Sun River Assessment

Prepared by:
Warren Kellogg
Stream & Watershed Consulting
38 Hidden Valley Drive, Clancy, MT 59634
March 2014

Sun River Assessment Final Report

Prepared for the:

Sun River Watershed Group
and
Cascade Conservation District

March 2014

Prepared by:
Warren Kellogg
Stream & Watershed Consulting
38 Hidden Valley Dr., Clancy, MT 59634

Table of Contents

1. Introduction

The Sun River Watershed Group (SRWG) is a consensus driven, multi-stakeholder partnership that strives to promote community-based efforts preserving their quality of life and livelihoods while promoting and enhancing the natural resources of their watershed.

Formed in 1994, the SRWG is catalyst in helping local people resolve natural resource issues in their watershed, which include weeds, water quality and water quantity. In 1996 the SRWG officially formed as a 501(c)(3) nonprofit organization to become eligible for additional funds to work on natural resource projects.

The SRWG is committed to the following objectives:

- maintain and/or improve a viable agriculture economy;
- control noxious weed infestations in the Sun River Watershed;
- reduce the sediment loads into the Sun and Missouri Rivers;
- improve the overall water quality of the Sun River;
- improve the flows in the Sun River and
- improve the fisheries of the Sun River.

1.1 Purpose of the Sun River Assessment

Following the objectives stated above, the SRWG decided to complete a comprehensive assessment on the middle segment of the Sun River from the Lowry Bridge to the Ulm-Vaughn Road Bridge.

The primary objectives for the Sun River Assessment were to:

- conduct a comprehensive condition and impact assessment of the middle Sun River;
- identify and determine the need and/or urgency of restoration projects;
- evaluate renewable resource benefits associated with restoration projects, answering the question: what renewable resource benefits will be gained from implementing the recommendations and to what degree?
- determine the technical feasibility of implementing restoration projects.

These objectives were the basis used for assigning priorities to the restoration recommendations included in this report.

1.2 Acknowledgements

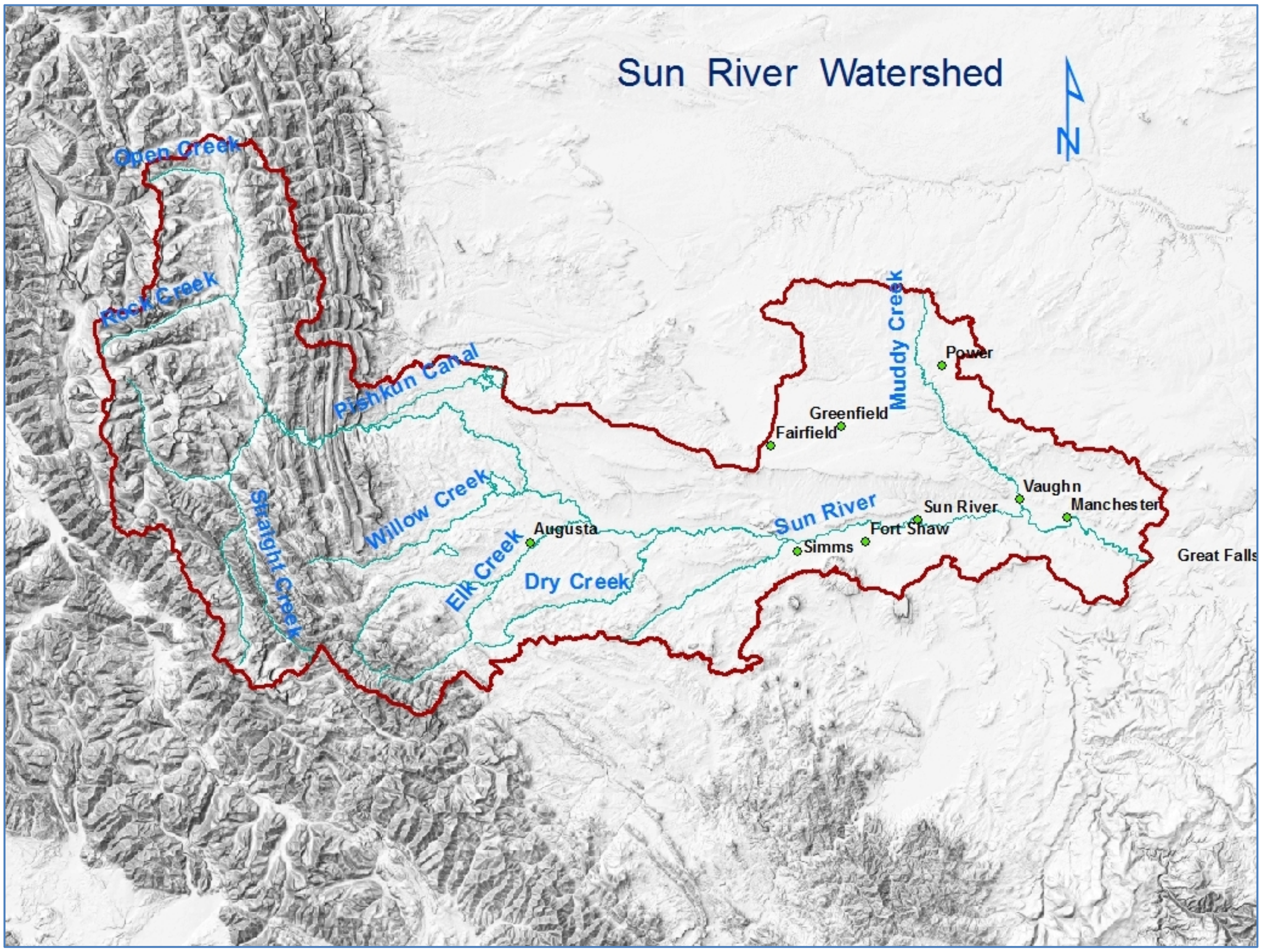
The members of the Cascade Conservation District and the Sun River Watershed Group are to be commended for their leadership on maintaining and improving such a significant resource as the Sun River.

Alan Rollo and Tonya Merryman dedicated a large amount of their time in helping me gather information on past stream restoration projects and to better understand the history behind resource issues in the Sun River valley. More importantly, their friendship and good humor made it a pleasure to work on this project.

2. Background Information

2.1 General Watershed Description

The Sun River watershed is located in Montana on the Rocky Mountain Front. It begins at the Continental Divide in the Bob Marshall Wilderness and flows east into the Missouri River near Great Falls, Montana. The watershed covers 1,875 square miles (1.2 million acres, 110 miles long and 30 miles wide) and includes three counties and eight small towns. The Sun River flows through the center of the watershed.



The major land uses in the Sun River valley include livestock grazing, crop production, forestlands, urban and rural residential, and wildlife habitat. Approximately 57% of the land is privately owned. The US Forest Service owns 33 percent of the land, primarily in the headwaters. The State of Montana owns 7 percent, the US Bureau of Reclamation owns 1.5 percent, the Bureau of Land Management owns 0.5 percent, and the US Fish & Wildlife Service owns less than 0.1 percent. Land cover is 35 percent cropland (approximately 40 percent irrigated lands and 60 percent dry lands), 28 percent rangeland, 35 percent forested, and 2 percent urban.

2.2 Brief History

The Sun River has a history as an important waterway for the early native people to present day landowners. The Blackfeet name for the Sun River, "The Great Medicine Road to the Buffalo," reflects the importance it held in their culture. The Sun River valley, once rich in nutritious grasses and abundant in buffalo and antelope, was said to be the best game country west of the Mississippi. Native tribes were in continual warfare over its possession. During the 1700s, the Flathead-Salish-Kutenai tribes lived along the Sun River, but lost control during wars in the early 1800s with the Blackfeet. In the mid-1800s, a major battle fought along the river almost decimated the Blackfeet and Crow nations.

In the summer of 1805, members of the Lewis and Clark Expedition walked along the banks of the Sun River. Meriwether Lewis commented that the Sun was "a clear river, never overflowing its banks."

In the 1830s, whites brought smallpox to the valley and an epidemic killed an estimated six thousand Blackfeet. An 1855 treaty led to the Federal Government establishing an Indian agency one-half mile upriver from the present day town of Sun River. The government's first agent, Colonel A. J. Vaughan and his contingent were the first known white inhabitants in the valley. In 1865 the Blackfeet killed some of the occupants and burned the agency to the ground.

In 1867, the U.S. Army built a post on a southern bluff overlooking the Sun River and called it Camp Reynolds. Shortly after its establishment, the Army renamed Camp Reynolds to Fort Shaw. Fort Shaw stationed 450 soldiers and included a hospital, library, and other buildings.

In 1869 cattle were brought into the valley and, in succeeding years, horses and sheep. With the large influx of animals came problems with cattle rustling, horse thieving, wolves, disease, and range management. To address these issues, ranchers banded together and, in 1883, formed the Montana Stockgrowers Association.

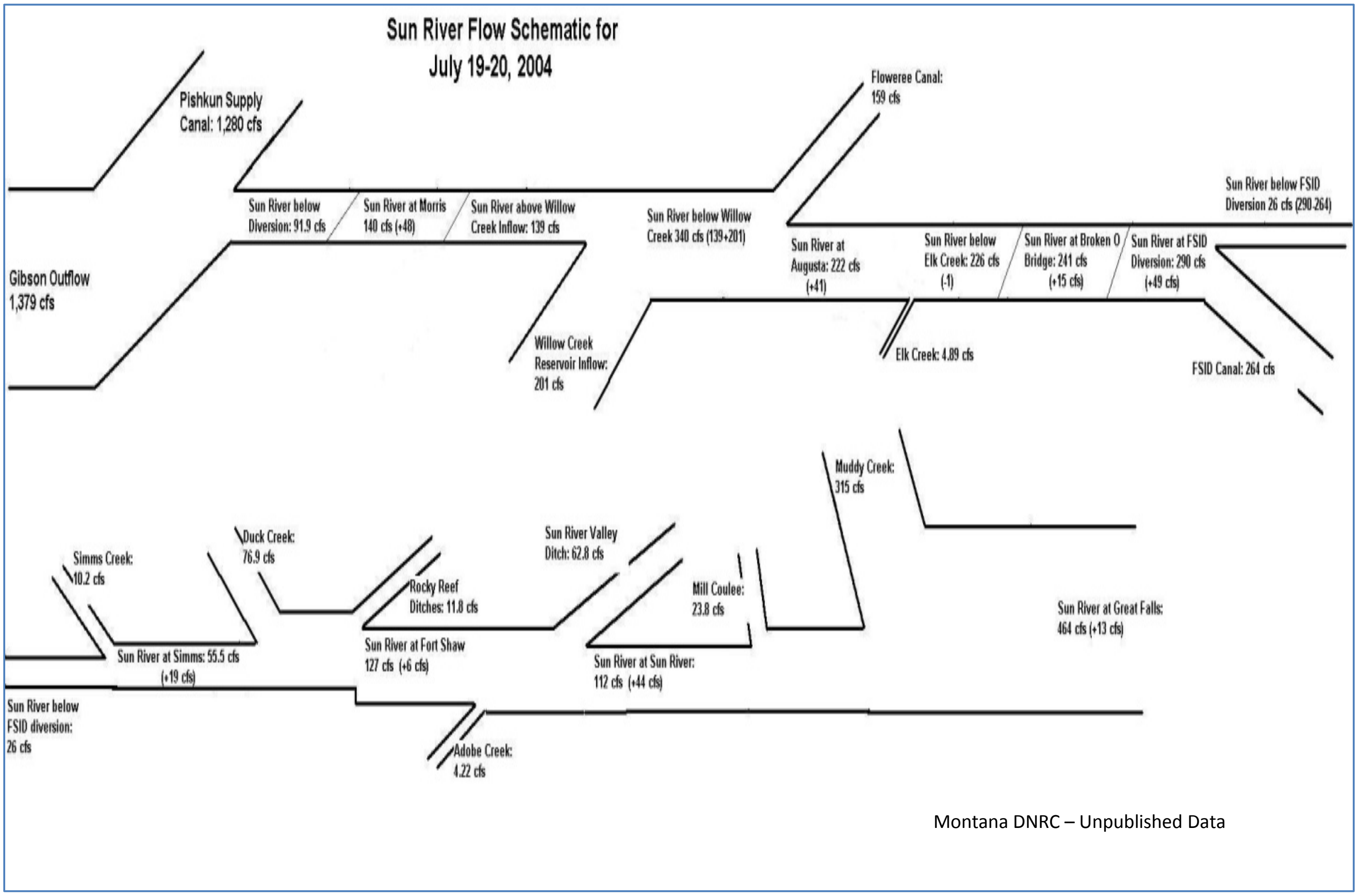
In the 1890s, U.S. Reclamation Service projects, like the Fort Shaw Irrigation Project’s construction of canals, diversions, and dams, supported homesteading in the valley. By the 1910s, the homestead boom was essentially over.

2.3 Hydrology

Stream flow data records for the Sun River date back to 1905. Widespread irrigation development in the Sun River Basin began in the early part of the 20th century. The US Geological Survey (USGS) began detailed flow measurements when large-scale irrigation was being developed in the valley. There are no flow records prior to irrigation development although hydrologic modeling could provide that information.

The most significant hydrologic influence in the watershed is the Sun River Project, a large irrigation project which includes three storage reservoirs, two diversion dams, 131 miles of main canals, 562 miles of smaller side canals, and 265 miles of drain canals. In 1907, the U.S. Reclamation Service approved construction of the project that includes two different divisions: Greenfields and Fort Shaw, each with its own irrigation district. Most of the Sun River Project lies north of the river as the 83,000-acre Greenfields Division, while the 10,000-acre Fort Shaw Division is south of the river. The Sun River Project’s impact on the Sun River hydrograph is yearlong although spring run-off is minimally affected since most high water is essentially run-of-the-river flow.

During the summer and early fall, the Sun River hydrograph is significantly altered as irrigation water is withdrawn from the river and irrigation waste water returned. In addition to the Sun River Project, there are other irrigation projects that affect the river including the Nilan Water Users, Broken O Ranch, Rocky Reef, and Sun River Valley Ditch Company. Each segment of the Sun River is affected differently depending on the irrigation diversion and return flow locations. The flow schematic below provides an example of withdrawals, returns, and in-stream flow relationships. The eight mile reach from Lowry Bridge (Site SR-1) to the Big Coulee mouth (Site SR-9) appears to be especially susceptible to dewatering during drought years. Due to close cooperation among water users, in-stream flows have been improving in recent years.



2.3.1 Flow Records - USGS Gage Stations

Active and inactive gage stations on the Sun River mainstem

- **Sun River below Willow Creek near Augusta (06082200)**:

Period of record is from 1964 to 2014. It is an active USGS gage station.

- **Sun River at Simms Bridge (06085800):**

An active USGS gage station is located on the north bank next to the bridge. Flow measurements have been recorded from 1966 to the present and water temperatures from 2006 to 2012. Gage records indicate that the three peak flows over the last 50 years are:

  - June 9, 1964 – 50,000 cfs (200 - 500 year frequency flood),
  - June 20, 1975 – 37,900 cfs (100 year frequency flood) and
  - June 8, 2011 – 13,900 cfs (10 - 25 year frequency flood).

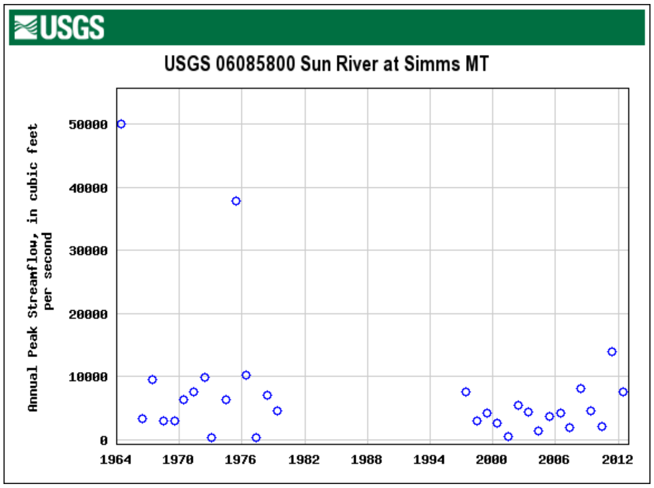


Chart showing the peak flows on the Sun River at the Simms Bridge. The period of record is from 1964 to 2013.

- **Sun River at Fort Shaw (0608600)**:

Between 1912 and 1928, flows were recorded by an USGS Gage Station (USGS Station 0608600) at the Fort Shaw Bridge. The gage station has been inactive since 1928. Discharge records show peak flows during that 16 year period occurred in 1916 (20,000 cfs: 25-50 year flood) and 1917 (16,400 cfs: 10-25 year flood). It was reported in the Bureau of Reclamation's 1917 Fiscal Year Annual Report that large areas of farm land on the south side of the river were damaged during these back-to-back floods.

- **Sun River at Sun River (06087500)**:

Between 1905 and 1912, flows were recorded by an USGS Gage Station (USGS Station 06087500). Discharge records show the peak flow during that 8 year period occurred in 1908 (27,200 cfs: 50-100 year flood). The gage station has been inactive since 1912. Discharge measurements were moved upstream to the Fort Shaw Bridge in 1912.

- **Sun River near Vaughn (06089000):**

An active USGS gage station is located on the Sun River downstream from the Muddy Creek confluence. Flow measurements have been recorded from 1934 to the present. Daily water temperatures have been collected from 1999 to the present and specific conductance from 1968 to 2000. Gage records indicate that the five peak flows over the last 60 years are:

- June 6, 1948 – 14,300 cfs (10 - 25 year frequency flood),
- June 4, 1953 – 17,900 cfs (10 – 25 year frequency flood),
- June 9, 1964 – 53,500 cfs (200 - 500 year frequency flood),
- June 20, 1975 – 32,600 cfs (100 year frequency flood) and
- June 10, 2011 – 14,800 cfs (10 - 25 year frequency flood).

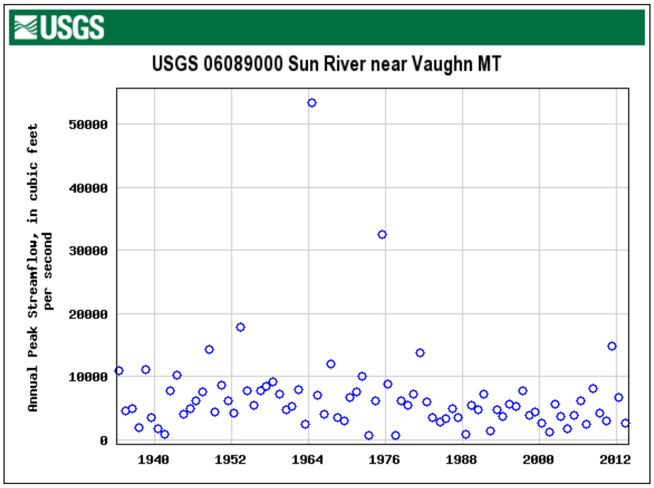


Chart showing the peak flows on the Sun River near Vaughn. The period of record is from 1934 to 2013.

Additional flow measurements have been taken on tributaries and irrigation canals. Many of these were for specific reasons over a limited period of time. They are not included in this summary.

3. Assessment Methodology

The Sun River Assessment was completed by walking and floating the river from the Lowry Bridge to the Ulm-Vaughn Road Bridge near Vaughn (28.2 total miles). Specific tasks included:

- compiling and summarizing all pertinent site reports, resource data and information that complement the field assessment;
- collecting and summarizing resource information with special attention given to irrigation infrastructure, channel stability, riparian area restoration, and noxious weed infestations;
- providing conceptual recommendations and prioritization of restoration opportunities.

The fieldwork was completed in July - September 2013 by Warren Kellogg under contract with the Sun River Watershed Group (SRWG). Funding was provided through the Cascade Conservation District with SRWG assisting in the process.

The Sun River Assessment focused on infrastructure condition and functionality, riparian forest sustainability, channel stability, and noxious weed infestations. Project prioritization is follows the criteria outlined in the assessment objectives under Section 1.1. Observations and restoration recommendations are based upon professional judgment and 35 years experience working on Montana streams.

2011 color aerial photography (NAIP – National Agricultural Imagery Program) was used as the base photography for the assessment and are included in the report. Older aerial photography/maps were used to determine change over time. The following sets of imagery are included in Appendix B:

- 1869 – 1907 Government Land Office Survey Maps (Scanned);
- 1946 Black and White Aerial Photography (Scanned);
- 1953-54 Black and White Aerial Photography (Scanned);
- 1975 Black and White Aerial Photography (Scanned);
- 1995 Black and White Aerial Photography (Georeferenced Images);
- 2011 Color Aerial Photography (Georeferenced Images);

- 1995–2012 Google Earth Imagery (On-Line Images) and
- USGS Topographic Maps (Georeferenced Images).

Detailed field notes and digital site photos were taken during the field assessment. All site photos are included in Appendix B. Each site was documented with GPS coordinates and listed in Appendix A. All sites are labeled on the aerial photography included in this report.

4. Observations and Priority Considerations

The Sun River Assessment begins at the Lowry Bridge and ends at the Ulm-Vaughn Road Bridge. The upper and lower reaches of the Sun River were not included in this assessment.

The following site descriptions are usually associated with a structure in or near the river channel. Conceptual restoration options and priority designations are included. Since this is a reconnaissance level assessment, restoration options discussed in the narrative will require additional survey, design, and construction oversight to assure project effectiveness and longevity.

Site SR-1 Stream Crossing – Lowry Bridge (Map 1) **Priority: No Action**

Steel beam bridge with a 200 foot span across the Sun River. Bridge abutments are treated wood pilings/timbers with rock rip-rap facing. Two channel piers, constructed from large diameter concrete-filled steel pipes, are off-set 20 feet from each bridge abutment. The bridge is located on Floweree Road and is in good condition. Because of the channel constriction, a large lateral gravel bar has formed upstream of the bridge along the south bank.

Site SR-2 Boat Ramp – BLM Lowry Bridge Recreation Site (Map 1) **Priority: No Action**

Gravel boat ramp at the BLM Lowry Bridge Recreation Site. The Recreation Site is located on the north side of the river downstream from the Lowry Bridge (Site SR-1). The Recreation Site is near the former site of Lowry. A post office was active at Lowry from 1897 to 1943.

Site SR-3 Bank Stabilization – Rock Flow Deflectors (Map 1) **Priority: Medium**

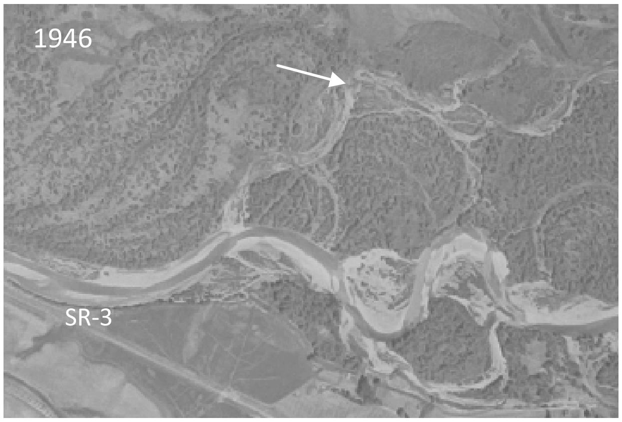
A high terrace was shaped, nine rock flow deflectors installed, and erosion fabric laid along 1,000 feet of south river bank in late 1997. The project purpose was to stabilize the terrace and protect an irrigated hay field. Two deflectors on the upper end are intact, a third deflector is close to being flanked, and the other six have washed out. Rock from one of the flanked deflectors is exposed in mid-channel. Another deflector is buried in a large gravel point bar on the opposite side of the river. Cottonwood saplings were planted along the bank on the upper third of the project and appear to be doing well. An additional 600 feet of river bank, downstream from the flow deflectors, was shaped and covered with erosion fabric. It has subsequently washed out.

During the 2011 flood, the river migrated 40 – 100 feet into the downstream end of the terrace bank. A gravel point bar on the opposite bank nearly doubled in size and is pushing the river channel into the terrace, increasing sheer stress along the terrace toe.

On the terrace bench, irrigation tailwater was allowed to spill over the terrace bank creating a deep gully. This has been resolved according to the landowner. The tailwater ditch (approximately 20 feet away from the terrace edge) and flood irrigation water continue to saturate the terrace bank, contributing to its instability.

Immediately downstream of Site SR-3, there are indications that the river may cut through a large meander ("avulsion" is the term used for such an event). If the avulsion occurs, 3,800 feet of the current river channel would be abandoned. 1946 aerial photography shows the river to be in nearly the same location as the potential avulsion. It is conceivable that the river will return to where it was 70 years ago.

Rock flow deflector on the upper end of the terrace that is still intact and functional.



Downstream from Site SR-3. White arrow (point of reference) on the 1946 and 2011 aerial photography shows the rapid channel migration over the last 65 years.

Recommendations:

1) Salvage the rock from the failed flow deflectors and use it to reinforce the third deflector. Leave the buried rock in the gravel bar on the north side of the river in-place.
2) Convert from gated pipe flood irrigation to wheel line sprinkler irrigation on the south hay field to reduce bank saturation and overland run-off. Gated pipe irrigation is a relatively efficient method of flood irrigation, but it can still contribute to excessive bank saturation when compared to the more efficient sprinkler systems. If flood irrigation is to continue, bank saturation could be reduced by widening the buffer between the terrace edge and the irrigated field by at least another 50 feet.
3) After each out-of-bank flood event, walk the floodplain/old channels and check for active headcuts. If active headcutting is found, armor the upper end of the headcuts to prevent further migration across the meander.
4) Plant additional willow/cottonwood cuttings on the bank toe upstream from the terrace.
5) Conduct aggressive noxious weed control targeting leafy spurge and spotted knapweed.

Site SR-4 Bank Erosion (Map 1) **Priority: Low**

Active bank erosion along a flood irrigated pasture on the south side of the river. The river eroded approximately 80 feet into the field during the 2011 flood. A large gravel point bar on the opposite bank continues to push the river into the bank. The eroding bank is 330 feet long and 6 – 7 feet high. Nearly 1/3 acre of pasture was lost during the flood. The river will probably continue eroding into the pasture in the future.

In 1946, the main river channel was approximately 800 feet north of where it is today. Over the last 65 years, the river shifted south to its current location. Major channel changes occurred during the 1964 flood. In the past, attempts were made to stabilize the bank with log cribs, but with short-term success.

Out-of-bank flows associated with high floods will access the floodplain southeast of Site SR-4. The river could recapture an old channel or irrigation lateral during a future flood event, although there are currently no indications (i.e. headcutting) that it will occur anytime soon.

Site SR-4: Active bank erosion along a pasture. The river migrated south approximately 80 feet during the 2011 flood.

Recommendations:

1) The eroding bank at Site SR-4 would be expensive to armor with traditional rock rip-rap. A less expensive option is a bank stabilization project using bioengineering techniques. This approach would still be expensive and come with a relatively high risk of failure.
2) Monitor old channel traces and irrigation laterals for active headcutting on the south floodplain downstream from Site SR-4. If active headcutting is found, armor the headcuts to prevent further migration across the floodplain.
3) Conduct aggressive noxious weed control targeting spotted knapweed.

Site SR-5 Terrace Erosion (Map 2) **Priority: High**

A landowner who recently built a house on the north terrace is concerned about the long-term stability of the terrace. The hillside has alluvial deposits overlying glacial lake sediments. The layer of alluvial deposits (1 – 6 feet deep) is sloughing off the steep terrace face along the river, exposing the glacial lake sediments.

Natural precipitation, irrigation water, and septic seep can quickly percolate through the surface alluvial materials (unconsolidated clay/silt/gravel) and eventually reach the laminated glacial lake sediment interface. The terrace's steep slope and water saturation of the interface are creating unstable conditions. Small seeps along the terrace face confirm the presence of water along this interface. Terrace stability may be further compromised by scouring of the terrace toe during high flow events. Seismic activity could exacerbate the situation although this site is not located in a high hazard seismic zone.

The 1995 aerial photography shows that the apex of the upstream bend has shifted, lessening the direct impact of the river current on the terrace. The river now has more of a parallel alignment with the terrace toe than it did 18 years ago.

Spotted knapweed plants are common throughout this site.

Site SR-5: House built on a high terrace. The terrace face is actively sloughing.

<u>Recommendation:</u>

1) Minimize the use of landscaping water. Divert all surface run-off away from the sloughing terrace.
2) Planting deep-rooted shrubs across the upper terrace slope will help utilize excess water and bind the soil.
3) Look for signs of increased slope instability which may include: 1) increased terrace sloughing; 2) new tension cracks parallel to the slope contour or; 3) bulges, cracks, and water seepage where there were none before. If slope instability begins to threaten the house, a professional contractor experienced in hillside slope stability should be consulted. They will likely suggest geotechnical approaches commonly used to treat unstable slopes (i.e. shotcrete, hill pins, geogrids, etc.). Such treatments are often expensive and require contractor expertise from outside of Montana.
4) Conduct aggressive noxious weed control targeting spotted knapweed.

Red lines show the 1995 channel bank superimposed on 2011 imagery. The terrace toe has slowly scoured over this 18 year period.

Site SR-6 Stream Crossing - Simms Bridge (Map 2) **Priority: No Action**

Concrete beam bridge on the Simms-Fairfield Road built in 1983. The bridge abutments are concrete with rock rip-rap at their base. The bridge has a 250 foot span across the Sun River and three in-channel concrete supports. During high flows, the bridge and its supports create an upstream backwater effect contributing to the formation of a large lateral channel bar along the north bank. This gravel bar is forcing the river towards the south bank. Bank scour is occurring along the south bank above and below the bridge. Downstream of the bridge, smaller channel gravel bars have formed on both sides of the river. Rock rip-rap extends approximately 300 feet downstream from the bridge along the north bank. Old bridge abutments, from a bridge constructed in 1912, are located 50 feet upstream from the existing bridge.

An active USGS Gage Station (Station 06085800) is located on the north bank next to the bridge. Flow measurements have been recorded since 1966; water temperature data was collected from 2006 to 2012. More information on this gage station is in the Introduction section of this report.

Site SR-1 to SR-6

Reach Description: Lowry Bridge to the Simms Bridge (4.5 miles)

Channel Characteristics: The valley along this reach is wide and has a well-developed floodplain. The river is slightly entrenched, meandering and gravel dominated with a riffle-pool channel. The river corridor is 4,000 feet at its widest and has an average slope of 0.3%, almost 20% less than upstream of the Lowry Bridge. The large bedload carried by the river is evidenced by the large point bars on nearly every inside bend. The streambanks are generally composed of unconsolidated alluvial material that is inherently erodible.

Due to the nature of the river along this reach, it will always be subject to rapid channel changes and meander avulsions. Aerial photography shows multiple channel traces across the floodplain. The best long-term management approach is to encourage a healthy riparian plant community along the river and invest in bank stabilization only where high value infrastructure (i.e. roads, buildings, irrigation structures, etc.) requires protection.

Major tributaries: Simms Creek (RM 41.4) enters the Sun River from the south between Sites SR-5 and SR-6.

The low gradient channel, wide floodplain, and large gravel bars are typical along this reach (photo looking downstream near Site SR-5). The gravel bar in this photo is an important “nursery” for new cottonwood and willow growth, critical for sustaining a healthy riparian plant community.

Riparian Characteristics: The riparian plant community is healthy and sustainable along this reach. The overstory is dominated by narrowleaf cottonwoods. Young cottonwood saplings and sandbar willows are commonly found on gravel bars and along the margins of the river. Over time, a natural transition of riparian vegetation occurs where mature cottonwood trees on the high floodplain are replaced by new growth on gravel bars.

Leafy spurge and spotted knapweed infestations are abundant along the river and across the floodplain.

Site SR-7 Bank Erosion (Root Wads with Rock)/Channel Avulsion (Map 3) Priority: High

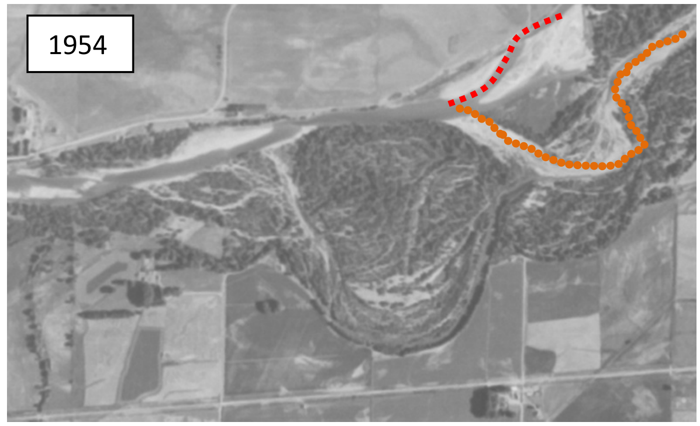
Active bank erosion on approximately 1,300 feet of the south bank, upstream from the inlet to an overflow channel. In 2000, a series of root wads were installed along an eroding bank and a rock sill constructed across the overflow inlet. The root wads have since washed out. On the lower end, root wad remnants can be seen 30 feet out into the channel. The rock sill at the overflow inlet may still be functional, but it is buried in gravel and difficult to evaluate. There may be some flanking of the sill, which has enlarged the inlet opening. In the 1990s and early 2000s, using root wads as bank stabilization was a common practice. It has since been learned that using root wads as bank stabilization on unregulated, high bedload rivers can be risky.

The 1907 GLO map and 1946 aerial photo show that the main river flowed through the north overflow channel during the first half of the 20th century. Sometime between 1946 and 1954 (10 – 25 year frequency floods in 1948 and 1953), the river cut through the meander (avulsion) and across a field, shifting the main channel nearly 1,000 feet to the north. A grove of cottonwoods on the north side of the river in 1946 is now on the south side. These types of avulsions are common on flat gradient, high bedload streams like the Sun River. Over the last 50 years, the river has been slowly migrating south to regain the length it lost. It may eventually reoccupy the old 1946 channel.

It is possible that the river could recapture the old 1946 river channel, ¾ mile upstream of the existing inlet. If this were to happen, the river would completely by-pass the eroding bank and current overflow channel inlet. Any restoration work considered for this site should be done with this possibility in mind.

Eroding bank where root wads were used as bank protection to prevent the river from reoccupy an old channel.

1946 Aerial Photo showing the main river channel nearly 1,000 feet south of where it is today (orange dashed line).



1954 Aerial Photo showing the new river channel (red dashed line) where a major avulsion occurred across a field. The 1946 channel (orange dashed line) became a secondary channel. The avulsion may have occurred during either the 1948 or 1953 flood.

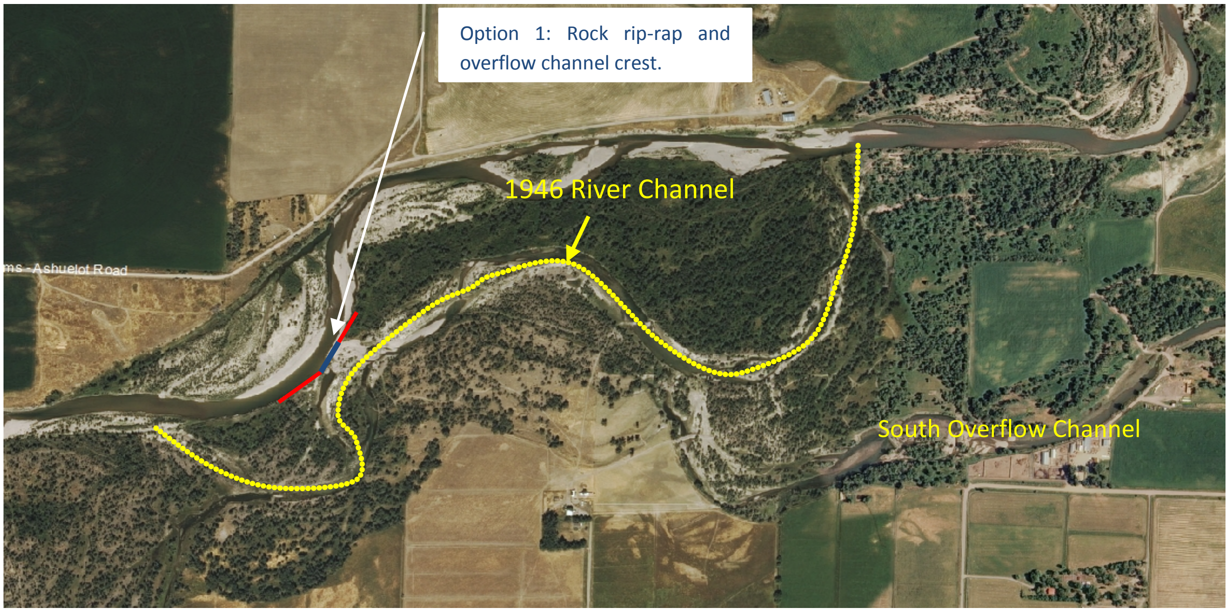
<u>Recommendations:</u>

1) Option 1: Install rock rip-rap along the bank upstream (minimum 230 feet) from the overflow channel inlet to keep the river from breaching into the overflow channel. Reconstruct the overflow channel inlet to provide vertical grade control, allowing bank-full flows to access the overflow channel. Armor both sides of the inlet to prevent the river from flanking the grade structure and to maintain a consistent channel inlet opening. There are uncertainties to this option because the river is so dynamic along this reach. It is feasible that the river could still flank the rip-rap or inlet structure during a high flow event.

   Additional investigation of the 1946 channel inlet, upstream from Site SR-7, is needed to determine the potential for the river to breach into the old channel at that point.

2) Option 2: Preventing the Sun River from accessing the north overflow channel will be a substantial investment of time and money with uncertain results. An alternative approach is to invest resources into preparing the north overflow channel (the old 1946 river channel) to again become the main channel. This option would require that all restrictions (large logs, excessive gravel deposits) be removed from the channel and a dense riparian vegetation buffer be maintained along its banks.

3) South channel: It may be unacceptable to the property owners and the Rocky Reef water users to have the river recapture the south overflow channel. Agricultural operations along the south channel would be threatened and the Rocky Reef Diversion would be completely by-passed. The upper end of the south channel was not evaluated during this assessment, but it may require bank armoring and grade control to prevent headcutting and over-bank scour. Redesigning some channel crossings to better accommodate flood water passage should be considered.



Site SR-8 Bank Stabilization – Rock Rip Rap (Map 4) Priority: No Action

Approximately 1,600 feet of rock rip-rap lines the south bank protecting a livestock facility. An irrigated hay field (center pivot) is 500 feet away. The rip-rapped bank averages 8 feet high and has a 2:1 slope. The rip-rap had some repair work completed after the 2011 flood. The Rocky Reef Diversion, located one mile downstream, contributes to winter ice build-up at this site. A ford crossing on the downstream end of the site is used during low flows.

Site SR-9 Big Coulee Confluence (Map 4) Priority: No Action

Big Coulee confluence with the Sun River. Big Coulee is a major source of sediment to the Sun River. Sediment and flow samples taken from 2005 to 2008 show that Big Coulee contributes up to 7,000 tons of sediment to the river each irrigation season. Augmented irrigation flows, rapid flow fluctuations, and fine glacial lake sediments along Big Coulee combine to create an extremely unstable channel (vertically and horizontally) and a major source of sediment. Only Muddy Creek contributes more sediment to the Sun River than Big Coulee.

Site SR-10 Rocky Reef Irrigation Diversion/Headgates (Map 4) Priority: High

The Rocky Reef Ditch Company irrigation project on the Sun River was developed in 1916. The project irrigates approximately 500 acres. The diversion structure is a large rock dam located approximately two miles northwest of the town of Fort Shaw and about one mile downstream from the Big Coulee confluence with the Sun River. Two headgates/ditches are served by this diversion: Birchmeade (upper headgate – 3 foot diameter inlet) and Rocky Reef (lower headgate – 5 foot diameter inlet). It is unknown how much water is actually being diverted, but the documented water right for the two ditches is approximately 57 cfs.

Over the last 15 years, many attempts have been made to design and construct a cross-channel diversion that would pass bedload, limit ice build-up, and ensure sufficient water is supplied to the two headgates/ditches.

It has been reported that winter ice build-up often extends over a mile upstream from the diversion. This ice build-up has created accelerated bank erosion and over-bank flooding. The tendency for ice build-up at a cross-channel weir generally depends upon two factors. The first is the gap width through the weir and the second is the average surface velocity in the pool upstream. The Rocky Reef diversion raises the water level several feet, increasing the cross-sectional flow area and reducing water velocity in the upstream backwater. A large gravel bar (1.6 acres) has formed along the south bank due to bedload deposition behind the diversion. This gravel bar build-up is further exacerbated by the eddy effect caused by the protruding "reef" on the north bank.

Approximately 700 feet of rock rip-rap and dike have been placed on the south bank above the diversion along the large gravel bar. The toe of the rip-rap is beginning to scour. Below the diversion, a 4 foot high dike faced with rock rip-rap lines the north bank and extends over 1,000 feet downstream.

Site photos of the Rocky Reef Diversion taken during the summer of 2013. The diversion backwater creates a wide cross-sectional area and low velocities. A large amount of gravel and silt have deposited upstream from the diversion.

Recommendations:

Option 1: To address the ice and sediment problems, create an opening in the upper weir that is wide enough to pass ice and sediment. The gap should be at least 80 feet wide, but this needs to be determined by a detailed hydrology/hydraulic analysis. Maintain large, low-head rock wings on both sides of the channel. During the irrigation season when flows are low, place portable pre-cast concrete blocks in the gap to check the water up to the needed elevation. It will take about 15 blocks (1500 - 2000 lbs each) to fill the gap. The blocks can be custom cast in a wide variety of sizes, shapes, and weights to fit the diversion site and stream velocity. The length of the blocks can be designed to match equipment lift capacities.

These barriers would be placed after early summer run-off, and removed in the fall after the irrigation season. The riverbed may need to be shored up to allow equipment (front end loader) access to place and remove the blocks. If the wing walls are wide enough, they may also serve as equipment access. Remove sediment off the upstream gravel bar to speed recovery.

Feasibility and costs associated with Option 1 would require a detailed analysis by a qualified and experienced river hydrologist or engineer. For the water users, this option would require additional operational steps (placing and removing portable blocks) during each irrigation season to keep the system functional. But, it would significantly reduce recurring maintenance costs and mitigate the impacts caused by a permanent weir.

Option 2: Convert from a gravity-based rock diversion system to irrigation pump(s).

- Advantages: 1) If the pump(s) are properly located, they would not be subject to high water and ice damage; 2) eliminating the diversion would allow sediment and ice to freely pass, reducing impacts on the river; 3) fish passage would not be impeded; 4) eliminates fish entrainment in the ditches; 5) less maintenance and expense with pump(s) than a cross-channel diversion; and 6) improved water use efficiency and increased crop production.

- Disadvantages: 1) Annual production expense – power to run the pump(s); 2) initial purchase of new infrastructure: pumps, power lines, conveyance system (buried pipeline) and/or additional sprinklers.

Site SR-11 Overflow Channel – Fish Habitat/Spawning (Map 4) Priority: Medium

Two mile long overflow/flood channel located on the south floodplain. This overflow channel is mentioned in the Site SR-7 description as the "south overflow channel." As stated in that description, it is critical that the overflow channel be allowed to pass flood waters. However, the landowners do not want the river to reoccupy this channel because of the existing infrastructure (corrals, buildings, pumps, access roads, etc.) in close proximity to the channel. Perennial flow in the flood channel is sustained by shallow groundwater and springs fed from upslope irrigation water. Local interest has been expressed in creating improved fish refuge habitat and spawning capabilities in this channel.

The following is a brief description of structures along the overflow channel:
11-1: Bank stabilization (rock rip-rap) – 100 feet long on north bank near a property line. The north floodplain appears to be a feeding area showing heavy livestock use.
11-2: Corrals along the south bank for about 1,100 feet. There is a 15 – 20 foot wide buffer separating the channel and the corrals. The buffer slope is faced with rock rip-rap. Nutrients from corral manure may be entering the adjacent channel from both surface run-off and shallow groundwater infiltration. Filamentous algae cover more than 80% of the channel substrate.
11-3: Irrigation culvert sump and pump on the south bank.
11-4: Channel crossing – three old culverts vary in diameter from 2 – 4 feet. They are well-placed and do not appear to impede fish passage. High water can readily pass around the crossing. There is a livestock water gap downstream from the crossing.
11-5: Water gap (south bank) and small pen (north bank). There are concentrated livestock impacts on a short segment of the channel.
11-6: Irrigation culvert sump and pump on the north bank next to a large pool. The pump delivers water to a center pivot located on the floodplain between the south overflow channel and the main river.
11-7: Irrigation culvert sump/pump on the north bank that delivers water to small hay fields. The sump/pump

is on a gravel bar next to a culvert crossing that washed out in 2011 and a flood channel. A rock flow deflector was built on the downstream side of the flood channel.
11-8: Bank stabilization (rock rip-rap) – 1,200 feet along the south bank. It is intended to keep the channel from eroding into an adjacent irrigated hay field and center pivot.
11-9: Channel crossing – two 4 foot diameter culverts. At the time of the assessment, the culverts were partially plugged with woody debris, both from floating debris and beaver dam plugs pooling water upstream of the crossing. When the culverts are plugged, it prevents fish passage into the overflow channel.

The upper 3,000 feet of the south overflow channel is under different ownership and was not assessed. There are floodplain dikes, elevated stream crossings and stockwater dams on this segment of channel. Some of the channel plugs have been breached in recent years.

The overflow channel is spring-fed and is a sequence of riffles and pools. The riffles are short, shallow, have high velocities and gravel bottoms. Algae growth is minimal. The pools are often large, deep and have low surface velocities. They typically have a silt bottom and harbor heavy algal blooms during the late summer months.

Algae growth during the summer is dense and sometimes covers the entire channel. In late summer, algae may lower the dissolved oxygen content to a level that will adversely affect fish. Nutrients, sunlight, and warm temperatures contribute to the substantial algal blooms.

Leafy spurge, spotted knapweed and Russian knapweed infestations are common along the length of the channel. Russian olive trees are beginning to encroach on the riparian corridor.

Recommendations:

The details and specific locations of the following fish refuge habitat and spawning redds recommendations would be based upon consultations with the local Fish, Wildlife and Parks (FWP) fisheries biologist.

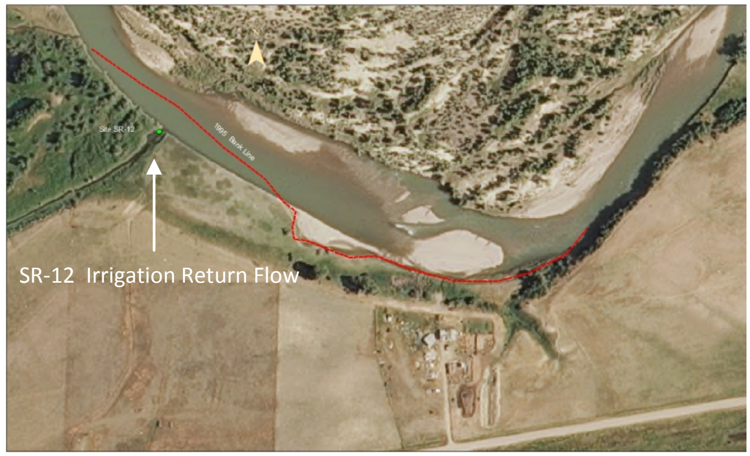
1) Construct riparian fencing on the channel banks where concentrated livestock use occurs (winter feeding and calving areas) to limit excessive hoof action. Approximately 1,400 feet of the north bank between Sites 11-1 and 11-4 should be considered for fencing.
2) Dig out accumulated sediment from the long pools and shallow runs, making them deeper and narrower. This action would require collaboration with the FWP fisheries biologist on selecting pools to excavate and locating a suitable place along the bank to dispose dredged materials. During the channel dredging, plant mature willow clumps along the bank.
3) Plant willow and cottonwood cuttings on the lower banks of the channel to create stability and shade. Focus the initial plantings on channel sections that currently have little or no riparian vegetation. It is suggested that the cuttings be harvested locally. There are several locations along the channel where a willow soil lift treatment would be effective. Aggressively control noxious weeds (leafy spurge, spotted knapweed, and Russian knapweed) along the channel to minimize competition with native riparian species. Eliminate all Russian olive trees before they spread beyond the point of control.
4) If both crossing are needed, remove culverts and replace with short-span bridges to allow better fish passage (Sites 11-4 and 11-9).
5) Evaluate corrals (Site 11-2) to determine whether or not they are a significant source of nutrients to the channel. Develop a mitigation strategy to reduce nutrient inputs.
6) In the 1946 aerial photography, the lower end of the overflow channel had more meanders than it does today. With the existing infrastructure (sump/pump/buried pipeline at Site 11-7), it would be too costly to reestablish the meanders. The existing channel alignment is sufficient for restoration.

Site SR-12 Return Flow Channel – Fish Habitat/Spawning (Map 5) Priority: Low

There is about ½ mile of irrigation return flow channel that could serve as fish refuge habitat and/or spawning grounds. The flow in the channel is perennial and can be as much as 30 cfs during the irrigation season. The Fort Shaw Irrigation District return flows enter the Sun River from the south. There are three landowners along the return flow channel.

The mouth of the return flow channel is 90 feet further south than it was in 1995. Immediately downstream from the return flow channel, the river has eroded into a small pasture. Over the last 18 years, ½ acre of the pasture has been lost. Concern was expressed in the late 1990s about an eroding bank downstream close to where buildings are located on a high terrace. This bank has eroded very little in the last two decades and is relatively stable as shown by the 1995 bank line (dashed red line on 2011 aerial photo below).

Site SR-12: The mouth of the irrigation return flow channel on the south bank of the Sun River.



The red dashed line depicts the 1995 bank overlain on a 2011 aerial photo. Over the last 18 years, ½ acre of pasture on the south bank has been lost.

Recommendation:

1) If landowners are interested, a detailed assessment of this ½ mile of channel would determine the potential for fish habitat/spawning grounds and provide specific options for modifying the return flow channel to improve the fisheries.
2) Aggressively control noxious weeds (leafy spurge, spotted knapweed, and Russian knapweed) along the return flow channel to minimize competition with native riparian species. Eliminate all Russian olive trees before they spread beyond the point of control.
3) Reduce livestock pressure on the bank and along the toe of the terrace downstream from the return flow where buildings are located. Plant additional willows and cottonwoods for long-term stability.

Site SR-13 Stream Crossing – Fort Shaw Bridge (Map 5) Priority: Low

A concrete beam bridge, rebuilt in 1998, crosses the Sun River on the North Fort Shaw Road. The bridge has a 280 foot span across the river and concrete bridge abutments faced with rock rip-rap. There are two in-channel concrete piers.

The Fort Shaw Fishing Access Site (3 acres) is located downstream from the bridge on the north floodplain. On the south terrace, an irrigation return flow cascades down a high bank. The irrigation return flow is lined with rock so it has not eroded a gully. Old car bodies and metal trash are scattered along the terrace slope further downstream.

Between 1912 and 1928, flows were recorded by an USGS Gage Station (USGS Station 0608600) located at the Fort Shaw Bridge. The gage station has been inactive since 1928. More information on this gage station is in the Introduction section of this report.

Looking downstream from the Fort Shaw Bridge. Old car bodies and metal trash are scattered along the right bank.

Recommendations:
Remove old car bodies and metal trash, minimizing bank disturbance to the extent possible. Re-vegetate where necessary and follow-up with weed control until the bank has healed over.

Site SR-6 to SR-13
Reach Description: Simms Bridge to the Fort Shaw Bridge (5.4 miles)

Channel Characteristics: The Sun River valley is about 1.5 miles wide and is bordered by shale bedrock overlain by either glacial lake or alluvium deposits. Bedrock along the north terrace is serving as vertical grade control.

The 100 year floodplain ranges from 1,800 to 4,500 feet wide. The average gradient of the river is 0.2%, slightly less than upstream of the Simms Bridge.

The river valley is very flat, creating a reach that is depositional. Several historic channel traces cross the floodplain. Because of the wide floodplain, low channel gradient, bedrock grade control and large bedload the river is extremely dynamic and subject to rapid channel changes. The best long-term management approach is to maintain healthy riparian vegetation and limit infrastructure development along the river. The river currently has less sinuosity than it has historically. The river is attempting to reestablish a stable pattern by increasing channel length, primarily through lateral bank erosion and recapturing old channels. Bank stabilization is risky and may only be worthwhile where high value infrastructure (i.e. roads, buildings, irrigation structures, etc.) requires protection.

Major tributaries: Big Coulee (RM 37.6) enters the Sun River from the north (Site SR-9).

Looking upstream between Sites SR-7 and SR-8. Throughout most of this reach the river flows along the north valley wall (glacial lake and alluvium deposits overlying shale bedrock). A wide floodplain lies to the south.

Riparian Characteristics: Over the last 100 years, large blocks of riparian forest have been cleared for agricultural development. Despite this development, the riparian plant community remains healthy and sustainable. Exceptions occur where concentrated winter feeding and calving areas have created a mature cottonwood overstory with no understory replacement plants.

Young cottonwood saplings and sandbar willows are common on inside bends and high gravel bars. These "nurseries" are essential to the long-term sustainability of the Sun River's riparian forest.

*Leafy spurge and spotted knapweed infestations are abundant along this reach. Russian olive trees are scattered, but appear to be increasing.

Site SR-14 Bank Stabilization - Rock Rip-Rap (Map 5) Priority: No Action

Approximately 1,100 feet of rock rip-rap lines the north bank. The rip-rap consists of small angular rock placed along an 8 foot high bank. The upper 700 feet is intact, primarily because it lies along a straight segment of river. The lower end has been flanked by the river leaving a line of rip-rap in the active channel. This segment failed because of the small rock and high sheer stress created by a secondary channel directing flow into the north bank. The land behind the failed rip-rap is floodplain pasture. Replacing the rip-rap would not be cost effective.

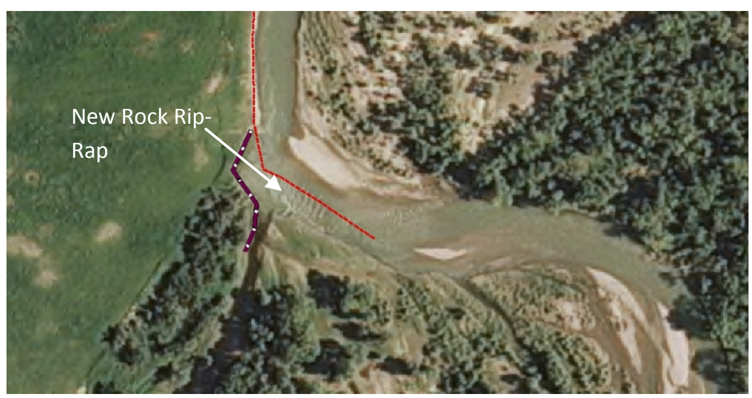
Site SR-15 Bank Stabilization - Rock Rip-Rap/Jetties (Map 5) Priority: Medium

Rock rip-rap and jetties were installed prior to 1975 on a north bank bend next to an irrigated field. Sometime between 1946 and 1975, the river migrated north nearly 600 feet, prompting the bank stabilization. Since then, the bend has been stable, except for the upper 350 feet. The river has eroded nearly 50 feet behind the upper jetty. Most of the erosion occurred during the 2011 flood. It is possible that the upper jetty and existing rip-rap could be flanked during future high water events.

On the lower end, there is a pile of rocks in the middle of the channel. These rocks are remnants of rip-rap flanked by the river many years ago. The rocks have split the flow, creating a small mid-channel gravel bar downstream.

Almost 70 acres of riparian forest on the north floodplain were cleared for agricultural development between 1946 and 1975. The fields are currently irrigated hay fields.

The upper end of Site SR-15. The river has eroded over 50 feet behind the jetty. Most of the erosion occurred during the 2011 flood.



The red line depicts the 1995 bank overlain on a 2011 aerial photo. The purple line is where rock rip-rap could be placed to prevent further bank erosion and potential flanking of downstream rip-rap.

1) Extend the rock rip-rap upstream from the upper jetty approximately 260 feet, as shown in the photo above. If the river continues to migrate south, it may be necessary to extend the rip-rap further up the flood channel to prevent flanking (upper right photo).
2) Remove the old rip-rap from the river channel on the downstream end of the site.

Site SR-16 Avulsion – Side Channel (Map 6) **Priority: High**

Root wads and rock rip-rap were installed over 10 years ago along the east bank to prevent the river from breaching into a side channel. A rock "hard point" was installed at the mouth of the channel to maintain adequate flow for a side channel irrigation pump.

Point #1: The side channel was the Sun River's main channel in 1946. Sometime between 1946 and 1975, the river shifted to the west making it a secondary side channel. The side channel is used as a conveyance to deliver water to an irrigation pump (adjacent hay field with gated pipe). A rock hard point was constructed over 10 years ago to maintain flow in the side channel and keep the Sun River in its present location. The hard point is close to being flanked. A narrow "isthmus" (10 feet wide) behind the rock point is actively eroding on both sides. If it erodes through, the hard point will become an isolated pile of rocks in mid-channel. It is uncertain how this would affect flows into the side channel, but it is conceivable that the side channel would again become the main river channel.

Point #1: Looking downstream at the hard point that separates the Sun River mainstem (left) from the side channel (right). Rock was placed to create this hard point over 10 years ago. It was repaired in late 2013.

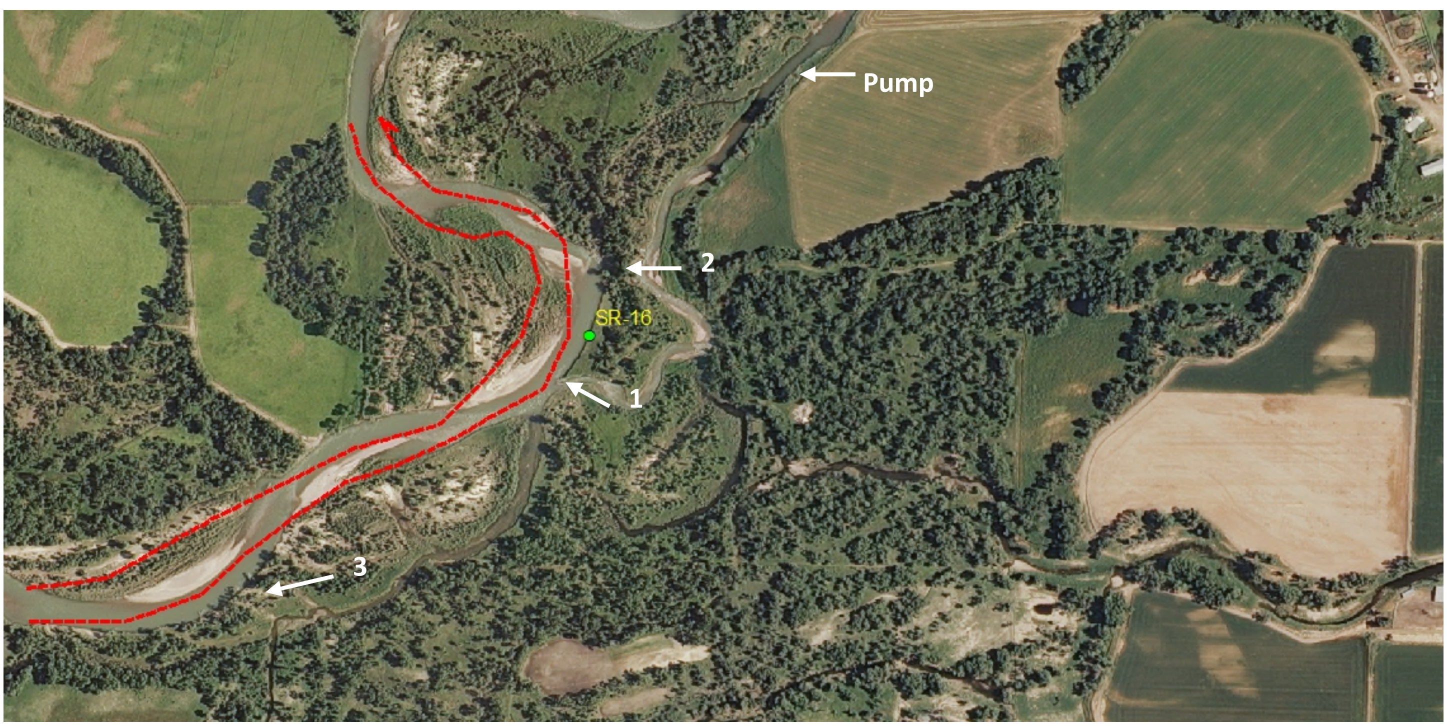
Point #2: On the Sun River mainstem, approximately 500 feet downstream from the mouth of the side channel, the river is close to breaching into the channel. Since 1995, the river migrated 130 feet towards the side channel. A 120 foot wide "neck" currently separates the main channel from the side channel. Over-bank flows have created several active headcuts across this "neck". The headcuts are migrating towards the main channel and if they are allowed to continue, the river will likely breach into the side channel.

Point #2: Active headcut traveling across a narrow riparian "neck" separating the river from the side channel.

Point #3: On a south bend, about 1 mile downstream from the side channel mouth (Point #1), the Sun River has migrated south nearly 150 feet over the last 18 years. Currently, 180 feet of riparian buffer separate the Sun River from Adobe Creek. If the Sun River were to breach into Adobe Creek, the river might realign with the Adobe Creek channel. Flows entering the downstream side channel would likely be affected.

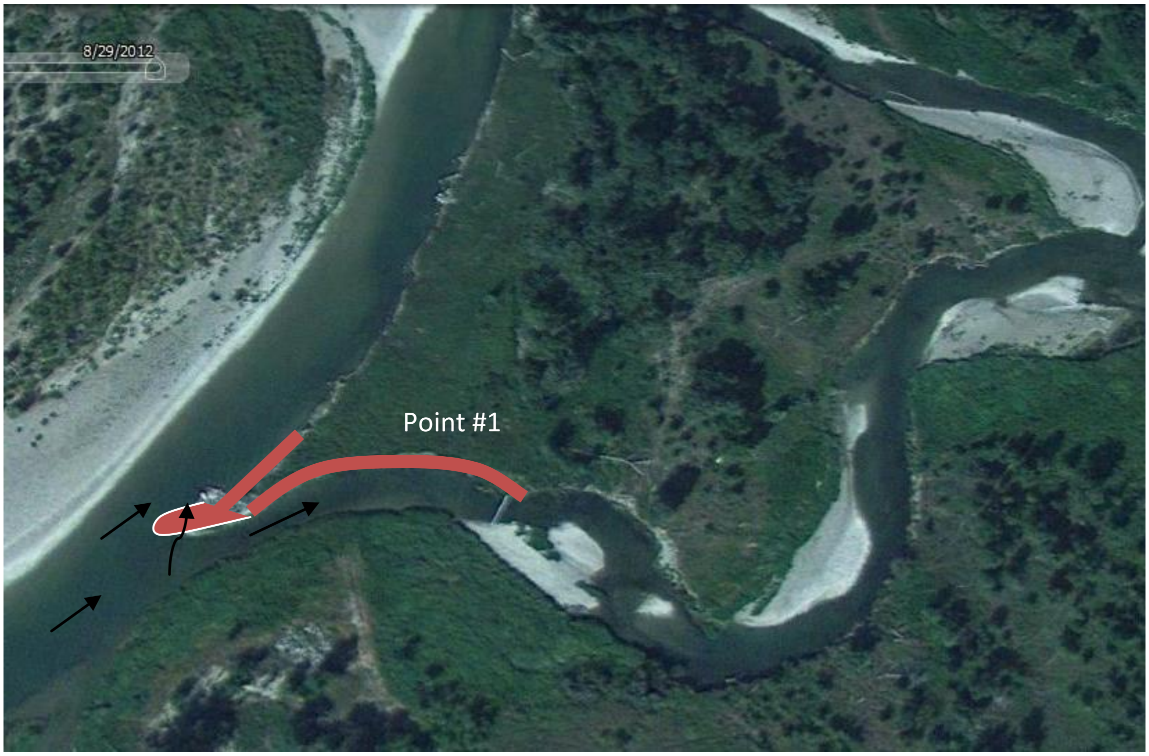
Adobe Creek enters the Sun River 150 feet upstream from the side channel mouth. Most Adobe Creek flow is Fort Shaw Irrigation District waste water. Water quality is reported to have elevated levels of salinity and nutrients.

Floodplain dikes east of the side channel may be affecting the direction of out-of-bank flows. The dikes were not looked at as part of this assessment.



Recommendations:

Point #1: Reinforce the rock hard point with additional rock extending down both sides of the “isthmus”, 70 feet on the river side and 170 feet on the side channel. Incorporate a short bendway weir flow deflector into the reinforced rock point. See the conceptual diagram below. Some repair work was completed on the hard point in late 2013.

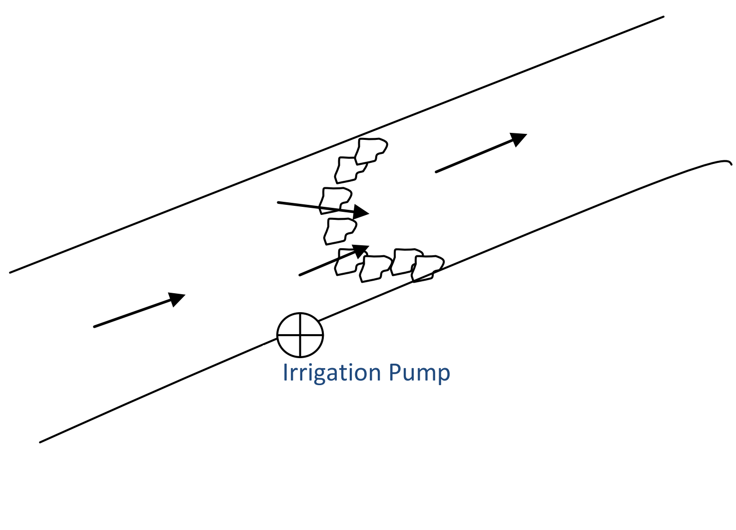


Point #2:

1) Rip-rap 300 feet of the east river bank at the “neck” separating the river from the side channel.
2) Place a rock sill across the head end of the active headcuts to prevent further movement. The sill needs to be extended far enough across the top of the headcut to prevent flanking by over-bank flows.

Point #3: Monitor the migration of the river towards Adobe Creek. If it comes to within 80 feet of the creek, consider rip-rapping the south bank to prevent the river from breaching into the creek channel.

Side Channel: Below the irrigation pump, 700 feet of side channel was shaped in 2013. Gravel was pushed up against the east channel bank. It is recommended that no further channel work be done. The channel will eventually narrow and deepen, creating meanders and point bars within the shaped channel. Install a permanent rock check structure for the irrigation pump instead of continuing to push-up a gravel berm each summer. See diagram below.



Looking downstream on the side channel below the irrigation pump. The photo shows a berm in the side channel intended to elevate the water level for an upstream irrigation pump.

Alternative Option: Use irrigation water from an alternative source. Instead of using the side channel and existing pump station, bring water in from the Fort Shaw Irrigation District (FSID). This option would be contingent upon the willingness of FSID to provide water and the eligibility of the land for FSID water. It would also require changes to the on-field irrigation system to accommodate the alternative source. This option would require an initial investment, but it would eliminate the uncertainties and on-going expenses associated with using the side channel.

East Floodplain: An on-site investigation is needed to determine the effects of the floodplain dikes on out-of-bank flows and what can be done to mitigate those effects.

Site SR-17 Bank Stabilization – Root Wads/Rock (Map 6) Priority: Medium

Over 10 years ago, approximately 400 feet of root wads and rock were placed along the west bank to protect an irrigated hay field. The majority of the bank stabilization is intact except for the upstream end where 80 feet is washing out. The apex of the upstream bend has shifted in the last 18 years. The river alignment along Site SR-17 is now relatively straight with reduced sheer stress on the bank.

Bank stabilization project eroding out on the upstream end of Site SR-17.

The red line shows the 1995 west bank. The black arrow shows the primary direction that the channel is migrating. Over 60 feet of bank has eroded over the last 18 years at the apex of the bend.

Recommendations:
If bank erosion and land loss continue, it will likely be directed towards the riparian forest/pasture upstream from Site SR-17 (black arrow on photo above). Investing in additional bank stabilization may be premature. Monitor the existing root wads/rock bank stabilization (Site SR-17) to ensure they remain functional, especially on the upstream end. If the river begins to flank the root wads, additional rock rip-rap may be necessary.

Site SR-18 Bank Stabilization – Rock Rip-Rap/Root Wads (Map 6) Priority: Low
Approximately 1,100 feet of rock and root wads were placed along the northeast bank. The bank stabilization work was completed about 10 years ago by Malmstrom AFB to protect a communications cable crossing. The river has since scoured around some of the rock causing it to slough down the bank. The bank was shaped at a steep angle to protect the tree line along the upper bank. The steep slope has contributed to rock sloughing down the bank.

Rock rip-rap sloughing down the bank. Leafy spurge dominates the upper bank.

Recommendations:
Maintenance: Additional rock is needed where rip-rap is sloughing down the bank. Incorporate angular rock of mixed sizes into the existing root wads and rip-rap. Aggressively control leafy spurge infestations on the upper bank.

Site SR-19 Bank Stabilization – Rock Rip-Rap (Map 6) **Priority: No Action**

Blanket rock rip-rap (750 feet) along the south bank of a bend intended to protect an Air Force missile cable. It is also preventing the river from migrating further into an irrigated hay field (flood irrigation – gated pipe). An irrigation ramp and pump are built into the upper end of the rip-rap. The rip-rap is in need of minor repair.

Site SR-20 Sun River Valley Irrigation Diversion (Map 6) **Priority: Low**

The Sun River Valley Ditch Company's adjudicated water right was established in 1868 and is the 2nd oldest on the Sun River. The irrigation diversion consists of a wide concrete apron that forms a low dam about two feet high across the river. During low water, concrete blocks are placed on the apron to increase water height. This structure backs water into an upstream side channel where the irrigation canal headgates are located. After the irrigation season, the blocks are removed and stored on the bank.

The headgates are located 1,320 feet down the side channel. The side channel re-enters the main Sun River approximately 3,000 feet downstream from the diversion. The main canal is 12 miles long and has a capacity of 75 cfs. The canal can also receive supplementary flows of at least 20 cfs from Mill Coulee Creek. The canal empties into Muddy Creek upstream of the town of Vaughn.

In the late 1990s, the water users constructed an annual gravel dike across the Sun River to divert water into the side channel. The current diversion structure is a great improvement over the gravel dike. The operation and maintenance costs are lower and the biological and physical impacts to the river are significantly reduced.

Sun River Valley Irrigation Diversion using portable concrete blocks to raise the water level in late summer.

Recommendations:

Clean out the floodway on the south bank to better accommodate over-bank flows. During the off-season, store the diversion blocks outside the floodway.

Site SR-21 Flow Deflector – Rock Jetty (Map 7) **Priority: No Action**

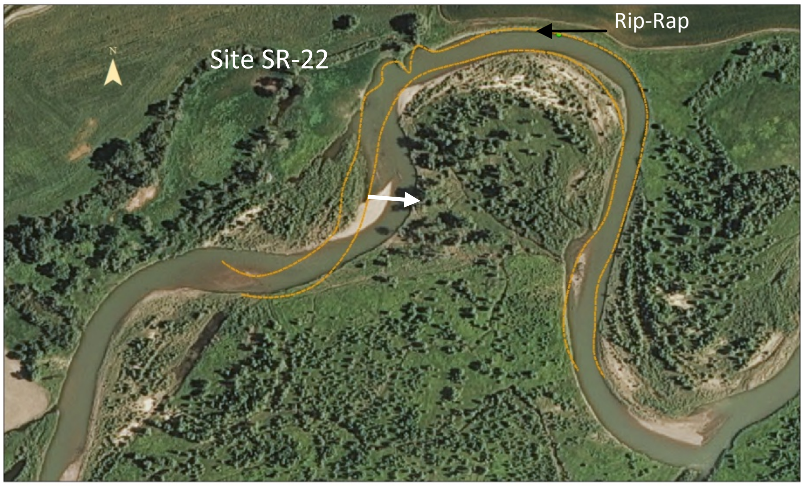
Large rock jetty on the south bank built to prevent the river from capturing a downstream overflow channel. The jetty is deflecting the current away from the side channel inlet and creating a backwater eddy that is depositing a large gravel bar along the south bank. The rock on the face of the jetty is scouring and requires maintenance.

Downstream from the jetty, a river bend has migrated into a riparian forest/pasture (180 feet since 1995). A large tree on the east floodplain was undercut during the 2011 flood and fell into the channel. Its stump is buried in the river bottom and has created a large gravel bar, increasing pressure on the bend.

Site SR-22 Bank Stabilization – Rock Rip-Rap/Jetties (Map 7) **Priority: Medium**

Bank stabilization on the north bank consisting of 3 rock jetties on the upper end, 1,100 feet of blanket rock rip-rap in the middle, and a rock jetty at the downstream end. The bank stabilization was installed to protect an adjacent irrigated hay field (wheel line sprinklers). The upper jetties have formed large upstream eddies that are actively eroding into the bank. The "gouges" have moved about 40 feet in the last 18 years. If the erosion continues, the jetties and rip-rap may become flanked by the river. At the time of the assessment, irrigation waste water was being released over the bank, contributing to the bank's instability.

The river is unable to migrate further north because of the bank stabilization. This "hard line" is contributing to the river's migration into the floodplain south of Site SR-22. The river has moved 165 feet in the last 18 years. The 2011 aerial photograph below shows the 1995 channel outline (orange lines). If the river continues moving in an easterly direction, it could eventually cut through the meander (avulsion) leaving Site SR-22 on a secondary channel.



1995 bank lines overlain on 2011 aerial photography. South of Site SR-22, the river has migrated 165 feet east over an 18 year period.

1995 bank lines overlain on 2011 aerial photography. This photo is a close-up of the rock jetties at the upstream end of Site SR-22. The river has moved about 40 feet behind the jetties over the last 18 years.

<u>Recommendations:</u>

1) Remove the jetty marked with the white arrow (photo above). After the jetty is removed, shape the bank to a 3:1 slope and place angular rock along 350 feet of bank. Use salvaged rock from the jetty for the new rip-rap. Key the rip-rap into the existing downstream rip-rap. See the photo diagram below.
2) Aggressively control the leafy spurge infestations on the upper bank.

Remove the middle jetty. Salvage the rock and use it along the outside bank (red line).

Site SR-23 Bank Stabilization – Rock Rip-Rap (Map 7) Priority: No Action

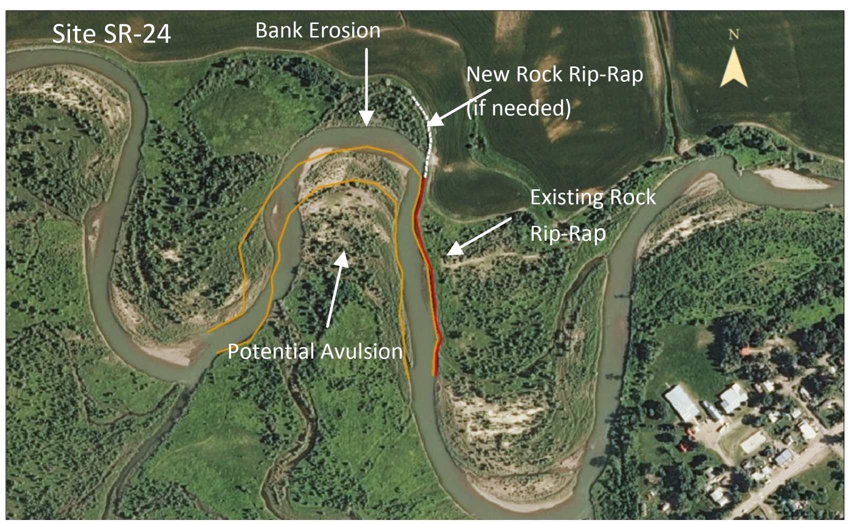
Rock rip-rap and jetties along 620 feet of east bank. The bank stabilization was probably installed to keep the river from reoccupying an old channel that loops south towards Highway 200. The south bend adjacent to Site SR-23 has migrated 90 feet south since 1995. The river could potentially flank the rip-rap as the bend continues migrating south.

Site SR-24 Bank Stabilization – Rock Rip-Rap and Bank Erosion (Map 7) Priority: Low

Rock rip-rap lines 600 feet of east bank. The rip-rap is intended to protect an adjacent hay field and pasture. Active bank erosion is occurring upstream from the rip-rap along the apex of the bend. Since 1995, the bend has migrated over 100 feet to the north and is currently 260 feet away from an irrigated hay field.

South of Site SR-24, the river is cutting into a meander. A future avulsion could shift the main river channel south, away from the eroding bend, but it is uncertain if or when this might occur.

1995 bank lines (orange lines) superimposed on a 2011 aerial photo showing the rate of channel migration over the last 18 years. The red line is existing rock rip-rap.



Recommendations:

1) Along the apex of the north bend, 260 feet of riparian buffer separates the river from the irrigated hay field. It would be expensive to rip-rap the bend. If the river continue moving north, instead of reinforcing the bend, extend the existing rock rip-rap up the east bank along the field border to prevent flanking of the existing rip-rap (white line on the photo above).
2) Aggressively control the leafy spurge infestations on the upper bank.

Site SR-25 Bank Stabilization – Rock Rip-Rap (Map 7) Priority: No Action

Rock rip-rap (1,200 feet) along the east bank protecting the town of Sun River. The rip-rap lies along the main channel and extends up the south side channel near Hwy 200. The river bend, just west of Site SR-25, has moved over 100 feet south since 1995 and 600 feet since 1946. The river is slowly eroding into the lower end of the side channel. This should not pose a problem for the Town of Sun River since there is rip-rap protection along the east bank of the side channel.

Site SR-26 Bank Stabilization – Rock Jetty (Map 8) Priority: Medium

Two rock jetties were constructed on the north bank, sometime before 1975. The upper jetty is forcing the river to make a "dog leg" to the south. The jetty is also creating large eddies that are actively eroding the upstream bank and depositing a large gravel bar immediately downstream. Approximately 50 feet of bank has eroded behind the upper jetty over the last 18 years (orange line depicts the 1995 north bank in the photo below). The upper jetty and rip-rap may eventually be flanked by the river and become a "pile of rocks" in the middle of the river.

The smaller jetty is about 280 feet downstream from the larger jetty, nearly buried by gravel deposits. It appears to be tied into the rock rip-rap described in Site SR-27. Rock rip-rap may connect the two jetties, but it was difficult to confirm because of the large gravel bar.

Large rock jetty that has created an upstream eddy. The eddy is eroding the bank on the upstream side of the jetty.

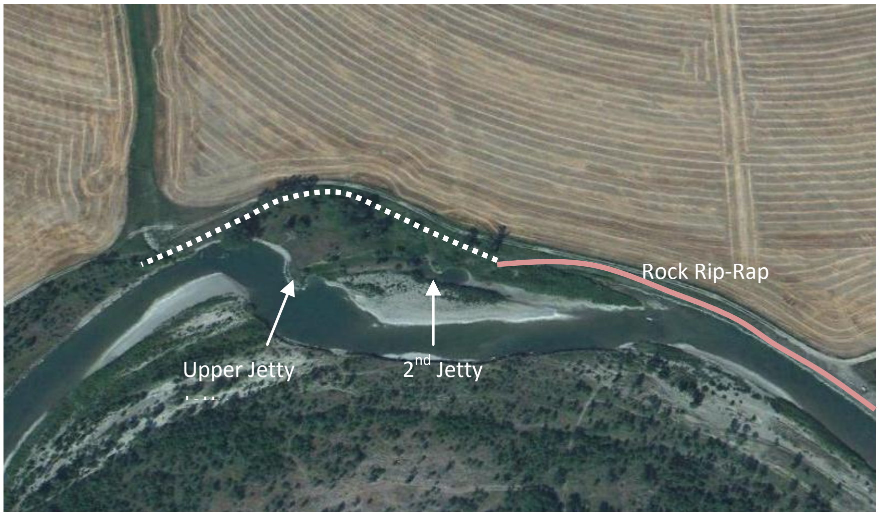
The orange line depicts the 1995 bank. Over the last 18 years, the river has eroded 50 feet into the bank.

Recommendation (See photo below):

1) Remove and stockpile rock from the two jetties and the rip-rap between the two jetties. Once the river has reestablished a stable curvature, erosion on the bend should lessen. However, if the river continues to actively erode into the bank and begins to threaten the irrigated field, use the field border as the "line of defense". Key

new rip-rap into the existing rip-rap and extend it along the field border as necessary. Cut the large tree on the bank above the first jetty, leaving the root ball in the bank.

2) Aggressively control noxious weeds, especially leafy spurge and spotted knapweed.



Conceptual view of recommended approach. The white dashed line is the proposed location of future bank stabilization along the field border if needed.

Site SR-27 Stream Crossing – Highway 200 (Sun River) Bridge (Map 8) Priority: No Action

The Sun River Bridge is located on a crossing that has been used since prehistoric times. The first bridge was a wooden toll bridge built in 1867. The current bridge is a steel beam bridge built in 1996. It has a 260 foot span that crosses the river and part of the west floodplain. Upstream from the bridge, blanket rock rip-rap lines 1,150 feet of the east bank.

Site SR-13 to SR-27

Reach Description: Fort Shaw Bridge to the Sun River Bridge (6.1 miles)

Channel Characteristics: The Sun River valley averages about 1.1 miles wide and is bordered by shale bedrock overlain by either glacial lake or alluvium deposits. The valley width is slightly less than the Simms to Fort Shaw reach. Bedrock along the north terrace serves as vertical grade control.

The 100 year floodplain encompasses most of the valley along this reach. The average gradient of the river is 0.14%, slightly less than upstream from the Fort Shaw Bridge.

The river valley is very flat, creating a reach that is depositional. Several historic channel traces cross the floodplain. Because of the wide floodplain, low channel gradient, bedrock grade control and large bedload the river is extremely dynamic and subject to rapid channel changes.

Over the last 70 years, large areas of riparian forest have been cleared for hay production. A corresponding amount of bank armoring has occurred where the river has migrated towards hayfields. This has resulted in a higher concentration of bank stabilization between Fort Shaw and Sun River than any other reach in this assessment.

River volatility makes it difficult and expensive to keep existing bank armor intact and functional. Several sections along this reach are in jeopardy of being flanked by the river. The best long-term management approach is to maintain healthy riparian vegetation and limit infrastructure development along the river. Bank stabilization may only be worthwhile where high value infrastructure (i.e. roads, buildings, irrigation structures, etc.) requires protection.

Major tributaries: Adobe Creek (RM 33.1) enters the Sun River from the south (near Site SR-16).

Looking downstream at Sites SR-22. Due to the dynamic nature of the river, bank erosion and channel migration are common. Because fields have been developed in the floodplain and on adjacent benches large amounts of bank armoring has been installed. Most bank stabilization has proven to be both expensive and difficult to maintain.

Riparian Characteristics: It is estimated that 30 – 40% of the riparian forest in the 100 year floodplain has been cleared for agricultural development. Overall, the remaining riparian plant community is in good condition. A few exceptions exist where concentrated livestock use along the river has affected riparian health and function. Young cottonwood saplings and sandbar willows are common on inside bends and high gravel bars. These "nurseries" are essential to the long-term sustainability of the Sun River's riparian forest.

*Leafy spurge and spotted knapweed infestations are extensive and affecting native plant growth. There are increasing numbers of Russian olive trees throughout the river corridor that, if not controlled, could become a problem in the future.

Site SR-28 Stream Crossing – Railroad Abutments/Piers (Map 8) Priority: Low

The site of the Great Northern Railroad trestle originally built in 1912 and abandoned in 1974. Old railroad trestle concrete abutments (dated 1941) are on both sides of the river. Rock rip-rap faces the east abutment, but not the west abutment. What remains of the trestle are two abutments and 30 – 40 piling stumps traversing the river. The piling stumps are exposed most of the year, creating a hazard to river recreationists. The west abutment is located on the Medicine River Fishing Access Site (FAS). Invasive Russian olive trees are scattered throughout the FAS and the west floodplain.

On the east side of the river, there is an old abutment between the Hwy 200 Bridge (Site SR-27) and the old railroad trestle (Site SR-28). It may be from an earlier bridge, however a corresponding abutment was not found on the west side. A large gravel bar has formed upstream from the old abutment.

Support posts from the old railroad trestle were cut off after the trestle was removed. The piling stumps are exposed most of the year.

Recommendations:

1) Cut the old trestle support posts as low as possible to lessen the safety hazard to river recreationists.
2) Aggressively control noxious weeds and remove Russian olive trees on the floodplain.

Site SR-29 Bank Stabilization – Rip-Rap/Rock Jetties (Map 8) Priority: No Action

1,800 foot segment of rip-rap and jetties on a long southwest bend. The jetties were installed before 1975, probably with increased exurban development. There are 14 jetties along this bank; all but the upper two are functioning as intended. There is 180 feet of bank erosion associated with the upper two jetties, although the bank has moved very little over the last 18 years.

Site SR-30 Bank Stabilization – Rock Rip-Rap (Map 8) Priority: No Action

Rock rip-rap along the south bank next to a pasture. The bank was shaped to a 2:1 slope with small angular rock placed on 425 feet of a relatively straight section of river. There is vigorous sandbar willow and grass growth covering all but the toe of the rip-rap. Small rock seems to work fine on slow, straight sections of the river, but it is not recommended on bends where sheer stress is high. Leafy spurge is common on the upper bank.

Mill Coulee enters the Sun River from the north about ¼ mile downstream from Site SR-30. Mill Coulee is a perennial tributary to the Sun River; however, this has not always been the case. Historic records describe Mill Coulee as an ephemeral stream, flowing only during spring snowmelt and high intensity rainfall events. The transition from an ephemeral to perennial stream is the consequence of a sustained baseflow and drainage from irrigated lands on the Asheulot and Fairfield Benches. During the summer, a large amount of sediment from eroding banks and irrigation waste water is conveyed down Mill Coulee and into the Sun River. Mill Coulee may be a key contributor to the brown trout population in the lower Sun River, serving as a spawning stream as well as providing refuge habitat for resident fish populations.

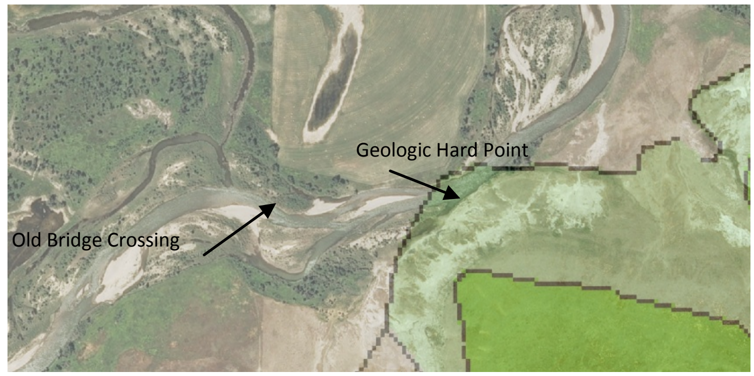
Site SR-31 Bank Erosion (Map 9) Priority: Low

Active erosion along 750 feet of the north bank. An irrigated field (center pivot sprinkler) comes to within 200 feet of the eroding bank. Since 1995, the bank has eroded a maximum of 50 feet. The 1869 Government Land Office (GLO) map shows the river to be in nearly the same location as it is today.

A bedrock “hard point” protrudes at the river’s edge (see photo below). The bedrock is hard claystone/sandstone and acts as a natural grade control. Upstream from the “hard point”, the river channel is highly depositional with shifting gravel bars.

The 1869 GLO map shows a historic toll bridge crossing (Middle Bridge) upstream from the eroding bank. Over the last 100+ years, all signs of the bridge have been erased.

Eroding bank on the north side of the river.



The light green geologic formation creates a "hard point" in the river.

<u>Recommendation:</u>
Since the river has not moved appreciably over the last 140 years, investing in rock rip-rap to stabilize this bank may be premature. There is 200 feet of buffer separating the river from the center pivot. It is advised to monitor the rate of erosion before making a decision to armor the bank.

Site SR-32 Bank Stabilization – Rock Rip-Rap/Jetties (Map 9) Priority: Medium
520 feet of rock rip-rap and jetties line the north bank, mostly built with large cobbles and concrete slabs. The bank stabilization was installed to protect a farmstead and corrals on the north floodplain of the river. The bank stabilization is intact except for the upper 30 feet which is need of repair.

Upstream of Site SR-32, the river has migrated east nearly 250 feet since 1995; of that, 190 feet occurred during the 2011 flood. The easterly migration has realigned the river towards Site SR-32, directing the main current into the north bank above the rip-rap. The bank could erode further, flanking the rip-rap.

Leafy spurge and spotted knapweed infestations are prolific throughout the floodplain.

The red dashed line depicts the 1995 east river bank. The river has migrated east nearly 250 feet over the last 18 years. The easterly migration has realigned the river towards Site SR-32 directing the main current into the north bank above the existing rip-rap.

Recommendation:
Monitor the bank erosion at Site SR-32 and upstream river migration to determine if additional rip-rap will be necessary. There is 80 feet of riparian buffer separating the river from a high floodplain bench. If the river begins to flank the upper jetty and rip-rap, it may then be worth installing 140 – 160 feet of rip-rap along the floodplain bench. The additional rip-rap would extend west from the existing rip-rap along the floodplain bench. Rock could be salvaged from the upper jetty and used on the extended rip-rap. See photo diagram below.

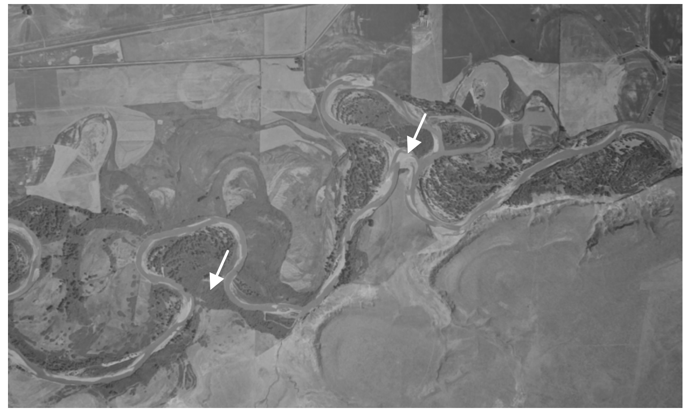
The orange line depicts the existing rock/concrete rip-rap. The red dashed line is where additional rip-rap could be installed if the river begins to flank the upper jetty and rip-rap.

Site SR-33 Bank Erosion (Map 9) **Priority: No Action**

There is active bank erosion along the east bank (approximately 950 feet long, 10 feet high). The river migrated almost 135 feet into the floodplain during the 2011 flood; nearly 200 feet since 1995. In 2002, concrete/root wad flow deflectors and root wad bank stabilization were installed in an effort to stabilize the bank. They have since washed out.

The 1946 and 2011 aerial photography below show the location of two major avulsions between Sites SR-30 and SR-33. These avulsions occurred during the late 1940s, abandoning two miles of river channel. Today, 70 years later, the river is still seeking to regain the channel length that was lost. This is why there is so much bank erosion and river movement along this reach.

2011 – White arrows show the location of two meander avulsions. Two miles of channel were lost since the 1940s.



1946 – White arrows show the location of two meander avulsions. The upper right meander avulsed in 1946. The lower left meander avulsed a few years later.

Recommendation:
Do not invest in bank stabilization on this reach unless high value infrastructure requires protection. As the river seeks to regain channel length, armoring the banks would be expense and difficult to maintain.

Site SR-34 Floodplain Dike – Gravel Pit (Map 9) Priority: No Action
An old gravel pit and dike on the south floodplain. The 1975 aerial photo shows active gravel mining in the river and adjacent floodplain during the 1970s. The gravel pit is now a shallow pond (24 acres) fed by groundwater and used primarily as waterfowl habitat. A 2,500 foot long berm, 4 – 10 feet high, borders the gravel pit on the north. The berm is preventing out-of-bank flow from accessing the historic floodplain. The floodplain has been reduced by 70% along this ½ mile reach. Minor bank erosion was noted on the upstream end of the berm. Leafy spurge infestations are extremely heavy around the perimeter of the pond.

Site SR-35 Bank Stabilization – Root Wads/Rubble: Largent's Bend FAS (Map 10) Priority: Medium
Approximately 200 feet of stabilization lines the east river bank at Largent's Bend Fishing Access Site (FAS). A temporary crossing was once located at this site to access a gravel pit on the south side of the river (Site SR-34). Root wads were installed on 125 feet of bank in 2002. They are still in intact and functioning well. An additional 75 feet of concrete pipe and miscellaneous rubble lies along the bank and is non-functional. It is contributing to the bank erosion and is a public safety hazard. The concrete pipe is a remnant from the temporary river crossing mentioned above.

Both river banks along this site are lined with dense stands of sandbar willow. Leafy spurge and spotted knapweed infestations are widespread across the FAS. On the downstream end of the FAS, a bedrock shelf along the south valley wall crosses the river and serves as a natural channel grade control.

The Largent's Bend FAS, acquired in 2009, consists of 163 acres. Before the land became an FAS, the property was heavily mined for gravel. The old gravel pits are now groundwater-fed ponds used for waterfowl habitat and fishing. Spoil piles are still evident across the FAS. Some pits serve as small tract sewage lagoons and may be contributing high levels of nutrients to the shallow groundwater table.

Concrete pipe and rubble scattered along the river bank. Rather than providing bank protection, they are contributing to the bank erosion and creating a public safety hazard.

Recommendations:

1) Remove the concrete pipe and rubble from the bank and dispose of it off-site. Minimize disturbance to the bank during removal; revegetate with sandbar willow cuttings. Nearly 200 feet of riparian vegetation buffer the river from the terrace bank. Installing expensive bank stabilization to protect a relatively small area is not worth the expense.
2) Aggressively control leafy spurge and spotted knapweed to better encourage native riparian plant growth along the river.

Site SR-36 Concrete Mass (Map 10) Priority: No Action

Large concrete mass on the north bank that has been undercut by the river. It has partially submerged in the river and extends nearly one-quarter way across the channel. It is not clear what it was used for. A mounded "bunker" nearby, on the upper bank, is reported to have been part of a past gravel mining operation.

The large concrete mass may be a safety hazard for floaters, but because of its size, it would be difficult to remove unless broken into pieces. It is probably not worth the expense of removal.

Site SR-37 Bridge Abutments and Ramp (Map 10) Priority: Medium

Abandoned concrete bridge abutments, concrete ramp approach, and wood pilings in mid-channel. It is not clear when and why this bridge was built. There is speculation that it was used to access the south side of the river to transport gravel.

The 1995 aerial photo shows these abandoned structures lying alongside the east bank of the river. Over the last 18 years, the river moved 230 feet east, flanking the structures, and leaving them in mid-channel. They currently pose a safety hazard to river recreationists.

Fourmile Creek enters the Sun River from the south about 240 feet downstream from Site SR-37.

Old bridge abutments, concrete ramp approach, and wood pilings in the middle of the river.

Recommendations:

Option 1: Remove the concrete bridge abutments and ramp approach from the river. Cut off the pilings as low as possible. This is a costly option, but it would immediately remove a safety hazard.

Option 2: Monitor the river to see if it will continue migrating east. If it does, the structures may eventually be on the west side of the river and will no longer pose a hazard.

Site SR-38 Bank Stabilization – Root Wads/Cobble Rip-Rap (Map 10) Priority: Medium

Nearly 1,000 feet of bank stabilization lines the outside bank of a bend. Root wads were installed in 2002 that have since washed out. A large rock jetty remains intact on the upper end. The bank moved very little during the 2011 flood; except for upstream of the rock jetty. The jetty has created an upstream eddy causing the river to gouge into the bank nearly 45 feet.

The landowner has been dumping cobbles (gravel screenings) over the bank in an attempt to stabilize it. The cobble rip-rap has been placed along a straight segment of river. Because of the low sheer stress along this bank, the cobbles have remained in-place, at least for now.

Upstream (south) of the bend, a 100 foot section of old rock rip-rap that lines the west bank is no longer functional. The channel is relatively straight at this location. The bank is beginning to heal and revegetate on its own.

Over the last 40 years gravel has been extensively mined on the floodplain and in the river, downstream from Site SR-38. The north floodplain (12 acres) has two open gravel pits and is completely void of vegetation.

The low floodplain next to the river, whether disturbed by gravel mining or not, is well suited for dense sandbar willow growth. Leafy spurge infestations are widespread across the floodplain.

Site SR-38: Cobbles dumped over the bank serving as bank stabilization.

Recent gravel mining on the north floodplain.

<u>Recommendation:</u>
1) Reclaim 12 acres of the north floodplain downstream from Site SR-38. Remove mining debris, shape the floodplain to an appropriate grade and revegetate with sandbar willow and cottonwood seedlings.
2) Aggressively control noxious weeds, especially leafy spurge.

Site SR-39 Bank Stabilization – Root Wads (Map 10) Priority: No Action

Root wads and rock shale were used to stabilize approximately 300 feet of the east bank in 2003 – 2004. Sandbar willows were planted with the rood wads and have successfully established. The bank stabilization remains intact and functional.

The project included redirecting the river into an old channel and constructing a rock sill across the inlet of the secondary channel to maintain the channel grade. The river and floodplain have been heavily manipulated by gravel mining over the last 35 years.

Site SR-40 Bank Stabilization – Car Bodies (Map 10) Priority: No Action

Car bodies and concrete rubble line 300 feet of the north bank. A dense stand of willows is interspersed with the rubble. Removal of the car bodies and concrete rubble may create unnecessary disturbance to the bank so it is best to leave it in place.

Site SR-41 Bank Stabilization – Car Bodies (Map 11) Priority: High

Old car bodies and miscellaneous scrap metal are strewn across about 1,000 feet of the north terrace bank. This site includes 600 feet of side channel and 400 feet of the active river channel. Immediately downstream from Site SR-40, car bodies are embedded in the river bottom. These car bodies pose a considerable hazard for river recreationists.

Old car bodies on the side of the terrace and in the river.

Recommendations:

Winch the car bodies off the terrace bank and out of the river channel. Salvage or dispose of metal off-site. The steep terrace bank is alluvial deposits consisting of loose sand that is inherently unstable. Attempts to revegetate the terrace bank upon removal of the car bodies will not be successful. However, disturbed areas along the side channel bank should be revegetated after the car bodies and scrap metal are removed.

Site SR-42 Irrigation Pump and Car Bodies (Map 11) Priority: Medium

Electric irrigation pump on the north bank located on a rock jetty. The jetty is creating a large upstream eddy causing the river to actively cut into the toe of a steep terrace bank. The river has eroded 50 feet into the terrace since 1995.

Downstream from the pump site, there is 450 feet of river bank lined with old car bodies and scrap metal. A narrow band of willows grows along the bank intermixed with the car bodies and scrap metal.

Old car bodies and scrap metal lining the north river bank.

Recommendations:

1) Move the pump site downstream about 300 feet to a straight and more stable section of channel. Remove the jetty to stop the back eddying and to slow the terrace erosion.
2) Remove the car bodies and scrap metal along the bank where significant disturbance to the river bank and willows can be avoided. Plant willow cuttings along the bank after removal.

Site SR-43 Bank Stabilization – Rock Rip-Rap (Map 11) **Priority: High**

A large bend in the Sun River is slowly eroding towards the Vaughn Levee. Bank stabilization efforts (1,100 feet) were attempted twice over the last eight years. At its nearest point, the river is 110 feet from the toe of the levee. The river bend has moved 35 feet since 1995, 70 feet since 1975, and 150 feet since 1946.

The first attempt to stop the erosion took place in 1996 with the placement of rock barbs designed by the Bureau of Reclamation. The rock barbs eventually failed because they were not maintained. The second attempt was made by landowners of property adjoining the levee in 2005 using rock rip-rap. The rip-rap is in various stages of disrepair following the 2011 flood.

The 2.5 mile earthen levee, built in 1969 by the Army Corps of Engineers, protects 250 households from Sun River flood waters. The impetus for building the levee was the 1964 flood which caused considerable damage to the area. The Vaughn Small Drainage District assesses fees for the maintenance of the levee. In the original Project Cooperation Agreement, the Drainage District agreed to maintain the project which makes it now ineligible for financial assistance from the Corps.

Rock rip-rap has partially failed on a river bend near the Vaughn Levee. The orange lines depict the 1995 bank lines.

Recommendations:

Restore 1,100 feet of rock rip-rap along the north bend of the river. Shape the bank to a 2:1 slope and line with well-placed angular rock. Complete the restoration work while there is still a buffer between the river and the levee providing space to construct the project. Salvage whatever rock is on-site to reduce project costs.

Site SR-44 Bank Erosion (Map 12) **Priority: Medium**

Active bank erosion along 200 feet of the south river bank opposite the Muddy Creek confluence. The Muddy Creek current hits the south bank of the Sun River, eroding nearly 35 feet of bank since 1995. The river's edge is approximately 30 feet from an irrigated grain field (center pivot). The river bank is 8-10 feet high and consists of fine sediments.

Bank erosion along the Sun River across from the Muddy Creek confluence.

2012 aerial photo showing the Muddy Creek current directly impacting the south bank of the Sun River.

Recommendation:
Shape the bank to a 2:1 slope and use a willow lift treatment along the bank. Aggressively control noxious weeds, especially leafy spurge.

Site SR-27 to SR-44
Reach Description: Sun River Bridge to the Ulm-Vaughn Bridge (11.2 miles)

Channel Characteristics: The Sun River valley is about 1.3 miles wide at Sun River, and gradually increases to nearly 2 miles west of Vaughn. It then quickly narrows to less than a mile east of Vaughn, near the Muddy Creek confluence. The valley is bordered by shale and sandstone bedrock overlain by glacial lake deposits and alluvium. When the river is up against the south valley wall, exposed bedrock serves as vertical grade control.

The average gradient of the river from Sun River to Largent's Bend is 0.13%, essentially the same as the Fort Shaw to Sun River reach. From Largent's Bend to the Muddy Creek confluence, the gradient becomes even less, dropping to 0.09%

Because the river is wide and flat, it is extremely dynamic and subject to rapid channel changes. There are numerous old channel traces across the north floodplain since the river generally hugs the south valley wall down to Fourmile Creek. From Fourmile Creek to Vaughn, the river corridor is at its widest; there are old oxbows on both sides of the river. Below Vaughn, the river quickly transitions into a single-threaded channel and narrow riparian corridor. There is very little gravel on this lower end. Most of it is finely grained suspended sediments.

Over the last 70 years, the amount of riparian forest in the floodplain has remained about the same. Some riparian forest has been cleared for field development while some fields were reclaimed by the shifting river. This reach has a low density of bank armoring.

Gravel mining on the floodplain and uplands from Sun River to Vaughn has been extensive over the last 50 years. Some mining continues today. There are old gravel pits and mining scars all across the floodplain. Some sections of river are still recovering from active channel gravel mining activity.

Because of the meander avulsions that have occurred over the last 70 years, the river is still seeking to regain the channel length it lost. This makes it difficult to hold the river in-place and keep bank armor intact and functional. The best long-term management approach is to maintain healthy riparian vegetation and limit infrastructure development along the river. Bank stabilization is expensive and should only be considered where high value infrastructure (i.e. roads, buildings, irrigation structures, etc.) requires protection.

Major tributaries: Mill Coulee (RM 26.2) and Muddy Creek (RM 17.1) enter the Sun River from the north. Fourmile Creek (RM 21.6) enters from the south.

Looking upstream and across the river towards Largent's Bend. (Site SR-35). Dense stands of willow are common along the banks of the lower Sun River. The exposed bedrock shown in the foreground serves as a natural channel grade control.

Riparian Characteristics: Since the 1800s, when farming came to the valley, over 50% of the riparian forest has been cleared for agricultural production. A slight increase in the riparian forest may be occurring over the last 40 years due to river avulsions and channel migration reclaiming some of these fields. Overall, the remaining riparian plant community is in good condition. Dense stands of sandbar willow can be found on the low floodplain next to the river. They are just as prolific in areas disturbed by gravel mining as those areas that are not. Middle-aged to mature plains cottonwood trees are common on the high floodplain benches.

*Leafy spurge infestations are extensive and may be affecting native plant growth. There are increasing numbers of Russian olive trees along this reach.

General Recommendations **Priority: High**

1. Bank Stabilization: The Sun River from Lowry Bridge to Vaughn is an extremely dynamic river. The wide, flat floodplain and large gravel bedload are the reasons that the Sun River is so sinuous and forever shifting around. Attempts to hold the river in-place with bank armoring or dikes can be expensive and is often frustrating. Bank stabilization should only be considered where high value infrastructure (i.e. buildings, bridges, roads) requires protection. Investing in bank stabilization to prevent the loss of a riparian forest or a dryland pasture is not cost effective.

   The following are bank stabilization measures that have been used on the Sun River:

   - Rock Rip-Rap: If bank stabilization is necessary, the best option for the Sun River mainstem from Lowry Bridge to Vaughn is rock rip-rap. Sheer stress along the banks is typically high. Using angular rock rip-rap on a sloped bank will provide less risk of failure. It has been shown on some straight sections of river where the sheer stress is less, blanketing the bank with small cobbles may suffice.
   - Rock Jetties: Rock jetties do not work. Unless incorporated into rock rip-rap, they usually create more bank instability than they prevent.
   - Bioengineering (root wads, willow lifts, etc.): For most of the Sun River mainstem, sheer stress along the banks during high water is often too great for bioengineering techniques to succeed long-term. However,

bioengineered bank stabilization treatments for reaches where the sheer stress is relatively low, along the Sun River below Muddy Creek and for flood channels, is a viable alternative to consider.

2. Noxious Weed Control: Encourage landowners to increase their efforts to control leafy spurge and spotted knapweed on the floodplain. The expansion of these plants is seriously jeopardizing forage production and riparian cover. These weeds are also threatening the long-term stability of the Sun River by inhibiting the new growth of deep-rooted native trees and shrubs. Areas of focus should include the Sun River corridor, tributaries, and irrigation canals; all of which provide ready transport of weed seed to other locations.

3. Hydrology Analysis: A detailed modeling of pre- and post-development hydrology and hydraulics has not been done on the Sun River. This would be worth pursuing to better understand the effects of irrigation and climate on long-term trends in water volume, flow duration, peak flows, low flows, and seasonal flows over the last 100 years and provide scenarios for future water availability. This model would also provide perspective on impacts to the physical and ecological integrity of the Sun River and help determine where to focus future restoration efforts.

4. Russian Olive Encroachment: Russian olive tree densities in the Sun River corridor are relatively light. Along some Montana rivers, Russian olive encroachment on the river corridors is creating a devastating ecological and economic impact. Some densities have become so high that it is now cost-prohibitive to treat them. To prevent Russian olive from expanding and encroaching on the Sun River native riparian plant communities, landowners should be encouraged to eliminate all Russian olive plants along the Sun River, tributaries, and irrigation canals.

Mature Russian olive tree next to the Sun River.

5. Channel Restrictions: The Sun River transports a large bedload. Channel restrictions slow water velocity and/or block bedload passage which in turn creates large gravel/silt deposits upstream and/or downstream from the restriction. These deposits can push the river current into a bank causing accelerated erosion. They also may cause ice jams that extend for miles, threatening channel stability and infrastructure. Design in-channel structures to minimize channel restriction. Bridge crossings should be built with as few mid-channel supports as possible. Construct irrigation diversions to pass bedload and not be a “catch point” for ice jams.

6. Historic Aerial Photography: Have the Government Land Office (GLO), 1946, 1953-54, and 1975 imagery georeferenced to allow for easy viewing and analysis of river trends over a 140 year period. This imagery will provide an important tool to landowners and permit managers to help them with their river management decisions.

5. References

Anderson, Bruce (2003) *"Orville Skogen, Sun River Project"* (Correspondence with Tonya Merriman) Land & Water Consulting, Inc. Sept 18, 2003.

Autobee, Robert (1995) *Sun River History* US Department of Interior Bureau of Reclamation 1995.

Buckley, Steve (2000) *"Project: Al Skogen Bank Stabilization Project, Simms"* (Correspondence with Alan Rollo) Watershed Consulting Apr 15, 2000.

Chadwick, Amy (2012) *"Rocky Reef Irrigation Division Elevation"* (Correspondence with Tonya Merryman) Watershed Consulting, LLC Oct 28, 2012.

Colenso, Jr. Wilfred J. (1995) *"Sun River Irrigation Diversion"* (Correspondence with Alan Rollo) US Department of Agriculture Natural Resources Conservation Service (Mar 27, 1995).

Confluence Consulting, Inc. (2010) *Evaluation of Sun River Overflow Channels and Floodplain Function With Respect to Channel Modifications on the Bob Murray and Orville Skogen Properties* Jan 12, 2010.

ECONorthwest & PBS&J (2008) *Technical Memorandum 2.5 Case Studies – Greenfields Irrigation District* Revised August 2008.

Ford, Lee (1959) Sun River Valley Played Important Role in State History. *Great Falls Tribune,* Nov 11.

Great West Engineering (2011) "*Rocky Reef Diversion on the Sun River"* (Correspondence with Amy Chadwick) Dec 6, 2011.

Hill, William J. (1976) *Water Quality and Quality of the Sun River From Gibson Dam to Vaughn, 1973-1974* Montana Department of Fish and Game May 5, 1976.

Hydrotech (1997) *Ray Goff Project – Sun River, Cascade County Project Workplan 1997.*

March, Daniel E. (2012) *"Wilson 310 Permit Application – Rocky Reef"* (Correspondence with Tonya Merryman) Atkins North America, Inc (Feb 13, 2012).

Montana Department of Environmental Quality (2004*). Water Quality Restoration Plan and Total Maximum Daily Loads for the Sun River Planning Area* website at: *https://archive.org/.../908F17E2-865F-417A-92DD-D.*

Montana Department of Environmental Quality (2008). *Clean Water Act Information Center* website at: http://deq.mt.gov/wqinfo/CWAIC/default.mcpx

Montana Department of Fish, Wildlife, and Parks. *Montana Fisheries Information System (MFISH) w*ebsite at: http://fwp.mt.gov/fishing/mFish/

Montana Department of Natural Resources and Conservation. *Water Resources Adjudication Information w*ebsite at: http://dnrc.mt.gov/wrd

Montana State Engineer's *Office, Water Resources Survey – Cascade County, Montana*, June 1961

Montana Watershed Coordination Council - *Watershed Directory* website at: http://mtwatersheds.org/Watesheds/WatershedDirectory.html

Mortson, Oswald C. (1897) The Sun River Valley. *Great Falls Daily Tribune,* Dec 21.

Natural Resource Information System Montana Geographic Information Clearinghouse website at: http://nris.mt.gov/gis

Rollo, Alan (1998) *"310 Application - Rocky Reef Division"* (Correspondence with Peter Skidmore) Cascade County Conservation District Jun 13, 1998.

Suchomel, Igor (1998) *Rocky Reef Diversion Dam Reconfiguration* Watershed Consulting, LLP 1998.

Sun River Watershed Group (1997) *Sun River Watershed Jan 1, 1997.*

Sun River Watershed Group website at: http://www.sunriverwatershed.org

Sun River Valley Historical Society (1989) *A Pictorial History of the Sun River Valley.* Shelby, Montana: Promoter Publishing.

Unknown Author (1921) The Story of Sun River When The Redskins Were Hostile and Buffalo Roamed Plains. *Daniels County Leader*, May 30.

US Geological Survey – Water Resources of Montana website at: http://mt.water.usgs.gov

Watershed Consulting, LLP (1997) *"Sun River: Simms to Fort Shaw Fluvio-Geomorphic Investigation"* 1997.

Watershed Consulting, LLP (1997) *"Sun River: Sun River to Vaughn Bank Stabilization" (Memo)* Jun 1997.

Watershed Consulting, LLP (1999) *"Sun River Orville's reach meander pattern analysis"* (Correspondence with Alan Rollo) Dec 10, 1999.

Appendix A: Sun River Assessment: Restoration Priorities

Site	River Mile	Bank	Latitude	Longitude	Site Description	Recommended Restoration Priority
SR-1	45.3	-	47.51266	-112.0097	Stream Crossing – Lowry Bridge	No Action
SR-2	45.2	L	47.51233	-112.0079	Boat Ramp – BLM Lowry Bridge Recreation Site	No Action
SR-3	44.6	R	47.50723	-111.9986	Bank Stabilization – Rock Flow Deflectors	Medium
SR-4	43.7	R	47.50577	-111.9833	Bank Erosion	Low
SR-5	41.9	L	47.50825	-111.9515	Terrace Erosion	High
SR-6	40.8	-	47.50220	-111.9327	Stream Crossing - Simms Bridge	No Action
SR-7	39.2	R	47.50738	-111.8993	Bank Erosion (Root Wads/Rock)/Channel Avulsion	High
SR-8	37.9	R	47.51312	-111.8741	Bank Stabilization – Rock Rip Rap	No Action
SR-9	37.6	L	47.51676	-111.8751	Big Coulee Confluence	No Action
SR-10	36.8	L	47.51798	-111.8584	Rocky Reef Irrigation Diversion/Headgates	High
SR-11	36	R	47.51030	-111.8629	Overflow Channel – Fish Habitat/Spawning	Medium
SR-12	35.4	R	47.50895	-111.8361	Return Flow Channel – Fish Habitat/Spawning	Low
SR-13	34.4	-	47.51284	-111.816	Stream Crossing – Fort Shaw Bridge	Low
SR-14	34.3	L	47.51471	-111.812	Bank Stabilization - Rock Rip-Rap	No Action
SR-15	33.7	L	47.51949	-111.8072	Bank Stabilization - Rock Rip-Rap/Jetties	Medium
SR-16	33	R	47.52268	-111.7909	Avulsion – Side Channel	High
SR-17	32.8	L	47.52541	-111.795	Bank Stabilization – Root Wads/Rock	Medium
SR-18	32	L	47.53141	-111.7797	Bank Stabilization – Rock Rip-Rap/Root Wads	Low
SR-19	31.8	R	47.52881	-111.7769	Bank Stabilization – Rock Rip-Rap	No Action
SR-20	31.2	L	47.53100	-111.7661	Sun River Valley Irrigation Diversion	Low
SR-21	30.1	R	47.53194	-111.7452	Flow Deflector – Rock Jetty	No Action
SR-22	29.8	L	47.53834	-111.736	Bank Stabilization – Rock Rip-Rap/Jetties	Medium

Site	River Mile	Bank	Latitude	Longitude	Site Description	Recommended Restoration Priority
SR-23	29.3	R	47.53409	-111.73330	Bank Stabilization – Rock Rip-Rap	No Action
SR-24	29.1	L	47.53748	-111.7297	Bank Stabilization – Rock Rip-Rap and Bank Erosion	Low
SR-25	28.8	R	47.53342	-111.7253	Bank Stabilization – Rock Rip-Rap	No Action
SR-26	28.5	L	47.53700	-111.7229	Bank Stabilization – Rock Jetty	Medium
SR-27	28.3	-	47.53536	-111.7177	Stream Crossing – Highway 200 (Sun River) Bridge	Low
SR-28	28.1	-	47.53324	-111.7155	Stream Crossing – Railroad Abutments/Piers	No Action
SR-29	27.7	R	47.52601	-111.7148	Bank Stabilization – Rip-Rap/Rock Jetties	No Action
SR-30	26.3	R	47.52692	-111.6883	Bank Stabilization – Rock Rip-Rap	No Action
SR-31	24.9	L	47.53107	-111.6629	Bank Erosion	Low
SR-32	24.5	L	47.53583	-111.6582	Bank Stabilization – Rock Rip-Rap/Jetties	Medium
SR-33	24.1	L	47.53748	-111.65130	Bank Erosion	No Action
SR-34	23.5	R	47.53836	-111.6391	Floodplain Dike – Gravel Pit	No Action
SR-35	23.2	L	47.53920	-111.6337	Bank Stabilization – Root Wads/Rubble: Largent's Bend FAS	Medium
SR-36	21.8	L	47.53867	-111.6099	Concrete Mass	Medium
SR-37	21.6	-	47.53790	-111.60690	Bridge Abutments and Ramp	No Action
SR-38	21.2	L	47.54422	-111.6009	Bank Stabilization – Root Wads/Cobble Rip-Rap	Medium
SR-39	21	R	47.54306	-111.6966	Bank Stabilization – Root Wads	No Action
SR-40	21	L	47.54541	-111.6957	Bank Stabilization – Car Bodies	No Action
SR-41	20.5	L	47.54770	-111.589	Bank Stabilization – Car Bodies	High
SR-42	20.4	L	47.54704	-111.5851	Irrigation Pump and Car Bodies	Medium
SR-43	19.6	L	47.54610	-111.5721	Bank Stabilization – Rock Rip-Rap	High
SR-44	17.1	R	47.54855	-111.5377	Bank Erosion	Medium

Appendix B: Files Contained in the DVD

- Sun River Assessment – Final Report
- Sun River Assessment – Maps/Site Locations
- Sun River - Field Site Photos 2013
- Sun River - Georeferenced Aerial Photography: 1995_2009_2011
- Sun River - Scanned Images: GLO_1946_1953_1975