:

- preserve SR 530 as the primary route between Rockport and Darrington by minimizing the risk of catastrophic loss of this section of roadway;
- minimize the need for corrective maintenance of the streambank on an ongoing basis;
- maintain or improve aquatic and riparian habitats that occur or would be expected to occur in and around the site.

Treatment alternatives that may meet the above objectives at this site are described as follows:

**(1) No action.** This alternative presumes that the hardened bank as designed and installed is sufficient to resist erosional shear and fluid momentum forces at flows up to an acceptable risk level. Even if the bank were shown to be adequate, there is some likelihood that erosion would continue immediately downstream of the site, as the lack of roughness and deformability of the hardened bank will tend to cause the erosional forces to propagate downstream.

Maintenance of the smooth, hardened bank will locally reduce channel roughness and arrest lateral channel migration. This will, in turn potentially reduce holding habitat for fish and large woody debris retention and recruitment. Mitigation may be required if this alternative is selected as a long-term solution.

No information regarding design or installation of the hardened bank was provided for this assessment. Further field assessment (floodplain cross sections, streambed characterization) and modeling will be required to allow evaluation of the adequacy of the bank and the propensity for erosion downstream.

**(2) Install flow-directional and/or structural bank treatments.** Installation of appropriate bank protection treatments can mitigate the adverse effects of the hardened bank by providing roughness and diverting flow and erosive force away from the bank.

Selection matrices from the Integrated Streambank Protection Manual were used to identify appropriate treatments for the site-based and reach-based failure mechanisms described earlier in this report. For toe erosion caused by reduced vegetative structure, a smoothed channel, and erosion along a meander bend, ISPG (Matrix 2) rates spur dikes (groins), engineered logjams, and roughness trees as “good” for this condition, a roughened rock toe was rated “good in combination with techniques rated ‘good’”, and buried spur dikes are rated “fair”. Removal or reduction of the gravel bar is also identified as a component of a potential solution (Matrix 1). Evaluation of individual treatments is as follows:

(a) **Spur dikes (groins) and barbs.** These linear structures are designed to add roughness and deflect flow toward the center of the channel. Constructed of rock and/or large wood, they extend from and are keyed into the existing streambank. Spur dikes differ from barbs in that they have a higher profile and consequently have a greater local effect on the channel.

By breaking up secondary flow cells (spiraling flow), spur dikes and barbs can greatly reduce shear stresses and scour potential on the streambank. Scour holes are formed at the tip of each structure, while sediment deposition zones develop between structures. Over time, the scour holes may coalesce to deflect the thalweg towards the point bar on the opposite bank and deepen the center portion of the channel. Conversely, a deposition zone (medial bar) may be created immediately below the last (most downstream) structure; diversion of flow around this feature may increase bank shear, leading to toe erosion of downstream banks.

The ability of spur dikes and barbs to deflect flow depends greatly on the angle of attack. Major channel changes and avulsions will alter the angle at which the river approaches these structures, and could impair their ability to deflect flows away from the bank.

Spur dikes and barbs have both positive and negative effects on aquatic habitat. Cover is provided by surface turbulence created by the structure, as well as by any large wood that is built into or trapped by the structure. Quiescent water between structures may provide resting and feeding areas for juvenile fish. Sediment deposition between structures may extend the bankline further into the channel, and allow revegetation, further strengthening the bank. However, local degradation of the channel caused by flow concentration toward the center of the channel may result in loss of redds constructed in that portion of the river.

Applicability of these types of structures may be questionable for this site if regulatory constraints preclude construction outside the “footprint” of the original bankline. Structures will probably need to extend both upstream and downstream from the site to be effective, especially if toe erosion downstream is to be avoided. Further field assessment and hydraulic analysis will be required to determine feasibility and for design.

(b) **Buried groins.** These structures are similar to spur dikes, except they are constructed some distance behind the existing bankline. These structures are designed to arrest further erosion of the streambank after some lateral migration is allowed to occur.

Once exposed, buried groins perform the same and have the same benefits and drawbacks as regular groins, while allowing for normal channel function (e.g. lateral migration, large wood recruitment) prior to exposure.

Installation of buried groins is not appropriate for this site if the intent is to maintain the current roadway alignment. They may be considered in the event that the road is set back from the channel (see Alternative 3).

- (c) ***Roughened Rock Toe.*** This structure consists of suitably sized angular rock placed between the estimated depth of scour and the estimated lower limit of woody vegetation. Rock toes are designed to maintain hydraulic roughness by virtue of an irregular bankline and “loose” placement of angular rock. Integration of large woody debris pieces may also be used to increase roughness and channel complexity. These structures are often used (and are most effective) in combination with other treatments, including bank reshaping, anchor points, and soil reinforcement.

Properly designed and installed rock toes are effective in arresting bank erosion and lateral channel migration. While rock toes do provide increased roughness over standard riprap, there is still potential for propagation of erosive forces downstream, increasing the potential for erosion of unarmored banks. Depending upon the degree of projection into the channel, rock toes may cause deepening of the thalweg near the structure.

Rock toes have both positive and negative effects on aquatic habitat. Cover is provided by interstices created by the “loose” placement, as well as by any large wood that is built into or trapped by the structure. Integration of vegetation treatments will allow for development of root reinforcement and bank roughness, further strengthening the bank. However, rock toes also eliminate the treated bank as a source of sediment and large woody debris, and local degradation of the channel caused by flow concentration may result in loss of redds constructed in that portion of the river.

Applicability of these types of structures may be questionable for this site if regulatory constraints preclude construction outside the “footprint” of the original bankline. This structure will probably need to extend both upstream and downstream from the site to be effective, especially if toe erosion downstream is to be avoided. Further field assessment and hydraulic analysis will be required to determine feasibility and for design.

- (d) ***Engineered Log Jams.*** These structures are constructed in series along the toe of the hardened bank. They function in a similar manner to spur dikes and barbs, diverting flow and erosional forces toward the center of the channel and creating deposition zones between structures. Habitat benefits and drawbacks are also similar the those of spur dikes and barbs, except that engineered log jams tend to attract more juvenile fish owing to their greater complexity and amount of interstitial space. Engineered logjams also add greater roughness to the channel bank, and are less vulnerable to channel changes that alter the angle at which the river approaches the structure.

Applicability this type of structure may be questionable for this site if regulatory constraints preclude construction outside the “footprint” of the original bankline.

Structures will probably need to extend both upstream and downstream from the site to be effective, especially if toe erosion downstream is to be avoided. Further field assessment and hydraulic analysis will be required to determine feasibility and for design.

- (e) ***Roughness trees.*** Roughness trees consist of whole trees placed with rootwads facing upstream along the toe of the bank. They can be cabled, interlocked, or anchored with rock or pilings. The branches, trunk, and rootwad add roughness to the channel, reducing shear stresses and increasing the bank's ability to resist erosion. Reduced flow velocity between structures creates sediment deposition zones that may subsequently become revegetated, further stabilizing the streambank.

Roughness trees, when properly installed in appropriate locations, have few adverse impacts to aquatic habitat. Beneficial impacts include increased cover and improved riparian function where revegetation of banklines occurs.

Application of this technique is not recommended for this site. Trees (with rootwads) of a large enough size to function individually in this large, high energy system are prohibitively expensive to obtain and install; in addition, keying these trees into an existing hardened bank having 2000-5000 lb. rock may also be problematic and expensive.

- (f) ***Gravel bar removal/reduction.*** This technique involves removal of all or a portion of the point bar opposite the affected streambank in an attempt to encourage the channel to retreat from the streambank.

Adverse impacts to habitat include removal of or damage to potential spawning and riparian areas. If removal or reduction is substantial, there may be unintentional and unpredictable geomorphic consequences upstream of downstream of the site.

This technique is not likely to be effective due to the site's location (apex of a meander bend). Some incidental reduction in the extent of the point bar opposite the CED site may occur if one of the in-channel treatments described above is installed.

- (3) ***Relocate the roadway.*** Relocation of the roadway away from the migrating channel would greatly reduce or eliminate the risk of catastrophic roadway failure associated with bank erosion at this site, reduce or eliminate the need for corrective ongoing maintenance of the streambank in or near the CED site, and provide opportunities for improvement of aquatic habitat. The alluvial terrace underlying the current roadway extends to the valley wall nearly one-half mile away from the current roadway location, providing ample room for an alternative alignment. Relocation also allows for replacing the hardened streambank with more ecologically functional streambank protection techniques including bank reshaping, buried groins, and roughness trees.

## CONCLUSIONS

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The existing hardened streambank and additional bank hardening immediately upstream were installed in response to erosion caused by two of the three highest flood events of record for the Sauk River. The primary site-based mechanism for bank failure identified by this assessment is most likely toe erosion by impinging flood flows; the location of the site along the outside of the meander bend and smoothing of the channel by the original riprap installed immediately upstream are also likely to be contributing site-based mechanisms. The observed lateral channel migration and potential for avulsion during large peak flow events are considered to be reach-based mechanisms for bank failure and are consistent with normal/natural channel dynamics occurring in this geomorphic setting.

Under most flow conditions, the failure risk for the existing hardened bank protection is low. However, during major flood events there may be some potential for undermining of the existing bank toe, and there will likely be propagation of erosive forces downstream, resulting in bank erosion at the downstream transition from hardened to unarmored bank. Installation and maintenance of the hardened streambank in its current condition will locally reduce channel roughness and arrest lateral channel migration, potentially reducing holding habitat for fish and large woody debris retention and recruitment. Mitigation may be required if this alternative is selected as a long-term solution.

Supplemental bank treatments may mitigate for the existing streambank and prevent downstream erosion. Site treatments considered appropriate for these general geomorphic settings mostly focus on adding roughness and complexity to the channel and include spur dikes/barbs, buried groins, roughened rock toes, engineered log jams, roughness trees, and gravel bar removal/reduction. Selection of an appropriate treatment or treatments will depend upon further hydraulic and geomorphic analysis, as well as any regulatory or cost constraints. Depending upon the treatment selected, additional mitigation may be required.

The presence of fish listed under the Endangered Species Act, as well as the designation of the Sauk as a “Wild and Scenic River” may limit or eliminate instream treatment options. In order to minimize impacts to aquatic habitat, instream structures should be kept as small as possible. In addition, given the potential for abrupt channel changes within the project reach, any instream structures should be designed to function over a range of flows and at different angles of flow impingement. Of the alternative treatments described above, small barbs or a roughened rock toe best fit these design considerations; however, none of the treatment alternatives will prevent downstream (unarmored) bank erosion if regulatory constraints preclude construction outside the “footprint” of the original bankline.

Relocation of the roadway away from the CED site offers the greatest potential for long-term reduction in risk to the roadway and cost for recurring maintenance, while offering the greatest opportunity to locally improve aquatic and riparian habitat. Suitable alternative alignments appear to be available on the alluvial terrace underlying the existing roadway. This alternative should be explored further because it would effectively be self-mitigating, as it would permit channel migration in the project reach and provide associated environmental benefits. If

relocation is selected as the long-term solution, then the need for interim measures to supplement and/or mitigate for the existing bank until relocation occurs should be assessed.

During the course of this assessment, the need for additional fieldwork and assessment was identified. This field work is of particular importance for formal design in the event that in-channel roughness features(as described above) are selected, Specific tasks include:

- (1) Field development of cross sections along the assessment reach;
- (2) Estimation of flow velocity, depth, scour, and shear stress along the face of the existing hardened bank to determine short- and long-term bank failure and scour risk, and to provide a basis for selecting one or more supplemental bank treatments;
- (3) Estimation of flow velocity, depth, and shear stress along the face of the unarmored bank downstream of the CED site to determine short- and long-term bank failure risk, and to provide a basis for selecting one or more bank treatments.

## REFERENCES

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- Federal Highway Administration. 1995. *Stream Stability at Highway Structures*. Report No. FHWA-IP-90-014 HEC 20. Office of Technology Applications, HTA-22. Washington DC.
- Skagit Watershed Council. 2000. *River Basin Analysis of the Skagit and Samish Basins; Tools for Salmon Habitat Restoration and Protection*.
- Tabor, R.W., D.B. Booth, J.A. Vance, and A.B. Ford. 2002. *Geologic Map of the Sauk River 30- by 60-Minute Quadrangle, Washington*. Geological Investigations Series I-2592. U.S. Geological Survey. Washington DC.
- USGS, 2003. *Realtime Flow Data for Washington State* (website - <http://waterdata.usgs.gov/wa/nwis/current?type=flow>). United States Geologic Survey. Washington DC.
- Washington State Aquatic Habitat Guidelines Program. 2003. *Integrated Streambank Protection Guidelines*. Olympia WA.
- WSDOT. 1997. *Hydraulics Manual*. Washington State Department of Transportation Hydraulics Branch.
- WSDOT. 2002. *Washington State Highway System Plan: 2003-2022*. Washington State Department of Transportation - Transportation Planning Office. Olympia WA.