Site and Reach Assessment Addendum
SR 530, Sauk River MP 58

Work Order XL2778

Jim Park

Senior Hydrologist

WSDOT Environmental Services

Watershed Management Program

October, 2007

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

Table of Contents

Figures

Summary

Report findings

- On November 8 and 9, 2006 the project area was subjected to a large flood event with a magnitude of 84,000 cubic feet per second (cfs) that represented a 30-year recurrence interval flood, and which resulted in significant geomorphic changes that have affected the project site and the project scope.
- Channel changes for the project reach were reexamined using existing and new aerial photography as well as LiDAR topographic data.
- The eastward migration of the Sauk River in the project reach for 2006 and 2007 was approximately 60 percent of the average channel width.
- The radius of this meander curve has increased from approximately 1530 feet to 1605 feet.
- Simultaneously the side channel network has been subjected to increasing over-bank flows associated with flood events.
- Comparison of the two watercourses indicates cause or concern regarding avul-sion risk.
- A chute cutoff avulsion of part or all of the mainstem flow at this location appears likely and may be imminent if the site is subjected to large flood events.

Report recommendations

- The HEC-RAS model for the bank protection structures should be modified by modeling larger mainstem flows through the side channel network.
- Budgetary concerns have led to consideration of reducing bank protection ele-ments of this project but given the increased risks detailed in this report, this should not be considered and in fact, the bank protection elements need to be rein-forced.
- The increasing risk of river avulsion has further exacerbated funding problems for this project and additional funds to deal with the increased risk to the highway may be required. HQ CED staff should work with the project staff to address the funding issue.

Introduction

This report presents supplemental information pertinent to the site and reach assessment for Sauk River SR 530, MP 58. A project to relocate and reinforce portions of SR 530 has been funded by the Washington State Legislature funded under the WSDOT Chronic Environmental Deficiencies Program. This project has an Ad date of January 5, 2009, and is scheduled for construction during the summer of 2009. On November 8 and 9, 2006, the project area was subjected to a large flood event. This event had a magnitude of 84,000 cfs and represented a 30-year recurrence interval flood. The flood event resulted in significant geomorphic changes that have affected the project site and in so doing affected the project scope. This report is intended to serve as a supplement to the SR 530 MP 58 Reach Assessment (Lautz, Schanz, and Park, 2004) that describes geomorphic changes that have taken place within the project reach since the original assessment was prepared.

Methodology

Channel changes for the project reach were reexamined using existing aerial photography as well as LiDAR topographic data. New aerial orthophotographs were obtained by WSDOT for the project reach in the spring of 2007. The channel configurations and metrics were then measures and evaluated for geomorphic change using GIS and LiDAR data. Flood hydrographs, substrate size estimates, and estimated shear calculations were also used to determine relative risk issues stemming form geomorphic changes occurring to both the mainstem and the floodplain terrace including the river's side channel networks. Present channel trends and configurations were then compared with the historical data to determine the extent of geomorphic change and the potential for those changes to affect the project area.

Reach Assessment Findings

Geomorphology

Examination of the 2007 aerial photographs indicates significant changes in both the mainstem and side channel network within the site reach. As Figure 1 shows, the active mainstem channel at the apex of the right bank meander immediately upstream of has migrated approximately 228 feet to the east. Channel width in the project reach range from 212 feet to 489 feet with an average active channel width of approximately 380 feet. Thus the eastward migration of the Sauk River in the project reach for the 2006 to 2007 period was approximately 60 percent of the average channel width.

The channel within the project area has a tortuosity (meander curve radius/upstream channel top width) of approximately 2.7 as determined from aerial photos. When tortuosity ratios are three or less, the primary components of longitudinal velocity impact the outer river bank at a very abrupt angle, resulting in significant cross-stream flow. The resulting momentum transfer of the fluid mass directly into the streambank and the work that the bank performs in turning the flow (in this case from due east to north-northwest) results in significant bank erosion. Hydraulic forces are highest on the outside/right bank and have resulted in considerable erosion of the floodplain terrace located very close to the side channel network that parallels SR 530. The erosive work being done along the right bank is driven by both longitudinal and helicoidal currents (Natural Resources Conservation Service, 2005).

The radius of this meander curve has increased from approximately 1530 feet to 1605 feet (see Figure 1). This has likely resulted in a slight reduction in shear forces along the river's right bank of approximately 0.3 lb/ft^2 . Shear was calculated to be approximately 9.37 lb/ft^2 at a point 1.5 feet above the toe of slope with a curve radius of 1530 feet. Conversely, the same calculation using a curve radius of 1605 feet yielded a shear value of 9.07 lb/ft^2 for the same point. This shows that the river channel is losing its energy and efficiency as the meander lengthens. This reduction in shear is slight and the river still has ample energy to continue erosion within the right floodplain terrace.

The migration of the meander to the east appears to have removed topographic features along the edge of the floodplain terrace that formerly served as a partial barrier between the mainstem and the side channel network which occupies a lower elevation on the terrace. The loss of the topographic features along the edge of the floodplain terrace has brought the side channel into a much closer hydrographic association with the mainstem, increasing the possibility of river avulsion into the side channel network.

Channel Migration and Avulsion Risk

Prior to the November 2006 flood event, much of the flow entering the side channel network was buffered by traveling through a large wetland complex located on the right bank upstream of the project area. With the loss of the topographic break on the riverward edge of the right bank floodplain, a progressively larger proportion of overbank flows bypasses the wetland complex and flows directly into the side channel network across the floodplain terrace. This defeats the velocity attenuation that has been provided by the wetland complex, and has shortened and steepened the channel gradient for the side channel network as a whole.

As the mainstem meander has lengthened, it has become less efficient at conveying flow. Simultaneously the side channel network has been subjected to increasing overbank flows associated with flood events. Comparison of the two watercourses indicates cause for concern regarding avulsion risk. The mainstem channel length is 6822 feet in length whereas the two principal side channels measure 5913 and 6065 feet respectively (see Figure 2). As the side channels grow in size due to erosion, they will become more and more efficient. They are shorter, and thus are steeper in gradient as well. This sets up pre-conditions for a chute cut off avulsion into the side channel network.

Channel Geometry and Flow Characteristics

The mainstem has occupied the side channel network area at least two instances within the photographic record (see Figure 2). The mainstem channel planiforms were located here in the 1964 and 1974 aerial photographs. This was the result of normal channel migration patterns, notably meander translation through the reach.

The geomorphic planiform of the project area today is quite different. Rather than being an alignment that results from the geomorphic translation of the upstream meander, the side channel network is being activated by overbank flows originating at the apex of the meander, which is located on the opposite (east) side of the active channel zone.

Thus the process by which the mainstem may reoccupy the side channel network doest not involve meander translation. Rather it stems from a growing tendency for side channel activation associated with flood events to evolve toward a formal chute cutoff avulsion from the mainstem into the side channel network. The river will cut a more efficient pathway through the floodplain terrace, rejoining the existing mainstem at the next meander downstream via chute cutoff avulsion.

As described above the side channel network being activated is approximately 900 feet shorter than the current mainstem channel. The elevation at the point of divergence for the side channel network is 344 feet. The LiDAR elevation for the point of convergence where the side channel rejoins the mainstem is approximately 320 feet. Because it is shorter, when flow goes down the side channel network the gradient of the river increases from 0.35 percent to 0.40 percent. Figure 3 shows the reverse slope leading away from the river and into the side channel network.

Side Channel Alignment and geomorphic changes

While considerable changes have occurred in the mainstem as a result of the November 2006 flood, considerable geomorphic change is also taking place within the side channel network immediately adjacent to SR 530. Generally, the increased volume and velocity of water entering the side channel network is resulting in erosive processes that are both widening and deepening the channel. In addition, changes to the bedload composition are occurring that suggest considerable increases in both shear and velocity are taking place.

Comparison orthophotographs for 2006 and 2007 makes it clear that the channel is responding to increased flow by becoming larger. Channel width increased by an average of approximately 44 feet for five stations evaluated for this report, and the average channel width in the side channel adjacent to the highway is now approximately 104 feet (see Figure 5). The increase in channel width is even more alarming given the fact that most of the channel width increase occurred as the result of increases erosion of the right bank, which supports the road prism for SR 530. Of the five stations evaluated for channel width increases, data indicated that for three of those stations the proportion of channel increase that resulted from erosion of the right bank exceeded 80 percent. This bank is the intended location of pile spur dikes and other bank stabilization elements of the SR530 MP 58 CED project. The loss of this bank places these proposed structures at increased risk in terms of both constructability and survivability. As more of the right bank is lost, the road is placed at greater risk. In addition, the loss of bank will make it more difficult to construct the bank protection structures without working in the water which may raise additional difficulties with regard to complying with environmental regulations, particularly the Wild and Scenic River designation for the Sauk River system, which is under the jurisdiction of the U.S. Forest Service.

As mentioned above, the increased inundation of the side channel network also appears to be accompanied by increases in flow velocity. While velocity measurements during the November, 2006 flood event were not possible, the changes in bedload composition indicate that this is the case. Before the November 2006 flood event, most of the bedload in the side channel network consisted of fine silts, sand and gravel, interspersed by small lateral bands of cobbles. Observations of the channel after the November 2006 floods indicate that the areas of exposed lateral bands of cobble/boulder have increased considerably. In addition the size of the cobles has increased as well, with a D 50 of up to two feet in the areas of the lateral cobble/boulder bands. Peak flow of between 12 and 14 feet per second would be necessary to move bedload material of this size (Reichmuth, 1994).

Conclusions

The observations and trend analysis described herein indicates that there has been a substantial increase avulsion risk associated with the activation of the side channel network stemming from the November 2006 flood event. It has always been understood that the potential channel migration zone encompasses the entire valley floor. Also, this part of the valley floor has been previously occupied by the mainstem as a result of meander translation. However, a chute cutoff avulsion of part or all of the mainstem flow at this location now appears likely and may be imminent if the site is subjected to large flood events. This conclusion is reached after studying the geomorphic changes in the mainstem channel planiform, the loss of topographic break on the edge of the floodplain terrace, and the increases in side channel slope, width, and depth resulting form increased flow entering it from near the apex of the mainstem meander.

Based on these findings, this report makes the following design recommendations:

1. The HEC-RAS model for determining scour depth for the bank protection structures should be modified by modeling larger mainstem flows through the side channel network. This will likely result in a deeper calculated scour depth for the anchor pilings than is currently being used the depth of the piles will likely have to be increased as a result of the revised model.
2. Budgetary concerns have led to consideration of reducing or eliminating some of the bank protection elements of this project. Given the increased risk of river avulsion detailed in this report, reducing bank protection elements should not be considered. Rather, consideration should be given as to whether some of the bank protection elements need to be reinforced, such as the scour depth of anchors, and the spacing between protective elements.
3. The increasing risk of river avulsion has further exacerbated funding problems for this project. Additional funds to deal with the increased risk to the highway may be required. HQ CED staff should work with the project office and project management on addressing this issue so that the safety and stability of the project are adequately assured.

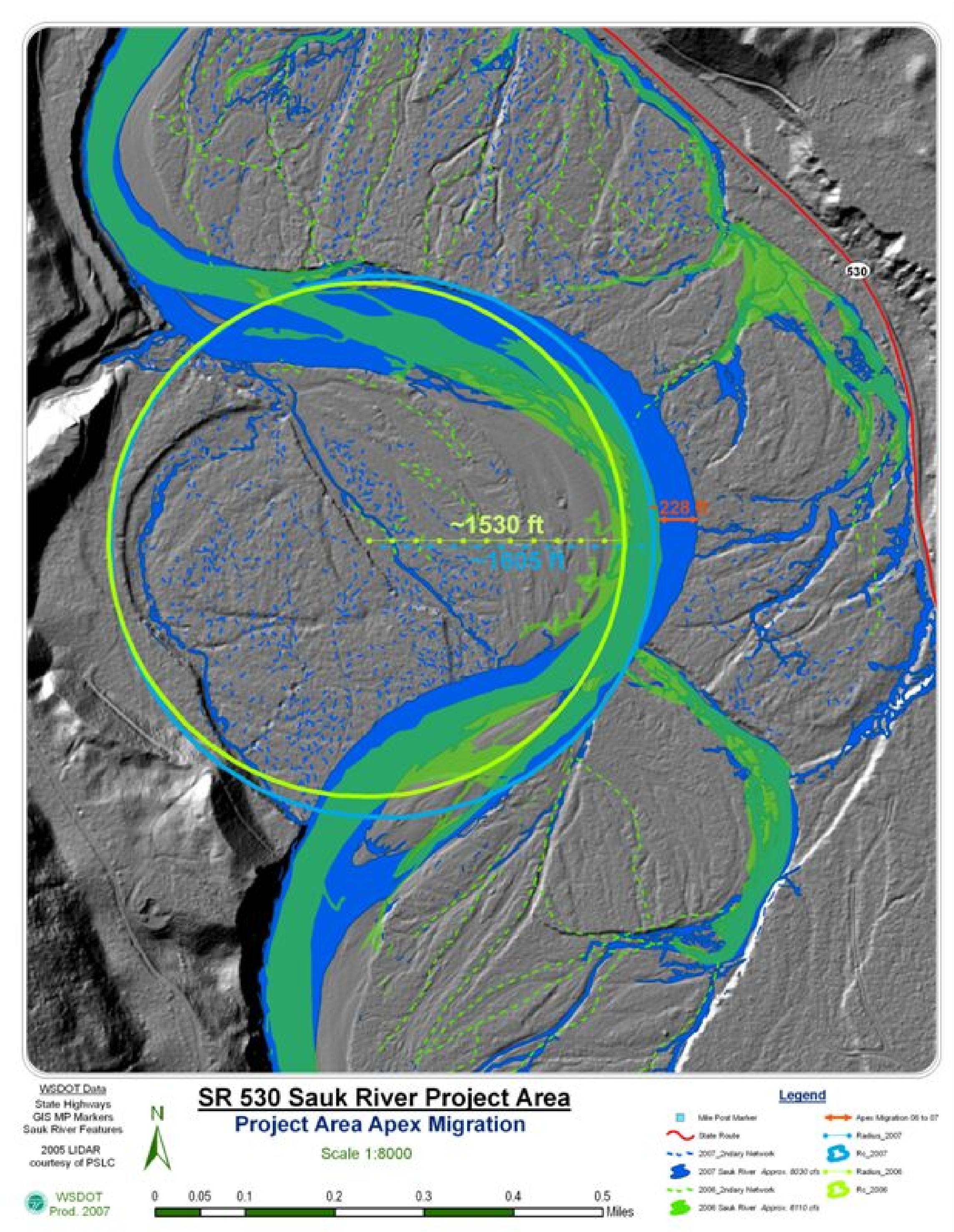


Figure 1. Apex migration and meander curve radius changes.

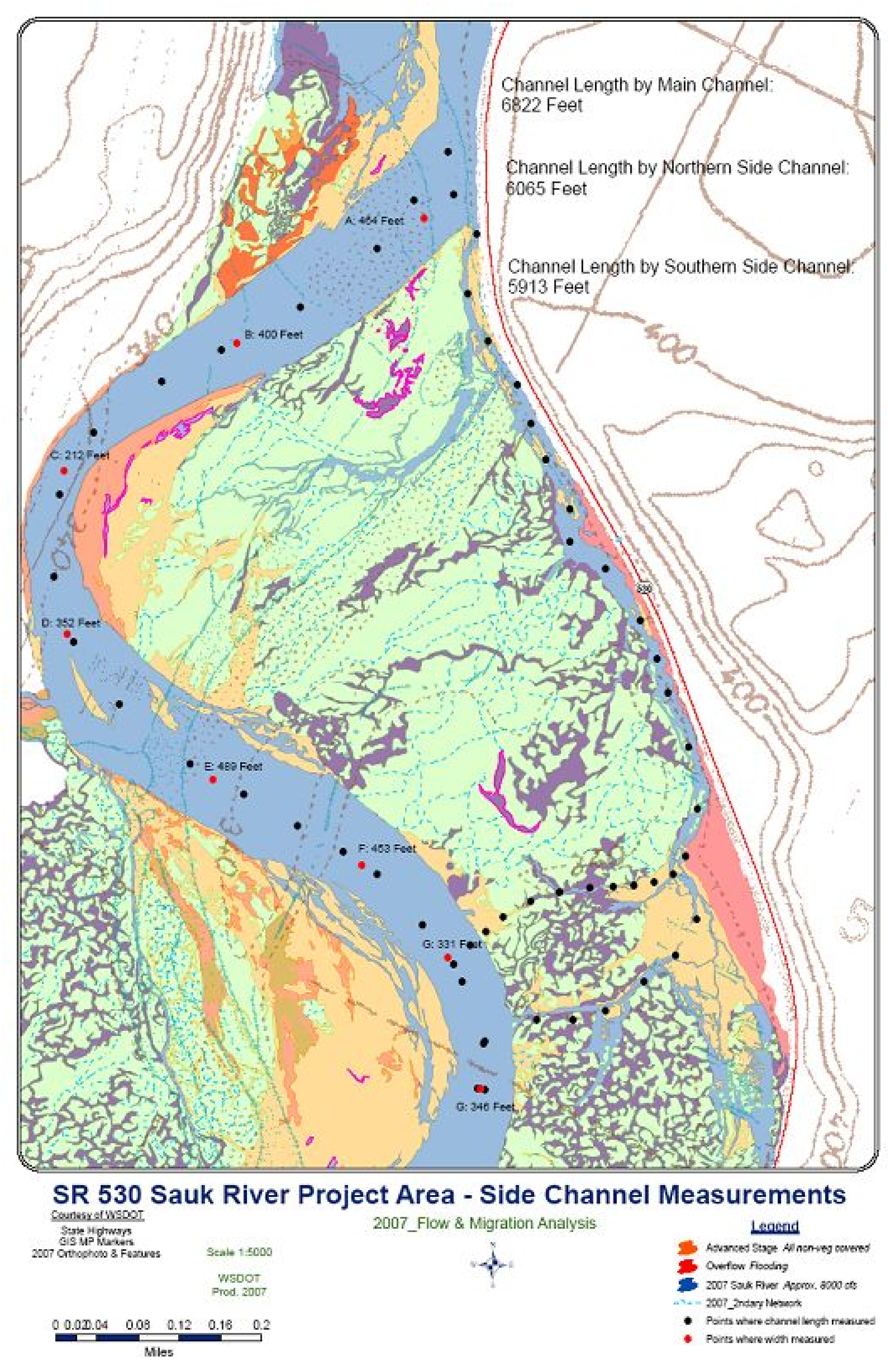


Figure 2. Side Channel Measurements.

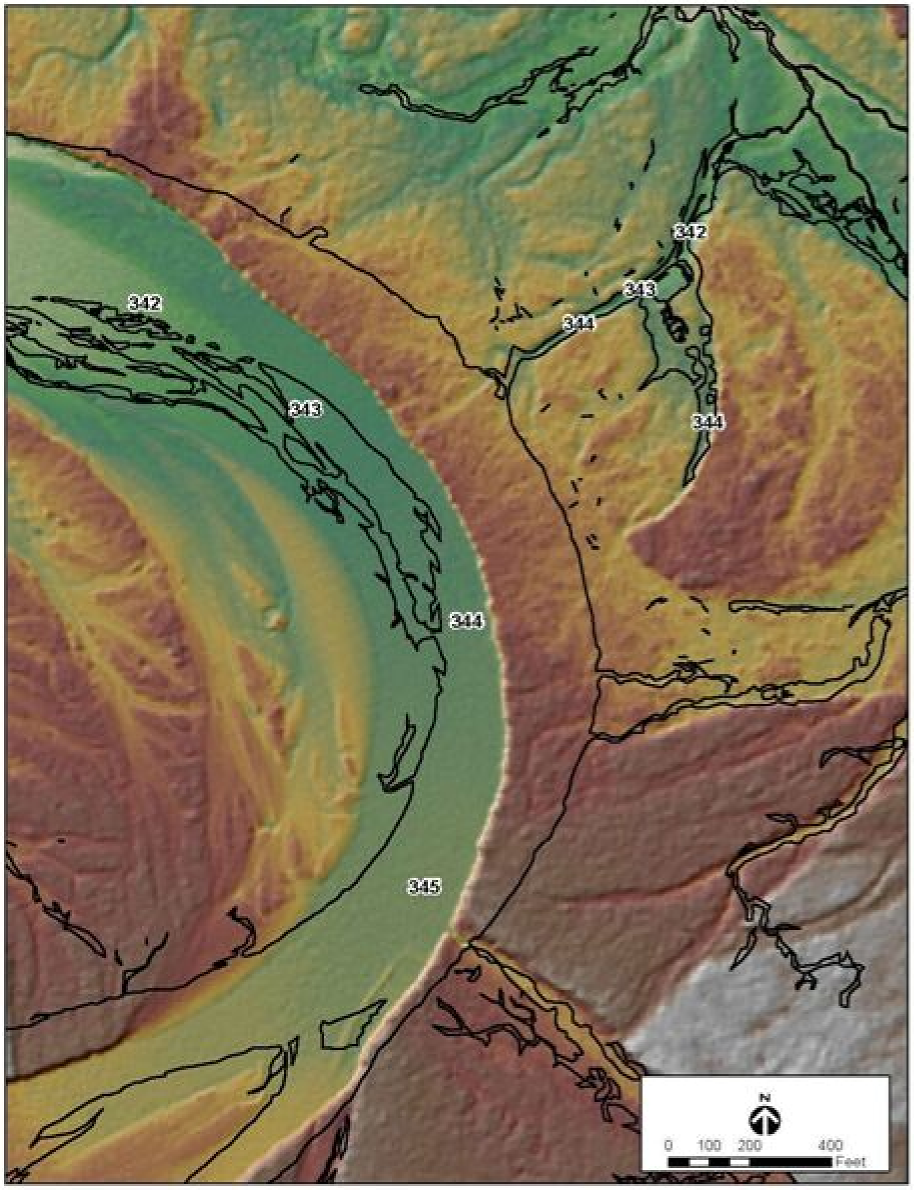


Figure 3. LiDAR elevations.

(Image used courtesy of Herrera Environmental Consultants)

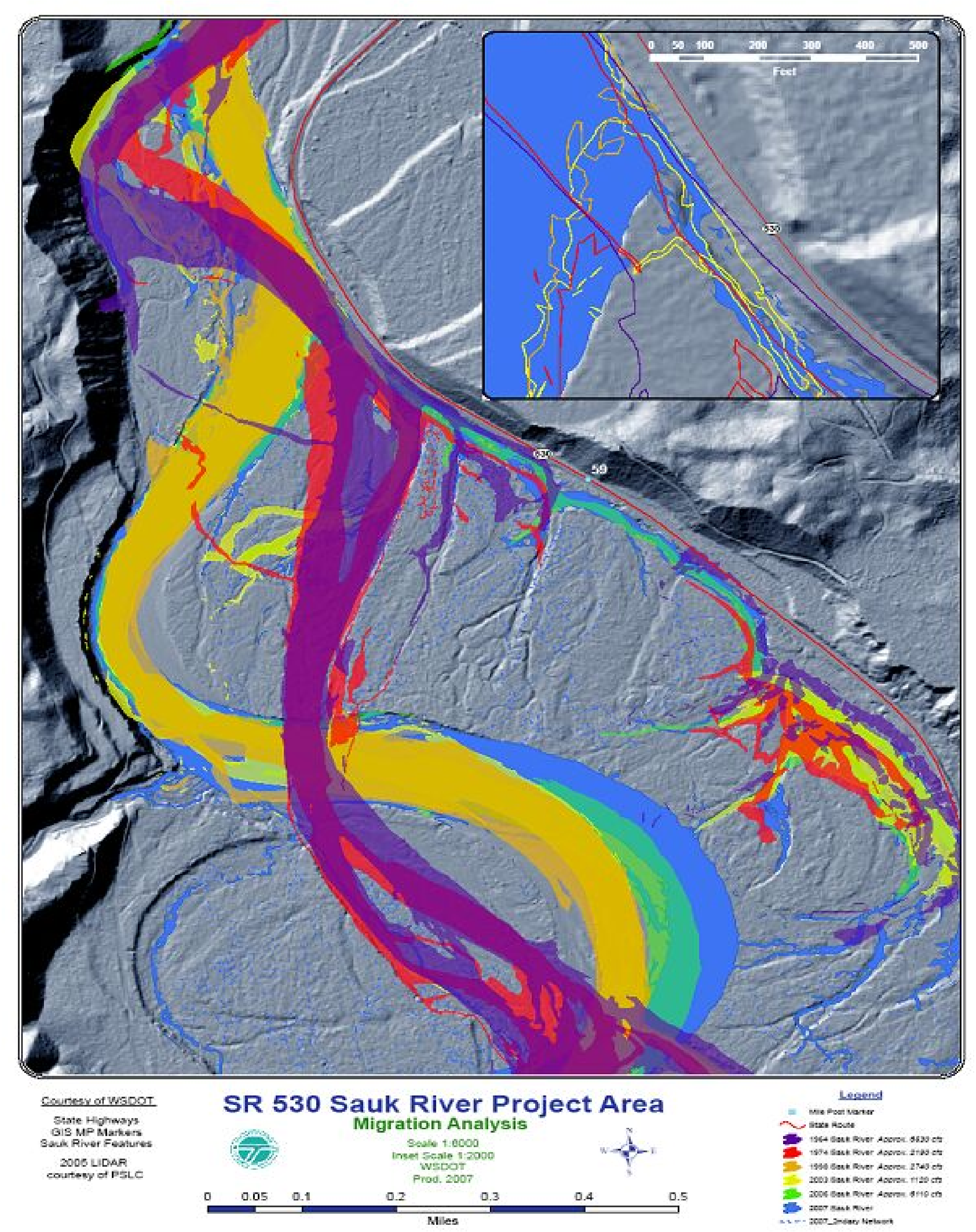
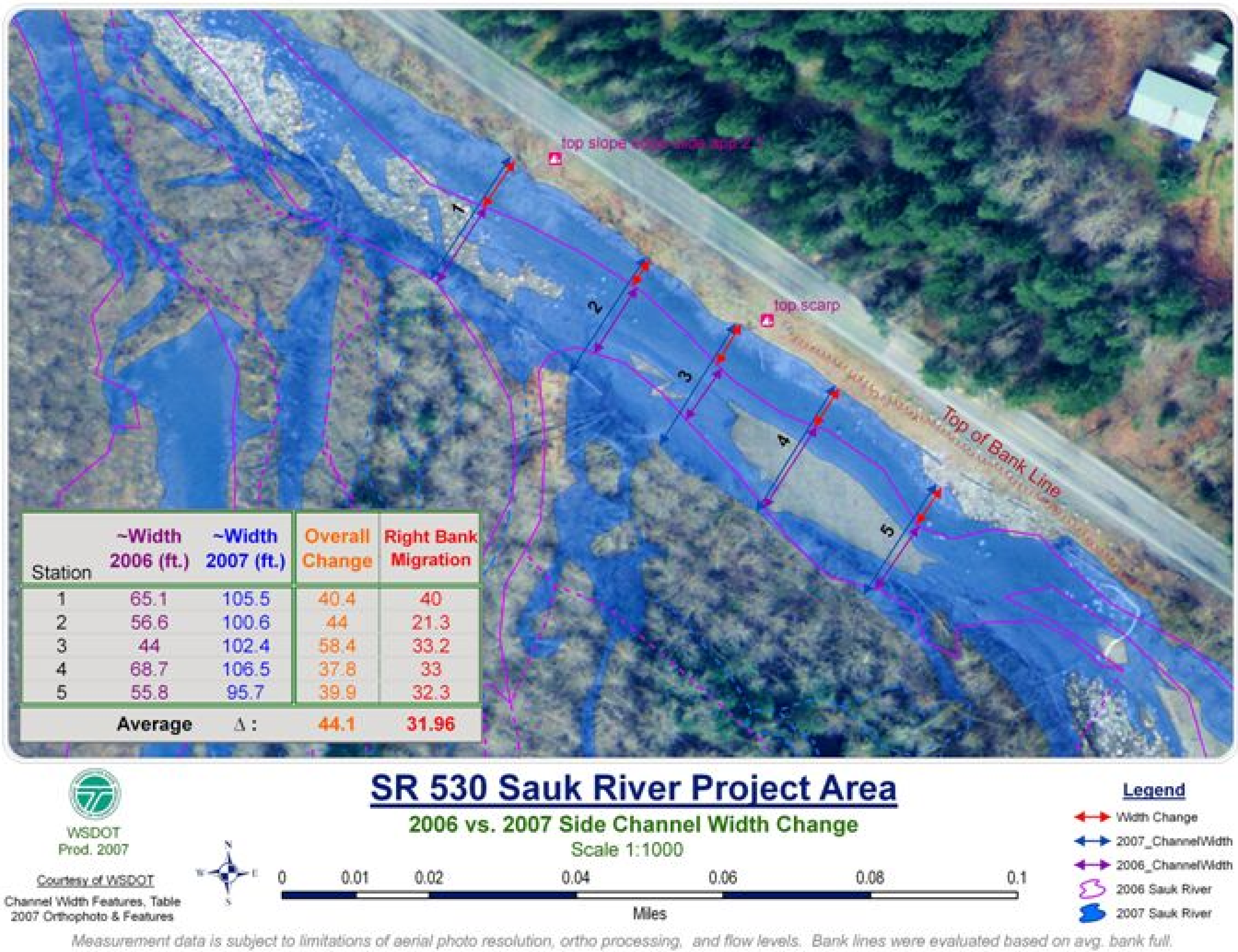


Figure 4. Channel migration trends.



Station	~Width 2006 (ft.)	~Width 2007 (ft.)	Overall Change	Right Bank Migration
1	65.1	105.5	40.4	40
2	56.6	100.6	44	21.3
3	44	102.4	58.4	33.2
4	68.7	106.5	37.8	33
5	55.8	95.7	39.9	32.3
	Average	Δ :	44.1	31.96

Figure 5. Sauk River Side Channel Width Change.

References

Alt and Hyndman. 1984. Roadside Geology of Washington. Mountain Press Publishing Company, Missoula, MT.

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.

Federal Highways Administration. 2001. Hydraulic Engineering Circular No. 20, Stream Stability at Highway Structures, 3rd ed.

Knowles, S.M. and Sumioka, S.S.. 2001, The National Flood-Frequency Program—Methods for Estimating Flood Magnitude and Frequency in Washington, 2001. U.S. Gological Survey Fact Sheet FS-016-01, 4 p. http://pubs.usgs.gov/fs/fs-016-01/

Mostrenko, Ian. Geomorphologist, Herrera Environmental Consultants, personal communication.

Natural Resources Conservation Service. 2005. Engineering Technical Note No. 23, Version 2.0, Design of Stream Barbs. Portland, Oregon.

Orr and Orr. Geology of the Pacific Northwest. 2002. Waveland Press, Long Grove, Illinois.

Rapp, Cygnia, and Tim Abbe. 2003. A Framework for Delineating Channel Migration Zones.

Reichmuth, D. 1994. Living with Fluvial and Lacustrine Systems

Sumioka, S.S., D.L. Kresch, and K.D. Kasnick, 1998. Magnitude and Frequency of Floods in Washington. USGS Water Resources Investigation Report 97-4277. Tacoma, Washington.

Sumioka, S.S., Kresch, D.L., and Kasnick, K.D., 1998, Magnitude and Frequency of Floods in Washington: U.S. Geological Survey Water-Resources Investigations Report 97-4277, 91 p.
http://wa.water.usgs.gov/pubs/wrir/flood_freq/.

U.S. Geologic Survey. StreamStats. http://water.usgs.gov/osw/streamstats

United States Department of Agriculture (USDA), Soil Conservation Service, 19XX. Soil Survey of Snohomish and Skagit Counties, Washington.

United States Geological Survey. NWIS Web at Real Time Data for Washington Streamflow website. http://waterdata.usgs.gov/wa/nwis/.

Washington State Department of Fish and Wildlife. 2003. Integrated Streambank Protection Guidelines. Aquatic Habitat Guidelines Program.
http://www.wdfw.wa.gov/hab/ahg/ispgdoc.htm.

Washington State Department of Fish and Wildlife. 2004. Stream Habitat Restoration Guidelines. Washington State Aquatic Habitat Guidelines Program.
http://wdfw.wa.gov/hab/ahg/strmbank.htm.

Washington State Department of Transportation GIS Data, LiDAR Coverage for Sauk River valley, Historical Orthophotographs 1964-2007.

Washington State Department of Transportation, 2004. Hydraulics Manual.

Washington State Department of Transportation, 2007. Design Manual.

Washington State Department of Transportation. 2007. Standard Specifications for Road, Bridge, and Municipal Construction, English Units.

Washington State Department of Transportation. 1997. Hydraulics Manual. Washington State Department of Transportation Hydraulics Branch.